Improving Knowledge Re-use to Reduce Rework Events in Plant Turnaround Projects

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Executive Summary

Research Background

The issue of re-using knowledge across projects, in general, remains a concern. Organizations are unable to absorb or put collected knowledge into practice (Duffield & Whitty, 2015). Turnaround maintenance (TAM) projects, as part of engineering projects, suffer similar challenges. TAM projects are defined as scheduled, periodic closure of a plant's processing unit or perhaps the entire facility to undertake maintenance, inspection, and repair of worn out or damaged equipment to maintain safe and efficient operations (Sahoo, 2013).

Failure to transmit gained experience or knowledge back into the system for future improvements is a significant flaw in the industry's current TAM methodologies (Al-Turki, Duffua, & Bendaya, 2013). Furthermore, in a study about TAM projects, it is evaluated that over 90% of critiques & recommendations are never implemented during turnaround projects, which is believed to be one of the causes of schedule slippage in approximately 50% of observed turnaround projects (Fertilizer Industrial Services Ltd, 2018).

The situation in Pupuk Kaltim is no different. Pupuk Kaltim is one of Indonesian government-owned enterprise that focuses on producing ammonia and urea. It conducts periodic turnaround projects mainly by themselves to maintain their plant reliability. The last 3 turnaround projects always have rework issues that prolong their schedule. Rework is described as the wasteful re-doing of a process or activity that was implemented poorly the first time (Love, 2002). The most prevalent reason for rework, among others, is a rule- or knowledge-based problem (Love & Josephson, 2004). Ideally, they should be able to learn from one project to another and improve the next project performance. However, based on the literature review and empirical problem, this still is a challenge. Therefore, this thesis aims to make recommendations for reducing rework events by enhancing the knowledge re-use between TAM plant projects. To achieve the research objective the main research question is formulated as follows:

How can the rework events in turnaround projects be reduced by improving the knowledge re-use process?

Research Methods & Findings

First, the problem is discovered through evaluating the cause of rework events in TAM projects. The process of assessing the rework event causes was done by comparing the desk research from the company's relevant documents and interview sessions with its employees. It is found that rework events are caused by hidden defects or spare parts quality or poor execution plan, knowledge issues, and lack of supervisor. Knowledge issues consist of 2 events, inattention of the worker with the work instructions and the knowledge gap between the employees involved in the TAM project execution stages. Both issues can be considered as knowledge reuse problems because of two reasons. First, work instructions contain explicit knowledge of executing a specific task, but they were not re-used as people were not paying attention to it. Secondly, the knowledge re-use process cannot be done when knowledge consumers do not know if such knowledge exists, which means that there is a knowledge gap among the employees.

Next, the Activity Theory is used to delve into the knowledge re-use issue. Many works of literature have shown that activity theory is known to be helpful in practice-based research approaches and,

most notably, in improving learning. Therefore, it is decided to use activity theory to evaluate the practice of knowledge re-use in the planning, execution, and closing stage of the TAM project setting. In assessing the current knowledge re-use process, the data also comes from desk research and interview sessions. It is found that knowledge re-use in the TAM project settings happens through both person-to-document and person-to-person approaches. However, the people-to-document method is still restricted to selecting the scope of work for TAM projects during the planning stage. While at the execution stage, the utilization of the person-to-document approach is also minimum as it is found that the source of explicit knowledge is incomplete, difficult to obtain and challenging to interpret. On the other hand, the people-to-people approach is maximum during the execution stage. People re-use the knowledge from more knowledgeable employees to solve the scope of work and the discovered work.

Thirdly, the barriers and enablers of knowledge re-use can be identified by recognizing the contradictions from the activity theory model in each stage of TAM projects. Based on the generic process of knowledge re-use process, there are six enablers of knowledge re-use. Those enablers are people found abnormality, leadership and working environment, familiarity among each other, a need for specifics and details, assistance from an expert/knowledge producer, and work's passive by-product to record the knowledge. On the other hand, the barriers to re-using the knowledge are low quality of explicit knowledge, explicit knowledge is not correctly indexed, the expert does not have any props, lack of incentives, and resources as well as standards for reporting and evaluation meetings to reintegrate knowledge.

Lastly, after acknowledging the contradictions of the knowledge re-use process within TAM project settings, solutions are given. It is proposed to use new web-based tools to capture the knowledge from the execution stage and update work instructions. Moreover, it is also suggested to develop guidelines to formally capture the knowledge at the closing stage and re-use it at the planning stage, which encompasses knowledge about equipment and failures, especially previous rework events. This solution is polished through expert validation where it must be reinforced by strong leadership and organizational support.

Scientific & Practical Implications

In terms of scientific implications, many works of literature claim that organizations are still failing to reuse the knowledge from their past. This idea also applies in TAM project settings. Moreover, it is also known that learning is one of the least researched aspects of maintenance management. Thus, this study provides empirical findings on such a discipline. Furthermore, this study has also identified the empirical findings on barriers and enablers in the knowledge reuse process. Lastly, to the best of the author’s knowledge, the application of AT in evaluating TAM projects is scarce. Hence this research also broadens the empirical use of AT.

On the practical implication side, the research findings, conclusions, and recommendations may be utilized as a basis for enhancing the knowledge reuse process in turnaround project contexts. Given the regularity with which Pupuk Kaltim does turnaround initiatives, this will undoubtedly be beneficial. Furthermore, because Pupuk Kaltim has four other sister companies in Indonesia that similarly conduct their turnaround projects, the conclusions of this study may apply to them as well.

Limitation and further research recommendations

This study used a case study of a petrochemical company that conducts their TAM project every 2-3 years. Furthermore, it has more than one plant. As a result, it is possible that there will be insufficient motivation to document the knowledge because they will have the same type of project on a regular basis. Instead, by participating in the TAM project on a regular basis, employees gain valuable experience. The findings could have been different if the study had been conducted across a broader range of industries, or from the perspective of a contractor who handles all aspects of operation and maintenance (O&M).

Second, this thesis seeks to reduce rework during the execution phase by evaluating the organization's knowledge reuse process. Nonetheless, this study discovered several causes of rework events, but they were not quantified. This means that the primary cause of rework events cannot be determined. Other dominant factors may contribute to rework, and efforts to reduce rework can begin by removing the dominant cause. To the best of the author's knowledge, there is little literature on the subject of the rework event in TAM project settings. Finding the dominant cause of rework events in TAM projects is thus recommended as a future research topic.

Third, this study discovered that knowledge re-use occurs primarily through a person-to-person approach. The degree of proximity between employees facilitates the process of reusing knowledge in this approach. However, employees come and go in a company, the old retire and are replaced by the new. The conditions depicted in this study could be the result of the company's regeneration period, during which there are significant generational differences among employees. Although empirical data cannot be obtained, the large employee age standard deviation may indicate this. As a result, it would be interesting to investigate how the TAM project's knowledge reuse process works when the employee's age standard deviation is taken into account.

Finally, the study's final result is a collection of suggestions for increasing knowledge re-use and minimizing rework occurrences. As a result, it will be intriguing to see how this concept is applied and whether it lowers rework instances. One way for carrying out this idea is action research. It's a method for bringing about conscious change in a fairly controlled environment (Duffield & Whitty, 2016). Furthermore, the systematic lesson learnt knowledge model (SYLLK) may anticipate the future gap when knowledge re-use enhancement efforts are adopted in the organization.

Keywords: Turnaround Maintenance, Knowledge Re-Use, Activity Theory, Rework, Petrochemical company

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1. Introduction

This chapter serves as the introduction to the master's thesis. This chapter explains how this research came to be and what the problem is that has to be solved. The research's background and problem definition including knowledge gap can be found in sections 1.1 and 1.2. In sections 1.3 and 1.4, the objectives and research question are stated. The report's structure is shown in Section 1.5.

1.1. Background

Acquiring experiential knowledge by learning similar projects is vital to ease the difficulty of estimating a project's efficiency, effectiveness, and impact (Samset K. , 2014). Moreover, learning from experience that comprises both tacit and explicit knowledge is considered a critical success factor. It is believed that it will lead to consistently successful projects through continuous improvement of project management processes and practices (Cooke-Davies, 2002; Williams, 2003; Bosch-Rekveldt, 2011).

Turnaround project, from now on called TAM (Turnaround Maintenance) project, is defined as a planned interruption of a plant activity for executing comprehensive maintenance or modification which cannot be done during regular operation within a relatively short period of time and limited budget (Duffua & Bendaya, 2019). Within TAM projects itself, learning from previous TAM and the feedback process is imperative for conducting TAM successfully (Ben-Daya, 2009). That is because learning will also connect knowledge management, build project capability, knowledge crossover, and rapid knowledge transfer for firms to execute projects (Liu, 2021)

Although knowledge reuse is strongly emphasized in current KM literature, project teams keep repeating mistakes and recreate solutions known in other business areas (Stenholm , Catic, & Bergsjö, 2019). This phenomenon is arguably also applicable to turnaround since turnarounds and their management share similarities with a typical engineering project. As a result of the inability to learn, from a benchmarking study of over 200 TAMs, it is known that schedule slips and cost overruns happened due to inadequate planning and coordination (Joshi, 2004). A study indicated that half of the observed shutdown projects are delayed by more than 20%, budget exceeded 10%, and scope increases unexpectedly up to 50% (Wanichko, 2016). Inadequate planning and coordination could be minimized if an organization can learn from their previous TAM. TAM is technically similar each time, although resources and the scope might differ (Hey, 2019).

This research was using case study from Pupuk Kaltim. It is a state-owned petrochemical company that focuses on producing ammonia and urea. Pupuk Kaltim also conducts regular TAM projects to ensure the plants' reliability. Ideally, Pupuk Kaltim as an organization should be able to learn from the previous project and implement the lesson learnt to improve the subsequent TAM project's performance. However, this is not the case. The problem they face regarding learning between TAMs will be elaborated on in section 1.2 below.

1.2. Problem Definition & Theoretical Gap

Organizations undertake projects to achieve their overall goals and objectives (Morris & Jamieson, 2007). In the context of the process industry, a company needs to ensure its plants' reliability as it directly affects its ability to generate income. In the Pupuk Kaltim case, they also must ensure their plants' reliability to fulfil the responsibility to ensure subsidized fertilizer availability in Indonesia. Plants' reliability can be achieved through proper maintenance activities, and the TAM project is one of those activities. In this context, achieving TAM project success will lead to better plant reliability, which eventually improves the company's revenue and maintains the provision of subsidized fertilizer across the nation.

It is also known that organizations try to repeat their project success and avoid recurring failure and even improve the next project by learning from previous projects (Buttler,2018). TAM projects are characterized as cyclical events to maintain and inspect the plants outside their regular operation (Duffua & Bendaya, 2019; McLay, 2011). TAM projects are conducted once every 3-5 years, depending on the type of the plants (Obiajunwa, 2010). Thus, it can be said that TAM projects offer room for learning, and the project's performance should be improved by reusing the knowledge acquired from the previous TAM.

Nevertheless, a study found that projects rarely learn from each other and thus repeat the same mistakes, resulting in rework, errors, and time overrun (Landaeta, 2008). Rework is defined as "unnecessary of re-doing a process or activity that was incorrectly implemented the first time" (Love P. E., 2002). Among others, rule- or knowledge-based issue is the most common cause of rework (Love, Edwards, Irani, & Walker, 2009). Love et al. (2009) described that a rule-based issue may be that a practitioner may simply misapply a rule that has worked in an earlier scenario, while a knowledge-based error may be a unique challenge that sits well beyond the range of his knowledge.

A study evaluated that during TAM in the petrochemical industry sector, over 90% of critiques & recommendations are never implemented, which is believed to be one of the causes of schedule slippage in approximately 50% of observed TAMs (Fertilizer Industrial Services Ltd, 2018). In addition, failure to transmit back this collected experience to the system for future improvements is a significant shortcoming in existing TAM procedures in the industry (Al-Turki, Duffua, & Bendaya, 2013)

Pupuk Kaltim is no different. TAM in Pupuk Kaltim has barely met its planned schedule since they have always had rework issues for the last 3 years (Pupuk Kaltim, 2018; Pupuk Kaltim, 2019; Pupuk Kaltim, 2020). This will negatively impact the organizations' revenue as more prolonged shutdown results in higher production loss.

Maqsood, Finegan, and Walker (2006) advocate reusing the project's past knowledge to minimize the repeat of identical mistakes, decrease abortive rework, and optimize the use of human resources by avoiding reinventing the wheel. Nevertheless, as can be seen in the paragraph above, it is essential to acknowledge that the knowledge reuse process in TAM projects still is a challenge.

1.3. Research Objective

A research objective is formulated to solve the problem statement that is defined in chapter 1.2. The aim of this research is:

To make recommendations for reducing rework events by improving the knowledge reuse between turnaround projects in Pupuk Kaltim based on assessment of the knowledge management process using activity theory

1.4. Research Questions

The objective of this research leads to the following main research questions (MRQ):

How can the rework events in turnaround projects be reduced by improving the knowledge reuse process?

In answering the main research question,4 sub-questions (SQ) are proposed as follow:

SQ 1: What is the link between knowledge reuse and rework in the TAM projects?
SQ 2: How is knowledge reuse being practiced in TAM projects through the Activity Theory lens?
SQ 3: What are the barriers and enablers of the knowledge reuse process within TAM projects?
SQ 4: What measures must be taken to address the barriers to knowledge reusing practice at TAM projects?

1.5. Report Structure

The structure of this thesis is described as follows:

Chapter 1 gives a general introduction to this research. The research objective, as well as the research questions, are presented.

Chapter 2 describes the theories and understanding related to TAM projects, rework in projects, knowledge reuse, and activity theory. The conceptual model that is used as a reference for this research are presented.

Chapter 3 describes the methodology of research that was taken to accomplish the objective of the study.

Chapter 4 provides the factors that cause rework events during TAM projects.

Chapter 5 unravels the knowledge reuse practice within the TAM project context at Pupuk Kaltim.

Chapter 6 expresses the measures that should be taken to improve the knowledge reuse process and reduce rework events.

Chapter 7 shows the validation result of both problem and preferred measures.

Chapter 8 completes this research by answering the research questions, providing scientific & practical implications, limitations, and further research.

2. Literature Review

This chapter provides a scientific background on the topic concerning this research. The literature came from academic journals, textbooks, and proceedings mainly obtained from Google Scholar, Science Direct, Scopus and other credible online sources. Conducting the initial literature review is essential in 3 ways. First, it is needed to familiarize the reader with the domain of TAM projects. Subsequently, as this is academic research, it is also necessary to review the theories that are predominantly about knowledge reuse and activity theory. Finally, a literature review is needed to find the knowledge gap that drives this research.

In section 2.1, a brief introduction about the TAM project covering its general characteristics, success definition, and stages. Next, as the focus of this research is about rework, a short introduction about rework in project is going to be presented in section 2.2. Subsequently, the concept of knowledge management that is focused on knowledge reuse is presented in section 2.3. In addition, the activity theory will also be introduced in section 2.4. Last, the conceptual research framework that summarizes the literature review and the knowledge gap will be given in section 2.5.

2.1. TAM Project

This section will present the general characteristics, the stages, and how success is defined in the turnaround project. It is expected that by reading this section, the reader will become familiar with this kind of engineering project.

2.1.1. Turnaround Project General Characteristics

TAM is defined as a planned interruption of a plant activity to execute comprehensive maintenance, inspection, or modification that cannot be done during regular operation within a relatively short period of time and limited budget (Duffua & Bendaya, 2019). The nature of TAMs is recognized as high-cost as it encompasses loss of production and maintenance cost itself, short-duration, high-risk and has impeccable scope (Sahoo, 2013; Emiris, 2014). Another essential characteristic of TAM is that it is done cyclically (McLay, 2011). It has a different typical cycle for another type of industry group. For example, oil refineries and power plants go through TAM once every 4 years, while petrochemical plants conduct TAM every 2 years (Obiajunwa, 2010).

Given the characteristic of TAM, which is temporary and having objectives that are also bounded with time and budget, TAM can be considered as a project (Hey, 2019). In addition, since TAMs require a phased approach, namely the preparation phase, the execution phase, and the termination phase, it means that TAM is a close resemblance of Engineering, Procurement and Construction (EPC) project (Hey, 2019; Sahoo, 2013; Lenahan, 2006). However, although the TAM project and EPC are similar, it does not mean that TAM should be managed identically as managing EPC projects (Ertl, 2005). That is because there are some distinctions between TAM and EPC, namely (1) the scope is dynamic and loosely defined since the scope might be increased once the equipment is dismantled, and this is (2) resulting in a work-order based, (3) requires extensive permits, (4) measured in hours or shift rather than days or weeks, (5) schedules are compressed thereby it is impossible to be accelerated (IDC Technologies, 2008). To conclude, the TAM projects are a different breed of engineering projects that need a different analysis approach.

2.1.2. Turnaround Project Stages

According to the works of literature, the complete turnaround management process can generally be separated into three parts, namely:

i. Phase 1 is the planning phase. This phase provides answers to the questions "what?" and "why?" (Levitt, 2004). The need for a turnaround is identified, and an appropriate solution is chosen and described (Sahoo, 2013). It also involves defining objectives, establishing policy, and appointing employees to form the preparation team and collect preliminary data (Lenahan, 2006). This phase also addresses feasibility and justification issues (Sahoo, 2013). One of the critical issues in this stage is that historical events or data that comes from previous TAM projects must be reviewed (IDC Technologies, 2008).
Once the objective is defined, the means to achieve it should be designed (Levitt, 2004). This is a significant point of the phase, and it is likely to take the most time. A small team of people work over a long period (months or even years). This phase should essentially cover all aspects of shutdown management, including budgets, activity definition, scope planning, schedule development, risk identification, staff acquisition, and procurement planning, among other things (Sahoo, 2013). The final stage of the planning phase entails communicating the Turnaround requirements to every person involved at any level (Lenahan, 2006).

ii. Phase 2 is the execution phase. The most significant workgroups involved in this phase. However, this group are engaged for the shortest and most intense period (Levitt, 2004). Essentially, the execution phase of a turnaround project is defined by the simultaneous completion of a large volume of tasks by many people with varying skills and from different disciplines, in a limited space and at different levels, while under time (sometimes severe) and financial pressure (Lenahan, 2006). Execution can be further subdivided into smaller sub-phases (Lenahan, 2006), all of which will fall under either ‘shutting down the facility’, ‘doing the work,' or ‘resuming operation of the plant.' Performance measures are also taken and analyzed to ensure that the turnaround is proceeding as planned. In this phase, corrective measures (in the case of unsatisfactory performance levels), as well as unplanned or discovered work (due to uncertainties relating to equipment or plant conditions), is also carried out (Sahoo, 2013).

iii. Phase 3 is the closing phase. There are two distinct elements involved in the project's termination. The first is to ensure that the plant is returned in favourable condition. The second is to de-brief every member of the Turnaround Organization. They also expected to capture the lessons learned from the event for future reference so that subsequent turnarounds can be executed more effectively (Lenahan, 2006).

With the explanation above, it is argued that TAM projects offer room to learn for organizations. One of the essential characteristics of TAM is that it happens cyclically. Therefore, it could be argued that TAM can be categorized as a “similar project” to an extent. Projects are regarded as similar when it involves similar capabilities and routines for its execution (Brady & Davies, 2004). In this context, the term “capabilities” is defined as sets of skills, knowledge, and experience required by an organization to execute projects, or in short, it is about project capabilities (Eriksson et al. 2017)

2.1.3. Turnaround Project Success Definition

Project success can be divided into 2 terms, which is tactical and strategic. In tactical terms or efficiency, a project is said to be a success when it is completed within the agreed budget and time. In contrast, success in strategic terms or effectiveness and impact is about achieving the desired outcome or the intended value once the project is finished (Samset & Volden, 2016). TAM also has various success criteria, considering that project success is subjective (Bakker, Arkesteijn, Bosch-Rekveldt, & Mooi, 2010). Several authors have defined TAM success rather than just the classical "iron triangle" (quality, budget, and time). The summary can be seen in Table 1.

Table 1 TAM success criteria from various authors as compiled by Jayakumar (2018)

		Lenahan, 1999	Duffuaa and Ben Daya, 2004	Obiajunwa, 2007	Pokharel and Jiao, 2008	Ben-Daya et al., 2009	Ghazali and Halib, 2011	Sahoo, 2013	Obiajunwa, 2013	Number of Citations
SC01	Meeting Budget	■	■	■	■	■	■	■	■	8
SC02	Meeting Schedule	■	■	■	■	■	■	■	■	8
SC03	Quality	■	■	■	□	■	□	■	■	6
SC04	Environmental incidents	□	□	■	□	□	□	■	■	3
SC05	Facility incidents	□	■	■	□	■	□	■	■	5
SC06	Personnel injuries	■	■	■	□	■	□	■	■	6
SC07	Successful commissioning	■	□	■	□	□	□	□	□	2
SC08	Contract claims	□	□	■	□	□	□	■	□	2
SC09	Stakeholder satisfaction	□	□	■	□	□	■	□	□	2
SC010	Resultant Benefits	■	■	■	■	■	■	■	■	8

In achieving successful TAM projects, there is also a critical success factor of TAM. Critical success factors are those elements of the project and its management which can be influenced to increase the chance of a successful outcome of the project (Turner, 2007). The critical success factors are (1) alignment of the turnaround commitment and corporate vision, (2) implementing structured planning and execution, (3) undertaking scope screening, (4) Applying Front End Loading, (5) using a critical path modelling tool, (6) utilize experienced contractors, (7) ensuring staff competence as well as knowledge on both technical and management fields, and (8) using lessons learned for next turnaround (Hey, 2019).

2.1.4. The Current Situation on TAM Project

A successful TAM project may be achieved by creating knowledge management practice for documenting, organizing, and sharing knowledge among the TAM project participants (Cormier & Gillard, 2009). That is because being cyclical is the TAM project's distinctive character over other engineering projects. It means that the organization should capture the knowledge at the end of the TAM project stage and plough it back into the next TAM project to continuously improve its performance (Williamson, 2019). Moreover, as Hey (2019) mentioned, it is known that reusing lesson learned for the next project is necessary to ensure the success of TAM projects.

Nevertheless, the issue of reusing knowledge between projects in general still is a challenge. Organizations are unable to adopt or execute captured knowledge (Duffield & Whitty, 2015). As a part of engineering projects, TAM projects also face the same situation. Failure to transfer acquired experience or knowledge back to the system for future improvements is a critical weakness in the industry's present TAM methods (Al-Turki, Duffua, & Bendaya, 2013). Moreover, Simoes et al. (2011) reveals that learning is one of the least studied areas within maintenance management. Hence, it is necessary to assess the knowledge reuse practice in the TAM projects domain.

2.2. Rework in Projects

As previously elaborated, TAM project success can be evaluated through various criteria. One of them is the quality criteria. In TAM projects, poor quality is depicted with a high number of rework events, startup incidents and commissioning incidents (Obiajunwa, 2010). Rework events are also one of reasons for the TAM project being behind schedule (Hey, 2019). Thus, it is necessary to reduce rework events.

To begin with, a rework event must be defined. According to Love et al. (2000), rework is the wasteful effort of repeating a process or activity executed poorly the first time. CII (2001) also defined rework as actions that must be completed several times or activities that remove previously installed work as part of a project. From these 2 definitions, it can be inferred that rework is basically redoing the work within the project's scope.

The most prevalent source of rework is a rule- or knowledge-based problem (Love, Edwards, Irani, & Walker, 2009). According to Love et al. (2009), a rule-based issue may be a practitioner just misapplying a rule that has worked in the past. Still, a knowledge-based error could be a unique difficulty that is way above his expertise.

The process of learning, in particular when the knowledge created in projects is allowed to move inside and between organizational members, is a fundamental principle that permits rework to be avoided in the future (Love, Ackermann, Teo, & Morrison, 2015). Maqsood, Finegan, and Walker (2006) also propose utilizing the project's previous knowledge to prevent repeating identical mistakes, reducing abortive rework, and optimizing the use of human resources. Therefore, it is also necessary to understand about knowledge reuse, which will be elaborated in the following sub-section.

2.3. Knowledge Reuse Theory

Knowledge can be defined as “a fluid mix of framed experience, values, contextual information and expert insight.” (Davenport & Prusak, 1998). According to Polanyi (1967), knowledge can also be divided into 2 forms, tacit knowledge and explicit knowledge. Tacit knowledge is context-specific and highly personal, which implies that it is stored in humans’ minds resulting in difficulties formalising and communicating (Polanyi, 1967). On the other hand, explicit knowledge is codifiable. It is stored as a written document or procedure that is easier to share and reuse (Egbu & Robinson, 2005).

Knowledge management (KM) is deemed to be essential for project-based organizations (PBO). In this organization, most of the products or services are delivered by having a project (Turner & Keegan, 2000). In the infrastructure business, incorporating knowledge from successful and unsuccessful projects into current project management procedures has become a need for being profitable and competitive (Liu, 2021). Haussner et al. (2018) cited that generating, managing, and reusing the knowledge has been identified as a critical prerequisite for long-term organizational goals. These include achieving and maintaining competitive advantages and avoiding past mistakes.

KM is defined as any systematic practice of creating or acquiring, documenting, sharing, and re-using knowledge, wherever it resides, to enhance learning and performance of both productivities and the effectiveness of members in organizations (Swan, Scarbrough, & Preston, 1999). Schacht and Maedche (2016) have compiled existing literature on knowledge management processes. They conclude that there are 5 main cyclical processes: knowledge acquisition, documentation, transfer, reuse, and protection.

Moreover, to ensure that the KM process can ultimately work, Markus (2001) has developed 3 prominent roles. First, the knowledge producer owns the knowledge and may transform it into an explicit document. Secondly, there is also a role of knowledge consumer who is seeking and eventually applying the knowledge. Between the first and second roles, the last role is called knowledge intermediary, which forms various functions in knowledge dissemination and facilitation (Markus, 2001). In their study, Schacht and Maedche (2016) expanded the role of knowledge intermediary as lessons learned expert and topic expert. Lesson learned expert orchestrates a lesson learned session where they plan, moderate, and document the captured knowledge. On the other side, the topic expert acts as a consultant during the knowledge reusing process. They search, prepare, and present the relevant knowledge to be reused (Schacht & Maedche, 2016). Thus, it can be concluded that there should be 4 roles in implementing KM.

Particularly in knowledge reuse, there are several paradigms for knowledge reuse in the literature. Some academics have created frameworks for knowledge reuse in the context of innovation (e.g., Majchrzak et al. 2004). In contrast, others have created frameworks for knowledge reuse in the context of replication (e.g., Szulanski 1996). Markus (2001) has developed a theory on knowledge reuse. The occurrence of knowledge reuse is categorized based on the distance between knowledge producer and re-user and the intention to reuse the knowledge. Markus' (2001) theory on knowledge reuse is going to be the main theoretical foundation in this research.

Markus (2001) defines 4 main situations: shared work producer, shared work practitioner, expert seeking novice, and secondary knowledge miner. Each situation is summarized below:

Table 2 Knowledge reuse situations, adapted from Markus (2001)

	4 types of Knowledge Reuse Situations			
Aspect	Shared Work Producer	Shared Work Practitioner	Expert-seeking Novice	Secondary knowledge miner
Relationship between knowledge producer and consumer	Producer and consumer are the same entity	Producer and consumer is different in terms of situations or settings	The consumer is a novice hence substantially different with producer although come from the same field of knowledge	Consumers and producers are from other areas of knowledge

	4 types of Knowledge Reuse Situations			
Aspect	**Shared Work Producer**	**Shared Work Practitioner**	**Expert-seeking Novice**	**Secondary knowledge miner**
Intention to use	Monitor and maintain current status and things that need attention	Get advice on how to handle new situations or problems	Solve an ad hoc problem	Create new knowledge
Example	Software support team access previous maintenance record	Oil field maintenance team across continents	A customer accessing product FAQ list	Data mining to see a particular trend

Knowledge reuse is part of the KM macro process, as Schacht and Maedche (2016) described. Nevertheless, zooming in on the knowledge reuse part itself, there is also a micro process. Markus (2001) defines that the order of the micro process starts from identifying and defining a problem, pinpoint the potential source of knowledge (an expert for tacit knowledge or expertise for explicit knowledge), selecting the appropriate source of knowledge, applying the knowledge. Finally, Petter & Vaishnavi (2007) adds the final step as integrating the knowledge where the result of reusing the knowledge is registered.

Petter & Vaishnavi (2007) also incorporate the generic barrier of the reuse process from an individual point of view in their model. The barriers consist of but are not limited to uninformed about the source of knowledge, poor quality of knowledge source, informational limbo (Almeida & Soares, 2014), inability to adapt with the knowledge and lack of time to register the result of reusing the knowledge (Petter & Vaishnavi, 2007). Koteshwar, Bengtsson, & Söderlund (2015) conducted a study on knowledge reuse in maintenance activity at a global automotive industry where they identified knowledge reuse challenges. This study then intensifies the conceptual propositions of the knowledge reuse barrier initiated by Petter & Vaishnavi (2007). The complete barriers for each phase of the knowledge reuse micro process can be seen in **APPENDIX A.**

Nevertheless, to the best of the author's knowledge, the literature about knowledge reuse in maintenance management is scarce. Koteshwar, Bengtsson, & Söderlund (2015) recommends conducting similar research but in different company settings. Moreover, on the theme of project management, it is found that there is a need to define how learning between projects is done for different contexts and businesses (Chronéer & Backlund, 2015). In addition, there is no single best way for an organization to learn, as the benefits and appropriate mechanisms depend on the firm and its situation (Dutton, Turner, & Lee-Kelley, 2014). Having said that, doing research on the knowledge reuse process in the TAM projects domain, which is at the crossroads of maintenance and project management, is thought to be helpful for scientific contribution.

2.4. Activity Theory

Activity theory (AT) is a psychological and social science approach that seeks to comprehend individual human beings and the social entities they comprised in their natural everyday living conditions by examining their activities' genesis, structure, and dynamic (Kaptelinin & Nardi, 2006). Judging by the definition, it is logical to say that the unit of analysis of AT is obviously an activity(-ies). AT is based on Vygotsky's concept of tool mediation and Leont'ev's concept of activity (Mwanza, 2001). In 1978, Vygotsky investigated individual learning and developed a triangle action model that investigated the relationship between human behavior and mediation (Kinsella, 2018). In 1987, Engestrom broke down the mediation into several aspects such as tools, rules, and division of labour. He also introduced a community element as human activity is perceived as collective and collaborative (Mwanza, 2001). The generic model of AT can be seen in Figure 1.

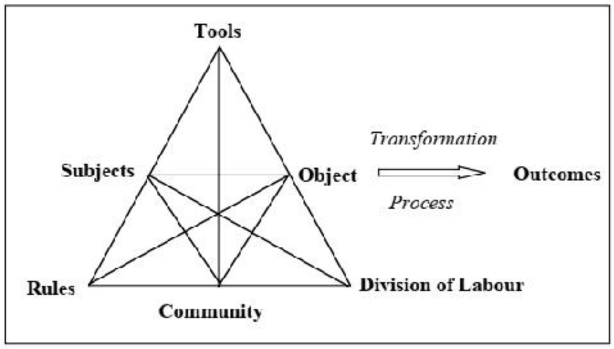

Figure 1 Activity Triangle Model (Engestrom, 1987)

The subject in this paradigm is the individual or groups of individuals conducting the activity. The tool contains artefacts that can serve as resources for the activity's subject in dealing with the object. The object is the activity's goal or purpose. The rules are any official or informal regulations that can influence how the activity is carried out to various degrees. The community is the social group to which the person belongs when participating in an activity. Lastly, the division of labor refers to how duties are distributed throughout society.

Other than that, Engestrom (1987, as cited in Vakkayil, 2010) also introduces contradictions. Contradictions, in essence, is a mismatch within a particular aspect of the activity system, between different parts within the system, or between multiple activity systems (Kutti, 1996). Engestrom (1987, as cited in Vakkayil, 2010) described that there are 4 types of contradictions. Vakkayil (2010) explained that the primary contradictions represent the inner tensions in each activity aspect. Secondary contradictions are those that arise between the elements of the activity system, such as tools and labor division. Tertiary contradictions reflect a clash between the current activity and a more evolved cultural form of the activity. The tension between the core activity and its peripheral activities is represented by quaternary contradictions.

However, Engestrom said that "*contradictions are not the same as problems or conflicts*" (2001, p. 137). Contradictions are the key to changing the system consisting of multiple activities (Marken, 2006). Contradictions have an impact on human behavior by introducing pressures that can either stimulate or stifle progress or provide the cause for changing the nature of the activity (Engeström 1993 as cited in (Yamagata-Lynch, 2010)).

The idea of Activity Theory also has developed over time. Engeström and Sannino (2020) identify four generations of the theory. This research will be focused on the third generation of activity theory. Engeström and Sannino (2020) described the third generation of activity theory as a step further way of analyzing activity as the basic unit of analysis, which is not only focusing on internal contradictions within an activity system but also multiple activity systems that share a common outcome and/or environment and even elements. This third generation introduces 2 new essential elements, which is called boundary objects and boundary spanners.

Star and Griesemer (1989) defined boundary objects as: *"…..flexible epistemic artefacts that 'inhabit several intersecting social worlds and satisfy the information requirements of each of them', adaptable to different viewpoints while being robust enough to maintain identity across them*". According to Wenger (2000), boundary objects can be categorized into 3 categories. The first category, dubbed artefacts, contained things like tools, models, and papers. The second is referred to as discourses. It is defined as a common language used to guarantee that individuals could interact across boundaries and negotiate meanings across communities. Processes are the last category, which includes routines and procedures designed to achieve cooperation among diverse groups. The development and maintenance of border objects are critical in creating and sustaining coherence among crossing communities with overlapping activities (Bowker & Star, 2000).

The second element, which is boundary spanners, is described as the activity's actor who continually moves across borders and is involved in several activities (Vakkayil, 2010). Vakkayil (2010) also explained that the boundary spanners could develop expertise as they are engaged in various activities, both spatial and temporal dimensions. He defined spatial dimensions as a dimension that shows the coexistence of two or more activities. In contrast, a temporal dimension is how these objects and people have transitioned from one activity to the next across time. From organizational kinds of literature, one of the examples of boundary spanners is a knowledge broker. Knowledge brokers might bring new ideas to a community due to their positions at the periphery of their communities and their simultaneous membership in other communities (Eckert, 1989 as Vakkayil, 2010).

To conclude, it is found that AT components are the appropriate beginning point for analyzing an activity. Moreover, it also may uncover contradictions among or within activities, thereby helpful in designing intervention or scenario. Thus, this framework would be used to identify the problem of knowledge reuse within the context of a TAM project.

2.5. Conceptual Research Framework

By conducting a literature review, it can be said that it is necessary for the scientific purpose to conduct a knowledge reuse process evaluation within the TAM project setting. Firstly, it is found from the literature that organizations are still failing to adopt or reuse captured knowledge. TAM, as a part of an engineering project, also encounters a similar issue. Many pieces of literature emphasize the need to plough back the captured knowledge into future TAM projects. Nevertheless, it is found that the failure to transmit learned experience or information back to the system for future improvements is a significant flaw in the industry's current TAM techniques. In addition, to the best of the Author's knowledge, the literature regarding knowledge management within the TAM project domain is still scarce. Thus, conducting research about the knowledge reuse process using the TAM project domain as a scene is regarded as an attempt to fill the knowledge gap.

As already presented before, turnaround projects consist of 3 stages, planning, execution, and closing. Moreover, it is known that the TAM project relies upon the knowledge that is captured from the previous project to ensure future TAM projects. It means that there should be a knowledge reuse process being practiced. In knowledge reuse process, it must be preceded by knowledge acquisition, documentation, and transfer. The process of adopting or even adapting existing knowledge comprises defining the problem, pinpointing knowledge, selecting knowledge, applying or adapting the knowledge. Eventually, the result should be reintegrated. These two concepts of TAM projects and the knowledge reuse process involve numerous activities and are related from one to another. AT is a framework that uses activity as the unit of analysis. Hence it is plausible to assess the knowledge reuse activities in turnaround project stages using AT elements. The conceptual framework can be seen in Figure 2.

This conceptual framework describes that in this research, an evaluation will be performed in all three TAM stages, planning, execution, and closing, while focusing on the knowledge reusing process. On the subject element, the actors who carry out the activity will be identified. It is also necessary to determine what tools are used to manage the knowledge on the tool element. For instance, what tool that is used as the source to re-use the knowledge. The rules that govern the process of re-using knowledge must also be identified, whether there is a guide or manual to do such knowledge re-use process. The community that the process of re-using knowledge will be assessed by Markus (2001) four knowledge reuse situations. This is necessary to see whether the current practice is aligned with what Markus (2001) recommends for each situation. The division of labor will be assessed by considering the four essential roles of implementing the knowledge reuse process. Lastly, the objective of each activity will also be established accordingly. Eventually, AT may reveal contradictions, an important feature required to identify the cause of the inability to reach the outcome and intervene in a situation.

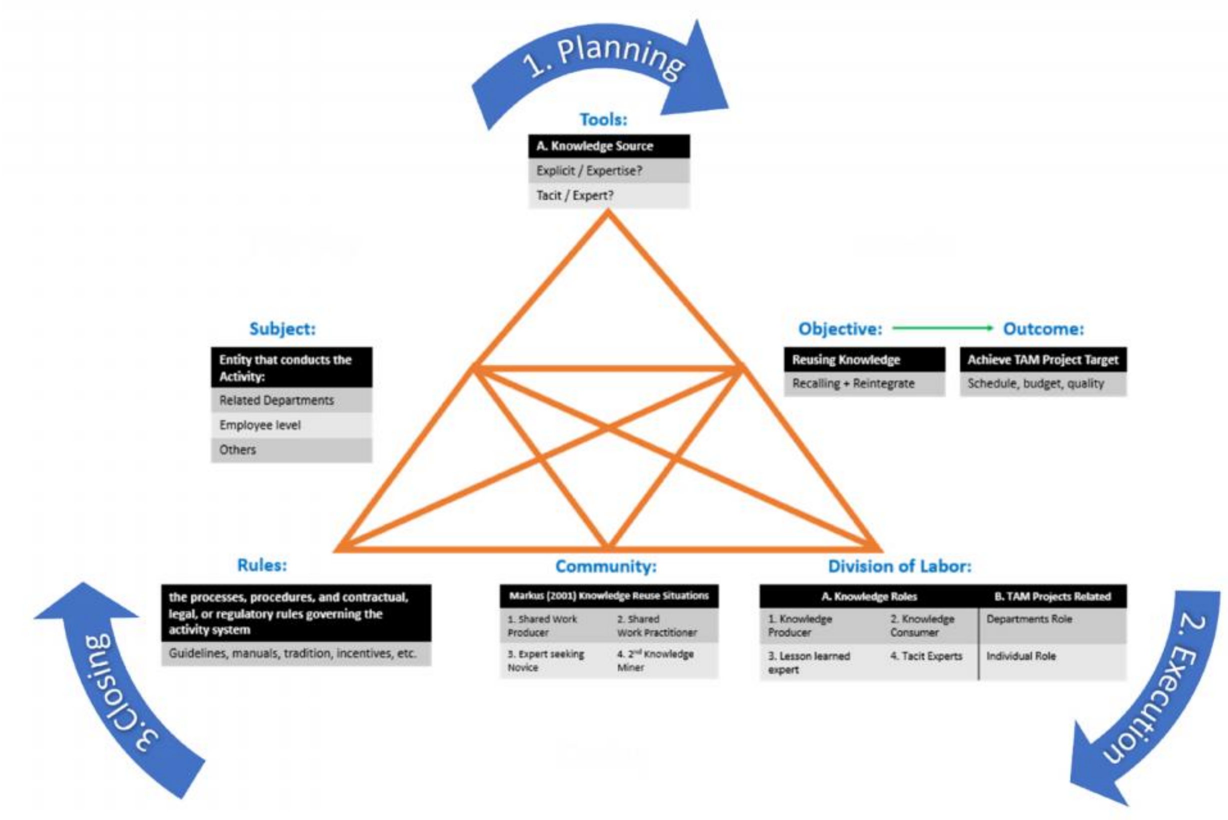

Figure 2 Theoretical Framework for Research

3. Research Methodology

This chapter describes how the research was planned and carried out. In general, research methodology begins with the research framework in section 3.1. Next, section 3.2 will describe the data collection process that comprises case study selection, desk research process, interviewee profiles and semi-structured interview process. Subsequently, the data analysis process will be given in section 3.3. Finally, the validity of this research is explained in section 3.4.

3.1. Research Framework

This thesis is regarded as qualitative practice-oriented and diagnostic research. A qualitative research method is selected as it involves garnering an in-depth understanding of issues such as process, situation, scene or set of social interactions (Dworkin, 2012). Moreover, being practice-oriented means that this research is built bottom-up, focusing on subjectively describing a process based on identified local actions (Blomquist, Hällgren, Nilsson, & Söderholm, 2010). On the other hand, by conducting diagnostic research, it is expected to contribute an intervention act to change an existing practical situation (Verschuren & Doorewaard, 2010)

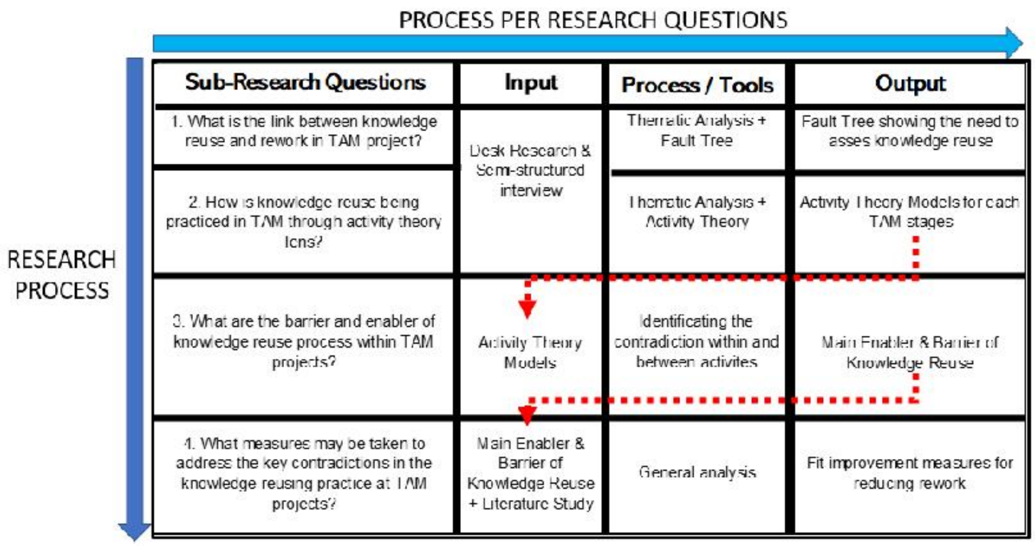

Figure 3 Research Framework

A research framework is presented in Figure 3. A research framework is a schematic representation of appropriate steps that must be taken to achieve the research objective. In this research, the whole research process follows the order of research questions which is going to be elaborated in the following points:

1. The first sub research question is needed to justify the need to evaluate the existing knowledge reuse practice. This research question will be answered using the data obtained from the desk research and semi-structured interview process. The output of this first sub research question is the fault tree that explains the cause of rework events in TAM projects.
2. The second sub research question is answered to understand the current knowledge reuse within the TAM project scene. This second sub research question will also be addressed utilizing data from desk research and semi-structured interviews. Using the

Activity theory model, the current situation in each TAM project stage will be presented as the output.

3. The output from the second sub research question is needed to answer the third sub-research question. Contradictions are mismatches within a given activity system element, between different elements within the system, or between other activity systems (Kutti, 1996). However, contradictions are not recognized independently; they are recognized when practitioners express and build them in words and behaviour (Sannino & Engeström, 2018). Thus, it should already be apparent the second and third sub research questions must be distinguished. The identified contradictions become the basis to define the enablers and the barriers of the knowledge reuse process.
4. Finally, once the barriers and enablers of the knowledge reuse process were known, the measures were proposed. Another study of the literature was performed on tools and approaches or concepts accessible and recognized in the literature to improve the knowledge reuse process. This thorough literature evaluation was carried out at the end of the research process. Following that, measures were chosen by connecting the present knowledge reuse process barriers to recognized best practices, tools, and methodologies, resulting in fewer rework events. For this sub research question, the literature review process will be elaborated further in Chapter 6**.**

3.2. Data Collection

This section explains the source of data that is used in each phase of the research. The data comes from the company's documents relevant to TAMs. At the same time, the interview sessions were done with people also from the same company. Each data collection process will be explained further in the following subsections.

3.2.1. Case Study Selection

As previously said, this thesis is classified as a qualitative practice-oriented and diagnostic study. This signifies that this research aims to get an in-depth process based on identified local action. Moreover, this research also attempts for an intervention act to modify a current practical situation. Thus, the case study is the best method. It allows researchers to identify relationships more effectively because it aims to explore a contemporary event in-depth and in its natural environment (Yin, 2018).

Pupuk Kaltim has 5 plants, namely Pabrik 1-A, Pabrik-, Pabrik-3, Pabrik-4 and Pabrik-5. The profile of the plants can be seen in the Table 3.

Table 3 Pupuk Kaltim's Plants

Plant Name	Ammonia Licensor	Urea Licensor	First Startup	Urea production/year (Ton)	Ammonia Production/year (Ton)
Pabrik-1A	Haldor Topsoe	Stamicarbon	1999	570,000	660,000
Pabrik-2	Kellog	Stamicarbon	1984	570,000	595,000
Pabrik-3	Haldor Topsoe	Stamicarbon	1989	570,000	330,000
Pabrik-4	Haldor Topsoe	Snamprogetti	2002	570,000	330,000
Pabrik-5	KBR-Purifier	Toyo-Aces 21	2011	1,150,000	825,000

Source: https://www.pupukkaltim.com/en/plant-production-profile-unit

This research is essentially conducted to see whether the knowledge from one project is reused in another project. Thus, multiple case studies were used. In this research, the selected case studies were the TAM Projects at Plant 1-A in 2018, P-5 in 2019 and P-2 in 2020. The reasons for choosing these cases are threefold.

First, the selected case studies should be the latest as they must represent the most updated situation of the company. For the last 3 years, these are TAM projects that have been executed by the company, which has complete closeout reports. The second reason is, the case studies must be comparable, which means that the scale of the project should be similar. These 3 cases incorporated all units such as the ammonia, urea, and utility unit in the scope of work. Lastly, there must be a considerable degree of difference between the three case studies. This is required to determine whether the acquired knowledge may be reused across projects. Specifically, whether the resulting knowledge may be reused but in a different plant.

3.2.2. Desk Research Process

In this study, desk research is defined as studying various existing documents from the object of research. The existing documents are the ones related to the TAM execution at Pupuk Kaltim. In this study, the source documents are:

1. Pupuk Kaltim. (2020). Turnaround Management Procedure. Bontang.
2. Pupuk Kaltim. (2018). *Closeout Report Turn-Around Ke-I Pabrik 1-A*. Bontang.
3. Pupuk Kaltim. (2019). *Closeout Report Turn-Around Ke-III Pabrik 5*. Bontang.
4. Pupuk Kaltim. (2020). *Closeout Report Turn-Around Ke-XVIII Pabrik* 2. Bontang.

The documents are in pdf format and were obtained through email correspondence with the thesis supervisor from the company.

The first document source was read through to understand how the TAM project should commence in the company. Moreover, it was also scanned to see whether it governs the process of knowledge reuse process. The interesting information that is relevant to answer the sub research questions were coded in the Atlas. TI software. Lastly, it was also used to define the interview participants, elaborated on in the following subsection.

The second, third, and fourth documents were used to evaluate the current TAM project performance. Furthermore, as this research focuses on reducing rework events, then the documented rework events were reviewed. Namely, the description of the event itself, the causes and the follow up of this event.

3.2.3. Interviewee Profile

The selection of the interviewees is based on Pupuk Kaltim's Turnaround Management Procedure (2020). In general, there are three categories of actors that are involved in the company's TAM. These three categories can be seen in Figure 4.

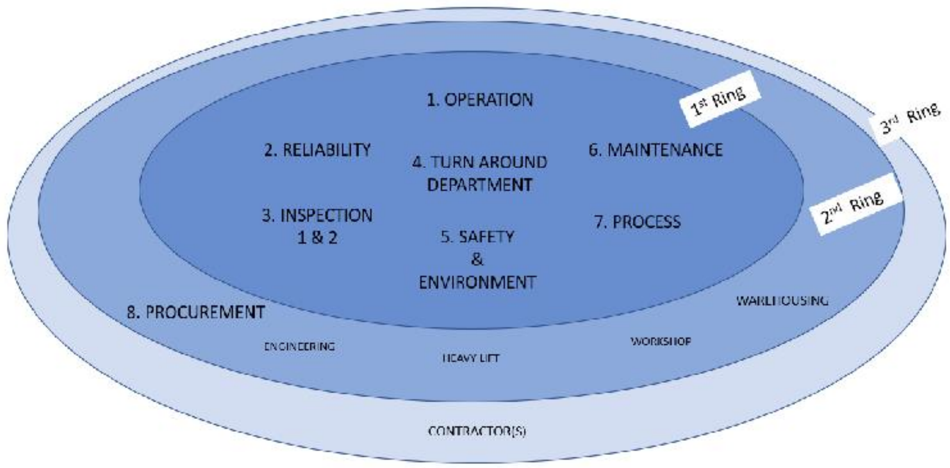

Figure 4 Actors in Company's TAM

According to the company's Turnaround Project Management procedures, the 1st category consists of Operation, Reliability, Inspection 1 & 2, Turnaround Department, Safety & Environment, Maintenance and Process Engineering Department. These actors are the departments within the company and are deemed vital because they are responsible for designing the TAM's target and master plan (Pupuk Kaltim, 2020). In addition, according to the turnaround project management procedure, these actors are the ones who are responsible for providing closeout reports for the closure phase. In the 2nd ring, these actors are also departments within the company. Yet, they are only responsible for attaining the project's target that has been designed by the actors from the 1st ring. Finally, the 3rd ring consists of actors outside the company, primarily contractors, consultants, or material suppliers.

Considering that the focus of this study is the learning situation within the company, thus the focus will be on the 1st ring. The interviews were done with nine members of the 1st ring, ranging from staff to managerial roles, thereby enhancing triangulation. The interviewee profiles can be seen in the following table:

Table 4 Interviewee Profiles

Department	**Code**	**Experience**	**Role**
Process Engineering	M1	>10 years	Responsible for managing the work under the scope of process engineering & proposing as well as validating the performance target of a turnaround project
Maintenance	M2	>10 years	Responsible for managing the work under the scope of maintenance
TAM Department	M3	>20 years	Responsible for coordinating the whole turnaround project management

Department	Code	Experience	Role
Safety & Environment	M4	>10 years	Responsible for managing the safety target during the turnaround project
Inspection	A1	>10 years	department representative during the whole turnaround project stages and coordinate the work scope of the inspection
TAM Department	S1	> 5 years	Day to day staff to manage TAM project
Inspection	S2	>5 years	Day to day executor of inspection work
Process Engineering	S3	>5 years	Day to day executor of process engineering work
Mechanical Maintenance	S4	>5 years	Day to day executor of maintenance work

3.2.4. Semi-structured Interview

The 1st and 2nd sub-research questions also use a semi-structured interview as the primary source of the data. The interview is conducted as this method allows the interviewer to see the respondents' perceptions and interpreted the respondent's perceptions (Weiss, 1995). The semi-structured interview is chosen as it still provides flexibility to pursue topics of specific interest to the respondent while still maintaining a degree of arrangement (Bryman & Bell, 2011).

The interview method adheres to the principles recommended by Yin (2016), which include speaking in a modest quantity, avoid asking leading questions, casting a neutral tone, maintaining a solid relationship with the respondent, utilizing an interview guide, and analyzing when interviewing. To assure the consistency of the results, each interview was performed in the same way. The protocol was taken as follows:

1. Propose
   Through formal and informal communications, the interviewees were proposed to participate in the interview. It includes a brief description of the research and why the interviewee's experience and knowledge are crucial in the interview process.
2. Planning
   The interviews were carefully organized because all interviewees live in Indonesia, where there is a 6-hour time difference from the author's local time. The date and time of the interview were arranged in formal and informal conversations, and once agreed upon, the author provided a video conference connection via Zoom.
3. Permission
   Permission to videotape the interview were asked at the beginning of the interview. In addition, interviewees were also asked for their consent about using their answers for the research. Finally, the data gathered during the interview was anonymized to protect the interviewee's privacy.

4. Process
   Each interview session lasted about an hour and consisted of two primary sessions. Following the presentation of the research information, the interview process proceeded. The first session is used to gather information for the first research question. In contrast, the second session is used to collect information for the second research topic. The first interview session focused on rework events and their causes, while the second examined the knowledge reuse process at each TAM level. The sample of interview questions from both the first and second sessions are available in **Appendix B.**
5. Preserving
   Notes are preserved anytime a respondent provides exciting information. To keep the interview moving, follow-up questions are created right away. The list of questions was verified throughout the interview to confirm that all essential subjects were covered.

This process is performed for each interview. A pen and paper to make notes, a list of questions, Zoom apps, and Google Voice Typing to aid in the transcription process is required for the interview.

3.3. Data Analysis

Interview sessions were conducted using *Bahasa Indonesia,* the native language for the author and the interview participants. As a result of employing the native language, the data is rich and thorough since participants were encouraged to offer in-depth and lengthy replies. Once the interview was done, then the record was transcribed.

Although the interview sessions were conducted in *Bahasa Indonesia,* the transcripts were carefully translated back to English. The translation is not literal to avoids grammatical problems and unnecessary information in the context being discussed. The transcription and translation results were then double-checked for final confirmation of the raw data interviews. This process was repeated in all interviews. Subsequently, using Atlas. Ti, the transcripts were coded and compared to the result from the desk research.

To answer the first research question, the causes of rework events are categorized. Next, the operators of causes were also derived. That is, whether the event is a series or parallel. Then, the result of the interview transcript coding was compared to the rework events available from the closeout report as a means of triangulation. Finally, using fault tree analysis, causes of a rework within TAM projects can be identified.

To answer the second research question, the translated transcripts were also coded using Atlas.TI per the conceptual framework in Figure 2. That is, which excerpt corresponds with the rule, tools, or division of labor, for instance. Moreover, the transcripts were also compared to the company's existing turnaround project manual document as a means of another triangulation.

3.4. Validation Process

The validity of study results is achieved using various techniques proposed by (Maxwell, 2013): triangulation and comparison. The triangulation is accomplished by asking the similar questions to several interviewees. In this research, the comparison is performed by comparing the answer to sub research questions with experts' opinions.

3 expert interviews were conducted to validate the research findings and, more significantly, the applicability of the suggested measure. The experts chosen are deemed objective since they had no influence, input, or knowledge of the research. The involved experts have > 20 years of experience in the field. 2 experts were retired ex-chief maintenance officers in Pupuk Kaltim. The other specialist works as an advisor for an oil and gas firm in the Middle East. Further explanation of the validation process and its result can be seen in Chapter 7.

4. Causes of Rework Events in Plant Turnaround Maintenance Projects

This chapter will attempt to answer the first research question, "*What is the link between knowledge reuse and rework in the TAM project?".* First, in section 4.1, the empirical findings from the desk research and the interview sessions will be presented. Subsequently, in section 4.2, the fault tree that shows the cause of rework will be shown. In section 4.3, the empirical findings will be discussed with the available works of literature. Last, the summary of this chapter will be given in section 4.4.

4.1. Empirical Findings

This section will provide the data that is gathered from the desk research and the first interview sessions. Later, these presented data will be used as the basis to form the fault tree.

4.1.1. Desk Review Result

The document used for this chapter is the TAM manual, closeout reports from the 3 selected case studies already explained in section 3.2.2. These documents were scrutinized, and valuable information relevant to the research objective is given below.

- *Current TAM Project Performance*

Looking at Pupuk Kaltim's turnaround project close out the report over the last three years, its performance can be summarized in Table 5 as follow:

Table 5 Pupuk Kaltim's Turnaround Project Performance Summary (Pupuk Kaltim, 2018; Pupuk Kaltim, 2019; Pupuk Kaltim, 2020)

Plant	Year	Safety Criteria	Environment Critera	Post Turnaround Performance		Budget Target	Quality Target	Time Target
				Production Target	Energy Target			
P-1A (Ammonia & Urea)	2018	Achieved	Achieved	-Ammonia is achieved -Urea is not achieved	-Ammonia is achieved -Urea is achieved	Achieved	Not Achieved	Not Achieved
P-5 (Ammonia & Urea)	2019	Achieved	Achieved	-Ammonia is achieved -Urea is achieved	-Ammonia is not achieved -Urea is achieved	Achieved	Not Achieved	Not Achieved
P-2 (Ammonia & Urea)	2020	Achieved	Achieved	-Ammonia is Achieved -Urea is not Achieved	-Ammonia is achieved -Urea is achieved	Achieved	Not Achieved	Not Achieved

At Pupuk Kaltim, the quality target is defined as "*No rework and no unscheduled shutdown after Ammonia and Urea production (due to internal factors)*" (Pupuk Kaltim, 2018; Pupuk Kaltim, 2019; Pupuk Kaltim, 2020). And time target is defined as a particular duration planned to complete a turnaround project (Pupuk Kaltim, 2018; Pupuk Kaltim, 2019; Pupuk Kaltim, 2020). Nevertheless, from the table above, it can be implied that the turnaround project success criteria in Pupuk Kaltim are not fully achieved. The quality and time target has not been accomplished for the last three turnaround projects.

It is worth mentioning that the performance target such as production throughput and energy consumption is also not fully achieved. However, as this research focuses on project management discipline, then the concentration will be more towards quality and time target.

- *Causes of Rework*

The rework events that occurred for each case study can be seen in the following table.

Table 6 Causes of Rework Based on Desk Research

Case Studies	Rework Event	Causes
P-1A, 2018	In the ammonia area, there was a leak in the diaphragm gasket E-0500	The installation of the diaphragm and jig tool is not following the equipment vendor drawings.
P-5, 2019	The hold-down grid is damaged at CO2 removal during the startup process	Debris from the job of replacing pall rings was plugging the hold-down grid.
P-2, 2020	during the startup process, it was found that tube row 7 no 41 experienced a hot tube event	It was found that the top tube condition in the connection area with the inlet socket was not perforated by a 3rd party

Each case study will be elaborated individually in the following bullets.

- P-1A, 2018
  In the P-1A turnaround, the rework happened in the ammonia unit. In the ammonia unit, there was a leakage after a repair on one of the ammonia plant unit equipment that resulted in an unscheduled shutdown. Work must be repeated to mend the issue, and it took additional 4.4 days to complete it (Pupuk Kaltim, 2018). It was found that the executor was misinstalling the equipment's cover, which damaged the gasket. As a result, the gas leaked out from the equipment, and the plant must be shut down.
- P-5, 2019
  In the P-5 turnaround, the schedule was extended by 8.08 days as there was a rework at the CO2 removal stripper (Pupuk Kaltim, 2019). It was found that there was a sudden high pressure during the plant startup process and resulted in a damaged hold down grid. When the equipment was dismantled, it was found that there was much debris. It was identified that the debris was coming from the work of catalyst replacement. Therefore, the equipment must be cleaned up, and the existing catalyst must be entirely replaced with the new ones.
- P-2, 2020
  In the case of the P-2 TAM project, the rework event causes a delay of 0,83 days (Pupuk Kaltim, 2020). During the plant startup process, it was found that there was a hot tube event at the primary reformer. The plant startup process must be terminated, and once the equipment is cool enough, it must be dismantled. Once it was dismantled, it was found that there was a defect in the repair, as there was no hole where it was supposed to. Consequently, the 3rd party commissioned to conduct the work must be responsible for drilling the hole according to the design. It is plausible to say that this rework event cannot be solely addressed to the 3rd party. Instead, there should be a supervisor who ensures the 3rd party quality of work.

From each case study, it can be derived that rework events at the TAM project always results in schedule slippage. This will harm the company's revenue and its responsibility to provide subsidized fertilizer across the nation. That is because the extra time needed to finish the turnaround project means less time for the production days.

- *Attempts to Reduce Rework*

Rework event is recorded, but it is not standardized. In Closeout report P-1A 2018, rework events are presented in chapter III, whereas at closeout report P-5 2019 at chapter VI. Moreover, some of the reports have an attachment that dedicated discuss the rework event, whereas the others do not. In addition, it can be seen that there is a repeating suggestion from one closeout reports to another. As a piece of evidence, in the closeout report of P-5 turnaround in 2019, one of the suggestions was,

> The implementation of tum around is always constrained by less-than-optimal preparation. Proposals and mitigation items to be included in the list of turnround items mostly appear near the tum around implementation period.

Surprisingly, on the closeout report of P-2 turnaround in 2020, the suggestion was,

> There are still additional items & modifications that cannot be done during the turnaround implementation due to a lack of data from operations and executors who are proposed to be incorporated as TA items during gatekeeping (planning) stage

The suggestion in terms of improving planning was always recurring. This also raises the question of how the knowledge reuse process is implemented.

4.1.2. Semi-Structured Interview Result

This part will provide the empirical findings based on the first interview sessions that discuss the rework events at the TAM Project. Moreover, this data collection process was also done as a means of triangulation to the data that was gathered from the desk research process.

- *Rework Definition*

It must be noted that the definition cannot be found in any documents. Thus, the definition is derived based on interview sessions, which can be concluded as,

"Re-doing the same work on the equipment that was within turnaround scope of work and failed during startup process up to 3 months of operation under normal conditions."

- *Causes of Rework*

During the interview sessions, the interviewees were asked about their experience of the causes of rework events. The interview transcripts were coded, and the results can be seen in the following table.

Rework Causes	Transcript examples
Hidden Defect in Equipment	➢ Every factory has its own characteristics in terms of various equipment. Consider the manufacturer of compressors. Each manufacturer has its own feature. (M3) ➢ At startup, the ammonia block valve is broken. We traced the fracture backwards, took a sample, and tested it; it turns out that the crack has been present for a long time. In fact, it was known from the prior TA report that there had never been a failure. Therefore, there was no need to check. This, I believe, is a type of hidden defect. (S2)

Rework Causes	Transcript examples
Spare parts quality	➢ After two months of operation, issues in the downstream secondary reformer unit surfaced. The facility was then shut down again because the dirt was found in the heat exchanger. The alumina ball had been abraded, and thus we must replace it with the new ones. (S3) ➢ It could also be due to spare part flaws. For example, suppose we need to replace the compressor rotor with a new spare. The test results indicated that it was fine, but when it was fitted, the vibration was severe. This will necessitate in rework event. (S4)
Poor Execution Plan	➢ The rework events, I believe, is caused by the incomprehensive gatekeeping process in determining TA items. This results in an enormous scope of work, not to mention that the work itself may not be adequately planned. (M3) ➢ Rework occurs during TA, usually as the first step, because the work should not be done but is being forced to be done. As a result, a temporary plan is implemented. Because it is quick, there is a considerable risk of equipment breakdown due to poor repair in the middle of the operation period. (S3)
Inattention to WI	➢ Okay, there are Work Instructions (WI), but do you always read them before starting work? No, not always. They rely on their own experience more. The issue is that everyone's experience is unique. Isn't that correct? So that it can be a hindrance during execution when A encounters barriers or problem X even though the others have previously passed that. (M1) ➢ Some people install gaskets without first examining the Work Instructions. As a result, the gasket can be installed in an angled or pinched position. After inspection, it may be discovered that it was tilted, so the gasket was discarded and required rework. (M2)
Knowledge Gap	➢ Perhaps it's because the mechanics have recently been rotated. If he is switched from ammonia to urea, his knowledge will need to be readjusted and updated. (M3) ➢ The problem of knowledge is that it is too unequally distributed between new and senior employees. Previously, the pioneers (senior employees) lacked documentation. They place a greater emphasis on experience (tacit knowledge). As a result, because there is no material to learn, it is difficult to achieve the same skill level. Furthermore, some equipment can only be dismantled during TA. So, if you are not participating in TA, you will not be knowledgeable. (S4)
Lack of Supervisor	➢ For example, there is 4 equipment that must be assembled at a time. While there is only 1 supervisor, he absolutely cannot keep an eye on the 4 of them simultaneously. Well, that is obviously prone to rework. (S4) ➢ For example, suppose there is an exchanger coordinator whose performance is poor; in this case, he does not adequately coordinate with us. He does not inform the working conditions regularly, and only when critical events occur does he do so. This will cause us, as planners, to rush to plan follow-up actions. (S1)

- *Attempt to Reduce Rework*

Rework events can be argued as a form of knowledge. The practice of identifying and classifying can also be considered as capturing activity. Hence, it can be said that one of the ways in dealing with a rework is through a proper capturing process. Nevertheless, such a practice does not exist in Pupuk Kaltim. S4 explained during the interview,

> The note (about rework) is just in the memo to file (in the final report). However, it is not compiled correctly. Thus, it is dispersed.

This is true as the author has identified the rework events through examining the closeout report, which is already presented in section 4.1.1. As a result, the dominant causes of rework events cannot be identified. Had they had a proper documentation process, then the knowledge about rework events and the causes can be reused to prevent it from reoccurring.

In dealing with rework events that are caused by the hidden defects, A1 explained,

> Rework should not be repetitive. Because when a failure happens, we in the inspection department eventually add the failed item to the inspection list and prepare for the following turnaround project, both for the same plant and others.

Regarding the quality of the spare parts, S3 followed up his story about the alumina ball as follows,

> the QC (quality control) findings (which only showed after the item was fitted) revealed that it did not qualify. Now from this experience, the PE department, if there is work on the secondary reformer involving new or used alumina balls, will be more careful with QC and retest crushing tests

The problem of knowledge issue should have been mitigated by commissioning extra qualified supervisors. However, this is not an easy task to do as increasing the number of workers, as a supervisor, is against the current company's policy. During the interview sessions, M1 explained,

> Nowadays, it is difficult for us to add more people on board as its focus is streamlining the number of employees.

Thus, the only remaining causes that should be eliminated are poor planning and issues related to knowledge.

4.2. Fault Tree Formation

Based on the empirical findings of both desk research and interview sessions, the fault tree of rework event in the TAM project scene can be established in figure 5 as follows:

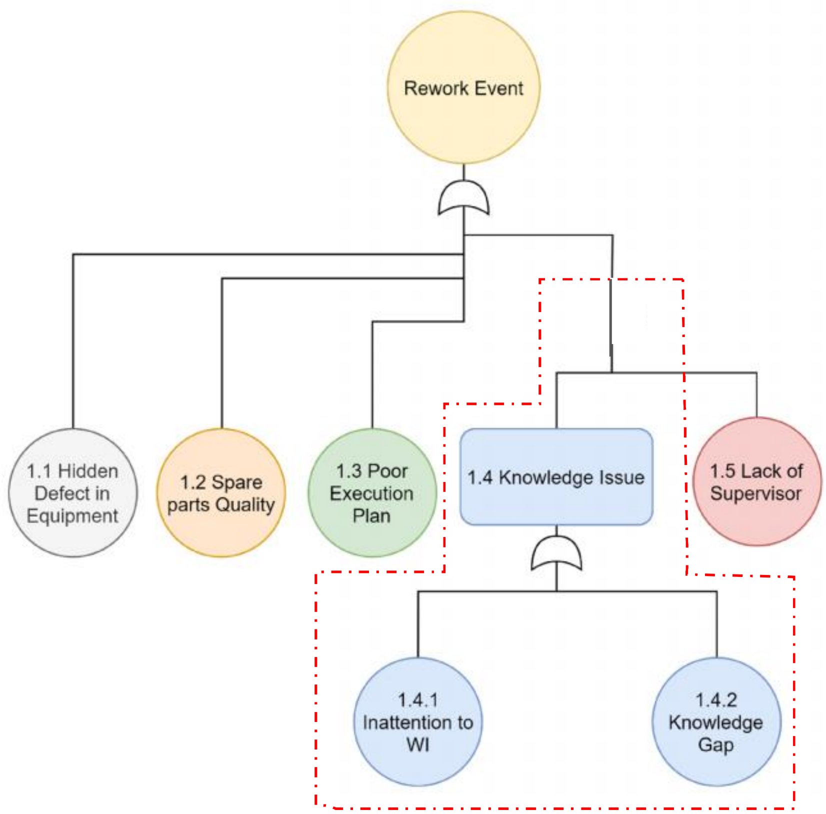

Figure 5 Fault Tree of Rework Event

It is found that the rework event in the TAM project at Pupuk Kaltim is caused by numerous reasons. The causes of rework events are (1.1) hidden defect, (1.2) spare part quality, (1.3) poor planning, (1.4) knowledge issue that consists of (1.4.1) knowledge gap, (1.4.2) inattention to WI and lack of supervisor (1.5).

Nevertheless, the causes do not necessarily happen simultaneously. For example, the rework case in P-2 2020 is dominantly caused by a lack of supervisors. Whereas the rework event in P-5 2019 is basically inattention to WI and in P-1A 2018 in the form of the knowledge gap. These findings imply that each event does not overlap with another resulting in OR gates. However, it is plausible that cause 1.4.1 and 1.4.2 can be categorized as one cause linked with knowledge. Thus 1.4.1 and 1.4.2 are classified as knowledge issues. Moreover, as already elaborated in section 3.1.2, this research's focus will be to eliminate the knowledge issues to reduce the rework events. The following paragraphs will elaborate on the link between rework events and the inability to re-use the knowledge.

The rework event in P-5 2019 is basically caused by inattention to WI (1.4.1). The closeout report also found out that the required follow-up from this event was to update the Work Instructions (WI) (Pupuk Kaltim, 2019). WI is a formal document that contains the steps of work that must be adhered to by the worker for ensuring the quality of the work. Thus, essentially WI is a source of explicit knowledge. Nevertheless, it was found from the interview sessions that people are rarely using WI and instead relying more upon their experience. It implies that the knowledge that is reused is limited to the individual level. The worker must keep reinventing the wheel by continuously being involved in the TAM project.

Looking at the desk research, the rework event in P-1A 2018 is a form of knowledge gap (1.4.2). In the closeout report, it is explained that the problem was caused by the inverted installation of the diaphragm and the jig tool. As a result, the gas was leaking. The closeout report also recommends that each executor have the same knowledge of performing such a task. It implied that there is a knowledge gap among the executors. Furthermore, based on the interview sessions, S1 also discloses that there is similar work on the other plants. This knowledge could be re-used in the P-1A case. However, the knowledge cannot be re-used simply because there is a knowledge gap among the executors. The executors do not become aware that such knowledge exists.

4.3. Discussion

This section will discuss the result of empirical findings regarding the rework events causes and its consequences with the available works of literature.

4.3.1. Impact of Rework Events on Project Success

According to the works of literature, rework may be related to quality deviations, nonconformances, defects, and quality failures (Burati et al., 1992; Abdul-Rahman, 1995; Josephson and Hammarlund, 1999; Barber, et al. 2000; as cited in Love P. E., 2002). Hwang and Yang (2014) have compiled various authors that provide definitions of rework. They conclude that rework is about rectifying the work that has been done due to non-conformance to the requirements. This definition also applies in Pupuk Kaltim.

A study in construction engineering and management by Love (2002) reveals that schedule slippage and direct rework were linked. Yet, rework events do not always increase slippage, as Love (2002) argued that construction project schedules could be accelerated. Through better resource reallocation and expense of extra cost, it will compensate for the delay due to rework

However, from the desk research presented above, it can be found that the rework event at the TAM project always results in schedule slippage. It is argued that in turnaround projects, the rework events frequently happen at the end of the turnaround project. The rework often can only be identified during the validation process or even the plant startup process. The slack is already minimal during this period, so there is less room to accommodate the delay. To make it worse, sometimes the rework event happens at the task that was not designed to be on the critical path and the rework event turned it into one. Without proper planning, on-the-fly adjustment is necessary to handle the essential shift of path.

This issue is also supported by literature which states that one of the turnaround project criteria is that TAM timelines are generally compressed (Obiajunwa, 2010). He means that there may be little or no chance of correcting the critical path by speeding the schedule. Furthermore, since rework is an unwanted event, the material or spare parts, tools, or even manpower may not be ready. Time is needed to fulfil this prerequisite for rework, and it eventually prolongs the project schedule. Hence, it can be said that it is necessary to reduce rework during turnaround projects as this event has an apparent adverse effect on the project’s schedule performance.

4.3.2. Knowledge Reuse to Reduce Rework Events

As already presented in section 1.2, the rework events might be caused by knowledge-based errors. Love et al. (2009) described it as a one-of-a-kind challenge that lies well outside a person's scope of knowledge. The empirical findings align with this idea. In this case study, people's ability is limited because they rely on their own experience rather than work instructions. Furthermore, there is also a knowledge gap among the workers.

It was mentioned that the junior employees do not have sufficient material to learn other than being involved directly in the projects. That is because the explicit form of knowledge is limited. Koteshwar, Bengtsson, & Söderlund (2015) also argue that the old men's (or 'baby boomers') tacit knowledge is the most challenging thing to capture these days. This also implies that the learning is oriented to individual learning. An employee must obtain the knowledge and experience by himself instead of having organized knowledge transfer sessions from the organization. Without any measures to improve this, it is believed to have an adverse effect on the organization. There will be slow progress on knowledge building as people have to reinvent the wheel.

Successful and low-risk turnarounds can be realized by developing a best practice for documenting, organizing, and communicating information, or in this case, knowledge (Cormier & Gillard, 2009). Moreover, effectively managing knowledge in a corporate environment is needed to enhance intellectual capital and impede rework (Jill, Burstein, & Mitchell, 2006). Schacht and Maedche (2016) compiled that knowledge management essentially comprises acquiring, capturing, sharing, and re-using knowledge.

The causes and events of rework must first be identified and classified (Hwang, Thomas, Haas, & Caldas, 2009). Rework events can be argued as a form of knowledge. Thus, the practise of identifying and classifying rework events can also be considered as capturing activity. Hence, it can be said that one of the ways in dealing with a rework is through a proper capturing process. Nevertheless, such a practice does not exist in Pupuk Kaltim.

To conclude, it can be derived that there is a problem of knowledge management practice such as the process of capturing, transferring as well as reusing the knowledge has been an issue at Pupuk Kaltim. The practice is deemed to be poor. Consequently, it is believed to be linked to the continuous occurrence of rework events. Thus, it is crucial to comprehensively evaluate the knowledge reuse practice within the TAM project stages at Pupuk Kaltim.

4.4. Recap

This chapter lays out the company's current TAM project performance, which is harmed due to rework events. The rework events always cause the schedule slippage in the TAM projects. In addition, it is already shown in the fault tree that the inability to reuse the knowledge has a positive link with rework events. The knowledge gained in this chapter justifies the need to delve deeper into the case study. The next chapter will show the use of the activity theory lens to analyze the current knowledge reuse practice at every turnaround project's stages.

5. Current Knowledge Reuse Practice in Turnaround Projects

This chapter will try to answer the second and third research questions. The chapter will be structured according to the TAM stages in the company; execution, closing, and planning, which are presented in sections 5.1, 5.2, 5.3, respectively. Because the rework events occur during the execution stage, the choice to begin the analysis at this point is made. In each section, the data and the AT model will be described. Furthermore, the models will be discussed in section 5.4. The discussion will comprise the relationship between the activities and the enablers and barriers of knowledge reuse within TAM Stages.

5.1. The Execution Stage

This section will present the AT model for the execution stage. The execution stage is started once the turnaround target, scope, volume of work, resources, budget, and schedule is finalized in the planning stage. It is worth mentioning that the rework events trigger the need to evaluate the knowledge reuse process. As the rework events occur in the execution stage, it drives the decision to start the analysis from this particular stage.

5.1.1. Data for Execution Stage AT model

This part will present the data obtained from the desk research and the second interview sessions. The documents utilized for desk research are the same as those shown in 3.2.2. These documents were examined, and relevant information concerning TA executions was gathered. This information is also assigned to the elements of activity theory from Figure 2. This coding procedure is also used for interview data. Once transcribed, the responses to the second session of the interview were similarly classified in this manner. Consequently, the following table shows the parts of activity theory that can explain how the knowledge reuse process happens at the execution stage.

Table 7 Data for Developing AT model for Execution Stage

Elements	Component	Source	Transcripts
Rules	(ER1): Adherence to Work Instructions	Desk Research: TAM Manual	*the execution of the work must be per the work instructions (WI) (Pupuk Kaltim, 2020)*
		Interview Sessions	*The Maintenance Manual mentions lifting the casing, but it doesn't specify what equipment to use or store it. This means that the PKT WI completes the maintenance manual, which is required to ensure quality. (M2)*
	(ER2): Discovered works	Interview Sessions	*> The scope of TA can be increased because there are discovered works at the time of TA. From there, you can determine what the following action will be. (A1)* *> Obstacles often occur because there are discovered work items. This means that we assumed 3 units of work on equipment X at the time of planning, but it turned out that 10 items had to be done when the item was opened. (M3)*
Tools	(ET1). Equipment Historical Data is difficult to find	Interview Sessions	*> Since it is impossible to use keywords, we must look for reports that discuss similar equipment. The report is then read and compared to existing standards. Because this (search) process is inconvenient, it is*

Elements	Component	Source	Transcripts
	and may incomplete		*preferable to ask people. (S2)* *> ....As a result, that person must go to the department's computer. Then, because there are no rules for saving files, a lot of data is lost. As a result, the data is still disorganized. (S4)*
	(ET2). Person-to-person approach	Interview Sessions	*>Yes, the same; ask the seniors. If the senior in question forgets, then you just have to look for it. (S1)* *> Considering that WI conditions are not yet perfect, the best way is direct practice and mentoring. (M2)*
	(ET3) Work Instructions are not utilized	Interview Sessions	*> They (the workers) rely more on their own experience because WI is tough to obtain by and sometimes, they are unaware that WI exists. Instead of searching, it is preferable to consult with coworkers or superiors in the office (M1)* *> The work instructions (WI) have not been updated in a long time and are no longer relevant to the present situation (M1)* *> However, various people, interpret the WI in different ways. For example, it is said measurements are taken from below, but the point of reference is not specified. This implies that WI lacks in-depth. Because WI is written primarily on words and seldom has images. It is easier for us to grasp when we see visuals. (S4)*
Division of Labor	(ED1). Senior employee shares knowledge with a younger employee	Interview Sessions	*> Usually, we share (the findings) with seniors when we find something unpredicted. If someone in our team has experienced it, it is better to take action immediately. (S4)* *> So it can be said that the "google" are senior people. When these people leave the department, knowledge can be lost. (S2)*
Objective	(OE 1) Complete the work orders according to TAM target	Desk Research: Closeout Reports	*Completing work orders including the discovered works while also adhering to the predefined TAM target that consists of SHE, Plant performance, Schedule, Cost, and Quality*

5.1.2. AT Model and Contradictions for Execution Stage

Based on the data that is presented in the section above, the activity theory model for the execution stage can be established and seen below:

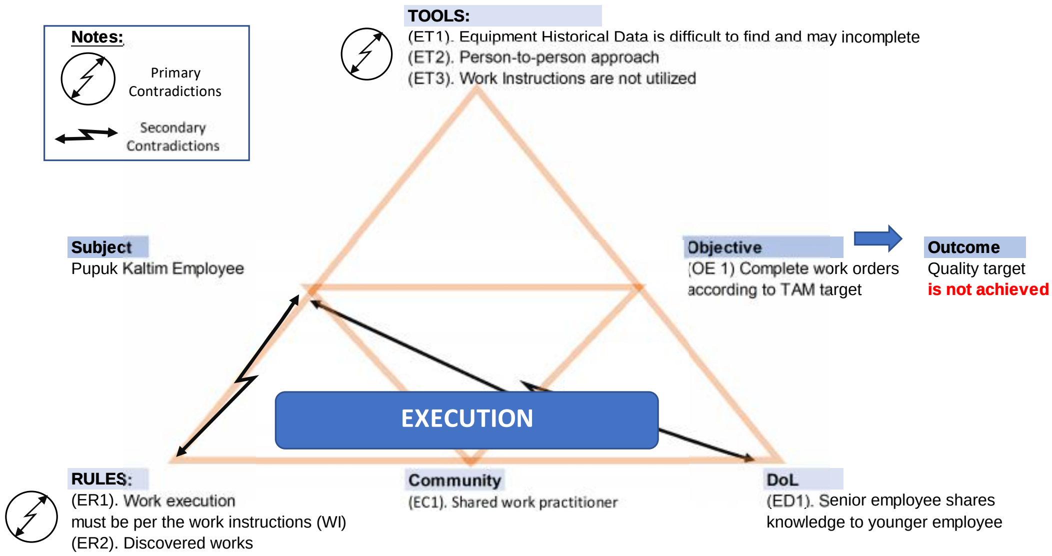

Figure 6 AT Model for Execution Stage

The elements of activity theory that comes from the empirical data are put in place. However, 2 things must be noticed. First, since the scope of the research is about the knowledge re-use process is within the company itself. Hence, the subject of the activity will always be the employee of this company.

Secondly, the justification of the community comes from inferring the current practice of reusing knowledge. To begin with, the identified knowledge that is being re-used from the interview sessions are primarily about technical know-what and know-how knowledge. That is, how to perform a specific task and is very limited to a particular discipline. For example, the knowledge about replacing a catalyst will only be re-used among the people within the process department. As a result, the community where the knowledge is reused is also specific.

Nevertheless, given the fact that the company has multiple plants with varying technology and manufacturer, thus the people within a department may work in different situations or settings. For instance, the mechanical department may be responsible for maintaining the turbine. Although the concept of turbines is the same, there could be a distinguishing aspect between gas turbines from manufacturers A and B. Thus, it is plausible to say that based on Markus (2001) knowledge reuse situations, this case study falls under the shared work practitioner.

Now that the AT model for the execution stage is established, the following table's contradictions can be seen.

Table 8 Contradictions in Execution Stage

Stage	Code	Type of Contradictions	Element involved	Descriptions
Execution	E1 (work quality is not standardized)	Secondary	Subject - Rules (ER1),	It is found WI is not getting attention from the Pupuk Kaltim Employee, resulting

Stage	Code	Type of Contradictions	Element involved	Descriptions
				in compromised quality of work
		Primary	Tools (ET3)	WI is sometimes not updated, not recognized by the people and may result in a different interpretation.
		Secondary	Subject-DoL (ED1)	This situation leads to utilising a person-to-person approach where the senior employees share their knowledge and experience with younger employees.
	E2 (poor solution to discovered work)	Primary	Rules (ER2)	The discovered work is unavoidable and requires historical data.
		Primary	Tools (ET1)	Equipment Historical Data is difficult to find and may incomplete

E1 (work quality is not standardized). The subject element and the rule element are the principal contradiction that is identified in this stage. In ensuring the quality of work, it is explicitly stated that the execution of the work must be per the work instructions (WI) (Pupuk Kaltim, 2020). According to M2, WI is a set of instructions on how a task should be performed. It is a development of equipment's maintenance manual containing best practices on how a work should be explicitly executed at Pupuk Kaltim. The best practice comes from the experience of the past executor.

Consequently, the work can be performed more effectively and efficiently. It also implies that WI is the source of explicit knowledge. Nevertheless, people neglect WI to finish the job and instead relying upon their own and peers experience. As a result, this may compromise the quality.

Apparently, WI as a tool is a primary contradiction. It is not utilized by the subject for 3 reasons. To begin with, people are reluctant to use WI because the worker does not realize that such documents exist. Secondly, once it is found, sometimes it is not updated. Finally, WI may also result in different interpretations among the workers.

E2 (poor solution to discovered work). Secondly, during the execution stage, the scope of work might be increased as there are works that can only be identified once a piece of equipment is dismantled. In this case, it is called a "discovered work" (Lawrence, 2012). The discovered works are perceived as problems that also need to be solved. The "discovered" work can be identified as recurring or unique. A1 explained,

> There are two types of conditions. First, the new problem appeared in Plant A, but it has also occurred in other Plants. Second, it could be a new issue in Pupuk Kaltim.

Most of the interviewees agree with this idea where the knowledge from 1 plant can be used in another plant. Although the plant is different in terms of the licensor, they are basically the same down to the equipment level. Since there are similarities between the plant, hence the knowledge of problem-solving that was captured from 1 plant can be reused for another plant.

In dealing with discovered work, the problem-solving process will follow the event tree depicted in the figure below:

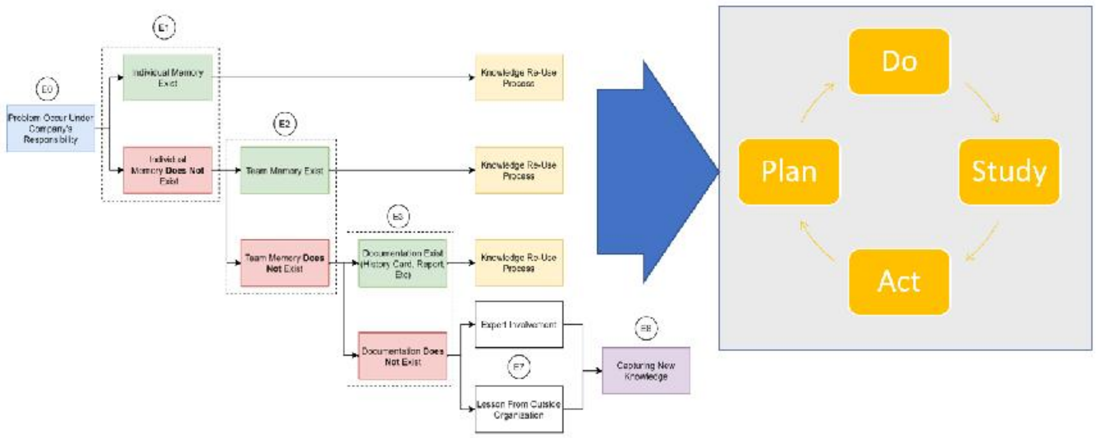

Figure 7 Solving process for discovered work

The core of the problem-solving process is retrieving the experience or knowledge with retrieval starting from individual memory, team memory, and lastly, written artefacts. First, the executor that detects the problem will try to remember whether he has the experience or not. If he does not have the experience, then he will bring the issue to the team, where it is expected that someone with more experience will have it. If no one has the necessary expertise or if a higher level of detail is required, the written artifacts will be visited last.

Once the knowledge is acquired, it will be re-used according to Kotnour's (2000) PDSA cycle. First, a plan will be made to adjust between the current problem and the experience they have. Subsequently, the program will be implemented accordingly, and the result will be reviewed. Once the result is satisfactory, then the procedure will ideally be recorded, most likely in the equipment historical data.

That being said, the written artefacts should be a complementary tool to reuse the knowledge during the project. That is because in reusing the previous knowledge, some details are difficult to remember. However, its poor quality may hamper the reuse process as poor quality is manifested in missing knowledge. A deeper analysis of why the documentation process is lacking will be described further in the closing stage, where the knowledge from the execution stage should be reintegrated.

5.2. The Closing Stage

The closing stage is started once the execution stage is finished. The TAM projects are classified as completed when the plant startup is successful, without unscheduled shutdown occurs within

3 months after plant handover. Looking at the micro process of reusing knowledge, this particular stage is focused on reintegrating the knowledge.

5.2.1. Data for Closing Stage AT Model

The process of generating the elements to establish the AT model for the closing stage is similarly conducted as in section 5.1.1. The data that justify the element of AT model for the closing stage can be seen below.

Table 9 Data for Developing AT model for Closing Stage

Elements	Component	Source	Transcripts
Rules	(CR1). Lack of Reporting guidelines and for documenting lessons learned	Desk Research: TAM Manual	*> The report must be submitted within 30 days after the last day of the execution stage (Pupuk Kaltim, 2020).*
		Interview Sessions	*> However, there are still no guidelines for producing quality reporting. The recommendation (for equipment) is the report's top priority. The emphasis is on the findings (maintenance) and relevant recommendations. There is no column for lessons learned. (M2)* *> In the final report, we must also attach our daily logbook. We will write every day-to-day activity during the execution phase, mostly about what problems were encountered and the solutions. For me, this may contain lessons yet very difficult to understand (S3)*
	(CR2). Missing guidelines for the lessons learned workshop	Interview Sessions (Internal Department)	*> As far as I remember, there is no (evaluation) in the department either because there are no rules. As long as there are no cases, there is no evaluation. But if there is a case, it will be discussed immediately when the problem occurs. (S3)* *> This (evaluation) program is carried out per area and routinely. But unfortunately, there is no documentation session (no meeting minutes). There are no meeting minutes because people think they have written the final TAM report. (S2)*
		Interview Sessions (Central Meeting)	*> For me, (the grand meeting) is merely a "check-off-the-box" procedure. Contains only requests for suggestions and input. And I don't know whether the advice that we will give later will be implemented. (A1)* *> So far, evaluation meetings whose primary purpose is only to determine the scope of the following TA (S1)*
	(CR3). No incentives from the company to produce WI	Interview Sessions	*> So, they question the purpose of WI. When it is explained, people feel they already know why it should be recorded. Then there is no support from the company (no incentives). This makes people unmotivated to create WI. (M3)*

Elements	Component	Source	Transcripts
	(CR4). Missing guidelines to develop WI	Interview Sessions	*> Now, in the company, no system requires employees to create high-quality WI.(M2)* *> The desire to create WI exists, but we are confused about where to start because there is no guide. Then a lot of work awaits. (S3)*
Tools	(CT1). Explicit knowledge is kept as a book (passive by-product)	Desk Research Documents	*The closeout report exists, and individual reports from mandatory departments are attached. Nevertheless, it only focuses on knowledge with regards to equipment*
	(CT2). Internal Departement Meeting	Desk Research Documents	*Inferred from the interview sessions, there is an internal department meeting, although it is not prevalent and consistent.*
	(CT3) Central Evaluation Meeting	Desk Research: TAM Manual	*> Closing and evaluation must be conducted once the TAM project is finished (Pupuk Kaltim, 2020)* *> Mandatory departments, namely reliability, inspection, process, safety, health and environment, should attend the evaluation meeting and submit their execution report to the TAM department (Pupuk Kaltim, 2020).*
Division of Labor	(CD1). Lack of staff resource	Interview Sessions	*> Now, they (mechanics) are also having a hard time working on the administrative aspect because there are no (staff) backups. (S4)* *> So, it's possible that the inspectors haven't finished the TAM report because they've already been assigned to other TAM projects. This is highly time-consuming for the inspector. (S2)* *> There are not many people, and there is a lot of breakdown maintenance. Thus, people need to go to the field, so there's no time or opportunity to make WI.(M2)* *> To be honest, during the TA evaluation, I only participated in the evaluation meeting once. And that's because no one (can) participate (lack of people.) This evaluation meeting is just a formality to me. (S1)*
Objective	(OC1) Capture the knowledge	Desk Research: TAM Manual	*>"Collecting data on the work results is concerned as a reference for improving, eliminating obstacles, and developing or formulating strategies in dealing with further work. This evaluation focuses specifically on "Critical Item" work and equipment in the "performance killer" category". (Pupuk Kaltim, 2020)*

5.2.2. AT Model and Contradictions for the Closing Stage

Based on the facts provided in the preceding section, the following activity theory model for the closing stage may be established:

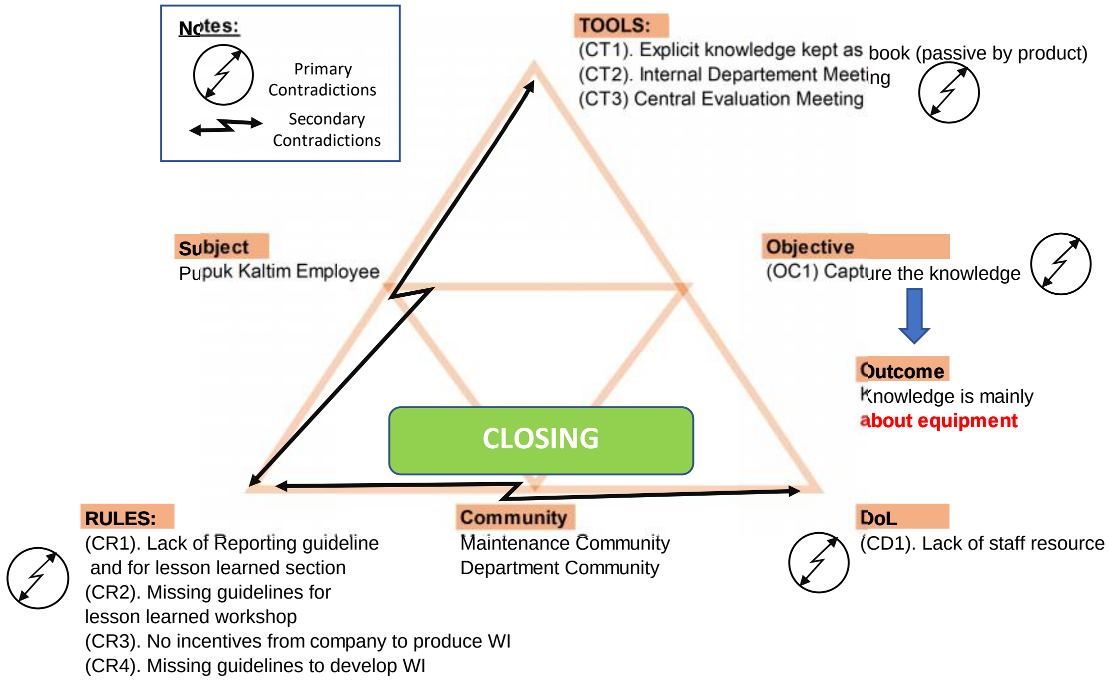

Figure 8 AT Model for Closing Stage

In this stage, the subject is still the same as the execution stage. However, the definition of the community is distinguished into 2 communities, namely the maintenance community and the department community. There are two sub-main activities within the closing stage: internal department meetings (CT2) and central evaluation meetings (CT3). As can be implied by the name, each is executed in a different community. Nevertheless, 3 main issues occurred within the closing stage, namely poor reporting quality (C1), overlooked evaluation meeting (C2) and absence of updating WI (C3). The contradictions that build these issues can be seen in the following table.

Table 10 Contradictions in Closing Stage

Stage	Code	Type	Contradictions	Issues
Closing	(C1) Poor Reporting Quality	Primary	Objective (OC1)	the objective of the closing stage is focused on collecting the knowledge about the equipment.
		Primary	Dol (CD1)	Lack of staffing resources becomes the primary contradiction as it gives impact on the process of reporting and central evaluation meeting
		Secondary	Rules (CR1)-Tools (CT1)	Since there are no rules that clearly define the structure of the report, the results may vary and does not contain a specific section about the lesson learned

Stage	Code	Type	Contradictions	Issues
		Secondary	Rules (CR1)-DoL (CD1)	With the limited number of the resource and no mutual agreement on the content of the report, the report's quality is dependent on the discipline of the employee who is responsible on the report
	(C2) Overlooked Evaluation Meeting	Primary	Tools (CT2)	The internal department evaluation meeting is not widely done.
		Secondary	Rules (CR2) and Tools (CT3)	The existing rules only mandated the TAM organization to conduct an evaluation meeting without further details on how to do it properly
		Secondary	Rules (CR2) and Division of labor (CD1)	Lack of staffing resource result in fewer people attending the central evaluation meeting
	C3 (Absence of Updating WI)	Secondary	Rules (CR4)-DoL (CD1)	As the staff is lacking and guideline is missing, people feel reluctant to develop a WI.
		Primary	CR(3)	Missing incentive exacerbates the situation

(C1) Poor reporting quality. The problem is basically rooted in the primary contradictions within the objective's definition. The objective is only focused on the knowledge regarding the equipment, such as which equipment was successfully maintained during the TAM execution stage and what they should do about the equipment in future TAM projects. The rules also clearly mandated that each 1st ring department must submit the report. Although it is not saying that there should also be a lesson learned section, there is explicit documentation that can be revisited during the planning stage. Nonetheless, with a lack of guidelines and staff resources, the quality of the report may vary.

(C2) Overlooked evaluation meeting process. There are 2 forms of evaluation meeting, namely internal department meeting and central evaluation meeting. The former is more informal as the empirical findings show that not all departments conduct such activities. Moreover, for those departments who perform such evaluation, it is also done informally. Meaning that there is no documentation and clear structure.

On the other hand, the company's TAM manual clearly states that there must be a central evaluation meeting once the execution stage is finished. However, the contradiction is still the same. The existing rule does not control the evaluation meeting process. Some interviewees disclose that they feel this central evaluation meeting is a mere "check-off-the-box" procedure. In addition, with a lack of staffing resources, the evaluation meeting is not fully attended by mandatory departments' representatives, resulting in partial knowledge input in the forum.

(C3) Absence of Updating WI. There is ample opportunity that the worker may find a safer way to execute a task during the execution stage or had a failure when completing the task. Thus, they should update the Work Instructions to repeat the success, or the loss is prevented from re-occurring in future TAM projects. However, this is not the case as there is no guideline to update the WI. This situation is also exacerbated by the lack of resources and missing incentives from the company.

Now that the problems at the closing stage are revealed, a deeper analysis of the planning stage will be presented. Later it will be seen what the impacts are of having these three problems.

5.3. The Planning Stage

The next TAM project is initiated from the Planning stage. It is started before the execution stage is commenced. In this stage, the knowledge from the past will also be re-used. Thus, this section will present the AT model for the planning stage.

5.3.1. Data for Planning Stage AT Model

The procedure of producing the elements to build the AT model for the planning stage is likewise carried out in the same manner as described in section 5.1.1. The data that justify the element of AT model for the planning stage can be seen in table 11.

Table 11 Data for Developing AT model for Planning Stage

Elements	Component	Source	Transcripts
Rules	(PR1). Limited guidelines in reclaiming lesson learned from closeout report	Desk Research: TAM Manual	*> Past TAM report shall be used to define the current TAM scope of work (Pupuk Kaltim, 2020).*
Tools	(PT1). Closeout report is mostly reused for knowledge about the equipment	Interview Sessions	*> Before TAM execution, what I did was to find out the history of the equipment that I was responsible for. For instance, when the treatment is carried out, the material that was replaced, the details of the activity, and the duration of loading and unloading the catalyst.*
	(PT2). Internal department planning	Interview Sessions	*> We were sharing expertise with professional resource individuals in their domains before the execution of the TA. Photographs and privately held documentation are also included. This sharing begins with one another's initiative. This means that it is not systemized and is ultimately determined by the person. (S4)* *> There is an agenda before the TA execution where all inspectors (all parts become one) explain the program they will do and review each other (S2)*
	(PT3). Gatekeeping meeting	Interview sessions	*> To me, these suggestions and obstacles aspects are fundamental. Unfortunately, this was frequently missed (during the gatekeeping sessions). I also think that to determine the scope, there are still a lot of backups, for example, notes from the inspection department or reliability. However, this aspect of project management is often overlooked.* *> In addition, near miss and first aid criteria are included in safety targets. This will be documented (in the closeout report), and the trend will be examined. What we attempt for*

Elements	Component	Source	Transcripts
			is that the safety target should be better from 1 project to another (M4)
Division of Labor	(PD1). Senior or knowledgeable employee shares knowledge to a younger or less knowledgeable employee	Desk Research	*Inferred from the **Internal Department Planning** process*
Objective	(OP1) Defining TAM's target, Scope of Work, Resources, etc	Desk Research: TAM Manual	*> The TAM project planning stage is intended to define TAM's performance criteria, scope as well as the volume of work, required resources ranging from material, spare parts, tools as well as manpower, budget, and schedule (Pupuk Kaltim, 2020).* *> a gatekeeping team consists of various departments, namely the turnaround department, process, safety-health-environment (SHE), reliability, operation, inspection, maintenance department, as well as the committee members created by high-ranking employees (Pupuk Kaltim, 2020).*

5.3.2. AT Model and Contradictions for Planning Stage

The following activity theory model for the planning stage may be built based on the information in the preceding section.

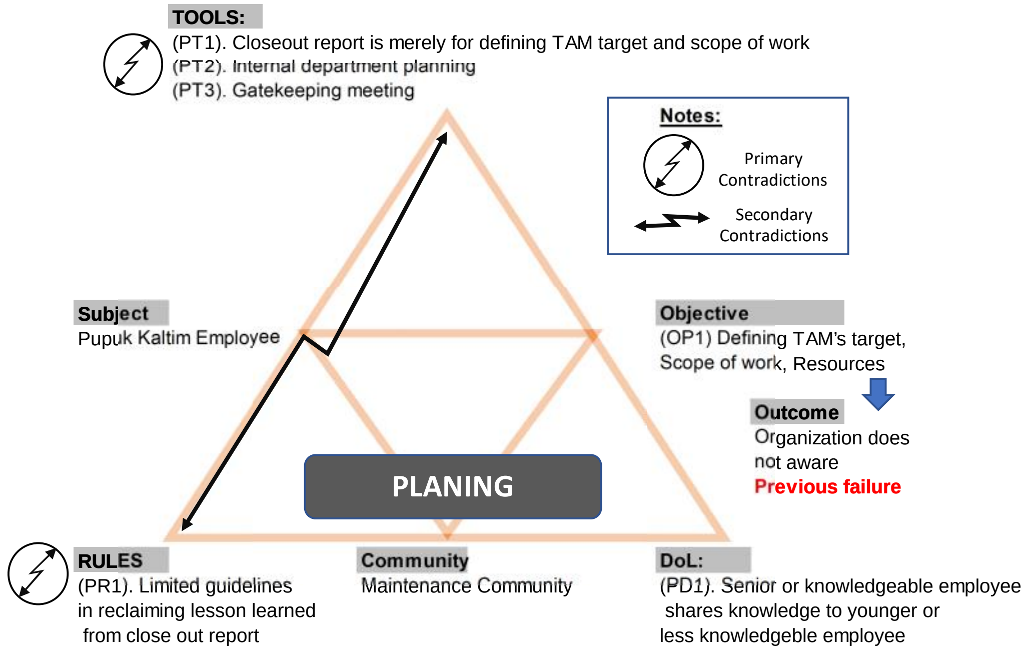

Figure 9 AT Model for Planning Stage

In this stage, the form of contradictions is mainly primary contradictions. The problem can be generalized as there was **no formal session on recovering lessons learnt.** As a result of the problem, the outcome of the activity becomes the organization not fully aware of the previous failure. The complete analysis of the contradictions can be seen in the following table.

Table 12 Contradictions of AT model for Planning Stage

Stage	Code	Type	Contradictions	Issues
Planning	P1(no formal session on reclaiming lesson learned)	Primary	Rules (PR1)	There are few rules for recovering the lessons gained from the closeout report. The available rules only mention that it is mandated to use the closeout report for planning at the gatekeeping. However, the extent is only limited to knowledge about which equipment should be incorporated in the following turnaround
		Secondary	Rules (PR1) - Tools (PT3)	Although the rules also mandated that there is a need to have the gatekeeping meeting, this tool is also limited to discussing the scope of work from the closeout report rather than the lessons learned
		Primary	Tools (PT1)	Most of the time, the closeout report is repurposed for equipment knowledge. That is because there is no specific section that elaborates the lesson that was gathered from the previous TAM Project

Stage	Code	Type	Contradictions	Issues
		Primary	Tools (PT2)	While it is good that there is internal planning, yet the timing is insufficient. Moreover, as the process is not standardized, then the results may vary. It means that it depends on the ability of the knowledge seeker to ask for the relevant knowledge. Lastly, as explicit documentation is also still troublesome, knowledge mainly comes from individual documentation or memory.

5.4. Discussions

The knowledge reuse practice within each stage of TAM projects at Pupuk Kaltim has been analyzed through the Activity Theory (AT) lens. The current practice of knowledge reuse within TAM projects at the company will be discussed using the third generation of activity theory. Moreover, the contradictions are identified using the AT lens. It becomes the basis to define the enabler and barrier of knowledge reuse. These two ideas will be explained separately in the following subsections.

5.4.1. Interactions of Activities in TAM Project Stages

The third generation of activity theory introduces two new element concepts, namely boundary objects and boundary spanners. In addition, the works of literature explain that these 2 elements may be involved in multiple activities which spread within the spatial and temporal dimensions.

It is plausible to say that this concept can explain the current knowledge reuse practice within TAM stages. The illustration of the current practice can be seen in the following figure.

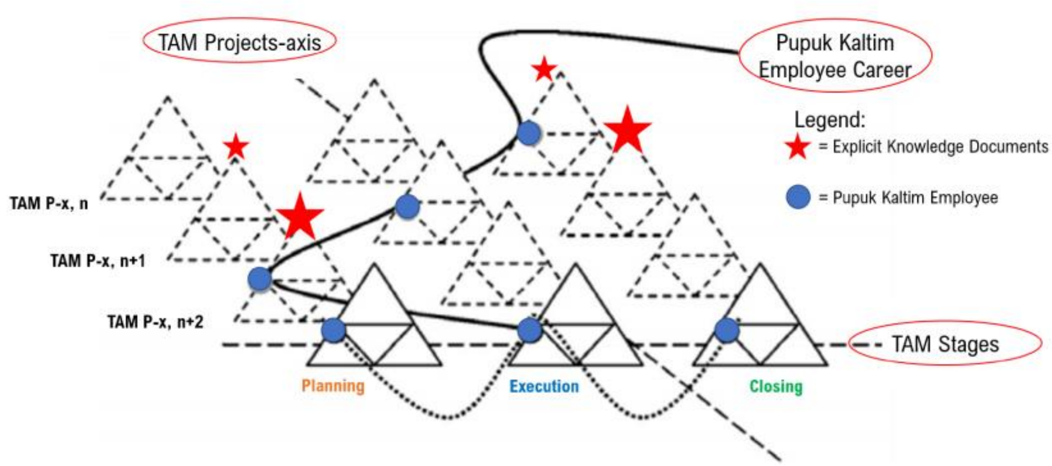

Figure 10 Multi activities interactions in TAM projects (adapted from Vakkayil, 2010)

To begin with, the case studies shows that the whole TAM project consists of three main stages: planning, execution, and closing. Using the theory, these 3 stages are envisaged as the spatial dimension ("TAM stages axis" in Figure 10). Works of literature defined group of activities are spread in spatial dimension when it is coexistent. These 3 activities must be coexistent to complete a TAM project, although it is not done simultaneously. For instance, ideally, the execution cannot be started without planning, and closing is meaningless when the project is not executed.

Moreover, the empirical findings also support the idea that TAM projects are done cyclically. For example, the P-2 TAM project in 2020 was its 18th TAM project throughout its lifetime. Thus, the TAM projects as an activity system can also be visualized through the temporal dimension depicted as "TAM Projects Axis" in the figure above.

Furthermore, the empirical findings also reveal that the explicit document that is produced during the closing stage performs as boundary objects (the red star symbol in Figure 10). In this case study, the explicit documents are the closeout reports, historical data, and work instructions. According to Wenger's (2000) boundary object typology, these explicit documents fit the artefact type. He provides an example of this typology as the medical record of a patient shared among doctors, nurses, and insurers to collaborate with each other. The explicit document in TAM projects also performs similarly. Although these documents are generated in the closing stage, they will be revisited during the future TAM project. Both in planning and execution and by various actors, namely the TAM department or other relevant departments. For instance, the closeout report is used as a basis to define the scope of work in the future TAM project by the TAM department. On the other hand, the historical data of equipment will be used by other employees when they discover additional work during the execution stage.

Works of the literature suggest that boundary object generation and maintenance are crucial in establishing and maintaining coherence among activity sets. As the project elapses in the realm of TAM projects, the plant's knowledge and performing a TAM project should also grow if the project is well documented. This is depicted in Figure 10 as the red stars getting bigger for every subsequent project.

However, this is not the case in this study. The closeout reports generation only focused on the knowledge with regards to the equipment condition. As a result, the generated knowledge is limited. Secondly, an employee may find a more efficient or safer way to perform a task in the execution stage. Supposedly, he must update the work instructions so the task's success can be repeated, or the failure can be prevented to re-occur by his peers. But this also does not happen in the case study as the work instructions are not updated systematically.

Moreover, it is also not maintained as the empirical findings show that WI is difficult to find and seldomly updated. The historical data is no different. For example, the project fails to keep its coherence so that the actor fails to re-use the knowledge from the previous project in the case of the P-1A 2018 rework event.

One of the main contradictions that explain the poor creation and reuse of boundary objects is the absence or unclear rule to do such activity. For example, the AT model for the closing stage shows no guidelines for developing WI (CR3). Furthermore, while the TAM manual states the need to form a closeout report, there is no clear rule to write the lesson learned section (CR1). On the other hand, there is a rule to use the previous closeout report at the planning stage, yet the extent is also not clearly defined (PR1). Consequently, there is no constraint or justification to produce the same object throughout the temporal dimension.

Nevertheless, the process of reusing knowledge is still helped by the boundary spanner, which is depicted as the blue dot in Figure 10. The boundary spanners, in this case, are the Pupuk Kaltim employees under the maintenance community. These employees are frequently involved in the TAM projects, which is not limited to 1 plant or area. As stated by the interviewee, a mechanical maintainer may be rotated from the ammonia unit to the urea unit. Thus, throughout their career, the employee grows their knowledge and perhaps may reuse it in the future.

Moreover, the empirical findings show that the community has an open mindset about knowledge. Meaning that the senior employees are willing to share their knowledge with the younger employee during execution and planning. However, the senior employee will not stay forever in the company. At some point, they will meet their retirement age or be promoted outside the maintenance community. Without proper knowledge documentation, they take with them priceless best practices, process knowledge, and expertise. Consequently, the knowledge is lost, let alone be reused.

5.4.2. The Enablers and The Barrier of Knowledge Reuse.

The contradictions are discovered using AT lens. It serves as the foundation for defining the facilitator and barrier to knowledge reuse. The enablers and the barriers can be seen in Table 13. These findings will be discussed through the theory of knowledge reuse micro process and compared with other available literature

Table 13 Identified Enablers and Barriers

Step		1		2		3		4	5
Process by Markus (2001)		The decision to look for knowledge		Search & Locate Expert or Expertise		Select the expert or expertise		Apply the knowledge	*Not available
Process Petter & Vaishnavi (2007)	Component	(A) Identify Problem	(B) Define Problem	(C) Identify expert (for tacit knowledge)	(D) Identify Expertise (explicit Knowledge)	('E) Communicate with expert	(F) Examine the explicit knowledge	(G) Implement the Knowledge	(H) Integrate Knowledge
Empirical study at Pupuk Kaltim	Enablers	AE1. People Encounter a discovered work/abnormality AE2. Organization variables such as leadership and coworker that promotes the need to find the knowledge	*Not identified	AC1. Organizational factors, People stays in the same building thus familiar to each other(shared work producer situation)	AD1. The need to find the details	*Not identified	*Not identified	AG1. Assistance from Expert/Knowledge producer	AH1. Part of procedure to keep the work's passive by product
	Barriers	AB1. unawareness of WI existence AB2. WI maybe not be updated or AB3. WI is difficult to interpret as it does not have sufficient illustration AB4. No guidelines to learn from past success or failure AB5. Lesson learned is implicit	*Not identified	*Not identified	BD1. Not indexed properly, inducing difficulties to find BD2. Closeout reports are not shared if it is not asked	BE1. The expert may not have props (picture, model, etc.)	F1. may be incomplete F2. may not exist	BG1. Relevant Expert that owns the expertise might already be retired	HB1. Lack of resources HB2. Lack of Guidelines of both reporting and evaluation meeting HB3. Lack of Incentives

a. The decision to look for knowledge. During the execution stage, it is found from the interview that discovered works always occur during the project execution stage. This is also confirmed through the information from the closeout reports. Discovered work may come from under-estimated anticipated work and the scope that is revealed only when work is performed (Raoufi & Fayek, 2014). This situation is also supported by the literature mentioned by Levitt (2004). He said the scope of work during a turnaround project may increase as the equipment is dismantled. Williamson (2019) also stated that there is no way to precisely identify discovered work. It is argued that discovered work is unavoidable as long as no technology can detect all faults without dismantling the equipment. Upon encountering the discovered work, people will start to look for relevant knowledge. This finding aligns with Petter & Vaishnavi (2007). They claimed that knowledge reuse is initiated when an individual discovers a problem.

b. Search and locate the expert or expertise. It is argued that the urge to find knowledge by starting from the expert is strengthened as "asking your peers" already becomes a habit in the company. Based on the interview sessions, it is found that almost all interviewees on the staff level state that they will ask their peers if they found a problem. The leaders also encourage the subordinate to ask rather than try to solve it by themselves because their own solution might be not yet proven and dangerous for the plant. This finding also aligns with an empirical study by Kulkarni, Ravindran, & Freeze (2006). They found that organisational variables such as leadership and coworker have a significant positive effect on knowledge use.

In searching the relevant knowledge, instead of looking at the written artefacts, people start to pinpoint the knowledge from an expert. Apparently, this is considered standard practice within the maintenance domain. A finding from a quantitative study by Refaiy & Labib (2009) shows a positive relationship between sharing tacit knowledge and maintenance performance measures. Moreover, this finding also supports a study by Mannonen & Hölttä (2013), which claims that during a problem-solving situation in the maintenance domain, the maintenance workforce frequently relies on maintenance workers' descriptions and insights, as well as their accumulated tacit knowledge throughout their career.

It is believed that reliance on the expert rather than expertise occurs because of the poor quality of explicit knowledge. As the explicit knowledge is not indexed properly, it induces difficulties to find. Furthermore, there is a chance that once it is found, the content may be incomplete. Consequently, it discourages people begin looking for knowledge from expertise. This finding turns out to be also congruent with the study by Kivrak et al. (2008) where they found that people in construction project settings think that trying to find explicit knowledge is time-consuming. Sometimes it is also challenging to find relevant expertise promptly. However, the need to find the detail in the available explicit document is still emphasized. There is a need to find the details of the past solution or equipment condition.

c. Selection of expert or expertise. The enabler of selecting the appropriate expert or expertise from the available options remains unknown. However, the idea from Petter and Vaishnavi (2007) about expert selection could explain the situation. It is plausible to say that expert selection depends on the ability of the experts to articulate the knowledge. On the other hand, the barrier of selecting an expert is the availability of the props to explain the knowledge, namely picture, model, etc.

d. Application of the knowledge. Next is the application of knowledge. In this case study, it is found that in developing the solution, the employee of the Pupuk Kaltim conducts a brainstorming session. In this session, the knowledgeable employee shows his experience in facing the situation. Thus, it will be easier to apply the knowledge as there is direct guidance from the knowledge producer. On the other hand, there is also a situation where the knowledge producer has retired and is not in the same location. This becomes the barrier to apply the knowledge. As it is not in the same location, the knowledge producer will deliver the knowledge through the phone, which is impossible to assist the implementation. Hence, the knowledge producer might feel reluctant to reapply the knowledge.

e. Reintegrate the knowledge. This is the last step of the micro process of knowledge reuse process. The knowledge that is re-used is reintegrated into the existing knowledge management system. In this study, the rule is the enabler for the people to reintegrate the knowledge. Although it is merely a passive by-product, at least the company produce every turnaround project. On the other hand, the barrier to reintegrating the knowledge is the lack of resources and guidelines for both reporting and evaluation meetings.

5.5. Recap

This chapter details the company's current knowledge reuse process within TAM projects. Moreover, the enablers and the barrier of knowledge reuse has been identified. It is found that the stages are closely interrelated, which can be envisaged through spatial and temporal dimensions. Within these activities, it turns out the knowledge reuse process is mainly based on a person-to-person basis. As the subject draws in along the TAM project with its recurring character, they also gain, reuse and develop knowledge.

Moreover, as each TAM project might involve a different subject and community, the knowledge transactions also occur. Subject may reuse the knowledge from the community or the other way around. That is because, for every problem they counter, they will strive to reuse their past knowledge or peers' expertise and come up with new knowledge.

The use of an explicit document cannot be avoided as some details cannot be fully remembered. However, the approach of document-to-person in reusing knowledge within TAM projects in this study is poor. The identified main reason is the lack of rules. There are no sufficient rules that guide the knowledge reintegrating process into the explicit document at the closing stage. On the other hand, there are also no rules to formally reclaim previous knowledge in the planning stage.

Thus, the next chapter will develop measures that mainly focus on introducing new tools and rules for the document-to-person approach while also strengthening the people-to-people approach.

6. Proposed Measures to Improve Knowledge Reuse Process

This chapter represents the final step of conducting a diagnostic approach. It is intended to contribute an intervention act to alter the current practical condition to the desired situation. From chapter 4, it is emphasized that to reduce the rework, the intervention must be made to minimise the poor execution plan and knowledge issue, which are comprised of inattention to WI and knowledge gap among workers. By conducting activity analysis within TAM project stages in chapter 5, the fault tree from chapter 4 can be sharpened. It is found that a poor execution plan is caused by the absence of reclaiming the lesson learned process. However, even if there is a procedure for reclaiming the lesson learned, the process will not be working smoothly. There is also an issue of capturing knowledge during the closing stage. Because of a lack of human resources, tools, and rules, collecting knowledge is hampered.

In section 6.1, a concept of Flawless project delivery will be introduced. This concept is known as a guide of the learning process between projects, which is dominantly used in the oil and gas industries. In section 6.2, interventions will be made for the closing stage. In section 6.3, the interventions will be presented for the planning stage. In section 6.4, the expected impact at the execution stage of conducting measures from sections 6.2 & 6.3 will be delivered.

6.1. Flawless Project Delivery (FPD)

FPD is a risk management-based concept to avoid recurrence of failure and quickly learn from incidents used as a prerequisite to achieving successful projects, particularly in the oil & gas industry (Christoffels, 2014). In this context, a flaw is described as a previously encountered failure of a system or an element to respond on demand and according to design (Cornelisse, Gort, & Westerink, 2012). However, flawless does not necessarily mean perfection; instead, it creates an effective barrier against known flaws through capitalization of structured and orchestrated lesson learned processes (Cornelisse, Gort, & Westerink, 2012) (Christoffels, 2014).

Flaws may be manifested into the organization, people, assets and are most likely to be repeated in other projects (Probst, 2009). Moreover, Probst (2009) also described those flaws occur during the plant start-up process. He also argues that it can be categorized as leakage, blockage, incident in HSE, system malfunction, etc.

In the FPD, there are 10 so-called quality or Q-areas where the flaws might also be assigned. The Q-area consists of Tightness, Cleanliness, Integrity, Operability, Safety, Prototype/Novelty, Complexity, Testing, Experience, And Coincidental Event (Christoffels, 2014). Christoffels (2014) thus emphasized that these known flaws during the start-up process and the lessons from the evaluation process of the previous project must be recorded and categorized by these Q-areas. Eventually, a database of flaws should be updated every time the TAM project is completed.

He also adds that these records should be embedded in the company's improvement system and finally shared with the company's employees (Christoffels, 2014). Thus, he recommends 5 generic approaches; appoint a quality area coordinator, set its key performance indicators, retrieve and mitigate the flaw list, and arrange Q-assurance plans. The plan must be executed at the execution stage, and expectedly, known flaws do not occur.

6.2. Measures for Closing Stage

Based on the AT analysis in chapter 5, the closing stage suffers from 3 main problems: poorly conducted reporting, overlooked evaluation meeting sessions, and the absence of updating WI. Thus, the suggested measures are developing a lesson learned spreadsheet, formalizing the project evaluation and developing a shared web-based work instruction. The renewed AT model for the closing stage can be seen below.

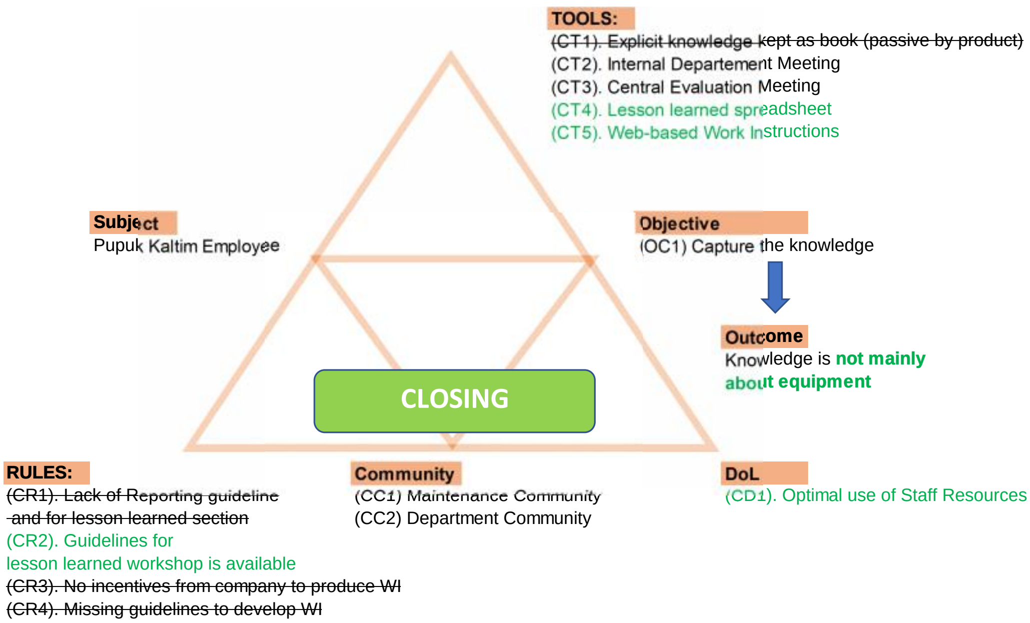

Figure 11 Renewed Closing Stage AT Model

Each measure will be elaborated further in the following sub-section.

6.2.1. Developing A Lesson Learned Spreadsheet

The idea of having lessons learned is also deemed necessary by the interviewees. However, they do not have the guide to do so. Thus, one of the measures is providing a guide to the writing lesson learned section.

Nonetheless, there is a constraint from the division of labour where there is a lack of staffing, thereby implicating that the process of reporting lessons learned should not take too much time. However, the most challenging aspect in knowledge codification is determining the extent of context that must be made for effective reuse (Schacht & Maedche, 2016). As cited in Markus (2001), a study found that when context requirement is too much, it will require too much time and thus discourage the knowledge producer from reporting his knowledge. On the other hand, insufficient context will result in the inability to recognize the knowledge. Hence, a fit amount of context must be provided in the lesson learned section.

Next, paper-based document dissemination is deemed one of the aspects of culture contributing negatively to the KM initiative (Maqsood, 2006). Thus, Masqood (2006) suggest moving to information technology (IT). IT is a crucial aspect of knowledge dissemination (Duffield & Whitty, 2015). Therefore, it is recommended to provide the lessons learned in a database that can be accessed easily by all organisation members related to the TAM projects.

Inspired by Engineering Check Sheet (ECS) developed by Stenholm, Catic, and Bergsjö (2019), it is recommended to provide the lesson learned in tabular form in *Google Sheet*. Stenholm et al. (2019) argue that ECS is primarily intended to divide and structure the knowledge or experience into thin slices of 'know what', 'know how', and 'know why". Consequently, it should be quickly filled and acquired. However, the author argues that this format is quite vague. Thus, it is recommended to expand a little about the content.

Based on the actual case study of the refinery unit in Singapore obtained by Milton (2010), the format can be expanded into 5 questions, namely '*what was supposed to happen?', 'what has actually happened?', 'why was there a difference?' , 'what have we learned?' , 'what actions need to be taken?'.* Moreover, it is also recommended to classify each entry based on the Q-performance areas of the FPD concept. One of the actual rework events from the P-5 TAM project in 2019 will be used as an example and can be seen in the following table.

Table 14 Example of Documenting rework event based on ECS

Entry No	***what was supposed to happen?***	***What has actually happened?***	***Why was there a difference?***	***What have we learned?***	***What actions need to be taken?***	***Affected Q-performance areas?***
1	*Normal foaming process in the CO_2 removal stripper*	*Abnormal foaming with excessive flooding thereby damaging hold down grid*	*Accumulated debris from pall ring unloading process*	*Ensuring The hold-down grid must be cleaned*	*Improve the WI of the pall-ring unloading process to reduce debris accumulation*	*Cleanliness*

This form is expected to be filled by every personnel that is involved during the TAM project. Eventually, there will be a lesson learned database that should be verified at the lesson learned session.

6.2.2. Formalizing Project Evaluation Workshop

It is also known from chapter 5 that Pupuk Kaltim already conduct an evaluation meeting on both the department and central level. Nevertheless, it is found that the former is not prevalent, meaning that all department does not implement it. On the other hand, the central level evaluation meeting focuses only on evaluating the TAM target and discussing the future work scope. The principal contradiction is that the guidelines are missing to conduct a proper one. As a result, the measures would be establishing a good lesson learned workshop. The workshop will be referring to the work by Buttler (2018).

Department level. For the department level, it is strongly advised to have a formal evaluation meeting regardless of whether the TAM execution is successful or not. It is recommended to review and vote on the most crucial individual input of lesson learned or flaw during the meeting. Subsequently, the selected lesson learned should be collaboratively analyzed to identify the impact, leading causes, and recommendations to avoid the event to reoccur. Finally, the product of the workshop sessions should be documented. The format for reporting the lesson, which is based on (Buttler, 2016)is provided in **Appendix C.**

Central Level Evaluation. Generally, how the lesson learned documenting process should be performed at the central level is similar to what is proposed at the department level. Instead of using individual input, each department should bring its final lesson to the central level meeting. Subsequently, they should collaboratively define the measures if the lesson learned involves a cross-department relationship. The measures should be clearly formulated and assigned to the responsible entity while being closely monitored if it requires changes in how the organization operates. Eventually, the lesson learned should also be documented and attached to the final closeout report. Finally, the closeout report should also be shared, which also means widely distributing the lesson learned.

6.2.3. Shared Web-based WI

WI is not updated regularly because the firm lacks manpower resources, direction to make a helpful WI and incentives. Moreover, based on the interview sessions, current WI situations are not evenly shared among the workers, are not updated, and are difficult to interpret. Thus, creating WI in a shared web-based environment, such as Google docs, where people may collaboratively renew the WI is recommended. The proposed template of WI can be seen in **Appendix D.**

First, it is suggested to set a meeting in the department and define the structure of the WI. Therefore, each person will have the same understanding of the content of the WI, resulting in a uniform interpretation. Subsequently, it is also suggested to allocate more time during the execution stage to document the work. These documentations then should be then attached to the WI to improve users' understanding. Finally, as incentives are regarded as enablers of successful Knowledge Management initiatives, it is also proposed to provide a reward for the best contributors and establish the organizational norm of regularly updating the WI that must be adhered to.

6.3. Knowledge Reuse Strategies for The Planning Stage

The main issue based on AT analysis is that there are no guidelines in reclaiming the captured knowledge. Moreover, it is perceived to be challenging to find or look at the WI while the worker is already at the execution stage. Thus, the ideas for measures on this stage are formalizing reclaiming lessons learned and collaboratively reviewing the work instructions. Schacht and Maedche (2016) argue that reviewing the available lesson learned at the planning phase is the most practical knowledge reuse. The renewed AT model for implementing the measures in the planning stage can be seen in the following figure.

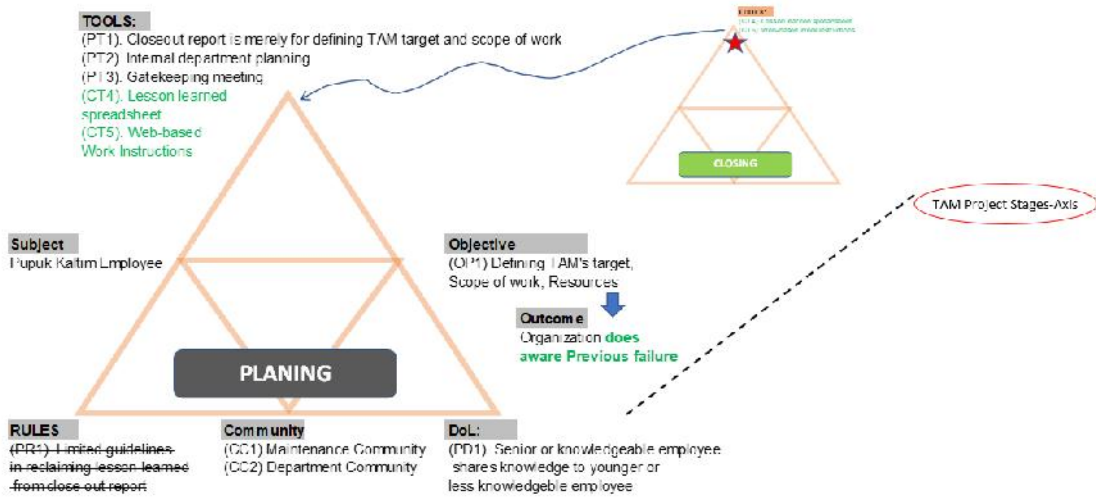

Figure 12 Renewed Planning Stage AT Model

6.3.1. Reclaiming Lesson Learned

The gatekeeping meeting should be about the scope of work definition and reviewing the database of flaws and lessons learned to ensure that the same mistake does not occur. The lesson learned spreadsheet (CT4) as the boundary object generated in the closing stage should be used. The loop of gathering and reusing knowledge can be seen in the following figure:

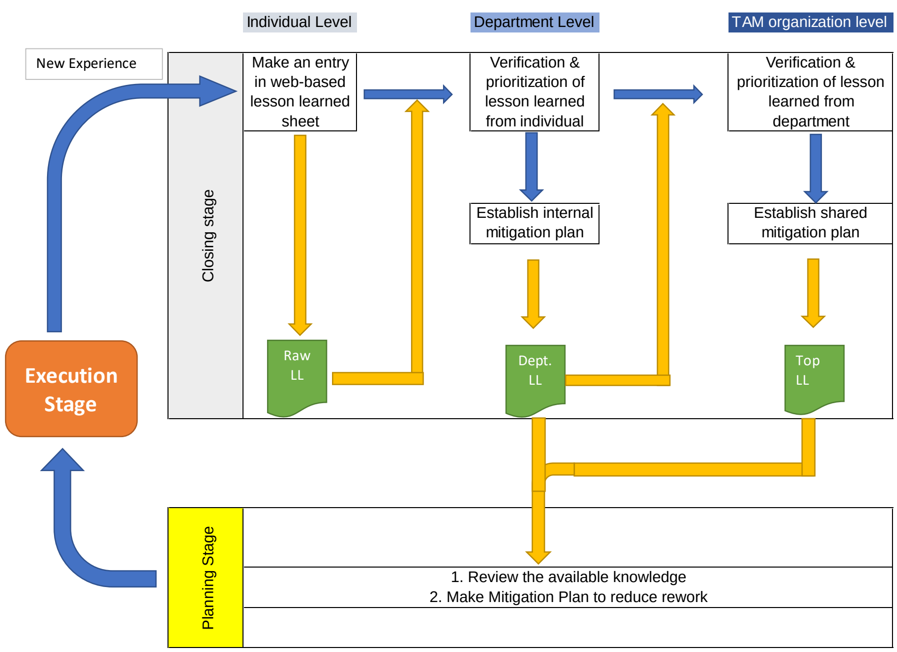

Figure 13 Link between closing stage and planning stage

The proposed steps are adapted from Schacht and Maedche's (2016) type 3 lesson learned session. First, collaboratively reviewed the available lesson learned data spreadsheet database (CT4 in the figure above). The most frequent problems for each Q-areas should be identified. Subsequently, a mitigation plan must be developed. There should also be a leading indicator that must be met by the people. Next, a responsible person for each relevant Q-areas should be appointed. Finally, this process is documented. It is also recommended to give credit to the originator of the lesson learned database. Giving credit is argued to be a form of intangible incentive. This way, it is expected to drive the people to keep providing lessons learned during the closing stage.

6.3.2. Collaboratively Reviewing WI Within the Department

Moreover, on the department level, it is also suggested to collaboratively review the shared web-based WI (CT5) and the lesson learned database. The reviewing process for each WI should be led by the people who have the most experience of the task. Expectedly, collaboratively reviewing the WI ensures that each person interprets how to execute the work similarly. Consequently, the work quality will be met.

6.4. The Implication to Execution Stage

The proposed measure of establishing the reports' template and checklist followed by firm report review should eliminate history card or report incompleteness. Also, reviewing the WI before going to the execution stage will minimize the inattention to the WI problem. Thus, removing the contradiction between subject and rule. The impact of implementing the measures in the closing and planning stage can be seen in the AT model for the execution stage depicted in green sentences as follows:

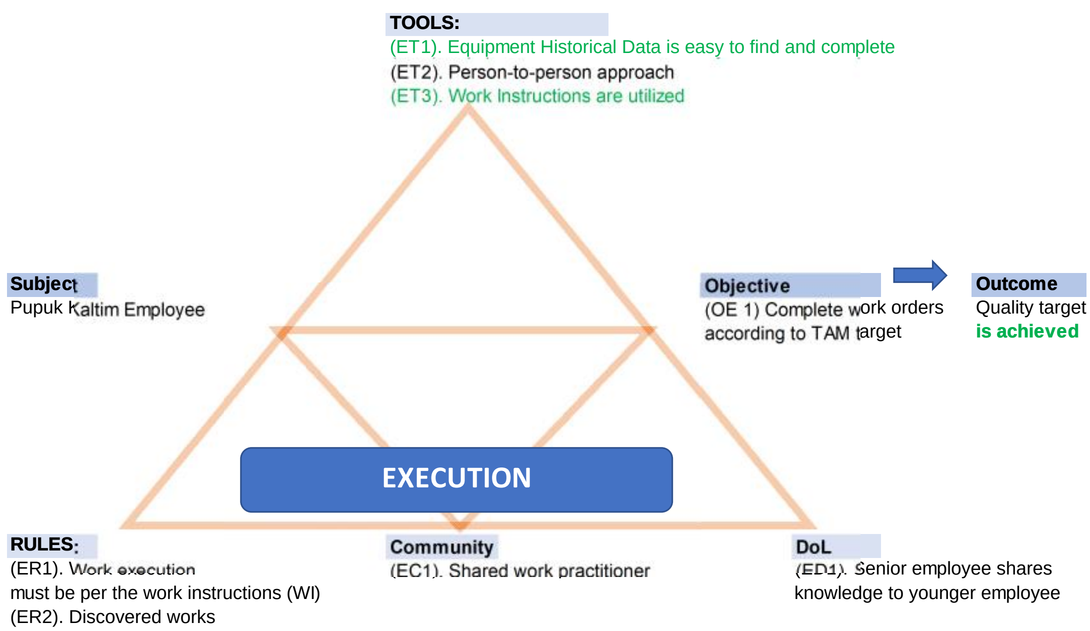

Figure 14 Expected Impact at the execution stage

Nevertheless, although these measures range from closing to planning are taken, it does not mean that flaw or rework will not reappear. It may appear in another form, namely in those 10 Q-areas. Thus, as long as the organization implementing the FPD, the likelihood of flaw, or in this case, rework occurrence, will gradually decrease.

6.5. Recap

This chapter has presented the recommended measures to improve the knowledge reuse process within TAM projects. First, adding new tools such as a lesson learned spreadsheet and shared web-based work instructions may improve the knowledge reintegration process in the closing stage. Secondly, still in the closing stage, there is a new direction for both department and central stage meetings to gather lessons learned. Lastly, the methods for recovering lessons gained using the FPD idea and collectively evaluating work instructions during the planning stage are presented at the planning stage. It is expected by performing these measures, the quality target is achieved during the execution stage.

Nonetheless, just because these steps, ranging from closure to planning, have been performed does not imply that flaws or revisions will not occur again. It might show up in a different form, such as in those ten Q-areas. As a result, the chance of a fault, or in this case, rework, will steadily diminish as long as the organization follows the FPD concept.

The next chapter will present the validation result for 3 items. First is the identified fault tree, followed by the problems revealed through the AT lens and the proposed measures.

7. Expert Validation

This chapter presents the validation of causes of rework events from chapter 4, the current practice of knowledge reuse within TAM project stages from chapter 5, and the proposed measures that are presented in chapter 6. To begin with, section 7.1 will show the validation process. Subsequently, in sections 7.2, 7.3 and 7.4, the result of validation for rework event causes, current knowledge reuse practice and proposed measures will be discussed, respectively.

7.1. Validation Process

A case study is the basis of this research. Hence, a validation process is deemed necessary to ensure that the findings can be generalized. The validation process is done by interviews with experts in the TAM projects setting. The expert profile can be seen in the table below:

Table 15 Experts' Profiles

Code	Qualifications	Years of Experience
E1	Expert in various process industries such as LNG terminals, offshore production facilities, project construction, commissioning, and start-up.	More than 30 years
E2	A retiree from the company previously was the Chief Maintenance Officer	More than 30 years
E3	A retiree from the company previously was the Chief Maintenance Officer	More than 30 years

Each of the interview sessions lasted for approximately 1 hour. The interview sessions were done using the Zoom app. The process of validation was divided into three parts. First, a short introduction was given to the expert to make them understand the research context. Subsequently, each finding from this study was presented to the expert. Discussion of each result was done after each conclusion was given rather than wait until all findings were presented. This was done to ensure that the experts could provide input comprehensively. The main questions during this validation process were *“To what degree are the results valid?”, "What are your thoughts?" “What can be done better?”*

7.2. Validation of Rework Causes

For this finding, the focal point of discussion was to see the degree of the acceptance of the rework event’s fault tree that can be seen in Figure 5. Based on 3 expert validation interviews, most of the responses agreed with the fault tree. But E1 hone the fault tree by suggesting that knowledge and supervision are actually about the leadership in managing the TAM project. Nevertheless, all experts agree that rework links the organisation's ability to learn, in this case, how knowledge is being reused.

7.3. Validation of Knowledge Reuse Practice in TAM Stages

After discussing the fault tree of the rework event, the discussion was continued for the findings within each TAM project stage. Each step was briefly presented, and the experts were asked about their opinion about it.

E2 & E3 confirmed that people rely on their experience instead of WI during the execution stage. E2 elaborated this practice is also affected by the organization culture. Younger generations see the senior conducting such practice, and they follow it too. E3 also agrees with this finding, stating that the tendency to not look at WI during execution is caused by people's perception that they have been doing the same work many times. Nevertheless, E3 objected to the idea that WI is not fully reused. People still need to review it to find more detailed information, such as clearance for installing a rotor. Moreover, the difficulty in interpreting the rework on the rework that happens from treating a discovered work, E2 & E3 agree that using the historical card is critical. E1 stated that people will start improvising without a complete history card, and time will be lost.

In the closing stage, E2 & E3 admitted that the post-TAM project evaluation in Pupuk Kaltim is frequently overlooked. E2 described that people think that when the TAM project is done, they can return to their department and start their daily routines. E3 also added that there could be another problem at another plant, and people will be allocated there to solve the problem. Thus, the evaluation meeting is postponed, and when the trouble is solved, people already forget to conduct the evaluation meeting. Nevertheless, the process of compiling the closeout report is still intact. Thus, they still capture the knowledge, at least about the equipment conditions. However, E1 described that if the knowledge that is being captured is merely about knowledge of the equipment, then it is fragmented. E1 stressed the importance of writing down what was planned and what the actual was.

At the planning stage, E2 & E3 accepted the finding that the focus is more towards selecting the scope of work during the planning stage. The managerial suggestions and problems from previous TAM projects are seldomly reviewed. E1 really stressed the importance of reusing past TAM experiences for the next TAM project. One of the important indicators is the number of unplanned works. The future TAM project's incidental work should be smaller than the previous one.

E3 realized that the sharing between senior employees and junior employees happens only for critical equipment such as turbines or pumps on the department level. Sometimes, it is limited due to the absence of photos to be shown.

7.4. Validation of Proposed Measures

The final step of the validation process was the discussion about the proposed measures. E2 supported the idea of having a template that can guide and collect lesson learned and categorize it based on FPD's Q-areas. He also adds that it is important to also identify the person who provides the lesson learned. So that it can be traced back in the future. E3 also supported the idea of revisiting the lesson learned database and the shared web-based WI during the planning stage. That ensures that the process is in closed-loop form, thereby reinforcing people as they will benefit from collecting the lesson learned and periodically updating the WI.

However, all experts said that this initiative cannot be working without support from the organization and the leadership. E1 really emphasize the need for strong leadership that can listen to what their subordinate needs. E3 also described that leadership is a necessary element as the proposed measure cannot solve the problem of reusing knowledge a night. The proposed measure is about changing the company's current way of working, which also means changing the company's culture. Thus, there is a need for a leader's consistency to periodically remind the people to stay focus on the mutual learning growth. Lastly, according to E2, organization support is also required for providing sufficient incentives for the people.

8. Conclusion and Recommendation

This is the report's final chapter, and it is intended to give concluding remarks on the study that was conducted. To begin with, in section 8.1, the research questions proposed in this research will be answered. Next, in section 8.2 scientific and practical implications of this research will be elaborated. Lastly, in section 8.3, research limitations and further research recommendations will be provided.

8.1. Answering Research Question

This research is executed to provide recommendations for reducing rework events by improving the knowledge reuse between turnaround projects in Pupuk Kaltim. This is done by assessing the knowledge management process using activity theory. In doing so, the main research question is:

How can the rework events in TAM projects be reduced through the improvement of the knowledge reuse process?

Four sub research questions are formulated to answer this main research question. In this section, it is going to be answered as follow:

- **SQ 1: What is the link between knowledge reuse and rework in the TAM project?**

A need to evaluate the link between knowledge and rework comes from the current situation in the company, where they always had rework events from their last 3 known TAM projects. In a turnaround project, rework events may hamper the schedule target accomplishment as time is needed to redo the work.

Based on the interview process, the results were cross-cased with the desk research results. It is found that rework events may be caused by the hidden defect, poor spare part quality, flawed execution plan, knowledge issue, and supervisors are lacking. On the knowledge issue side, it comprises 2 causes; disobedience to work instructions WI and the disparity of knowledge and experience among the employees.

The decision to focus on the knowledge reuse process is made because the event of the hidden defect and spare part quality has already received attention from the company. Once the hidden defect is found, they will add more inspection work. As for the spare part quality, they will improve the quality control for spare part procurement. In the event of lacking a supervisor, it is found that the company has streamlining policy that inhibits the ability to add more employees to become a supervisor. Thus, the only option left is focusing on the solving-knowledge issue.

Knowledge issue comprises inattention to work instructions (WI) and the disparity of knowledge and experience among the employees. WI is a form of explicit knowledge source that should also be a living document that captures best practices on performing particular work. Nevertheless, it is often neglected or re-used to maintain a certain level of quality in this research focus. Secondly, the employees' disparity of knowledge and experience is caused by a deficiency of material to learn. Hence, the younger employees must reinvent the wheel by staying involved in turnaround projects to build their knowledge. This is also deemed to be a problem of inability to reuse the knowledge. As a result, the difficulty in reusing knowledge has a favourable relationship with rework occurrences. This is thought to justify the necessity to assess the company's existing knowledge reuse practice.

• SQ 2: How is knowledge reuse being practiced in TAM projects through the Activity Theory lens?

It is found that knowledge reuse is used moderately during the planning and execution stage. The knowledge reuse process happens mainly through a people-to-people approach, although it mostly happens informally. On the other hand, the people-to-document approach is still limited to selecting the scope of work for TAM projects.

The planning stage aims to establish a turnaround target, scope and the volume of work, required source (s), budget and schedule to accomplish the project. In establishing the turnaround target and the scope of work, it is known that one of the sources of explicit knowledge comes from the closeout reports, and this is performed successfully. Nevertheless, the suggestions are often overlooked as there are no guidelines to do such activity.

During the execution stage, knowledge reuse happens when discovered work is encountered. In completing the discovered work, people rely on a person-to-person approach. Subsequently, they are going to use explicit documents as a backup. Nevertheless, it is found that the quality of the document is not complete as some information may be missing.

Still, at the execution stage, it is also found that the quality of work may be compromised as people neglect the use of Work Instructions. However, it is explicitly mandated in the company's turnaround manual. Work Instructions can be perceived as a form of explicit knowledge. That is because it should be a living document that captures the best practice as it evolves. Nevertheless, on the reuse side, it is found that people prefer to rely on their experience.

Finally, the experience throughout the execution stage should be documented at the closing stage. It is known that the capturing process happens through a joint session called central evaluation meeting where it involves various departments, internal department evaluation (although not prevalent) and providing a closeout report as well as updating the work instruction. These first 2 activities are even explicitly written in the company's turnaround project manual. However, the process of capturing the knowledge is also lacking.

First, it is found that during the evaluation meeting, it is primarily based on habit and not prevalent and not yet systematically managed. Secondly, it is also revealed that the process of documentation that encompasses building closeout reports, updating WI, as well as repositories are hampered due to lack of resources of both time and manpower, no formalization/guidelines and lack of incentive

• SQ 3: What are the barriers and enablers of the knowledge reuse process within TAM projects?

Having AT models established for all TAM project stages, the contradictions associated with the enablers and the barriers for knowledge reuse can be identified. Starting from the need to find knowledge, the enabler of doing so is encountering discovered work during the execution stage. Subsequently, it is found that to find relevant knowledge, they rely upon their network. That is because the setting TAM project is basically a shared work producer where people work in the same domain. Furthermore, it is found that the person-to-person approach is claimed to be common in the maintenance domain. However, in terms of doing the work that is already planned in the TAM project scope of work, people neglect WI. That is because WI is perceived to be difficult to be located, no longer relevant, and challenging to interpret. These 3 reasons are the barrier to reusing explicit knowledge.

Reintegrate the knowledge is part of reusing knowledge, and this should be performed during the closing stage. The knowledge is indeed captured but primarily only to the extent of knowledge with regards to equipment. That is which equipment should be incorporated in the future TAM project's scope of work. Capturing process is obstructed by the fact that there is a lack of resources, guidance on establishing lessons learned, and an incentive from the company.

Lastly, in the planning stage, the knowledge shall be reused is again. Still, it is mostly about knowledge regarding the equipment and TAM target, particularly about safety and the environment. That is because the source of knowledge, the closeout report, is predominantly filled with that knowledge. Moreover, there are no guidelines that ensure people reclaim the previous lesson learned. Hence, the limited source of knowledge and lack of guidelines are deemed to become a barrier to knowledge reuse.

- **SQ 4:** What measures must be taken to address the barriers to knowledge reusing practice at TAM projects?

The measures focus on capturing the knowledge and formalizing the process of identifying the knowledge before starting the execution stage. First, it is recommended to develop a new tool that is a web-based spreadsheet that can collect the failure experience as knowledge from the execution stage and categorize each entry to relevant quality areas based on the FPD framework. Another recommended tool is a shared-web based page where people can collaboratively review and edit the WI. Next, it is recommended to develop a set of guidelines and checklists that ensure the completeness of historical equipment records. Finally, it is also recommended to formalizing the process of TAM project evaluation at the closing stage.

At the planning stage, it is also recommended to formally review the available knowledge derived from the web-based spreadsheet tool. By officially reviewing it, it is expected that people will not repeat the same mistake. Next, it is also recommended to collaboratively study the WI between the senior and younger employees before continuing to the execution stage. Lastly, based on the expert interview, it is also recommended to establish strong leadership and organizational support to execute these measures. By then, the rework event during the TAM project can be reduced.

8.2. Scientific and Practical Implications

This section will cover the scientific and practical implications that result from conducting this research. The scientific implications will be presented in section 8.2.1, whereas in section 8.2.2, the practical implications will be suggested.

8.2.1. Scientific Implications

Numerous studies indicate that organizations continue to fail to reuse prior knowledge (Landaeta, 2008; Duffield & Whitty, 2015; Stenholm, Catic, & Bergsjö, 2019). This claim turns out to be also applied to the TAM projects. Furthermore, it is well recognized that one of the least explored areas of maintenance management is learning (Simo˜es, Gomes, & Yasin, 2011). As a result, this research presents empirical findings in this field. Furthermore, the empirical findings on barriers and enablers in the knowledge reuse process were found in this study. Finally, AT has not been used to evaluate TAM initiatives to the best of the author's knowledge. As a result, this study broadens the empirical use of AT.

8.2.2. Practical Implication

In terms of practical implications, the research findings, conclusions, and recommendations might improve the knowledge reuse process in turnaround projects. This will definitely be advantageous, given the frequency with which Pupuk Kaltim conducts turnaround projects. Furthermore, because Pupuk Kaltim has four other sister companies in Indonesia that similarly execute turnaround programs, the findings of this study may also apply to them.

8.3. Research Limitation and Recommendation for Future Work

This research used a petrochemical company case study where they conduct their TAM project every 2-3 years. Moreover, it has more than 1 plant, meaning that they could have a TAM project every year yet in the different plants. This can be seen from the selected case studies, which were conducted continuously from 2018 to 2020. Thus, it is plausible that there could be not enough drive to document the knowledge as they will have the same kind of project frequently. Instead, the employees' experience accumulates quickly through frequent involvement in the TAM project. Furthermore, the owner is in charge of the turnaround projects used as case studies. The results could have been different if the research had been conducted across a broader spectrum of industries, or perhaps from the perspective of a contractor who handles complete operation and maintenance (O&M) work.

Second, through evaluating the organization's knowledge reuse process, this thesis seeks to reduce rework during the execution phase. Nevertheless, this study also found various causes of the rework events, but it was not quantified. This means that the dominant cause of rework events cannot be identified. Other dominant factors may cause rework, and efforts to reduce rework can be started by eliminating the dominant cause. To the best of the author's knowledge, the literature on the grounds of the rework event in TAM project settings is scarce. Thus, finding the dominant cause of rework events in the TAM projects is also recommended for further research.

Thirdly, this research founds that the knowledge re-use process happens dominantly through the person-to-person approach. The method of reusing knowledge in this approach is facilitated by the degree of proximity between employees. However, employees come and go in a company; the old retire and are replaced by the new. The conditions depicted in this study may arise because of the company's regeneration period. There are significant generational differences among employees. Although it is not possible to gain empirical data due to time limitations, this could be indicated by the considerable employee age standard deviation. As a result, it would be interesting to investigate how the TAM project's knowledge reuse process works when the standard deviation of the employee's age is considered.

Finally, the final outcome of this study is a set of recommendations for improving knowledge re-use and reducing rework occurrences. As a result, it will be fascinating to observe how this idea is implemented and whether it reduces rework incidents. Action research is one method for carrying out this proposal. It's a strategy for bringing about conscious change in a somewhat controlled setting (Duffield & Whitty, 2016). Furthermore, the systematic lesson learned knowledge model (SYLLK) may predict the future gap when knowledge re-use enhancement initiatives are implemented in the company.

8.4. Reflection

This last section will be dedicated to express the Author's reflection on completing this master thesis. The main idea of this reflection revolves around the word "Question". Questions, in this case, research questions, should have been carved as the research guide. However, the Author must disclose that he did not establish his final research questions until two weeks before the greenlight meeting. Consequently, conducting the research was like walking in a dark tunnel without seeing the end of it.

First, the author finds pleasure in reading and reviewing the literature. It was pleasing in the beginning, as it felt like going back to be a child where it was an endless question of "What?", "Why?" and "What Else?". He was just eager to know every new thing perfectly and set a firm foundation for understanding the relevant theories. The problem was the topic of Knowledge Management is enormously abundant. Not to mention that it overlaps with other streams of research such as organizational learning, lessons learned, etc. In the end, he felt clueless and overwhelmed.

As a result, it became more difficult to understand the Activity theory. Especially the part of "Object", "Objective", and "Outcome". It seems that there is no single agreement on how to use these Activity theory elements. Moreover, in the mid-term meeting, one of the decisions was to find the link between the rework events and the re-use of knowledge that was not initially planned. Therefore, the author must understand these 3 concepts simultaneously: Knowledge management, Activity theory, and the relation between rework and the re-use of knowledge.

Then the child turned into an adult. It was not pleasing anymore to ask those discovery questions. The pressure of simultaneously being a new father of 2 daughters and a final year masters student started to drain the Author's spirit. All he could think was how to finish the thesis. Thus, he audaciously conducted the interview sessions, although the understanding of the theories was not yet firm.

The author did use works of literature to set up his interview questions. Another problem was when the questions were delivered in *Indonesian Language*, it felt stiff and seemed unnatural. Frequently, the interviewee did not find the question understandable. Moreover, as the process of understanding the theories were still ongoing, the data that must be obtained was also kept growing. Many changes of questions were made as the interview sessions progressed. This situation was also exacerbated by the fact that semi-structured interviews often lead to follow-up questions. Thus, it led to rich data but in a divergent direction. As a result, the author felt more clueless and overwhelmed as he fell into information limbo of both related theories and his obtained data.

Until the author realized that there would never be enough theories and the data he obtained. Fortunately, at least the author had the idea that this research should recommend the company on how to improve their work processes. Thus, he started to analyze and write with what he understood and had. And gracefully, although there are still many rooms for improvement, at least now his thesis is completed.

The author learned from this experience that understanding everything and gathering all of the data required to write a perfect paper is nearly impossible. Because what is planned may not always work out as planned thereby the adaptation process is critical. Trying to plan and organize everything in detail, on the other hand, is nearly impossible. Conducting research is characterized by full of twists, turns and uncertainty. So, rather than predicting and controlling all the paths, it is better to just go with what is there. When a stumbling block appears, simply being adaptable by looking for alternate tracks can help.

The second lesson that the author learned is the need to ask questions for help. The author must also disclose that he failed to manage a close relationship with the supervisors until the mid-term meeting. He did not provide sufficient questions to them. The perception was, asking too many questions equal to showing weakness. During his bachelor, it was not common to ask questions with the supervisors but rather to discuss with fellow students or seniors.

Nevertheless, the COVID-19 pandemic hits, and there were few opportunities to discuss with fellow master students. Asking master's thesis supervisors was not in mind due to his experience. Apparently, this is totally wrong. Asking questions for help is not showing weakness. Instead, asking questions is a way to show that we are not giving up.

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APPENDIX A: Barrier of Knowledge Reuse from works of Literature

Step	1		2		3		4	5
Process by Markus (2001)	Defining Search Question		Search & Locate Expert or Expertise (based on familiriarity)		Select the expert or expertise		Apply the knowledge	Not available
Process Petter & Vaishnavi (2007)	(1a) Identify Problem	(1b) Define Problem	(2a) Identify expert (for tacit knowledge)	(2b) Identify Expertise (explicit Knowledge)	Communicate with expert	Examine the explicit knowledge	Implement the Knowledge	Integrate Knowledge
Barrier By Petter and vaishnavi (2007)	**a)** No incentive to acquire knowledge. Normally the need to use knowledge is "pull" based (encountering a problem) **b)** Decide to reinvent the wheel. Because (i) Not invented here syndrome (ii)Leader emphasize on innovation + creativity (iii) Does not know that such knowledge exist	Wrong problem definition normally for novice knowledge consumer	* Few social contact * Based on convenience rather than expert quality or credibility	* Poor quality source of explicit knowledge * do not know where to start finding * Poor access to explicit knowledge	* The expert does not have the time to provide knowledge * The expert ability to articulate the knowledge is poor * No proper medium to communicate (if separated in distance) * Expert may not have props (picture, model, etc)	* Knowledge is not found * Too much knowledge (knowledge limbo) as a side effect of having project. Projects execution generates information at a high pace, from formal, offcial documents to informal, unstructured personal or group notes (Almeida & Soares, 2014)	* Distrust to knowledge as it is not proven * Innability to understand the knowledge and adjust to current problem due to lack of experience mastery * Forget about the knowledge	* Lack of time to document the knowledge * Everybody already know thereby demotivate the need to register the knowledge
Solution by petter and vaishnavi (2007)	**For reason (a):** * The use of auditor to find problem * Push knowledge to alert the individual **For case (b):** * Create sharing knowledge culture about current problem * Create psychological safety environment--> People feel safe to ask	* Provide training, mentoring, for novice so he may define problem better * Provide expert assistance?	* create a knowledge map (or personalized knowledge management system) within the organization. (*Who knows what)* The knowledge map itself is an explicit knowledge * Team building	*Organizations could provide a list of potential sources for knowledge, such as knowledge repositories, websites, books, or other documented sources.	* restructure job responsibilities of experts or manage his work load. * Train the expert for storytelling ability * The need to document the knowledge through ECS	* Provide better indexing and AI (?) * Proper Documentation process * Introduce Case Based Reasoning. The keyword is the case	* Validate the knowledge by knowledge intermediaries or Topic experts, or best practice management (Dani, S. S. J. A., Harding, J. A., Case, K., Young, R. I., Cochrane, S., Gao, J., & Baxter, D. (2006)) * Training, mentoring, apprenticehip to raise the level of knowledge consumer playing field	
Challenges by Koteshwar, Bengtsson, & Söderlund (2015)	*Different work styles and mindsets			*The absence of standard language to report the breakdowns		*Difficulty to search the similar problem history from different times *The lack of contextual information in after action reports or descriptions	*Difficulty in educating and training novices	*Difficulty in codifying experiences or tacit knowledge *The lack of motivation to spread experiences through documentation
Solution by Koteshwar, Bengtsson, & Söderlund (2015)			*implement a more organized experience-sharing meeting	* The development of a standard language and indexing system * a set of guideline questions can be prepared to ensure document quality * encouraging narrative story descriptions with audio clips and pictures * Simplifying the RCA template and making the previous RCA reports visible on intranet or other places is needed		* The use of and integrate a Wiki platform within the CMMS		* management encouragement in some form of rewards and recognition

APPENDIX B: Interview Questions

No	Theme	Questions
1st Sesssion		
1	The link between rework and knowledge management practice	i. In your opinion, what is the link between experience/lesson learned/knowledge management and rework or unscheduled shutdown? ii. In your opinion, what causes rework to still occur in turnaround at Pupuk Kaltim despite it has been there many times? iii. What efforts have been made by Pupuk Kaltim to avoid rework or unscheduled shutdown? iv. What needs to be done to avoid rework or unscheduled shutdown? v. How are best practices developed in TA implementation?
2nd Session		
1	Activity Theory: Planning Stage	i. How to determine the scope, duration, resources, and Steps of TA work? (DoL, rules, subject) ii. What knowledge is used from the closeout report? (object) (link to closing/closeout report) iii. How are the suggestions and obstacles listed in the previous COR catalogued? (tools) iv. How to prevent mistakes in the previous TA from repeating in the next TA? Is there a special person/role or system that guarantees? (rules)
2	Activity Theory: Execution	i. Can you tell us about the activities during the execution phase for [INSERT THE DEPARTMENT] in general? ii. Can you tell me, if there is a problem during execution, what are the steps to solve it? What inspires you to make the solution? iii. Who is involved? iv. What tools, media, references are used to carry out these activities? v. How to access these tools (source of knowledge)? Difficult? Easy? vi. How is the division of labor in carrying out these activities? (DoL) vii. Are there any rules/customs used in carrying out these activities?
3	Activity Theory: Closing	i. Can you tell me about the TA closing process, what activities/what were discussed? ii. What is the result of the closing process? iii. Who is involved in closing activities? iv. Tell me about the rules, written or unwritten, regarding closing?
4	Activity Theory: Closeout Reporting	i. What inputs are needed to close/make a closeout report? How to get obstacles and suggestions? (object) ii. Tell me about the rules, written or unwritten, regarding closing/making closeout reports? (rules) iii. How is the division of labor in the framework of preparing a closeout report? (DoL) iv. What do you do with the closeout report? (link to planning)
5	Improvement in the Learning process	i. In general, what do you think about the learning process within a turnaround project context? ii. What measures do you think that is needed to improve the learning process? iii. What do you think about establishing learning as project success criteria?

APPENDIX C: Format of Documenting lesson learned (Buttler, 2016)

A. Negative Lesson Learned

Title *short title referring to the effect or incident*

Problem Description *a short description of the problem*

Symptoms *a list of symptoms that characterizes the problem*

Expectations and Actual Events: *should answer the questions "What was done?", "What was the expected result?", "What was the actual events/ consequences?"*

Metadata *contextualize the lessons learned and provide keywords of this particular lesson learned*

List of Contributing Factors: *lists all (relevant) factors that contribute to the gap. Each factor results in a single lesson learned described through the following table:*

No	Title	Description	Recommendation
#	*short title referring to the contributing factor*	*How does the factor contribute to the gap?*	*What should be done to reduce the influence of this factor (or eliminate its influence)?*

B. Positive Lesson Learned

Title *short title referring to the positive lesson learned*

Problem Description/ Opportunity for Improvement *why and in which situations the solution should be implemented*

Symptoms *a list of symptoms that characterizes the problem Solution (and Rationale) provides a high-level description of the solution and how it contributes to solving the problem*

How to Do It *provides details regarding the implementation of the solution*

Danger Spots *describes danger spots, where the implementation can easily go wrong, and the disadvantages of the solutions, links to other lessens learned that might address the danger spots*

Metadata *contextualize the lessons learned and provide keywords of this particular lesson learned*

APPENDIX D: Template of WI

WORK INSTRUCTIONS FOR

[insert the name of the work at which equipment]

1. Applicability

[Describe the Location, Equipment, Process, Facility, Work Center, where this instruction applies]

2. Equipment, Tools, Gages Requirement

[Insert the type of equipment and tools for performing the work]

Item	Type (Equipment, tools or gage)	Photo	Number

3. Hazard & Controls

[Collect the risk and mitigation for performing the work]

Originator	Risk	Mitigation	Notes

4. Comments: Job Notes, Modifications

[Provide the list of job notes, modification on the particular equipment]

Originator	Modifications	Modification date	Notes

5. Procedures

[Provide the order of the task, including the photo (if any) and the quality that must be met]

No	Procedure	Breakdown of task	Documentations	Quality Check