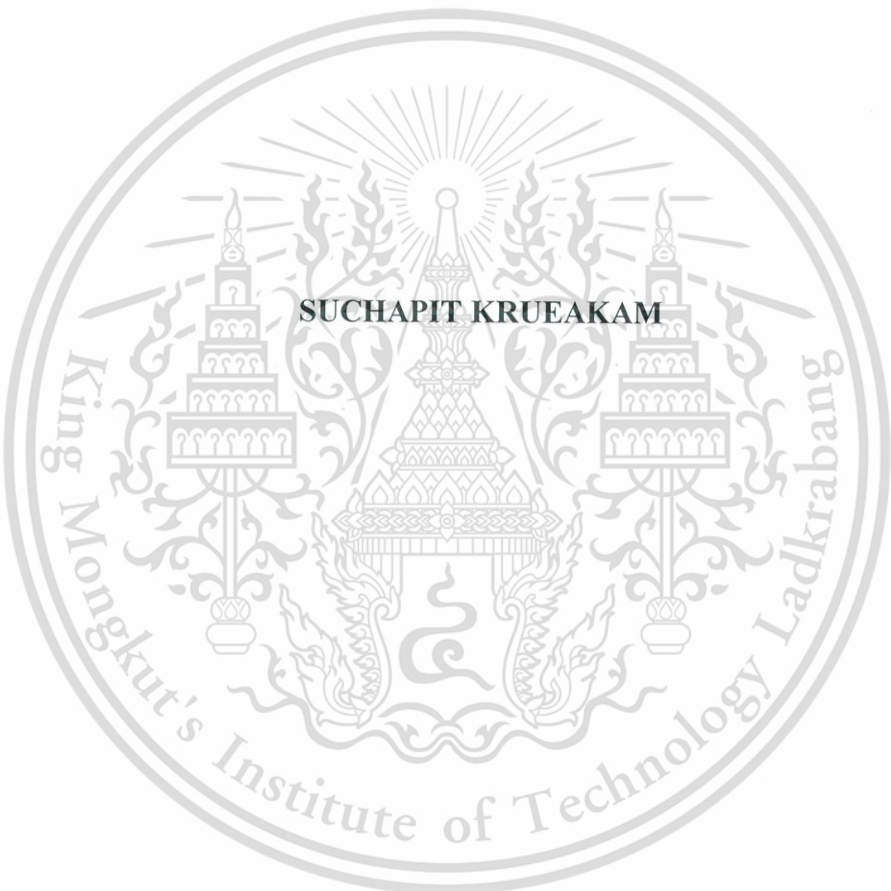
# SUPPLY CHAIN OPERATIONS REFERENCE MODEL FOR THE FLIGHT SIMULATOR MAINTENANCE SERVICE PROCESS MODEL: A CASE STUDY OF ASIAN AVIATION TRAINING CENTRE

SUCHAPIT KRUEAKAM

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## ABSTRACT

The objective of this paper is to present an implementation of a flight simulator maintenance process model through a supply chain operation reference (SCOR) model. To avoid failures and improve the effectiveness of the system and mechanical, it is necessary to implement the maintenance processes. Moreover, a flight simulator operator needs to ensure that the performance of the flight simulator training devices (FSTDs) qualified with the international regulations published by EASA, ICAO, and FAA. This paper demonstrates the maintenance process model which is adapted to the SCOR model. The SCOR model has many limitations such as semantics and process types when applied to the services industry. It was found that the structure of the SCOR model is shaped to the structure of Supply Chain Management (SCM). Theoretically, the SCOR model is established in manufacturing and is described as inapplicable in the services section. The main objective of this study to justify that the SCOR model can be developed within the maintenance management which is services supply chain management. In this paper, the maintenance process was characterised and applied to the services sector, with the intention to improve services through maintenance management, like supply chain

Management. It is challenging that there is no much research has focused on the specific class of services which related to the SCOR model. Finally, the maintenance process models were purposed with the most popular notation which is the Business Process Model and Notation (BPMN2.0) to support the identification and visualisation of the processes.

## ACKNOWLEDGEMENT

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Suchapit Krueakam

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## LIST OF DEFINITIONS

| | |
|---|---|
| AATC | Asian Aviation Training Centre |
| EASA | European Aviation Safety Agency |
| FAA | Federal Aviation Administration |
| FFS | Full Flight Simulator |
| FSTD | Flight Simulator Training Device |
| ICAO | International Civil Aviation Organization |
| SCM | Supply Chain Management |
| SCOR | Supply Chain Operations Reference |
| SSCM | Service Supply Chain Management |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Business aviation well-established in the 1920s, it is a part of general aviation that focuses on the business use of airplanes and helicopters (NBAA, 2018). The International Business Aviation Council describes the definition of the business aviation that it is the sector that deals with the operation or use of aircraft by companies. The business aviation was classified into four divisions: corporate, owner, operated, fractional ownership, and commercial. The business aviation has grown to be a substantial contributor because of high level of its benefits. Flying is an exclusive experience; it becomes the alternative primary travelling. Allowing across vast distances with low-priced made the number of passengers handled by the airline industry globally from 2004 to 2018 is growing up. On scheduled flights of commercial airlines around the world, they carried over four billion passengers in 2017. The Federal Aviation Administration estimates that every year some 2,587,000 passengers fly in and out of U.S. airports (FAA, 2018). Not only faster and cheaper than other transportations, but flying is also the safest way to travel. Dr. Wilson states on his Anxieties website that the chance of a boarding a flight that will be in a fatal accident is one in seven million from the research of Dr. Arnold Barnett which was conducted over the fifteen years (Wilson, 2018). The growth passenger and air cargo traffic rates from 2018-2037 are expected to grow by 4.7 per cent (Statista, 2018) as shown in **Figure 1.1.** According to cheaper oil prices and the result of increasingly

affordable flight rates, and growing up of low-cost airline, passenger and cargo air traffic, the growth passenger is estimated to grow importantly through 2037.

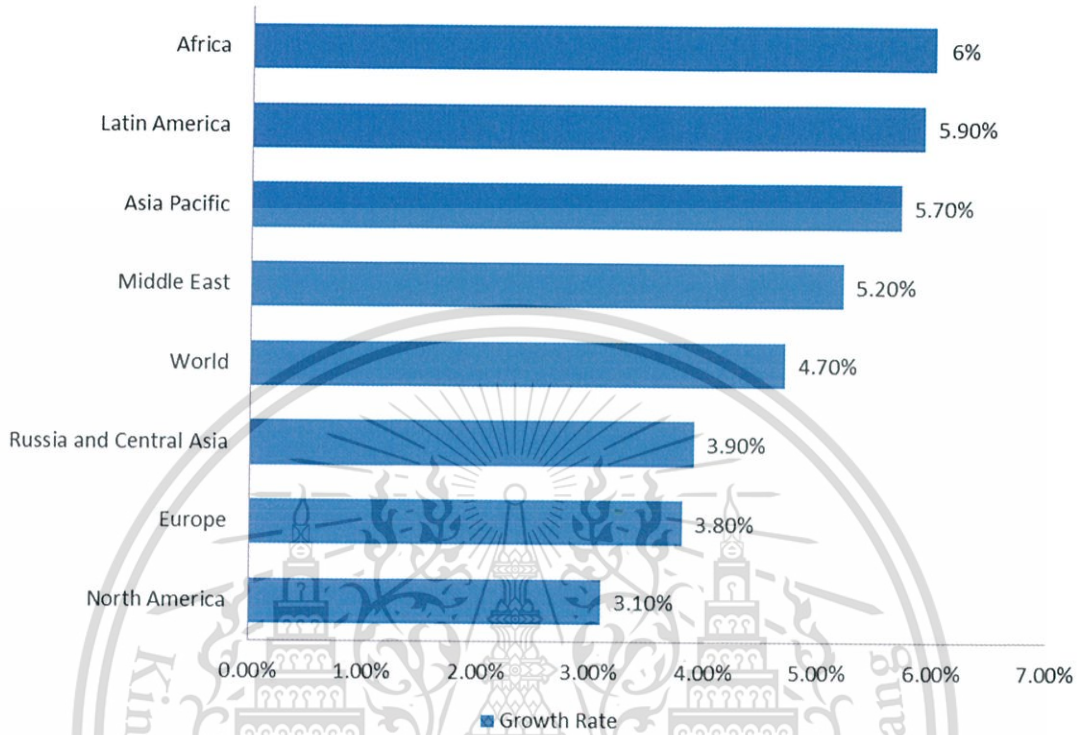



**Figure 1.1** Annualgrowth rates for passenger air traffic from 2018 to 2037

Source: Air traffic - passenger growth rates forecast 2018-2037: Statista, 2018.

Additionally, Thailand's aviation business is also growing rapidly; it is rising at three times faster than the global market. The number of visitors to Thailand increase as well as the travellers in domestic routes, so the expansion of Thai Airlines is mainly driven by the demand for low-cost carriers. Thailand Board of Investment 2016, claimed that the market share of low-cost airlines currently contributes to only about 30% of the total market share, which showcases the huge growth opportunity in this sector. Moreover, there were 823,575 aircraft take offs and landings in 2017, an increase from 790,194 in 2016 (Kositchotethana, 2017). Growing of business of aviation is not just only the increasing of airlines revenue, but it included all components of the aviation industry which growth with aviation's business such as

aircraft manufacturer, energy, insurance, technology, and human resources. Human resources represent another key consideration with respect to growing aviation's business. In such a safety requirement from aviation standard, human resources expertise such as pilots, engineering maintenances, cabin crews, ground services, and air traffic controllers is required for the aviation industry. Aviation industry jobs are specifically job which needs to attend competency training, thus, flight training academy is one of the businesses that has been growing in the aviation industry. Airline jobs are not going away. Most in demand right now are pilots and mechanics, although as technology continues to evolve, there was no doubt being new careers with new skills requirements. At the moment, careers in aviation account for over $1.5 trillion in the U.S. economy alone (Wright, 2017).

Civil Aviation Training Policy was launched new version policy in the sixth meeting of its 208th Session 2016 which aims to support the human resources development strategies and aviation training. It is considered as a support function of International Civil Aviation Organization or ICAO; all ICAO's aviation training activities shall be planned, managed and coordinated by the Global Aviation Training Office or GAT (ICAO, 2016). They are responsible for the planning, management, and coordination of all training and human resources activities. Aircraft crashes are the most disastrous of all transport accidents, largely because they often involve a catastrophic loss of life. Aircraft crashing can kill as many as four or five hundred times more people than a car accident. Therefore, the global aviation organizations emphasize the standard of aviation training to meet aviation priorities and implement the specific training to develop the human resources to meet an aviation safety's standard. This is one of the reasons why aviation training centers are required and needed.

## 1.2 Problem Statement

According to the demand of commercial airlines pilot especially in the Asia Pacific increased 40 percent from 2016-2035 (Statista, 2018). The demand for qualified pilots raised the demand for aviation training centre growth significantly. One of the important units in aviation training which is every pilot need to be trained by the training centre is a flight simulator. There are 42 full flight simulator training centres around the world and around 10 full flight simulator training centres in the Asia Pacific (Aviation Voice, 2018). Flight simulators play an increasingly important role in pilot training and due to high fidelity and reliability so adoption of flight simulator as well as training centre competition are increasing. To create a customer experience which is relevant and useful at every touch point, flight simulator's performance is another way to maximize customer satisfaction. As the AATC does not have the process model before, there are so many wasted processes or the process that's inefficient. The study will focus on designing and creating maintenance service process model. Therefore, the new model helps the organisation to ensure that engineer work processes which affect flight simulator's performance is effective and efficient.

## 1.3 Objectives of the Study

The objective of this study is to design and create new a maintenance service process model base on the SCOR model and illustrate by BPMN, the objectives are as follow:

1. To improve service level by implementing maintenance services
2. To create a standardized maintenance services process model based on the SCOR model

3. To apply BPMN to maintenance service process model

## 1.4 Scope of the Study

The scope of this research will be limited designing and planning maintenance service activities that taking the place in flight simulator maintenance service from a customer request, sourcing supplies, fulfil service, deliver service to the customer. This research focuses on the design and creates a maintenance service supply chain model in the aviation training centre at AATC Company in Bangkok, Thailand. The structured framework of processes will design base on the SCOR model and BPMN to modify the workflow and measure the performance system by interviewing 20 participants which consist of Engineering management team and Supervisor Engineers.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Aviation Industry

Over the past 50 years, the aviation industry has grown exponentially due to escalating global travel demand. The revenue of civil aviation flight training and simulation market is expected to reach 8.3 billion dollars by 2023 (Aircraft Type and Geography - Growth, 2018). Increasing demand for air travel and the needed for the pilot have significantly increased, observed from the statistic of demand for commercial airline pilots in 2016-2035 especially in Asia Pacific region (Oshkosh, 2015) as shown in **Figure 2.1**.

This qualified pilot demand also increased more and more the demand for the flight simulation market. Wright said that airline jobs are not going away because most in demand right now are pilots, and the aviation careers in aviation account for over $1.5 trillion in the U.S. economy alone (Wright, 2017).

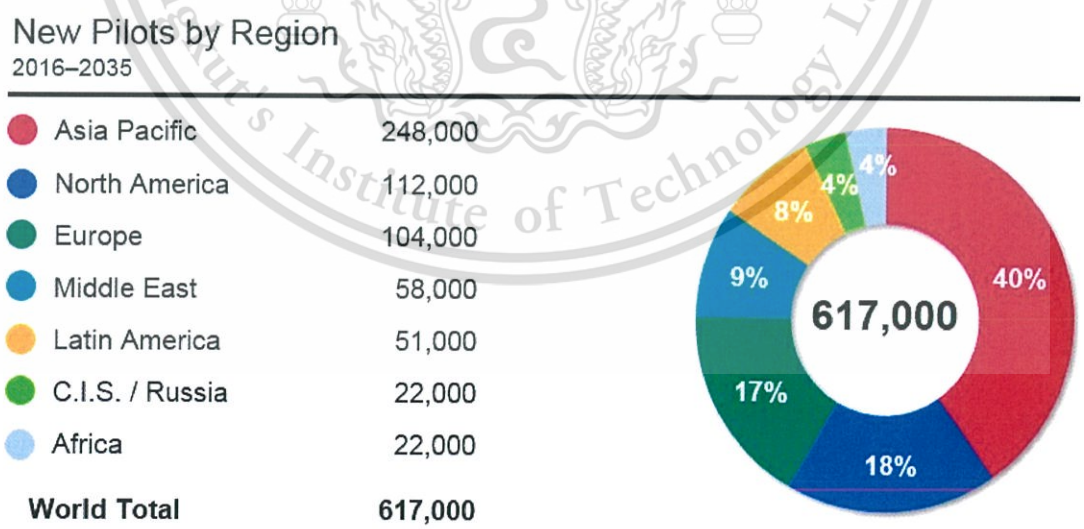



**Figure 2.1** Demands for commercial airline pilots

Source: Boeing Forecasts High Demand for Pilots and Technicians: Boeing-Media, 2015.

Another key consideration is human resources. A commercial pilot operates a flights and controls to navigate and fly the aircraft. The pilot also checks hydraulic and engine systems for pre-flight safety and monitors fuel consumption and aircraft systems in-flight. Pilots must realise a set number of flying hours intentionally and be in good physical and mental health to fly an airline carrier. Pilots have to deal with hazard events, such as turbulence, fatigue, and unfavorable weather conditions. However, they also might get to travel and see all over the world.

The pilots must be certified before they can operate an aircraft; therefore, global aviation needs an academy for developing qualified pilots. It is a very complicated process to be a pilot due to safety regulations as illustrated in **Figure 2.2**. Becoming a pilot, the candidate needs a bachelor's degree in aircraft operations, aviation, aeronautical engineering, or a related field. The require skills are specified for this career such as good communication, problem-solving, multi-tasking, good depth perception and reaction time, time management, and the ability to operate aircraft computer and navigation systems.

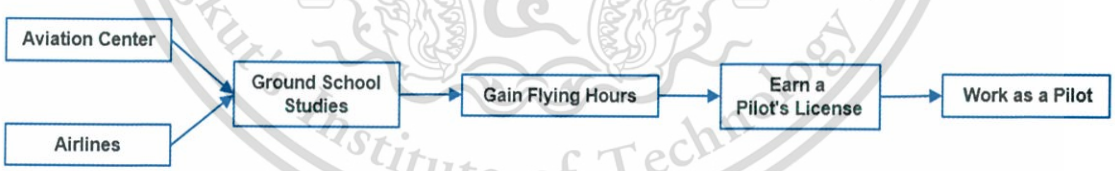



**Figure 2.2** Pilot Supply Chain

Aspiring airline pilots and private pilots are required to complete a certain number of hours of a flight training simulator to qualify for licensure. To obtain a commercial pilot's license, Civil Aviation Authorities of Thailand (CAAT) requires 32 hours of flight simulator training time for initial training as shown in **Table 2.1**. Once became a pilot, the pilots are generally required to recurrent pilot's license six-monthly, by training in a flight simulator for 4 hours.

Additionally, the requirement of flight simulator training hour it depends on the purpose of training. There are several types of training such as Initial Training, Transition Training, Difference Training, Upgrade Training, and Recurrent Training. The pilots need to be learning both ground and air school after that they have to collect their flying hours from flying flight simulator training follow the requirement of civil aviation authorities in each country. Finally, pilots will be required to have a commercial pilot's license and may need instrument rating certification or airline transport pilot certification.

**Table 2.1** Training Session

| Family of Aircraft | Initial Training FPT/FSTD (Sessions) | Transition Training FPT/FSTD (Sessions) | Difference Training FPT/FSTD (Sessions) | Upgrade Training FPT/FSTD (Sessions) | Recurrent Training FPT/FSTD (Sessions) |
|---|---|---|---|---|---|
| Reciprocating | PIC – 5/7<br>SIC – 5/7<br>F/E – 5/5 | PIC – 5/7<br>SIC – 5/7<br>F/E – 5/7 | PIC – 2/2<br>SIC – 2/2<br>F/E – 2/2 | SIC to PIC – 2/4 | PIC – 1<br>SIC – 1<br>F/E - 1 |
| Turboprop | PIC – 5/7<br>SIC – 5/7<br>F/E – 5/5 | PIC – 5/7<br>SIC – 5/7<br>F/E – 5/7 | PIC – 2/2<br>SIC – 2/2<br>F/E – 2/2 | SIC to PIC – 2/4 | PIC – 1<br>SIC – 1<br>F/E - 1 |
| Turbojet/Turbofan | PIC – 6/7<br>SIC – 6/7<br>F/E – 5/5 | PIC – 5/7<br>SIC – 5/7<br>F/E – 5/7 | PIC – 2/2<br>SIC – 2/2<br>F/E – 2/2 | SIC to PIC – 2/4<br>F/E to SIC – 7/8 | PIC – 1<br>SIC – 1<br>F/E - 1 |

Source: Flight Crew Member Training Programmes-Airplane: The Civil Aviation Authority of Thailand, 2016.

### 2.1.1 Flight Training Devices

The flight training simulation is simulated real flying by using motion and visual systems, the majority of flight training devices are used for pilot training. The use of flight simulators is widely accepted around the world because one of the important benefits of flight simulator training is training time in a simulator can replace training time in an aircraft. And these are the significant factors that drive the revenue of training simulation market includes rising fuel prices and the growing international regulation of emissions and noise pollution. The development of flight

simulator began since World War I, it was developed and evolve to further technology continuously. The first known flight simulation device was the Antoinette monoplane, which helped the pilots to simulate the flight (Koblen & Kovacova, 2012). In 1927, Edwin Link built the flight simulation called the Link Trainer which provided a pneumatic motion platform driven by inflatable bellows. The Link Trainer gave the pilot cues as to real angular motion in pitch, roll, and yaw; consequently, the U.S. Army Air Corps purchased six Link Trainers (Koblen & Kovacova, 2012). This is the start of the world flight simulation industry. The engineers were looking for new technologies to develop the training devices as the real aircraft specifically using of computer innovation. Koblen and Kovacova divided further flight simulators development into the three following periods: Analogue Computing (1945–1965), Digital Computing (1965–1985), and the Microelectronics Revolution (1985–present). And it finally was developed to a Full Flight Simulator (FFS).

The European Aviation Safety Agency (EASA) defined the different types of flight simulator training devices into the three following FSTD qualification levels: Flight and Navigational Procedures Trainer (FNPT), Flight Training Device (FTD), and Full Flight Simulator (FFS). The EASA also states that other types of FSTD do exist, however, they are not considered in EASA standards and therefore do not deliver any approved training credits, nevertheless, they can be very useful in particular for initial training (EHEST, 2015). The Full Flight Simulator (FFS) is the highest category of flight simulator which designed for training in several types of aircraft such as Airbus 320, ATR 72-600, Boeing 737 and others.

Primarily, the Full Flight Simulators (FFS) are classified as Level A through Level D according to the FAA and EASA regulation, thus, the highest level is Level D as shown in **Figure 2.3**. It comprises of six degrees of freedom in motion platform, supporting an aircraft cabin with an outside-world horizontal field of view in visual systems, and the realistic sounds in the cockpit. Moreover, the flight simulators are available in a variety of games such as Flight Gear, X-plane, Ys Flight Simulation 200, as well as available in the commercial flight simulators such as Microsoft Flight Simulator Series or Google Earth Flight Simulator (Koblen & Kovacova, 2012).

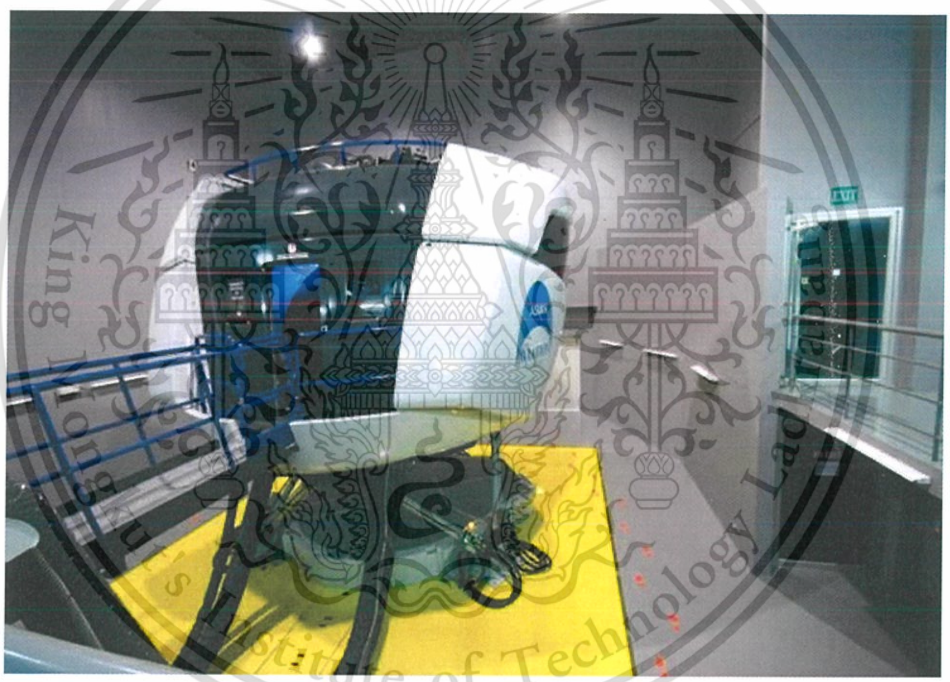


**Figure 2.3** A Full Flight Simulator

Asian Aviation Training Centre or AATC is certified as Asia's leading independent Approved Training Organisation by EASA.ATO.0024 and well known in South-East Asia. AATC provides approved training for pilots combining state-of-the-art Full Flight Simulation technology with enhanced Flat Panel Trainer technology and operates twenty-four hours a day, seven days a week. In order to provide quality service, to achieve the highest customer satisfaction and to prepare for the increase of

flight training market, AATC would like to develop a new maintenance process, which is an integrated system for flight training reservation, maintenance management, shipping and store management. Operation and installation all the flight simulators must be provided under the current regulatory standards, criteria, and requirement of aviation regulation from ICAO and EASA. The principal ICAO document regarding the issue of qualification of Flight Simulation Training National Aviation Authorities (NAA) provided the methods, procedures and testing standards in the ICAO's manual.

For qualifying the international standards, high performance of flight simulator is needed. Even flight simulator manufacturers create a suitable manual for both of maintenances and procedures, but the flight simulator operators still need a potential maintenance process as well. As a consequence of the complex systems of full flight simulator designed the complex maintenance which consists of various technical procedures. The AATC's engineering department is composed of the maintenance team, shipping part, and store part.

### 2.1.2 Supply Chain Management

Many businesses that rely on effective supply chain operations can gain major benefits from the supply chain management processes. The purpose of Supply Chain Management or SCM is to keep chaos concerned by integrating the activities of the network. All supply chain management processes created to manage an organization's demand and supply network which consists of three primary activities including Demand Management, Supply Planning or Matching Assets with Demand, and Analytics Workbench as well as two secondary activities including Available to Promise, Inventory Modeling, and Policy (Fordyce, 2017). The Global Supply Chain Forum developed the definition of Supply Chain Management as the integration of

key business processes from end user through original suppliers that provides products, services, and information which added value for customers and other stakeholders (Croxton, Garcia-Dastugue, & Lambert, 2001). In this study, there are a few supply chains which concerned; airport supply chain, airlines supply chain, pilot supply chain, and maintenance supply chain. The pilot supply chain is a chain to become a commercial pilot as described previous chapter. The **Figure 2.4** is an airport Supply Chain which describes flow between airlines and passengers. The last one is an airlines supply chain as shown in **Figure 2.5** describes the interchange of passengers from airport to the destination airport by airlines services.


**Figure 2.4** Airport Supply Chain


**Figure 2.5** Airlines Supply Chain

## 2.2 Maintenance Service

Maintenance is the process of maintaining or preserving activity to ensure the machine is in a good condition. The maintenance activity concerns checking, repairing, replacing, and servicing. Service refers to work that is performed by someone or organisation that benefits others. Although, maintenance service and maintenance activity have the same objectives, but the environments under the operation is significant different. The purpose of maintenance service is provided a menu of available technical services from which to select desired technical services as

a customer desiring. On the other hand, maintenance activities are an activity that aims to complete the tasks that keep machine or equipment longevity. The United Kingdom Civil Aviation Authority (CAA) recognises three primary maintenance processes: Preventive, Predictive, and Corrective maintenance as summarised in **Figure 2.6**.

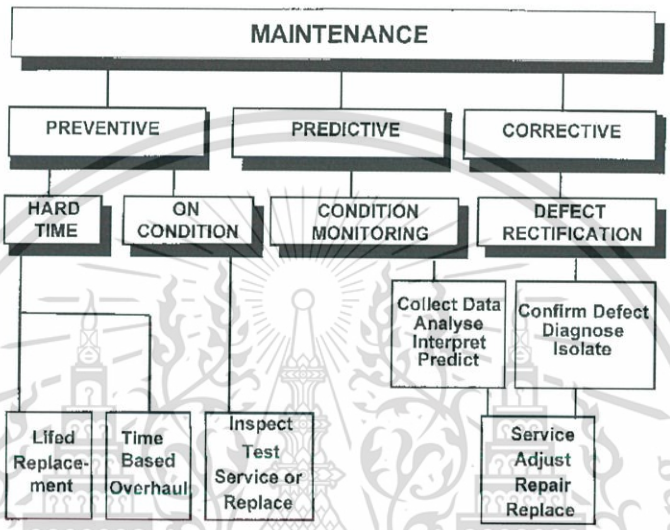



**Figure 2.6** Summary of Maintenance Process

Source: The maintenance management framework A practical view to maintenance management. Journal of Quality in Maintenance Engineering, 167-178. (CAA)

As the three primary maintenance processes, this section describes terms and definitions in the maintenance processes (B.S. Dhillon, 2002) as well as directly and indirectly maintenance used in engineering maintenance as follow:

- Maintenance: All activities which appropriately retain equipment and part in, or restoring it to given condition.
- Maintenance engineering: The activity of equipment or item maintenance that develops concepts, criteria, and technical requirements in conception and acquisition phases to be used and maintained in a current status during the operating period to assure effective maintenance support of equipment.

- Preventive maintenance: The action of precautionary to protect breakdown by checking an item to follow a planned or a schedule to keep the item in a good condition though. The preventive action would better than the corrective action after the issue happened due to cost saving. Moreover, the reliability had relied on the preventive maintenance as well.
- Corrective maintenance: The unscheduled maintenance action for a breakdown of a machine and an item. This includes returning defective items or equipment to the manufacturer or supplier.
- Predictive maintenance: It is the used of the design measurement methods to predict the inaccurate of an item during the operation which causes of breakdown.
- Maintenance concept: A description of the overall maintenance concept of an item for supporting operational development. This includes the maintenance policy to control the type of maintenance action for an item under consideration.
- Maintenance plan: A documented plan that guides the technical and maintenance management. This includes the detailed in the procedure of machine maintenance.
- Reliability: The quality that an item will perform its stated function satisfactorily for the desired period when used per the specified conditions.
- Maintainability: The successful repairing action that will be restored to a working condition within a given time.
- Active repair time: A part of downtime while an engineer is activating to affect a repairing system. This included since the period of preparing until the finished time.

- Mean time to repair (MTTR): The average time required to solve or fix the unserviceable item. Basically, the MTTR is a measure of how an organisation maintains the item. The time will be calculated the period between an item failed until return to production status.

There are differences between service and maintenance, primarily to address a frequent confusion of priorities for reliability engineering maintenance. Generally, maintenance is a partial or total renewal of an item. Maintenance reduces the physical age of a machine or breakdown by maintaining some or all of its components. On the other hand, service was described by Nowlan and Heap as activities necessary for achieving the design life of the asset (Wiseman, 2011). In the case of services, the item flowing toward the customer will be a service, not a physical product. The concept of introducing the customer in the actual chain should be where the customer takes an active part in adding value to the service (Weyers, 2017). This is illustrated in **Figure 2.7**.

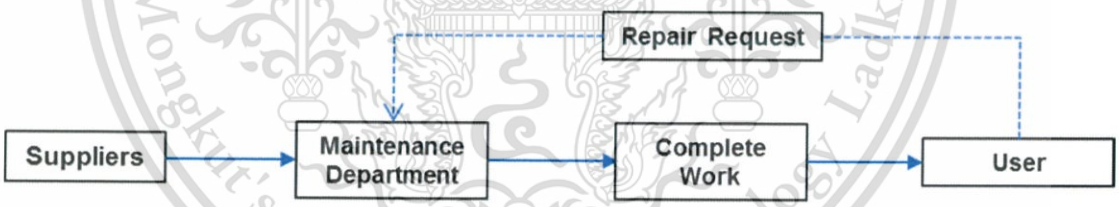



**Figure 2.7** Maintenance Service Supply Chain

The main objective of maintainability is to maximize equipment and facility availability. The other maintainability objectives include: reduce predicted maintenance time and costs by simplifying maintenance through design, determine labor-hours and other resources needed to perform the projected maintenance, and use maintainability data to determine item availability or unavailability. Some of the terms and definitions associated with maintainability are as follows:

- Downtime: The total time in which the item/equipment is not in a satisfactory operable condition.
- Serviceability: The degree of ease/difficulty with which an item or equipment can be restored to its satisfactory operable state.

### 2.2.1 Flight Simulator Maintenance

Although, the flight simulator training devices are always fully booked but each flight training device needs to be maintained and monitored regularly, especially, working twenty-four hours and seven days of the devices. Any technical issues of a flight simulator cause not only trouble to engineers but can also lead to serious problems for training centers, therefore, engineers usually perform a routine maintenance of simulators such as Daily, Weekly, Monthly, Quarterly, Six Monthly and Yearly to ensure uninterrupted operation and reduce the risk of any failures during pilot training. The SimHelp company categories the example of weekly and monthly routine maintenance of a flight as illustrated in **Table 2.2**.

**Table 2.2** Flight Simulator Routine Maintenance

| **Weekly Routine Maintenance** | |
|---|---|
| **Drawbridge Assembly** | Check indicator lamps |
| **Visual Image Generator** | Check all fans and check all filters for cleanliness. |
| **Instructor Operations Station (IOS)** | Clean touch screens with a soft cloth slightly dampened with commercial liquid cleaner |
| **Oxygen System** | Check system mechanics and function of air supply and check operation of oxygen mask |
| **Monthly Routine Maintenance** | |
| **Visual Image Generator** | Check power supplies |
| **Control Loading System** | Check for damage and oil leakage |
| **Air Conditioning** | Check air filters for cleanliness, test display lamps for correct operation, Check pipes and hoses for leaks and deterioration |
| **Host Computer** | Make general check for abnormalities of the computer and clean filters |

## 2.3 Services Supply Chain

Service Supply Chain Management (SSCM) focuses on operations managements at its core, which is concerned with delivering services to customers as well as managing the process that delivers the services while implementing continuous improvement. Service supply chain involves the customer as an active participant in the production process unlike physical goods supply chains. Effective supply chain management is as essential in the services industry, as it is in the manufacturing industry. The units of suppliers, service providers, consumers and other supporting units are the sector which performs the functions of a transferring of resources required to produce services; transfer information to the resources into supporting and core services; and the delivery of these services to customers as shown in **Figure 2.8**.

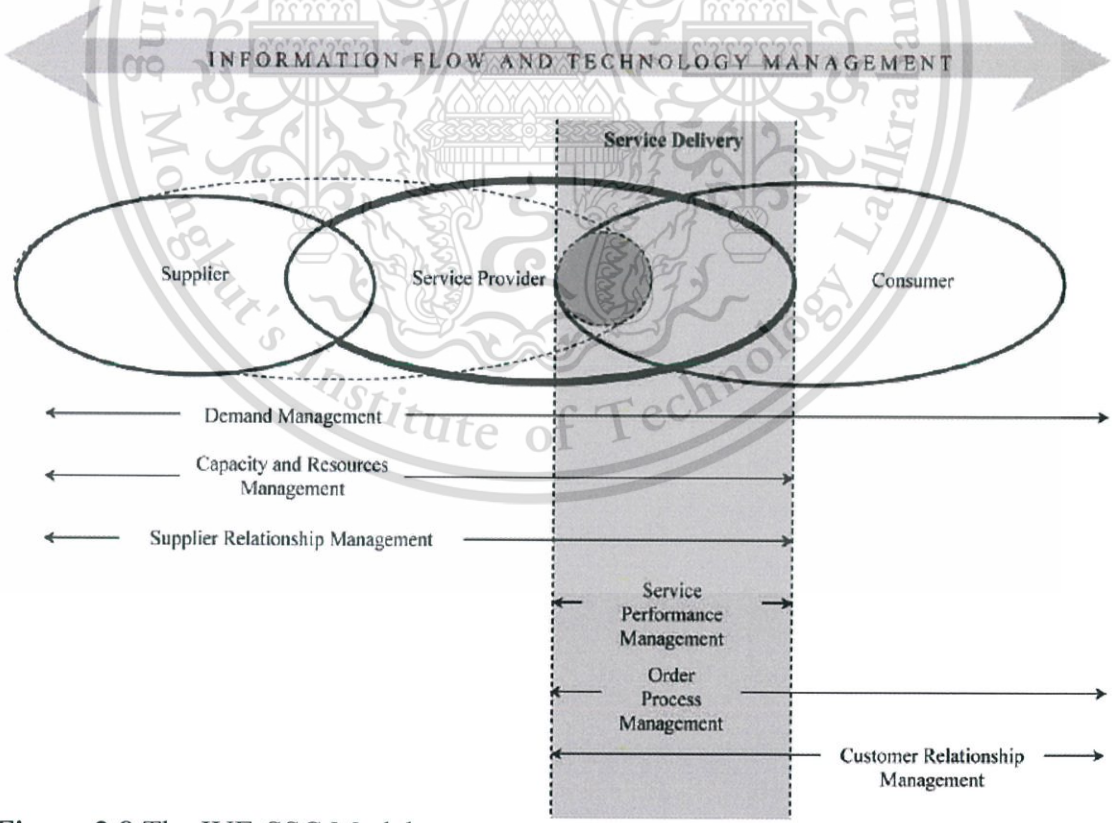



**Figure 2.8** The IUE-SSC Model

Source: A New Framework for Service Supply Chains. The Service Industries Journal, 27(2), 105-124. (Baltacioglu et al, 2007).

### 2.3.1 Manufacturing and Services

Services and manufacturing are markedly different with a different managerial approach. Not all principles applied successfully for products, can automatically be assumed relevant in service environments. Nevertheless, the concepts like demand management, customer relationship management supplier management, which are important in manufacturing supply chains, are also important in service supply chain.

Allen and Chandrashekar (2000) summarise the differences between services and manufacturing in **Table 2.3**.

**Table 2.3** Manufacturing and Services Differences

| | Manufacturing | Service |
|---|---|---|
| **Definition of Expectations** | Precise. Represented by engineering drawings and standards. | Usually imprecise. Broad definitions with many exceptions. |
| **Quality** | Emphasis on objective and measurable criteria. | Some objective and many subjective and perception-based criteria. |
| **Points of Contact** | Few. Communication usually channeled by a few people, such as purchasing or the project manager. | Many. The service provider often interacts directly with end users as well as the program managers |
| **Physical separation of host firm and contractor facilities** | Separation is normal from host company. This allows the use of any contractors--- even international--to control costs, etc. | Separation is difficult as most services must be provided on the host company's site and cannot be inventoried or stored. |
| **Predictability of demand** | Dependent on the accuracy of forecasts for final customer demand | Dependent on both internal priorities and external demand, both of which are dynamic |
| **Work content/cost determination** | Work content is a direct function of the number of units consumed, so costs are easy to determine. | Work content is situation specific, so needs to be monitored and accounted for |
| **Security of information/data** | Information can be shared with contractors on a need-to-know basis | Contract workers may be exposed to confidential information during the delivery of their services (hallway conversations, access to restricted areas). |
| **Problem resolution** | Formal procedures with clear responsibilities can be easily specified. | Difficult to create a process because problems often occur due to interpersonal issues or vague, illdefined expectations; problem resolution requires greater flexibility. |
| **Transition between contractors** | With planning, it is usually possible to change contractors with no noticeable effect on supply; inventory can be maintained during change, | Transition is more visible, requires more communication to minimize problems; disruption is often unavoidable because services cannot be stored and new contract workers are introduced to the site. |

Source: An Application of the Supply Chain Operations Reference Model for the Service Supply Chain for Standardised Back Office Services. Weyers, M. (2017).

## 2.4 SCOR Model

The SCOR modeling framework is the standard implementation roadmap which has been created and developed by the Supply Chain Council (SCC) for the supply chain standardization, measurement and improvement (APICS, 2017). According to the Supply Chain Council (SCC), it provides a unique supply chain management framework that links the processes in business together and also include metrics which evaluate business model performance, technology features and best practices. These things can be used to support communication between supply chain partners and to improve the supply chain activities. The Supply Chain Council developed the SCOR model to describe the business activities since suppliers' supplier to end users which is customer's customer associated with the phases of satisfying customer demand. The SCOR model combines four basic elements together including Process elements, Executions, Metrics, and Best practice. The structure of the SCOR model is classified to five basic processes, called: PLAN (P), SOURCE (S), MAKE (M), DELIVER (D) and RETURN (R) as illustrated in **Figure 2.9**.

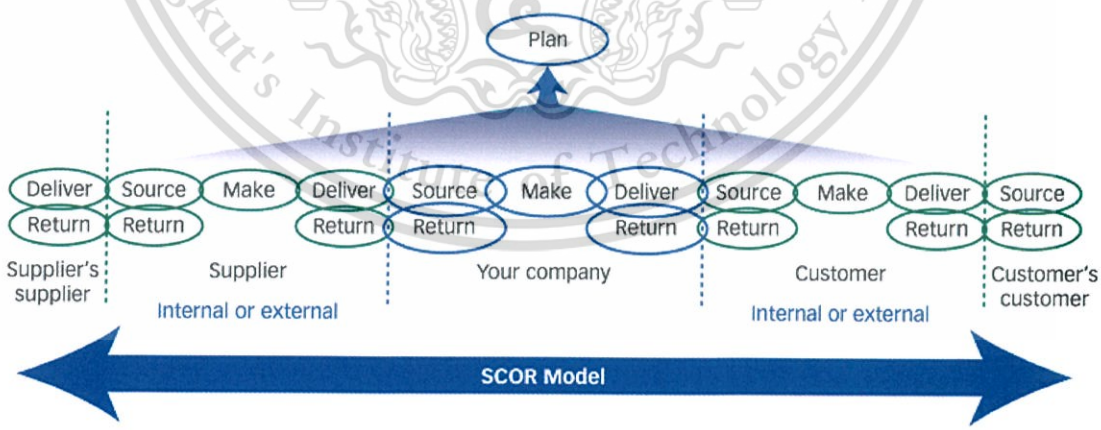



**Figure 2.9** SCOR Framework

Source: Supply Chain Operation References Model (SCOR Vol.12).

The SCOR model mainly contains with three levels of process details, level four as shown in **Figure 2.10**. Level 1 is the top level that deals with process types which defines a scope of a supply chain. Level 2 is the configuration level which deals with process categories. The lowest level in the SCOR model is Level 3 which is the process element or executes.

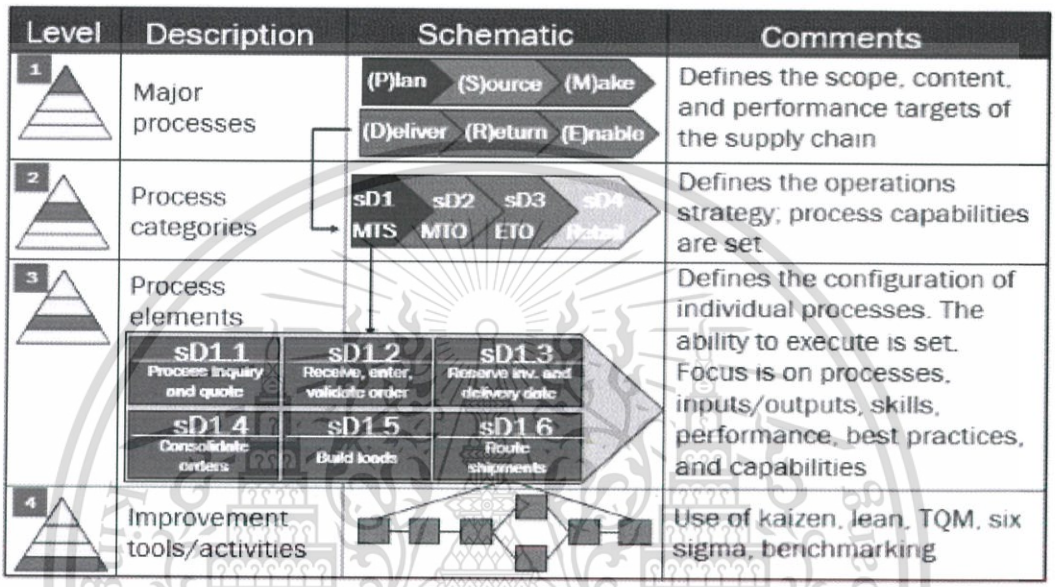



**Figure 2.10** SCOR Process Hierarchy

Source: Supply Chain Operation References Model (SCOR Vol.12).

In SCOR, each process has its own performance metrics to monitor overall supply chain performance which attributes: Reliability, Responsiveness, Agility, Cost, and Assets management efficiency. Each process is measured against these performance attributes; it has been widely used in global organization and commonly accepted. The performance measures are used to improve the process for future, the objectives of performance measures reveal the gap between planning and execution, and help organization solve the gap by identifying potential problems and areas for improvement. The supply chain council designed the metrics' structure in five performance attributes: Reliability, Responsiveness, Agility, Costs, and Asset

Management Efficiency following **Table 2.4** and **Table 2.5** had shown the metrics of level 1.

The SCOR performance or metrics focus on the outcomes of the supply chain consists of two types of elements: Performance Attributes and Metrics. The first three performance attributes are considered customer-focused. The latter two of attributes are internally focused. Generally, there are three levels of metrics that are recognized for performance attributes which is focused to help to improve specific process of level 2 and 3. Level 1 metrics known as strategic metrics and key performance indicators, level 2 metrics aim to identify causes of performance gap for level 1 metrics, likewise level 3 metrics serve as diagnostics for level 2metrics.

**Table 2.4** The SCOR Performance Attributes

| Performance Attribute | Definition |
|---|---|
| **Reliability** | The ability to perform tasks as expected. Reliability focuses on the predictability of the outcome of a process. Typical metrics for the reliability attribute include: On-time, the right quantity, the right quality. |
| **Responsiveness** | The speed at which tasks are performed. The speed at which a supply chain provides products to the customer. Examples include cycle-time metrics. |
| **Agility** | The ability to respond to external influences, the ability to respond to marketplace changes to gain or maintain competitive advantage. SCOR Agility metrics include Flexibility and Adaptability. |

| | |
|---|---|
| **Costs** | The cost of operating the supply chain processes. This includes labor costs, material costs, and management and transportation costs. A typical cost metric is Cost of Goods Sold. |
| **Asset Management Efficiency (Assets)** | The ability to efficiently utilize assets. Asset management strategies in a supply chain include inventory reduction and in-sourcing vs. outsourcing. Metrics include: Inventory days of supply and capacity utilization. |

Source: Supply Chain Operation References Model (SCOR Vol.12)

**Table 2.5** The SCOR Level-1 Metrics

| Performance Attribute | Level-1 Strategic Metric |
|---|---|
| **Reliability** | ▪ Perfect order fulfillment (RL 1.1) |
| **Responsiveness** | ▪ Order fulfillment Cycle Time (RS 1.1) |
| **Agility** | ▪ Upside supply chain flexibility (AG 1.1)<br>▪ Upside supply chain adaptability (AG 1.2)<br>▪ Downside supply chain adaptability (AG 1.3)<br>▪ Overall value at risk (AG 1.4) |
| **Costs** | ▪ Total cost to serve (CO 1.001) |
| **Asset Management Efficiency (Assets)** | ▪ Cash-to-Cash cycle time (AM 1.1)<br>▪ Return on supply chain fixed assets (AM 1.2)<br>▪ Return on working capital (AM 1.3) |

Source: Supply Chain Operation References Model (SCOR Vol.12)

### 2.4.1 SCOR Model in Differences Scenarios

The SCOR model normally creates for manufacturing industries. However, the model can be adapting in several businesses even the service business sector though. The researcher classified papers and works related to the adaptation of the SCOR model into five categories as followed (Georgise, 2012):

1) To the manufacturing industry environment
2) To the service industry environment
3) To the military environment
4) To the geographical information system and IT environment
5) To the logistics operation's environment
6) To the collaborative supply network environment.

Although the SCOR model was designed and applied for manufacturing industries, based on identified limits and weaknesses, researches and results from different practitioners and academicians, then the SCOR model can be extended further increasing its proven practical relevance. The SCOR models have so many limitations when applied to the services industry but there are a few research papers on an adaptation of SCOR model to the service industry environment. Weyers (2017) adapted the SCOR model to back-office services environment base on the concept of services. According to the ambiguity and complexity of services that descents to manufacturing industries which easy to understand the goods physical conceptual. Therefore, Weyers' approach model was adapted by using semantics, removal of elements and limited addition of elements that relate to services. The study claimed that the SCOR model could be created for services business and the model was useful to participants that work with back office services.

**Table 2.6** An overview of SCOR model applications

| Application area | SCOR model application | SCOR model extensions and adjustments | Reference |
|---|---|---|---|
| Military environment of the United States of America. | The SCOR model is used to provide a structured approach that can be used to implement modern day supply chain management processes in Department of Defense (DoD) logistics organisations. | A Maintain management process is used instead of Make, due to the need for materiel repair in the DoD supply chain. The Return management process is excluded from the study. | Deputy Under Secretary of Defense (2000) |
| Geographical Information System (GIS) industry in South Africa. | The SCOR model is used to introduce supply chain management into a GIS unit in order to improve the effectiveness and efficiency of the unit when creating a GIS product. This SCOR application focuses on the management of the data used by a GIS unit. | In the extended version of the SCOR model, GISDataSCOR, the original five management processes are used and the Make management process is extended to include an extra process category for maintenance (M4: Maintain-to-Stock). | Schmitz (2007) |
| Thin film transistor-liquid crystal display (TFT-LCD) industry in Taiwan. | Critical metrics for the sourcing processes in the TFT-LCD industry supply chain are established by using the SCOR v7 model. | Although the study focuses on the Source management process, the other four management processes are also considered. No extensions are made to the model. | Hwang et al. (2008) |
| Information Technology (IT) and technology consulting industry. | The SCOR model is used as a basis for developing a complete methodology and framework for supply chain management problem solving. | The SCOR model is not adjusted, but simulation and optimisation techniques are used with the SCOR model to develop SmartSCOR, which is an integrated platform that supports end-to-end supply chain transformation using various techniques. | Dong et al. (2006) |
| Ethanol and Petroleum industry in the United States. | Documentary data obtained in a study of the U.S. Petroleum and Ethanol industry are coded in accordance with the five SCOR model management processes. The SCOR model is then used to synthesise data of operational activities and identify links, challenges and strategic priorities in the petroleum and ethanol supply chain. | The five SCOR management processes, i.e. Plan, Source, Make, Deliver and Return, are used as a basis for supply chain analysis. No extensions are made to the original SCOR model. | Russel et al. (2009) |
| Professional services industry. | The SCOR model is applied to the professional services industry in order to investigate the relevance of the model in the services sector. It is concluded that the SCOR model does not fit the services industry as a whole. | Although the SCOR model is not adjusted explicitly, a number of potential modifications are identified in the article. The Make and Deliver processes should be one process and the Return process is not required in the services industry. Provision should be made for additional work if a service is not acceptable to a customer. | Ellram et al. (2004) |
| Lamp production industry. | The SCOR model is used as a basis to develop a complete Supply Chain Performance Management System (SCPMS) for a company in the lamp production industry. | No adjustments or extensions are made to the existing five management processes in SCOR. Selected SCOR metrics as well as other additional metrics are used to develop the integrated SCPMS. | Vanany et al. (2005) |
| An Application of the Supply Chain Operation Reference Model for the Service Supply Chain for Standardised Back Office Services | The SCOR model is adpated for standardised back office services or services industry. | The five SCOR management processes, i.e. Plan, Source, Make, Deliver and Return, are changed semantics, i.e. Plan, Request, Fulfill, Deliver, which relevent with back office service business model | Morné Weyers (2017) |
| A Business Process Modelling Framework for Air Cargo Supply Chain Management | The SCOR model is adpated for Air Cargo Supply Chain Management with Business Process Framwork | The five SCOR management processes, i.e. Plan, Source, Make, Deliver and Return, are change semantics, i.e. Plan, Receive, Put away, Storage, Order and pack, Deliver, Return, which relevent with air cargo business model | Somvang Kavanh (2018) |

Source: Adapting the SCOR model to suit the military: a South African example. 14th Annual Logistics Research Network Conference, (pp. 343-344). Bean, W., Schmitz, P., & Engelbrecht, G. (2009).

### 2.4.2 SCOR Model in Service Industry

In adapting the SCOR model for services specifically Stein, Heddier, Knackstead and Becker (2014) state that the immaterial nature of services, together with the key role that the customer plays within the actual delivery of the services, makes the application of the SCOR model as it stands inappropriate. Zuniga et al. (2013) agree that current frameworks are built around manufacturing and do not address the service industries central complexity which is the customer. According to them, the SCOR model must be adapted in the service industry to model its processes. They believe that to correct the deficiencies the following must be understood:

1) What is the service?

2) Who is the customer?

3) How is the service delivered?

4) When is the service delivered?

The two largest limitations of SCOR models for the service industry: semantics and process types (Georgise, F. B., 2012). As an example of the adaptation of process types, Giannakis (2012) added additional process elements. Consequently, the SCOR model integrity had changed to such an extent that the use of the SCOR model was irrelevant. An example of the semantics is the definition and use of the "Make" process. Semantically, the "Make" definition in SCOR is the process where the value is added to the product. Translating this "Make" concept to the service sector creates a situation where some of the intent and concepts, specific to manufacturing, may be lost in the translation to a new concept. There is no direct translation of "Make" in the service industries (Georgise et al., 2012).

## 2.5 Business Process Management Notation (BPMN)

### 2.5.1 Business Process Management

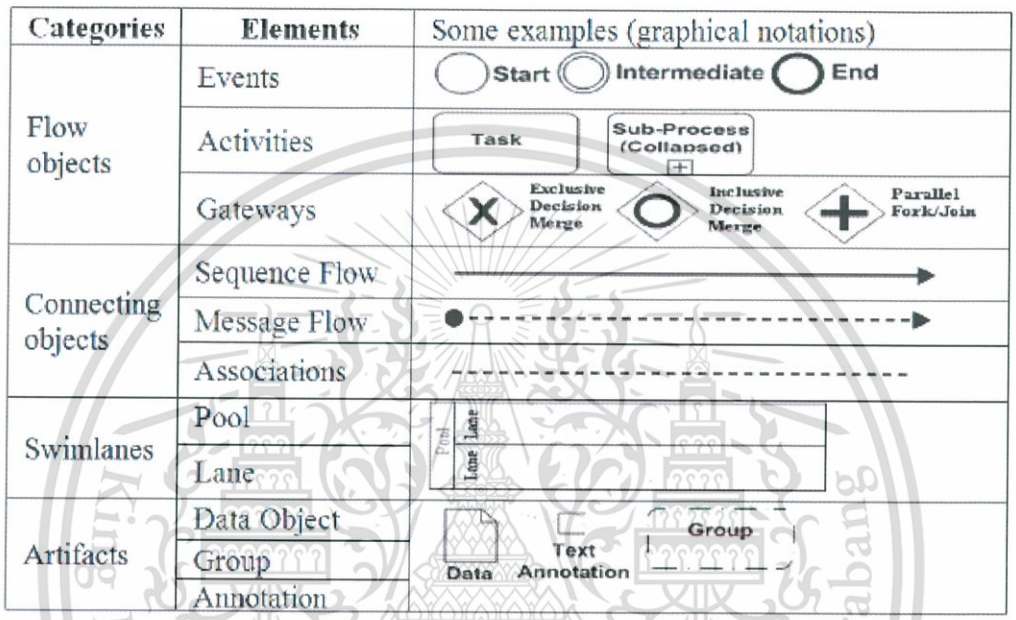
Business Process Management (BPM) has its roots in early studies of organizational design (Taylor, 1911). This process is dedicated to analyze, design, and implement business process management. The BPM activities can be grouped into a set of activities such as process design, process modelling, process execution, process monitoring, and optimization which is called business process management life-cycle. It is an effective and useful methodology to use in crisis time because the BPM can help an organisation to look at and control the processes that are represented in the organisation, it will show a better and more cost efficient organisation. The simplest way of business process management is workflow which is known as routing. Workflow is more than telling moving things from process A to process B to process C to process D or combine all tasks together because it also carries out tasks in parallel, increase productivity and save time.

### 2.5.2 Adopted BPMN Method

Business Process Modelling Notation or BPMN is a method of communication between organisation and developer by using a graphical model represent an organisation business process. The purpose of BPMN is to facilitate communication and understanding business processes, the BPMN is a language which can be easy to understand for business industry. Therefore, the BPMN is one of the most popular business process languages. In this research focused on BPMN 2.0 a standard which is the current of the standards. The main advantage of BPMN 2.0 is Visio supporting which the developer or user can develop through Visio directly. Moreover, the advantage of BPMN 2.0 is the users who write code to automate processes can

understand BPMN 2.0 as well. Basically, using BPMN is represented in the form of a business process diagram (BPD) which is normally used to represent, the current processes ("as is") and improved ("to be") processes. BPMN diagram elements shown in **Figure 2.11**.

**Figure 2.11** BPMN diagram elements




Source: Fuzzy Extended BPMN for Modelling Crime Analysis Processes, (Cotofrei, P., & Stoel, K. 2014).

There are four categories; comprise of flow objects, connecting objects, swimlanes, and artifacts. Flow objects consist of three main elements; events, gateways, and activities. Events consist of three main types; it is represented as a circle which indicates where the processes start and end. An activity is a task of work. It can be either a task or a sub-process. A sub-process can describe as a process within the main process (Reale, 2016). A gateway can be a question that is asked at a point in the process flow to define a process to continue which alternative pathways. Furthermore, a gateway is a routing construct from decision making. There are three event-based gateways, firstly, an exclusive gateway which is only one of the alternative pathways will be chosen. Secondly, parallel fork gateway or AND-Split

which is divided a path into two or more pathways. The last, inclusive is created for selecting at least one path from all combination paths. Connecting objects represent a connection between flow objects; with sequence flows link all objects in the same pool together and message flows link all objects in different pools together. Another important element in BPMN is swimlanes. Swimlanes contain two kinds of element; a pool and lane elements. A pool is graphical represents an organisation, as well as a pool can represent others such as function, application, location, and class. A lane is a sub-partition which represents a division of on organisation. Nonetheless, pool and lane elements are interchangeable and different organisation can also be separated by lanes in the same pool.

## 2.6 Model Validation

There are some methodologies available to help organisation business process improvement, one of the most famous tools for a business process called BPI or business process improvement methodology. BPI methodology help an organisation find the ways to improve business process such as Lean and Six-sigma. Michal Rosik stated that Business Process Improvement is a strategic approach to identifying 'as-is' process of an organisation's and designate specific actions in that process that can be modified, removed or replaced to achieve a pre-defined goal (Michal Rosik, 2018).

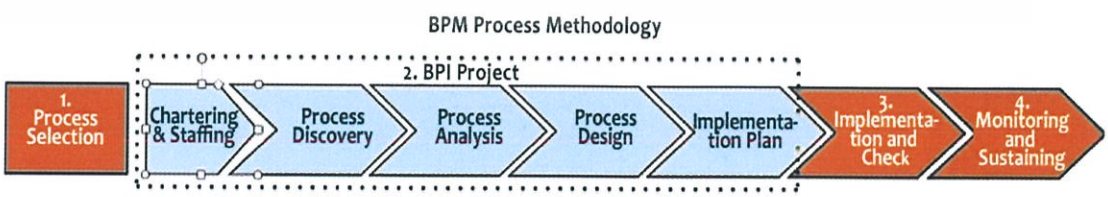



**Figure 2.12** The Business Process Improvement (Sweet, 2014)

In this study, the model validation and testing base on the review from 20 experts in a case study company through an evaluation methodology for the business process designed by Sola A. and Tim B. Testing methodology was refined to applicable with maintenance service model testing then the questionnaire was set out to determine the following (Sola A., & Tim B., 2005):

- Could the methodology be used in practice?
- Are there any problems and difficulties with the model?
- Are the designed models worth the effort and are they useful to the host organisation?

The questionnaire adopted from Weyers which tested with the back-office service before (Weyers, 2017). It was separated in Pre and Post round. The participants were given the questionnaire with the adopted SCOR model without explanation. After that, the Post round will be conducted again after finished workshop round. The workshop round will be discussion group, to find out the best solution for adopted SCOR model. The results will be conducted after finish all of the process and compare the comment between the Pre and Post round.

A procedure to assess whether the methodology was working adopted form Platts (1990). It is a procedural approach of evaluating process research. The subsequent assessment procedure consisted of three categories of measurement were Feasibility, Usability, and Usefulness (Sola A., & Tim B., 2005):

- Feasibility: Can the adapted model be followed?
- Usability: Is the adapted model workable? Are the steps and techniques easy to use and apply?
- Usefulness: Is the adopted model worth following? Does the model produce results that the business finds helpful?

Evaluation is based on the description above of feasibility, usability, and usefulness was involved in the model validation process. The results were obtained from the participants included organisation's management level. Maintenance service process improvement was developed through the feedback from expertise so that the maintenance service model processes earn more effectively and efficiently.

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Semantics

The second principle to SCOR model adaptation will be adapting the model only through the changing of words, using a direct translation or similar concepts. Barnard (2006) proposes new names to the processes, to better describe the various stages through the chain. Changing process name does not make a large difference in the approaching model. For instance, the item of Make, the concept of Deliver is used. This covers the meaning of Make but also makes the language applicable to services (Weyers, 2017). In this process will analyses level processes through Weyers' approach, each description is analysed with the decision to perform on or more of the following options:

1) Remove the process element,

2) Change process reference of process element (e.g. sP1 to msP1),

3) Change the title of the process element,

4) Keeping the process description as is,

5) Change the description of the process element through semantics,

6) Remove references to product-specific concepts,

7) Add concepts specific to services, and

8) Provide a totally new description.

The approach is shown in **Figure 3.1**. In summary, semantic changes to the processes of Plan, Source, Make, Deliver and Return can now be translated to Plan, Source, Fulfil, Deliver and Return, respectively.

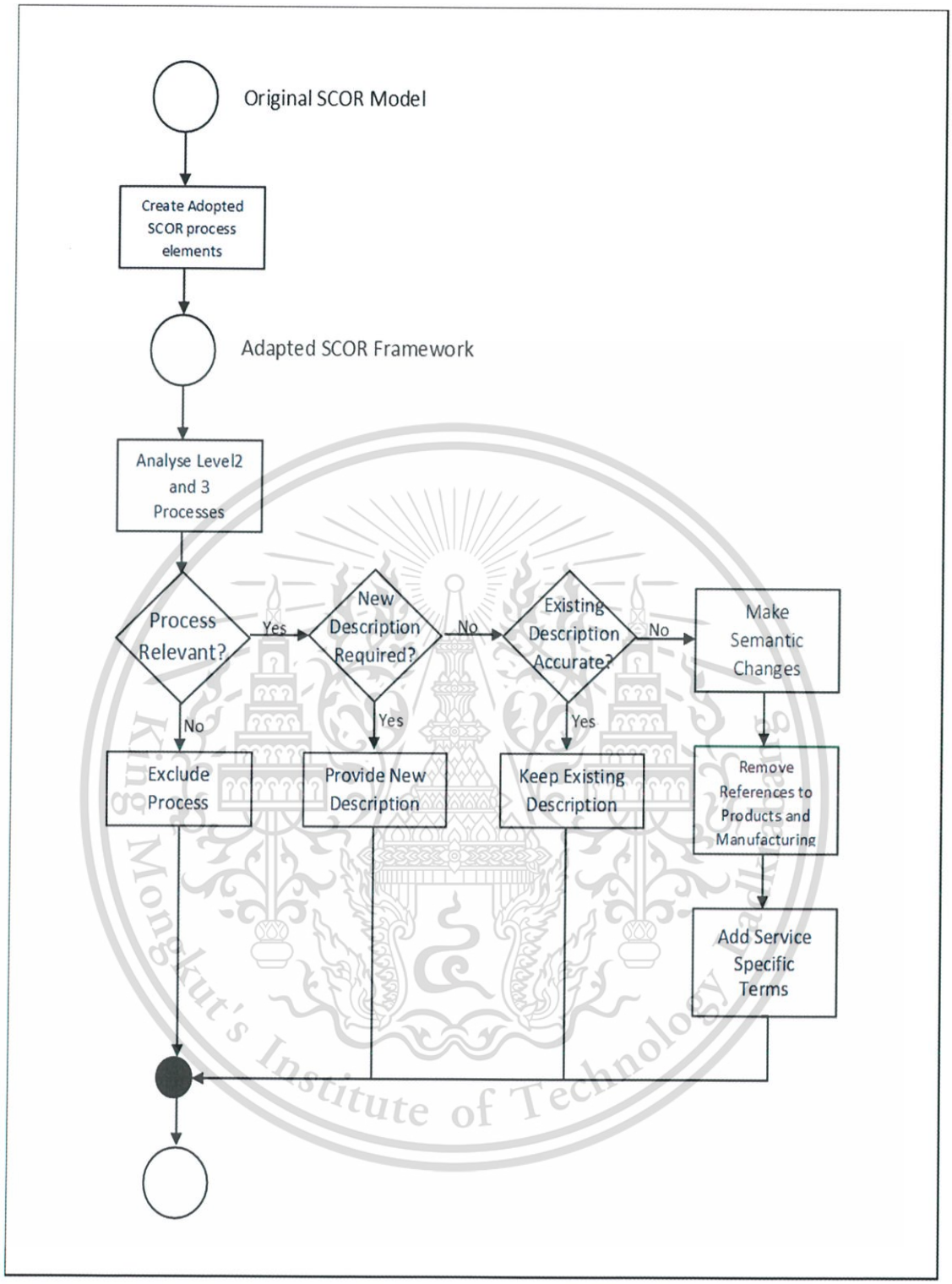



**Figure 3.1** SCOR Process Adaptation Approach

Source: An Application of the Supply Chain Operations Reference Model for the Service Supply Chain for Standardised Back Office Services: Weyers, M. (2017).

### 3.1.1 Plan Process

Processes that balance aggregate demand and supply to develop a course of action which best meet the established business rules include gathering information and requirements. The plan process semantics are changed to cover the processes not relevant to services. The changes of original SCOR model name to new process name, words like 'Material' changed to 'Services' or 'Resources' if it was applicable. **Table 3.1** illustrated the changes made in adapting the Plan processes.

**Table 3.1** Plan Process Name Analysis

| Process Reference | Original Process Name | Process Removed | New Process Reference | New Process Name | No Title Change | Semantic |
|---|---|---|---|---|---|---|
| sP1 | Plan Supply Chain | | msP1 | Plan Maintenance Service Supply Chain | | x |
| sP1.1 | Identify, Prioritize and Aggregate Supply Chain Require... | | msP1.1 | Identify, Prioritize and Aggregate MS Supply Chain ... | x | |
| sP1.2 | Identify, Prioritize and Aggregate Supply Chain Resources | | msP1.2 | Identify, Prioritize and Aggregate MS Supply Chain ... | x | |
| sP1.3 | Balance Supply Chain Resources with Supply Chain... | | msP1.3 | Balance MS Supply Chain Resources with MS Supply ... | | x |
| sP1.4 | Establish and Communicate Supply Chain Plans | | msP1.4 | Establish and Communicate MS Supply Chain Plans | | x |
| sP2 | Plan Source | | msP2 | Plan Source | x | |
| sP2.1 | Identify, Prioritize and Aggregate Product Requirement | | msP2.1 | Identify, Prioritize and Aggregate Source Services ... | | x |
| sP2.2 | Identify, Assess and Aggregate Product Resources | | msP2.2 | Identify, Assess and Aggregate Services Resources | | x |
| sP2.3 | Balance Product Resources with Product Requirements | | msP2.3 | Balance Service Resources with Service Requirements | | x |
| sP2.4 | Establish Sourcing Plans | | msP2.4 | Establish and Communicate Sourcing Plans | | x |
| sP3 | Plan Make | | msP3 | Plan Fulfil | x | |
| sP3.1 | Identify, Prioritize and Aggregate Production Requirement | | msP3.1 | Identify, Prioritize and Aggregate Fulfil Requirement | | x |
| sP3.2 | Identify, Assess and Aggregate Production Resources | | msP3.2 | Identify, Assess and Aggregate Fulfil Resources | | x |
| sP3.3 | Balance Production Resources with Production... | | msP3.3 | Balance Fulfilment Resources with Fulfilment ... | | x |
| sP3.4 | Establish Production Plans | | msP3.4 | Establish and Communicate Fulfil Plans | | x |
| sP4 | Plan Deliver | | msP4 | Plan Deliver | x | |
| sP4.1 | Identify, Prioritize and Aggregate Delivery Requirement | | msP4.1 | Identify, Prioritize and Aggregate Delivery Requirement | x | |
| sP4.2 | Identify, Assess and Aggregate Delivery Resources | | msP4.2 | Identify, Assess and Aggregate Delivery Resources | x | |
| sP4.3 | Balance Delivery Resources and Capabilities... | | msP4.3 | Balance Delivery Resources and Capabilities... | x | |
| sP4.4 | Establish Delivery Plans | | msP4.4 | Establish and Communicate Delivery Plans | | x |
| sP5 | Plan Return | | msP5 | Plan Return | | |
| sP5.1 | Assess and Aggregate Return Requirements | | msP5.1 | Assess and Aggregate Return Requirements | x | |
| sP5.2 | Identify, Assess and Aggregate Return Resources | | msP5.2 | Identify, Assess and Aggregate Return Resources | x | |
| sP5.3 | Balance Return Resources with Return Requirement | | msP5.3 | Balance Return Resources with Return Requirement | x | |
| sP5.4 | Establish and Communicate Return Plans | | msP5.4 | Establish and Communicate Return Plans | x | |

### 3.1.2 Source Process

Source processes describe procuring material and services to meet customer demand. However, maintenance services do not need materials to produce any products so the word 'Product' changed to 'Spare part'. The purpose of the Source process is to maintain a level of inventory for spare parts. The word 'Make' does not relevant in this process so it was changed to 'Ordering'. Other processes that not

concern in services was removed from Source process and applied in another process. For instance, Source Engineer-to-Order Product would be removed from Source and applied in Fulfil process after changing semantic. Even the transfer product from the manufacturer (msS2.2 Receive spare part) is specific to the handling of inventory but the process is kept because it relates to keeping the stocked spare part. **Table 3.2** described the changes in Source processes.

**Table 3.2** Source Process Name Analysis

| Process Reference | Original Process Name | Process Removed | New Process Reference | New Process Name | No Title Change | Semantic |
|---|---|---|---|---|---|---|
| sS1 | Source Stocked Product | | msS1 | Source Stocked Spare part | | x |
| sS2 | Source Make-to-Order Product | | msS2 | Source Ordering Spare part | | x |
| sS2.1 | Schedule Product Deliveries | | msS2.1 | Schedule spare part Deliveries | | x |
| sS2.2 | Receive Product | | msS2.2 | Receive spare part | | x |
| sS2.3 | Verify Product | | msS2.3 | Verify spare part | | x |
| sS2.4 | Transfer Product | x | | | | |
| sS2.5 | Authorize Supplier Payment | | msS2.4 | Authorize Supplier Payment | x | |
| sS3 | Source Engineer-to-Order Product | x | | | | |
| sS3.1 | Identify Sources of Supply | x | | | | |
| sS3.2 | Select Final Supplier and Negotiate | x | | | | |
| sS3.3 | Schedule Product Deliveries | x | | | | |
| sS3.4 | Receive Product | x | | | | |
| sS3.5 | Verify Product | x | | | | |
| sS3.6 | Transfer Product | x | | | | |
| sS3.7 | Authorize Supplier Payment | x | | | | |

### 3.1.3 Fulfil Process

The original process name of 'Fulfil' is 'Make' which is the process of transforming materials to finished goods following customer's requirements. On the other hand, there is no changing or producing materials in the services business. Thus, this Fulfil process is changed to the process of repair, stock, and spare part. But the process repair, in this case, is the process requires future services to complete the process which concerns in shipping part. The intention of the Fulfil process need to be ensured the maintenance service activities fulfilled and each part of services available to support Deliver process all the time. **Table 3.3** summarises the changes that have been made on each process.

**Table 3.3** Fulfil Process Name Analysis

| Process Reference | Original Process Name | Process Removed | New Process Reference | New Process Name | No Title Change | Semantic |
|---|---|---|---|---|---|---|
| sM1 | Make-to-Stock | x | | | | |
| sM2 | Make-to-Order | | msF1 | Fulfil Scheduled Service | | x |
| sM2.1 | Schedule Production Activities | | msF1.1 | Schedule Fulfilment Activities | | x |
| sM2.2 | Issue Sourced/In-Process Product | x | | | | |
| sM2.3 | Produce and Test | | msF1.2 | Fulfill and Test | | x |
| sM2.4 | Package | x | | | | |
| sM2.5 | Stage Finished Product | x | | | | |
| sM2.6 | Release Finished Product to Deliver | | msF1.3 | Release Fulfilment Documentation | | x |
| sM2.7 | Waste Disposal | | msF1.4 | Waste Disposal | | x |
| sM2 | Make-to-Order | | msF2 | Fulfil Unscheduled Service | | x |
| sM2.1 | Schedule Production Activities | | msF2.1 | Schedule Fulfilment Activities | | x |
| sM2.2 | Issue Sourced/In-Process Product | x | | | | |
| sM2.3 | Produce and Test | | msF2.2 | Fulfill and Test | | x |
| sM2.4 | Package | x | | | | |
| sM2.5 | Stage Finished Product | x | | | | |
| sM2.6 | Release Finished Product to Deliver | | msF2.3 | Release Fulfilment Documentation | | x |
| sM2.7 | Waste Disposal | | msF2.4 | Waste Disposal | | x |
| sM3 | Engineer-to-Order | | msF3 | Fulfil Engineer Service | | x |
| sM3.1 | Finalize Production Engineering | | msF3.1 | Finalize Fulfilment Engineering | | x |
| sM3.2 | Schedule Production Activities | | msF3.2 | Schedule Fulfilment Activities | | x |
| sM3.3 | Issue Sourced/In-Process Product | x | | | | |
| sM3.4 | Produce and Test | | msF3.3 | Fulfill and Test | | x |
| sM3.5 | Package | x | | | | |
| sM3.6 | Stage Finished Product | | msF3.4 | Release Fulfilment Documentation | | x |
| sM3.7 | Release Product to Deliver | x | | | | |
| sM3.8 | Waste Disposal | | msF3.5 | Waste Disposal | | x |

### 3.1.4 Deliver Process

In the original Deliver process, it refers to material flow or goods removing. Basically, the original process provide finished goods and services to meet actual demand, even in maintenance service does not has finished goods but the Deliver process still be kept for providing services. Therefore, the maintenance service process will change material flow to services flow. The delivery service process is taking complete execution work to a user with high performance including delivering unscheduled service. The summary of the Return process will be illustrated as **Table 3.5**.

**Table 3.4** Deliver Process Name Analysis

| Process Reference | Original Process Name | Process Removed | New Process Reference | New Process Name | No Title Change | Semantic |
|---|---|---|---|---|---|---|
| sD1 | Deliver Stocked Product | x | | | | |
| sD2 | Deliver Make-to-Order Product | | msD1 | Deliver Scheduled Service | | x |
| sD2.1 | Process Inquiry and Quote | | msD1.1 | Process Inquiry and Quote | x | |
| sD2.2 | Receive, Configure, Enter and Validate Order | | msD1.2 | Receive, Enter and Validate requirement | | x |
| sD2.3 | Reserve Inventory and Determine Delivery Date | | msD1.3 | Identify Capacity and Determine Delivery Date | x | |
| sD2.4 | Consolidate Orders | x | | | | |
| sD2.5 | Build Loads | x | | | | |
| sD2.6 | Route Shipments | x | | | | |
| sD2.7 | Select Carriers and Rate Shipments | x | | | | |
| sD2.8 | Receive Product from Source or Make | | msD1.4 | Receive Services from Source or Fulfil | | x |
| sD2.9 | Pick Product | x | | | | |
| sD2.10 | Pack Product | x | | | | |
| sD2.11 | Load Product & Generate Shipping Docs | x | | | | |
| sD2.12 | Ship Product | x | | | | |
| sD2.13 | Receive and verify Product by Customer | x | | | | |
| sD2.14 | Install Product | | msD1.5 | Verify Service | | x |
| sD2.15 | Invoice | | msD1.6 | Invoice | | x |
| sD2 | Deliver Make-to-Order Product | | msD2 | Deliver Unscheduled Service | | x |
| sD2.1 | Process Inquiry and Quote | | msD2.1 | Process Inquiry and Quote | x | |
| sD2.2 | Receive, Configure, Enter and Validate Order | | msD2.2 | Receive, Enter and Validate requirement | | x |
| sD2.3 | Reserve Inventory and Determine Delivery Date | | msD2.3 | Identify Capacity and Determine Delivery Date | | x |
| sD2.4 | Consolidate Orders | x | | | | |
| sD2.5 | Build Loads | x | | | | |
| sD2.6 | Route Shipments | x | | | | |
| sD2.7 | Select Carriers and Rate Shipments | x | | | | |
| sD2.8 | Receive Product from Source or Make | | msD2.4 | Receive Services from Source or Fulfil | | x |
| sD2.9 | Pick Product | x | | | | |
| sD2.10 | Pack Product | x | | | | |
| sD2.11 | Load Product & Generate Shipping Docs | x | | | | |
| sD2.12 | Ship Product | x | | | | |
| sD2.13 | Receive and verify Product by Customer | x | | | | |
| sD2.14 | Install Product | | msD2.5 | Verify Service | | x |
| sD2.15 | Invoice | | msD2.6 | Invoice | | x |
| sD3 | Deliver Engineer-to-Order Product | | msD3 | Deliver Engineer Service | | x |
| sD3.1 | Obtain and Respond to RFP/RFQ | | msD3.1 | Obtain and Respond to requirements | | x |
| sD3.2 | Negotiate and Receive Contract | | msD3.2 | Negotiate and Receive Confirmation | | x |
| sD3.3 | Enter Order, Commit Resources & Launch Program | x | | | | |
| sD3.4 | Schedule Installation | | msD3.3 | Schedule Execution | | x |
| sD3.5 | Build Loads | x | | | | |
| sD3.6 | Route Shipments | x | | | | |
| sD3.7 | Select Carriers & Rate Shipments | x | | | | |
| sD3.8 | Receive Product from Source or Make | | msD3.4 | Receive Services from Source or Fulfil | | x |
| sD3.9 | Pick Product | x | | | | |
| sD3.10 | Pack Product | x | | | | |
| sD3.11 | Load Product & Generate Shipping Docs | x | | | | |
| sD3.12 | Ship Product | x | | | | |
| sD3.13 | Receive and verify Product by Customer | x | | | | |
| sD3.14 | Install Product | | msD3.5 | Execute Service | | x |
| sD3.15 | Invoice | x | | | | |
| sD4 | Deliver Retail Product | x | | | | |

### 3.1.5 Return Process

The return process concern defected products returning and any materials. There are activities which the service has to be returned because the work was not appropriate. Return MRO product was removed but this does not mean that this process would not use. The return MRO product moved to Fulfil and Source process because there are processes where related to with shipping. The summary of the Return process illustrated as **Table 3.5**.

**Table 3.5** Return Process Name Analysis

| Process Reference | Original Process Name | Process Removed | New Process Reference | New Process Name | No Title Change | Semantic |
|---|---|---|---|---|---|---|
| sSR1 | Source Return Defective Product | | msR1 | Source Return Defective Service | | x |
| sSR1.1 | Identify Defective Product Condition | | msR1.1 | Identify Defective Service Condition | | x |
| sSR1.2 | Disposition Defective Product | | msR1.2 | Disposition Defective Service | | x |
| sSR1.3 | Request Defective Product Return Authorization | x | | | | |
| sSR1.4 | Schedule Defective Product Shipment | x | | | | |
| sSR1.5 | Return Defective Product | | msR1.3 | Return Defective Service | | x |
| sDR1 | Deliver Return Defective Product | | msR2 | Deliver Return Service | | x |
| sDR1.1 | Authorize Defective Product Return | | msR2.1 | Authorize Defective Service Return | | x |
| sDR1.2 | Schedule Defective Return Receipt | x | | | | |
| sDR1.3 | Receive Defective Product (includes verify) | | msR2.2 | Receive Defective Service (includes verify) | | x |
| sDR1.4 | Transfer Defective Product | | msR2.3 | Transfer Defective Service | | x |
| sSR2 | Return MRO Product | x | | | | |
| sDR2 | Deliver Return MRO Product | x | | | | |
| sSR3 | Source Return Excess Product | x | | | | |
| sDR3 | Deliver Return Excess Product | x | | | | |

## 3.2 Adapted SCOR model

The previous section changed the name of elements processes and adapted SCOR model for maintenance service process model, based on the above changes, an adapted SCOR model is derived with the processes as shown in **Figure 3.2**. As the AATC never organised the maintenance service model before, the maintenance workflows both of preventive and corrective maintenance were conducted by

interviewing the Engineering management team and Supervisor Engineers, then analysis maintenance service workflow to maintenance service process model.

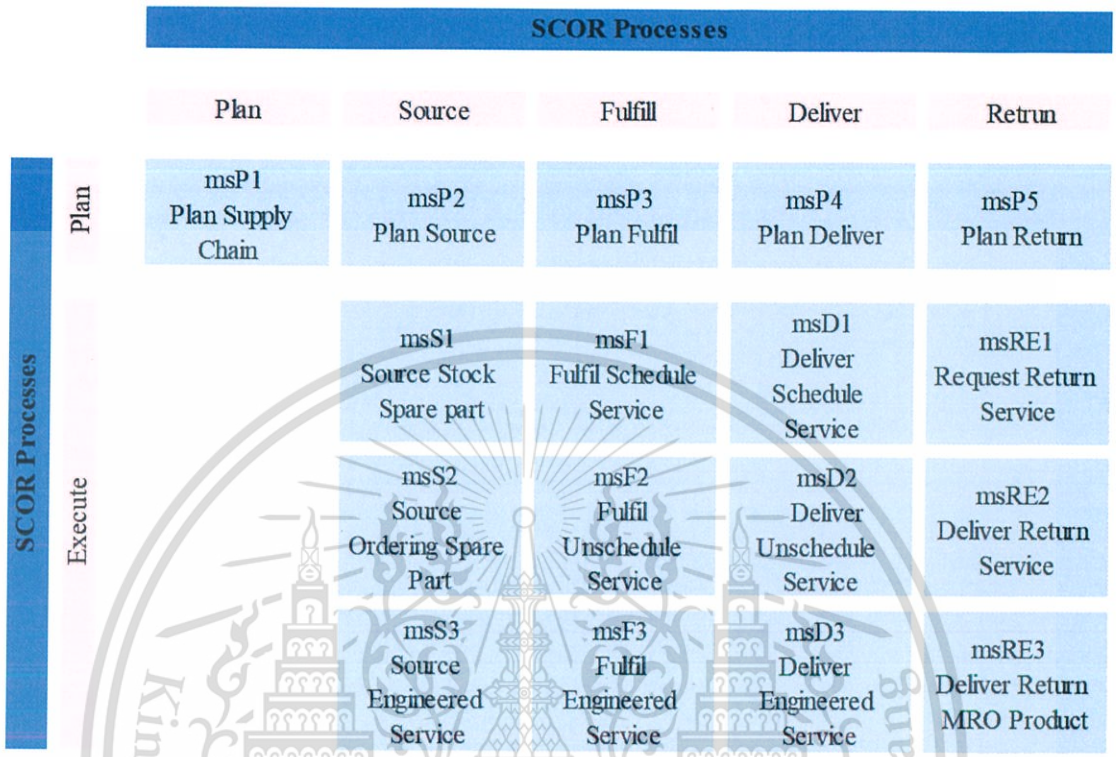



**Figure 3.2** Adapted Service SCOR Process Elements

To adapt SCOR in the process, the author composes the SCOR model by two parts included design processes base on SCOR by using BPMN and identify the performance base on SCOR as well. After the adapted process in the scope of the SCOR model have been generated. The implement of supply chain management with in the company processes, a good thing of the SCOR is the hierarchical decomposition, where each level's process can be further described with more detail in low level. In this procedure, it is easier to find what the metrics and processes are important in each role. The work with adapting the method in the process of maintenance service supply chain has followed the design of SCOR model in total five process elements as **Figure 3.3** shown the overview of adapted SCOR model process elements.

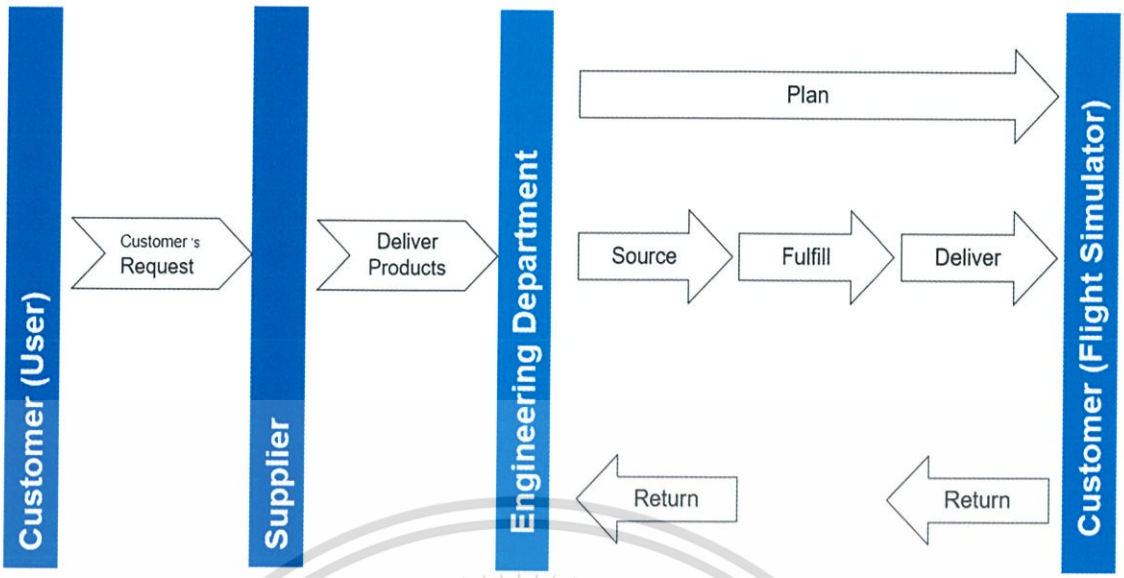



**Figure 3.3** An Overview adpated SCOR Model Process Elements

### 3.2.1 Maintenance Process "As-Is" Analysis

First of all, the maintenance workflow has to analysis 'As-Is' model of preventive and corrective maintenance service, then the model would be adapted to SCOR model level 1, level 2, and level3 respectively. The maintenance workflow was generated from the discussion and interview the staffs in the company as summarised in **Figure 3.4**, the workflow can divide into two categories: Corrective maintenance service and Preventive maintenance service. The workflow will be analysing to 'As-Is' model of corrective and preventive maintenance service which shown in **Figure 3.5 and 3.6**.

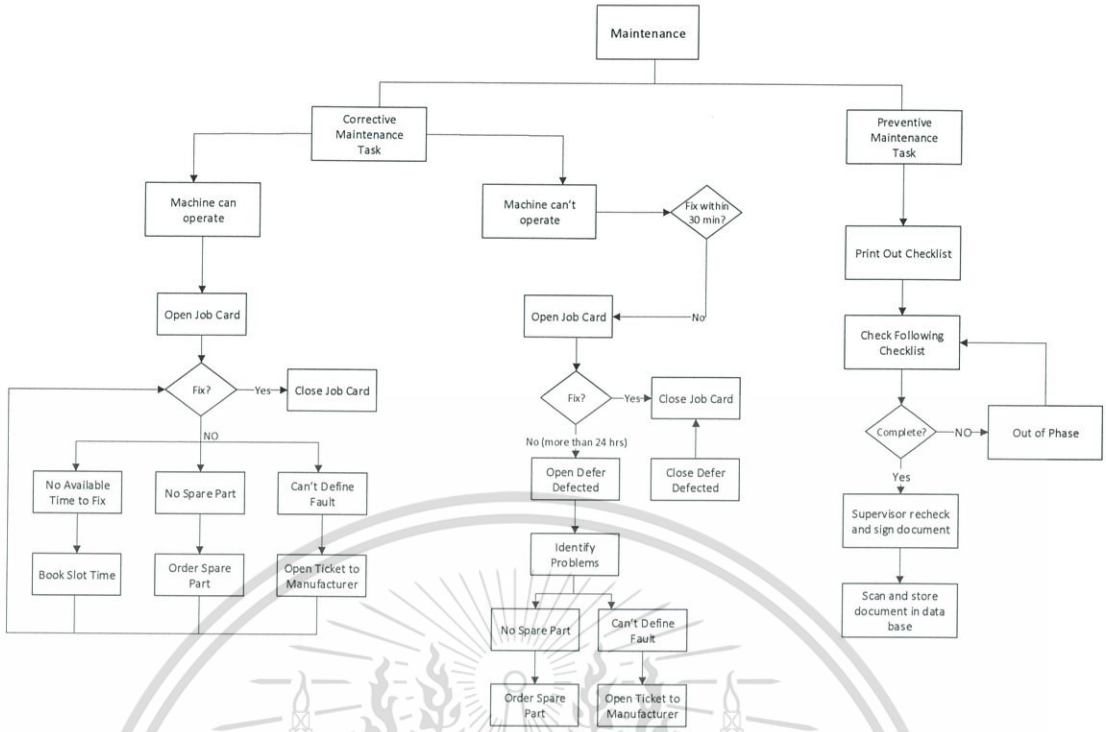



**Figure 3.4 Maintenance Service Workflow**

Corrective maintenance starts from receiving a call from a customer to report faults, then categories into two cases: the FFS can operate and cannot operate. Then the engineer will discuss and inform a problem to customers and sourcing a spare part as well as an applicable engineer for preparing. Then the engineer will go to solve the problem or in some cases, the suppliers will in charge of the problem.

On the other hand, preventive maintenance starts from print maintenance checklist out, then checking to follow the activities on the list. The preventive maintenance activities should be finished on time follow the cycle such as weekly, monthly, or even annually. The significant factors which effect on preventive maintenance activities are unreliable schedule, spare part shortage, and uncontrollable issues such as an electric power system down. The engineering supervisor will in charge of out of phase tasks.

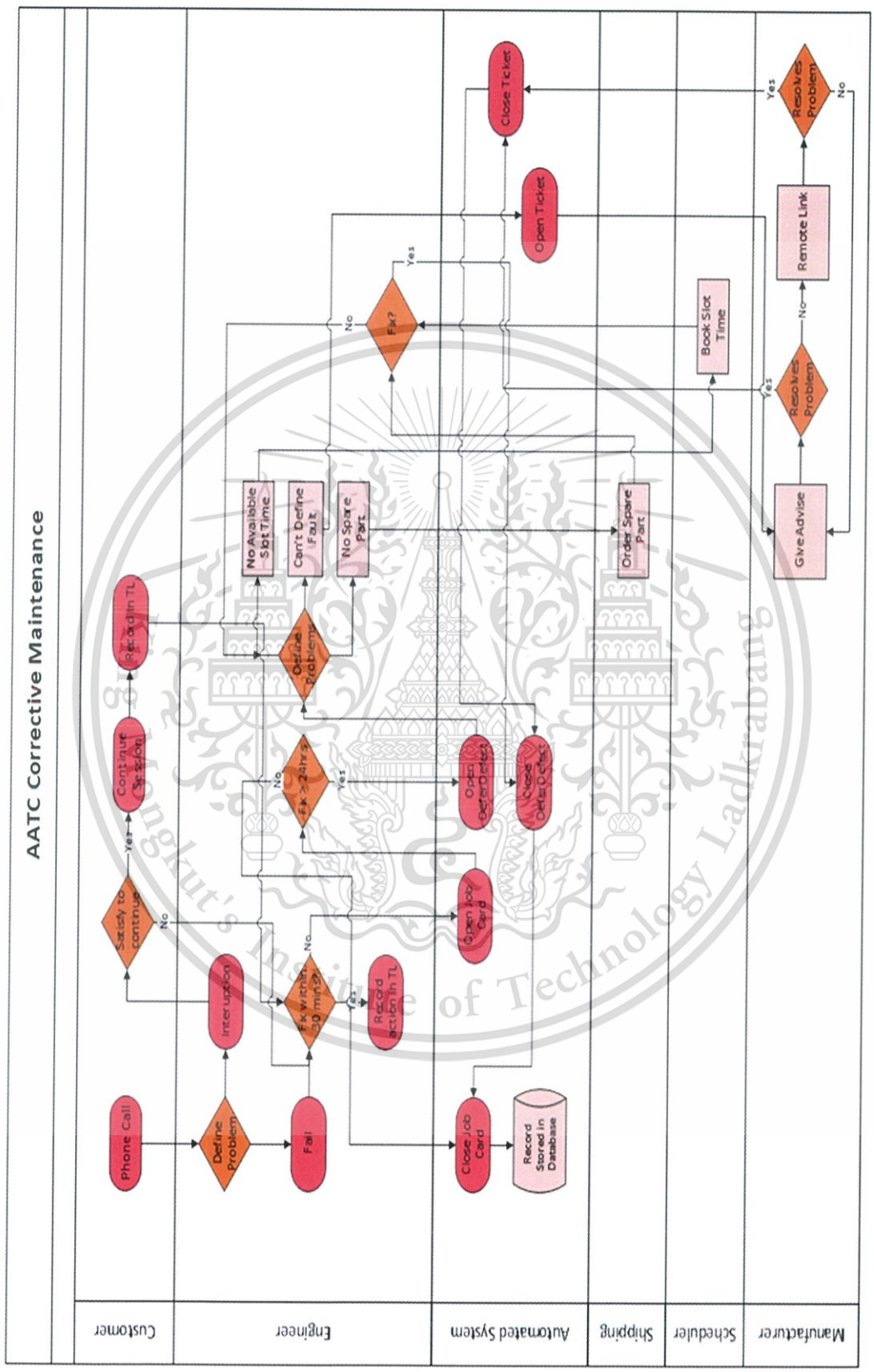



**Figure 3.5** Corrective Maintenance Service "As-Is" Analysis

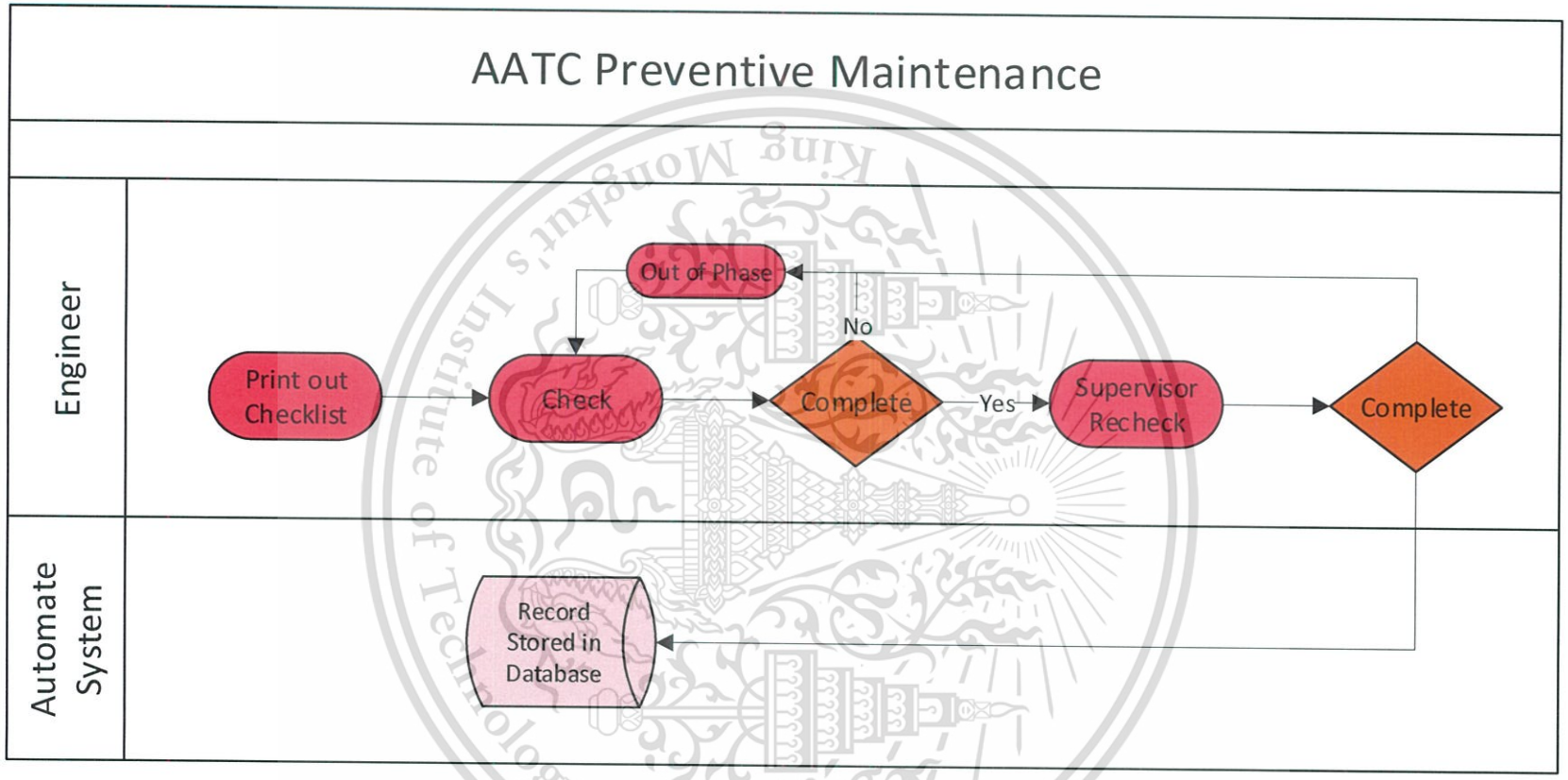



**Figure 3.6** Preventive Maintenance Service "As-Is" Analysis

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Modeling Approach

The adopted model is based on five different management processes. The processes after the implementation consist of Plan, Source, Fulfil, Deliver and Return processes of the case study company, together with those of suppliers and customers. It is a language for communicating among supply chain partners. The adapted SCOR model covers all department interaction, all customers' interaction and all physical parts interaction. The model was designed in two separated model: Preventive maintenance model and Corrective maintenance model. As described earlier, the SCOR model does not attempt to apply in every business process or activity but it is developed to apply in the service business as shown below. The model uses SCOR standardised and common definitions so it can be adapted for a complex of a maintenance service supply chains. The model focuses on 3 processes levels, each level comprises of 5 management processes as briefly described as follow:

- PLAN: Processes that balance requirements and actions to achieve the process planned for both preventive and corrective maintenance.
- SOURCE: Processes that procure spare parts both from MRO and local company to meet maintenance planned and customer demand.
- FULFIL: Processes that fulfil or prepare the properly services before delivery engineer to solve problems to meet planned and customer demand.

- DELIVER: Processes that deliver services to meet customer required, typically including scheduled service, unscheduled service, and engineering service.
- RETURN: Processes affiliated with returning or receiving returned services and spare parts for imperfection reason, this process develop from customer support.

### 4.1.1 Level 1 Adapted SCOR Model

Level 1 describes the workflow of top-level management; establish strategies and planning to meet customer demand as illustrated in **Figure 4.1**.

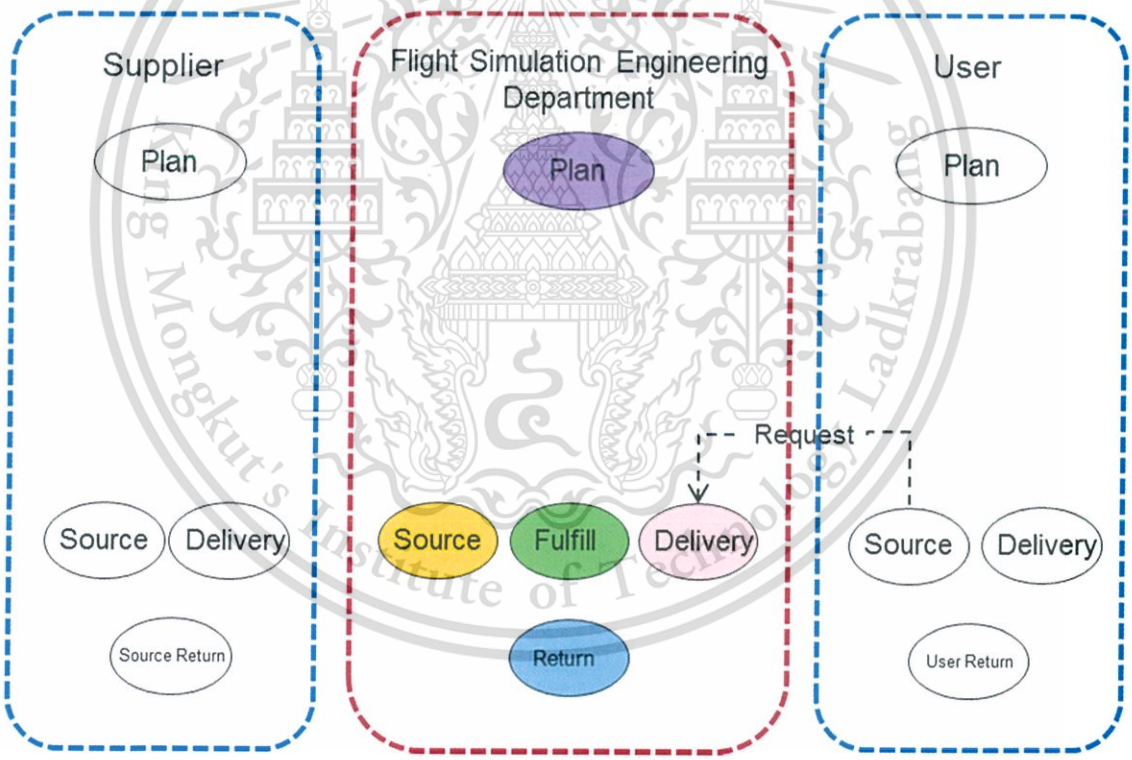



**Figure 4.1** The SCOR Level 1 Process

### 4.1.2 Level 2 Adapted SCOR Model

In this level, describes process categories which break down from level 1. The process categories are defined components of a supply chain and connect all participants together with suppliers. The most appropriated level 2 execution process categories are described along with their activities which are used in **Figure 4.2**.

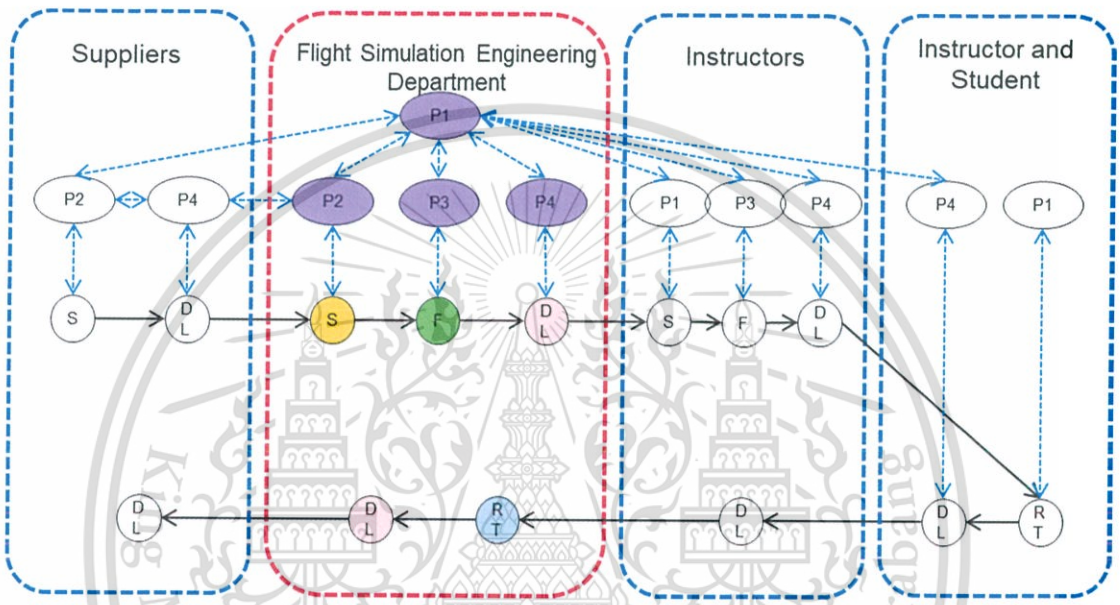



**Figure 4.2** The SCOR Level 2 Process

### 4.1.3 Level 3 Adapted SCOR model

The SCOR level 3 process elements are used to define and determine the relevant process that will enable implementing in the operation. At this level is a detailed activity which the activities from level 2 will be described elaborate. This modeling is based on maintenance service activities, the training center played an important role in providing services, and it offers the flight training services. Hence, the modeling concern about maintenance service activity to make the services meet customer demands. Level 3 has determined as 6 processes; Plan, Source, Fulfil, Deliver, and Return.

**Plan Process**

Plan process is the process development in management level, the plan processes divided into 6 plans include:

**Plan Maintenance Service Supply chain (msP1):** The Maintenance Service Plan processes describe the maintenance service planning activities associated with operating a supply chain. This process includes assembling all customer requirements and available resources, to balance the requirements and resources. Thus, the planning can determine planned capabilities and resource gaps.

**Plan Maintenance Service Source (msP2):** The Maintenance Service Source Plan process describes the sourcing available spare part and ordering or scheduling spare pare. The process includes purchasing orders, scheduling deliveries, receiving, goods verifying, and accepting invoices.

**Plan Maintenance Service Fulfil (msP3):** The Maintenance Service Fulfil Plan process describes the activities associated with the conversion of materials or the creation of the content for services. This process emphasises on available resources rather than production or manufacturing because Fulfil is not transforming the material. It represents all types of resources: spare part, maintenance plan, scheduling, manpower, supplier, and other resources used in maintenance processes.

**Plan Maintenance Service Deliver (msP4):** The Maintenance Service Deliver Plan process describes the activities associated with the creation, maintenance, and fulfillment of customer orders. It includes Schedule and Unscheduled maintenance plane and the execution on a qualified engineer.

**Plan Maintenance Service Return (msP5):** The Plan Maintenance Service Return process describes the activities associated with the reversed flows of service which back from the users. These flows extend from engineers and customers support. The Maintenance Service Return process includes the identification of the need for a return of fault spare parts or services, the disposition decision making, the schedule of the return, and the shipment and receipt of the return goods.

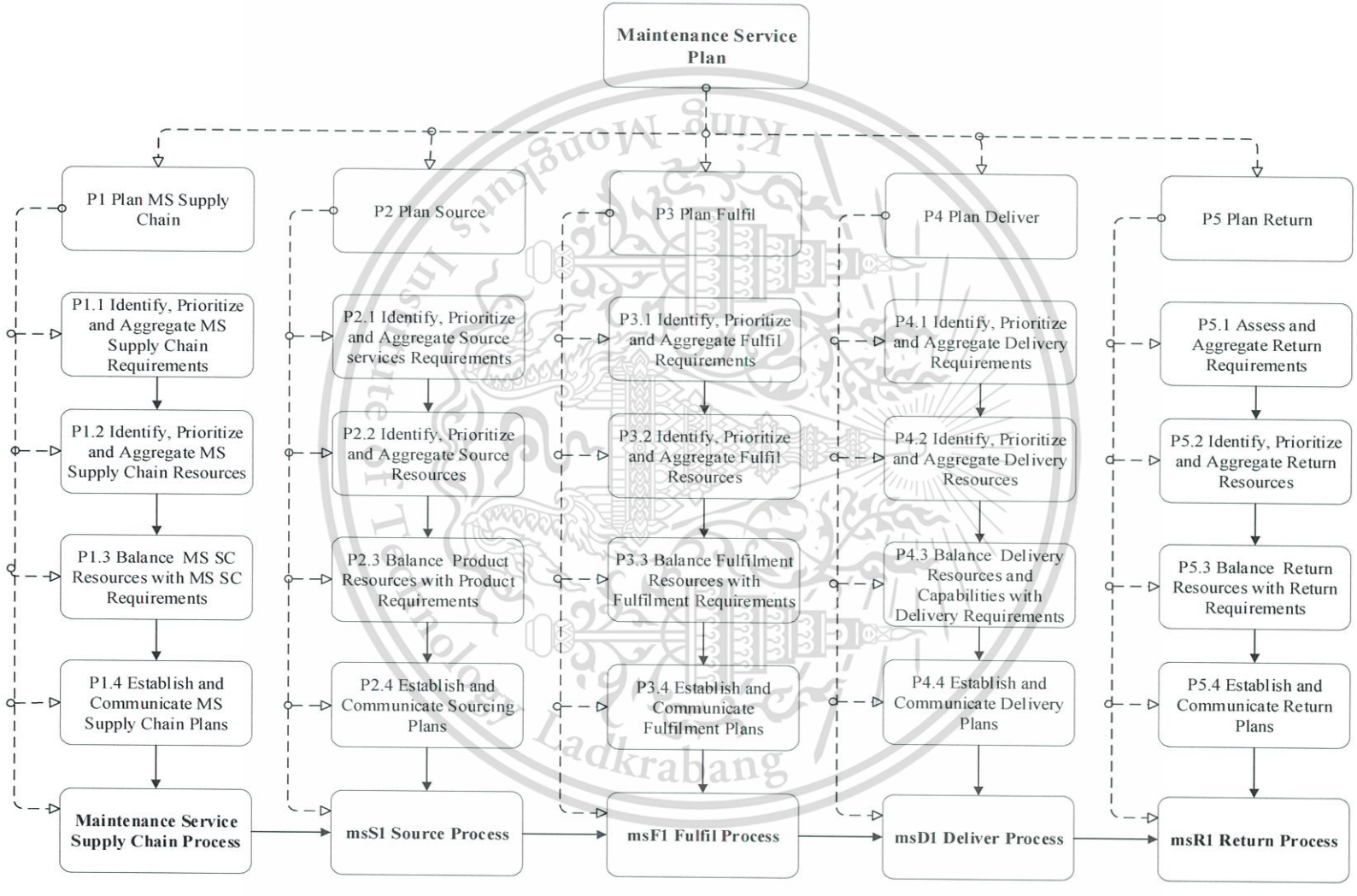



**Figure 4.3** The Adapted SCOR Level 3 Plan Process

**Source Process**

Source process in a service business is the process that concern with spare parts stocked for maintenance as well as the documents between vendors and the company. According to the case study is in the aviation field, some of the spare parts need to order the real aircraft part from MRO which take time for delivery. As source stocked spare part have no element process, in this study, it was combined with other element processes of source ordering spare part. Even though some defects were fixed by subcontract but the company needs to stock a spare part by themselves, so the company have to ensure that all parts effort to be served for maintenance services. The source process consists of 6 processes include:

**Source Stocked Spare Part (msS1.1):** The Source Stocked Spare Part process describes the counting and checking spare parts activities to reach a minimum stock standard of the parts, included matching available spare parts stocked with the number in a database.

**Source Ordering Spare Part (msS2):** The Source Ordering Spare Part describes the process of ordering schedule and ordering plan to ensure that the spare parts in stock meet the minimum requirement the standard of the spare parts.

**Schedule Spare Part Deliveries (msS2.1):** The Schedule Spare Part Deliveries describes the communication between company and suppliers to arrange the delivery schedule included future delivery together link with the msS1.6 process.

**Receive Spare Part (msS2.2):** The Receive Spare Part describes the process and associated of receiving spare parts between a company and suppliers to ensure a company will receive the shipment on time, sometimes called 'catching up' process.

**Verify Spare Part (msS2.3):** The process that describes testing of spare parts to verify performance and ensure that all kind of parts meets the requirement of the flight simulator system before kept it in stock.

**Authorise Supplier Payment (msS2.4):** The process between shipping department, financial department, and supplier after verifying spare parts, included the agreement between a company and suppliers for parts or services purchased for a future delivery period. The agreement related with the Schedule Part Deliveries (msS1.3) which help the procurement process easier and faster.

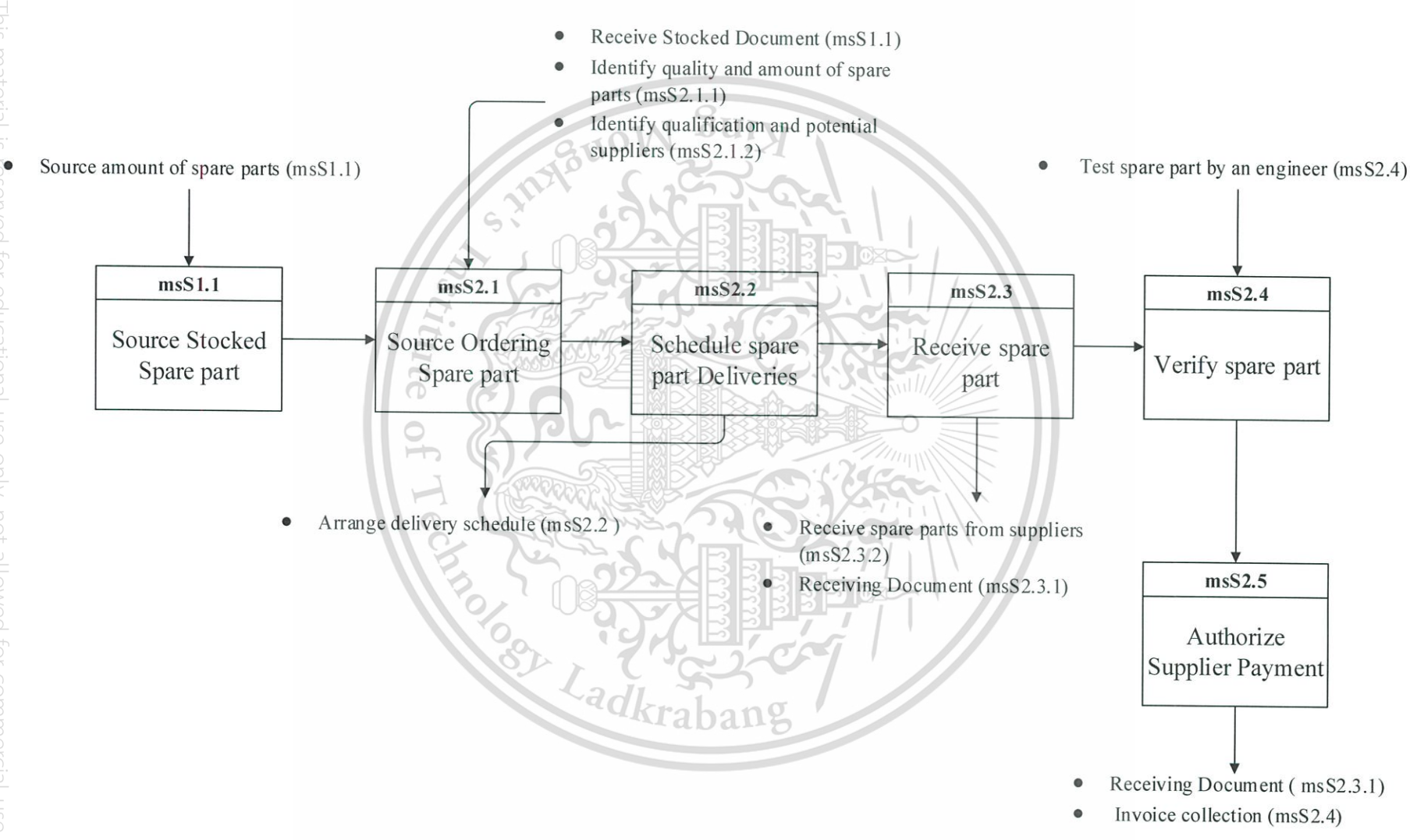



**Figure 4.4** The Adapted SCOR Level 3 Source Process

**Fulfil Process**

Fulfil process is the process before delivering services to customers. The categories in fulfill process similar to source process which focused on the stoked, whereas the fulfill process focused on the practicable services such as providing a high level of engineers for a particular job, and preparing an available slot time the for maintenance activities. As described above, the maintenance was defined as two models; preventive maintenance service which is scheduled service and corrective maintenance service which is unscheduled service.

Furthermore, accomplishing the fulfill process completely, we as well as generated the Fulfil Engineer Service. Therefore, the fulfil process consist of the Fulfil Scheduled Service (msF1), the Fulfil Unscheduled Service (msF2), and the Fulfil Engineer Service (msF3).

**Fulfil Schedule Service**

The first process of the fulfil process is the Fulfil Scheduled Service (msF1) involve with 4 processes as follow:

**Schedule Fulfilment Activities (msF1.1):** The Schedule Fulfilment Activities describes activities which are in normal schedule including daily, weekly, monthly, and annually plan including maintenance plan from suppliers.

**Fulfil and Test (msF1.2):** The Fulfil and Test process is the execution activities which involve with booking the schedule of the flight simulator devices or rearranging the schedule for maintenance service including the services from

suppliers. This also included preparing tools and parts if necessary for maintenance activity.

**Release Fulfilment Documentation (msF1.3):** The Release Fulfilment Documentation is the process that describes communications between departments in a company and a company and suppliers by using the documents to approve all activities fulfilled and ready to be released.

**Waste Disposal (msF1.4):** The process that concern about hazardous waste managing after maintenance services such as a battery, oil, and electronic parts.

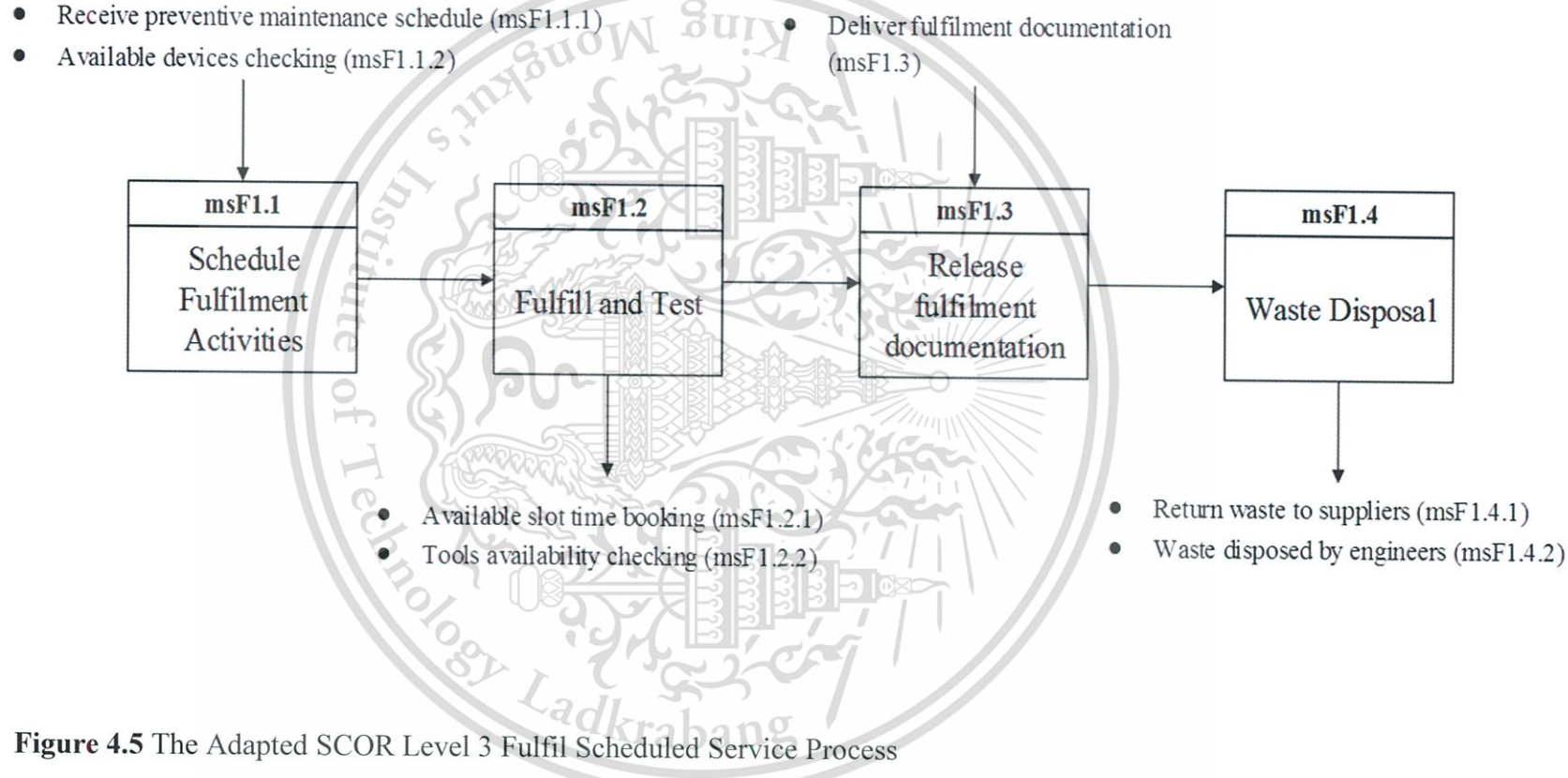



**Figure 4.5** The Adapted SCOR Level 3 Fulfil Scheduled Service Process

**Fulfil Unscheduled Service**

The process of Fulfil Unscheduled Service (msF2) involve with 4 processes as follow:

**Schedule Fulfilment Activities (msF2.1):** The process that describes the planning of unscheduled service after noticed the issues including unscheduled services from suppliers if necessary.

**Fulfill and Test (msF2.2):** The Fulfil and Test process is the execution activities of unscheduled services which involve with providing an available schedule of the flight simulator devices or rearranging the schedule for maintenance service including the services from suppliers if necessary. This also included preparing tools and parts if necessary for maintenance activity.

**Release Fulfilment Documentation (msF2.3):** The Release Fulfilment Documentation is the process that describes communications between departments in a company and a company and suppliers by using the documents to approve all activities from unscheduled service fulfilled and ready to be released.

**Waste Disposal (msF2.4):** The process that concern about hazardous waste managing after maintenance services such as a battery, oil, and electronic parts.

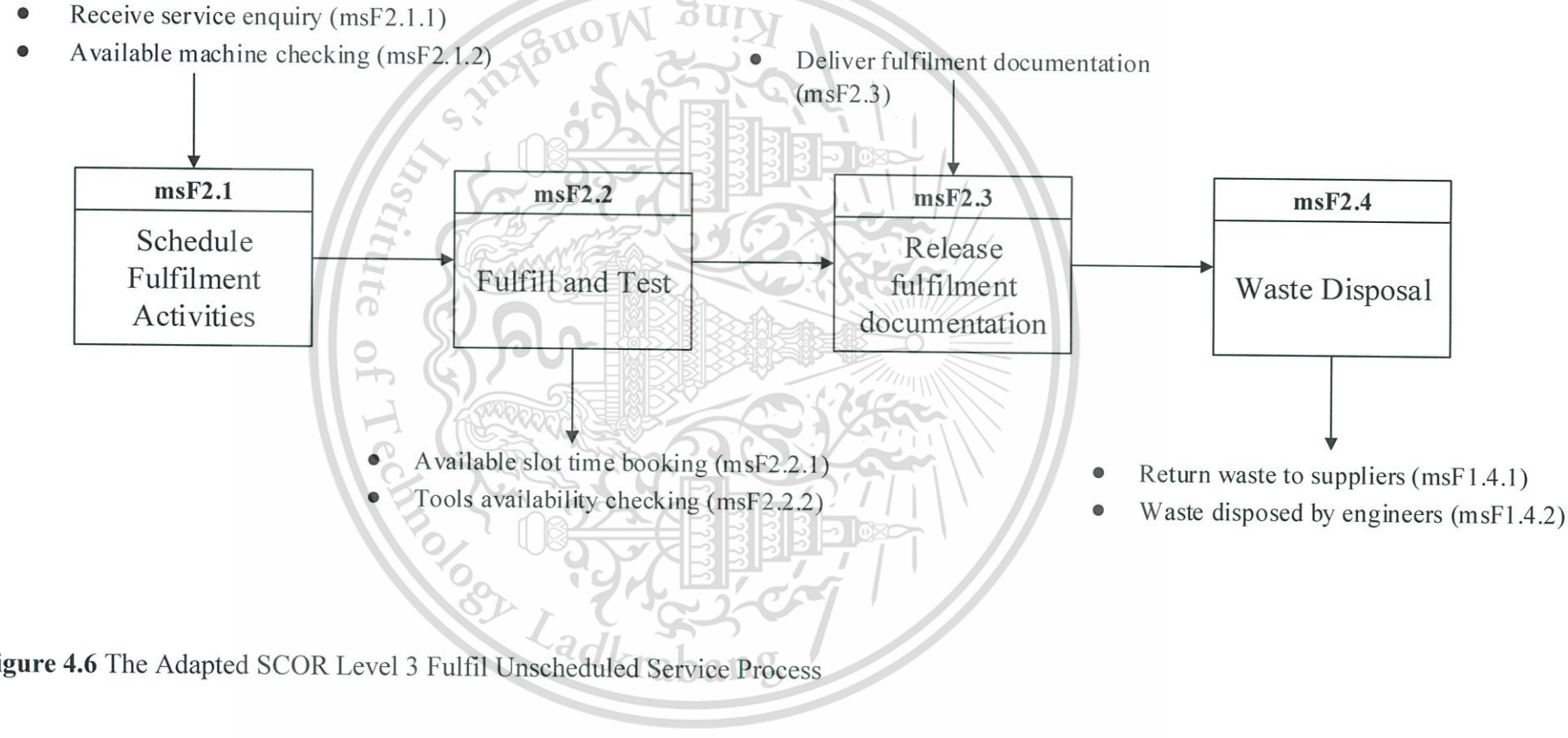



**Figure 4.6** The Adapted SCOR Level 3 Fulfil Unscheduled Service Process

**Fulfil Engineer Service**

The last process of fulfil process focuses on engineering services. The qualified engineer can increase reliable maintenance services because of high skilled. To maintain the maintenance service reliable, providing an appropriated engineer to solve the issues is significance. The Fulfil Engineer Service (msF3) which involves with 4 processes as follow:

**Finalise Fulfilment Engineering (msF3.1):** This process determines engineer who appropriates with those issues as well as authorised suppliers.

**Schedule Fulfilment Activities (msF3.2):** The process describes the activities of providing qualified engineer and qualified suppliers to ensure that the suppliers can support a company in case of an emergency issue. This process included an arrangement's available time of engineers and suppliers.

**Fulfil and Test (msF3.3):** The Fulfil and Test process describes the execution activities of solving any problems or issues and test functions before delivering services to users.

**Release Fulfilment Documentation (msF3.4):** The Release Fulfilment Documentation is the process that describes communications between departments in a company by using the documents to approve all activities from engineering service fulfilled and ready to be released.

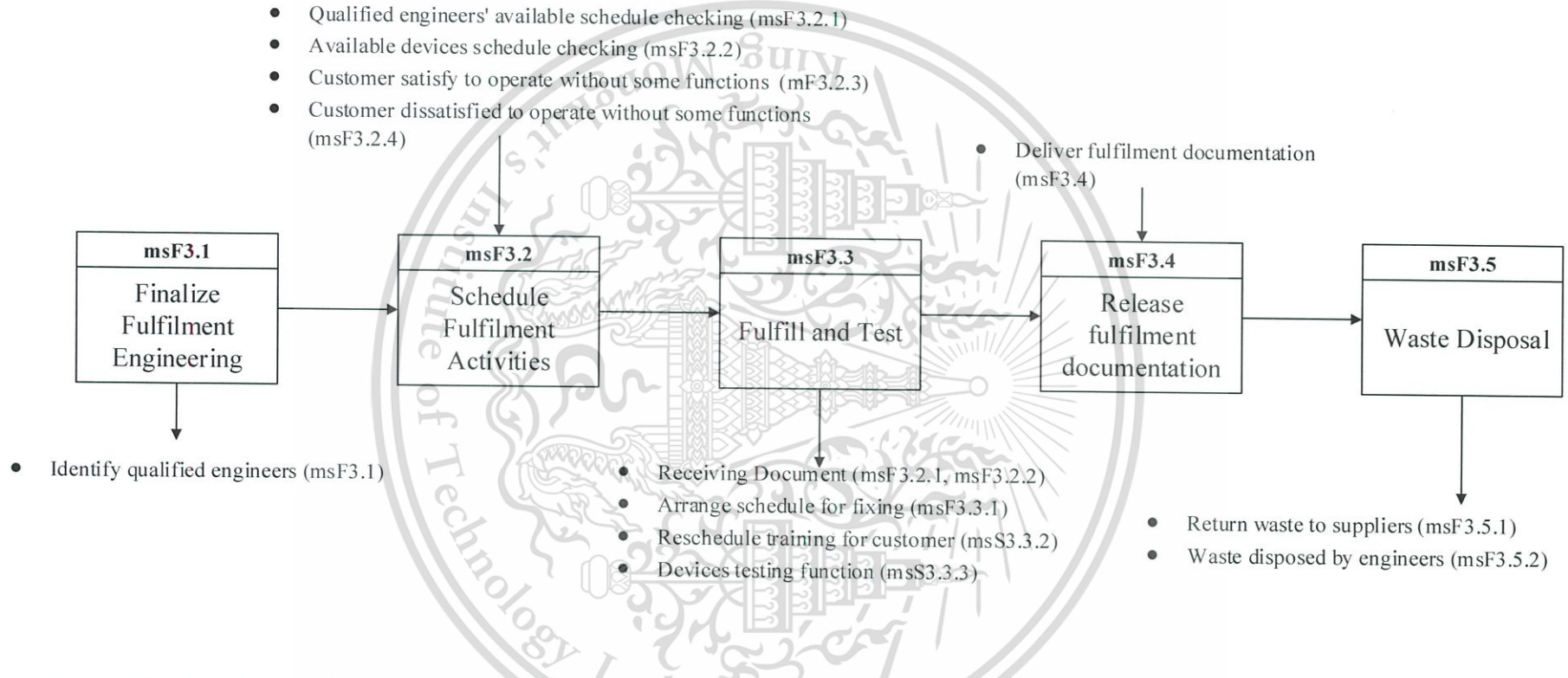



**Figure 4.7** The Adapted SCOR Level 3 Fulfil Unscheduled Service Process

**Deliver Process**

The Deliver process describes the process of sending completely work to users or customers. As normally maintenance service model so the Deliver process was defined as three models; preventive maintenance service which is the Delivery Scheduled service (msD1), corrective maintenance service which is the Delivery Unscheduled Service (msD2), and the Deliver Engineer Service (msD3) which is sending a qualified engineer to solve problems.

**Deliver Scheduled Service**

The Deliver Scheduled Service process associated with delivering completely execute to a customer following the schedule, the Deliver schedule service process consists of 6 processes include:

**Process Inquiry and Quote (msD1.1):** This process concern about details or conditions of fixing and cost documents before execution.

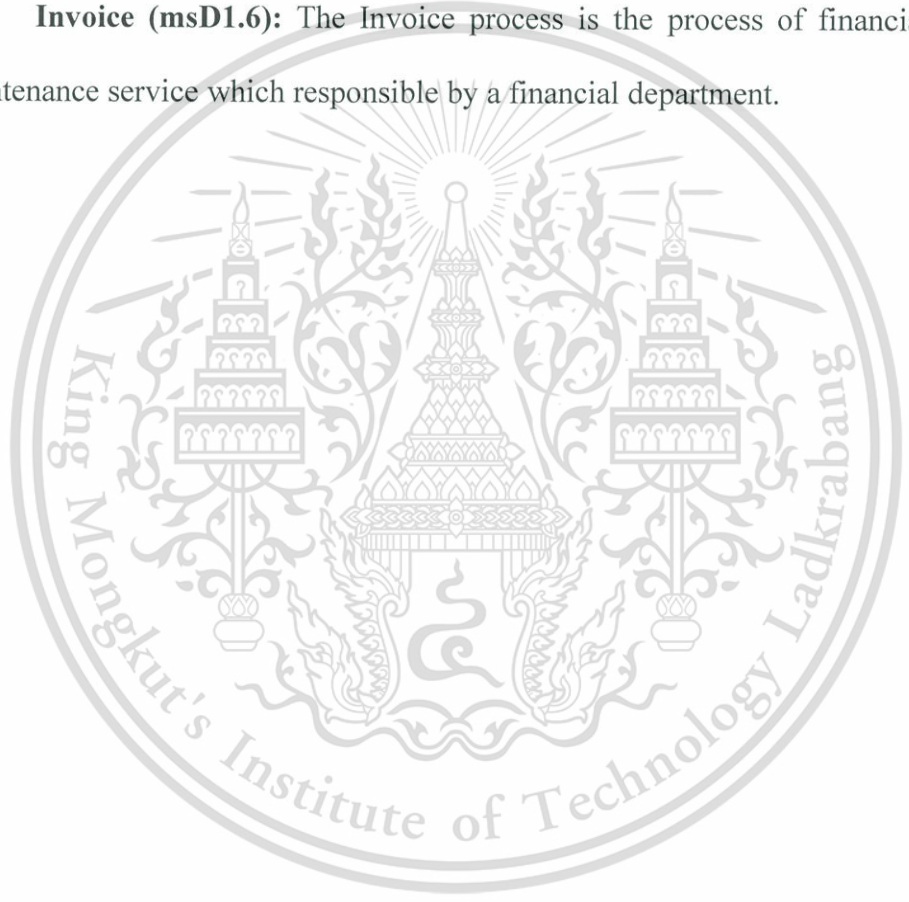
**Receive, Enter and Validate requirement (msD1.2):** Receiving information and documents from suppliers or sourcing process, validate the information and confirm requirements.

**Identify Capacity and Determine Delivery Date (msD1.3):** This process determines an available source after receiving the fulfilment documents and identify delivery time after that expect finishing date.

**Receive Services from Source or Fulfil (msD1.4):** The process of receiving the confirmation document from source and fulfil process. Information can be received through email, phone, or fax.

**Verify Service (msD1.5):** The process describes work done by engineers or suppliers and verifying that the execution was fixed complete and the service meet customer requirements. The execution can be verified by an engineer or a user.

**Invoice (msD1.6):** The Invoice process is the process of financial cost for maintenance service which responsible by a financial department.



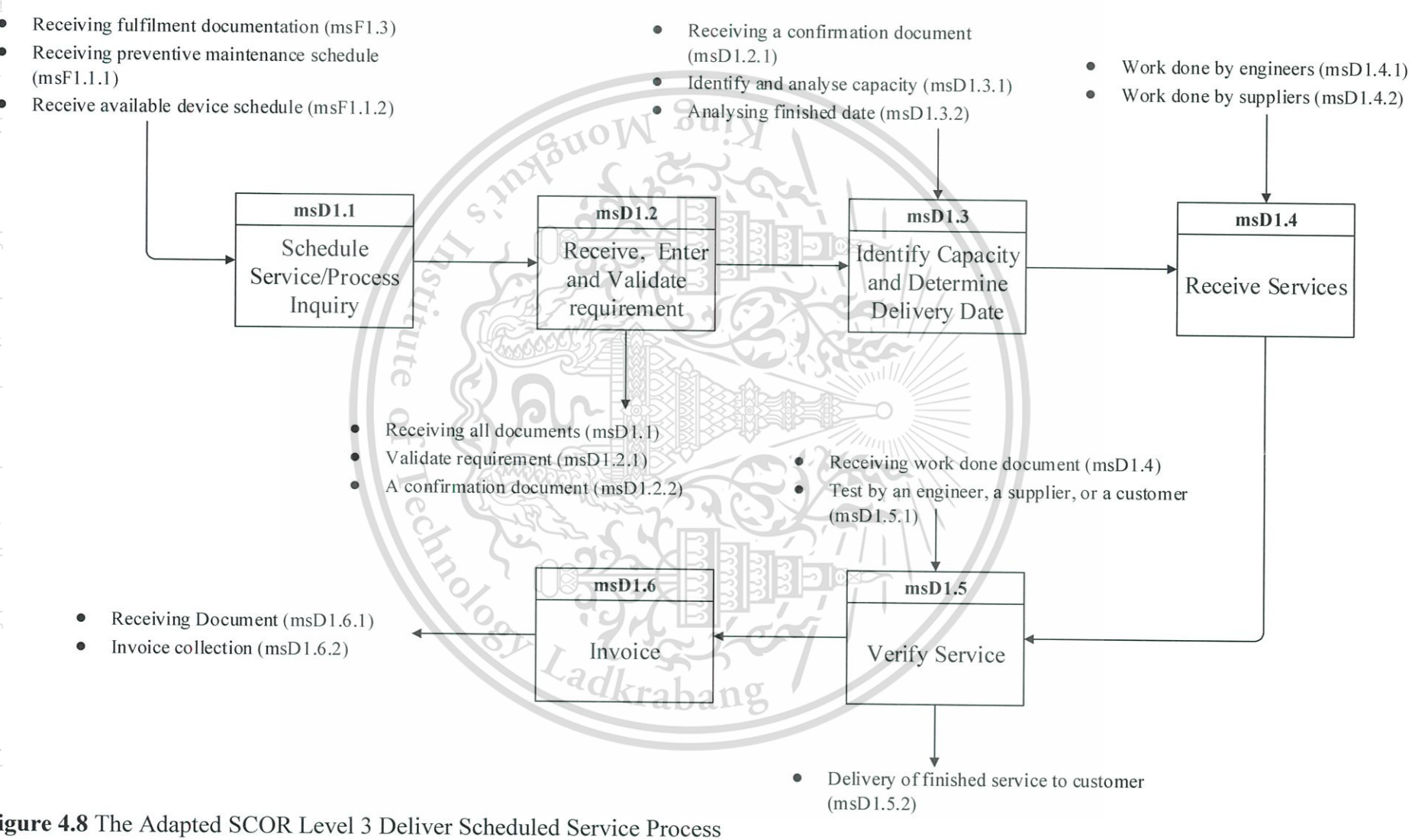



**Figure 4.8** The Adapted SCOR Level 3 Deliver Scheduled Service Process

**Deliver Unscheduled Service**

The Deliver Unscheduled Service disparate from the Scheduled Service process, the entire requirement may be unavailable for unscheduled service due to the issues being unscheduled. Hence, most of the Deliver Unscheduled service activities related to the Fulfil and Source process. This process consists of 6 processes include:

**Process Inquiry and Quote (msD2.1):** This process concern about details or conditions of fixing and cost before execution.

**Receive, Enter and Validate requirement (msD2.2):** Receiving information and documents from suppliers or sourcing process, validate the information and confirm requirements.

**Identify Capacity and Determine Delivery Date (msD2.3):** This process determines an available source after receiving the fulfilment documents and identify delivery time after that expect finishing date.

**Receive Services from Source or Fulfil (msD2.4):** The process of receiving the confirmation document from source and fulfil process. Information can be received through email, phone, or fax.

**Verify Service (msD2.5):** The process describes work done by engineers or suppliers and verifying that the execution was fixed complete and the service meet customer requirements. The execution can be verified by an engineer or a user.

**Invoice (msD2.6):** The Invoice process is the process of financial cost for maintenance service which responsible by a financial department.

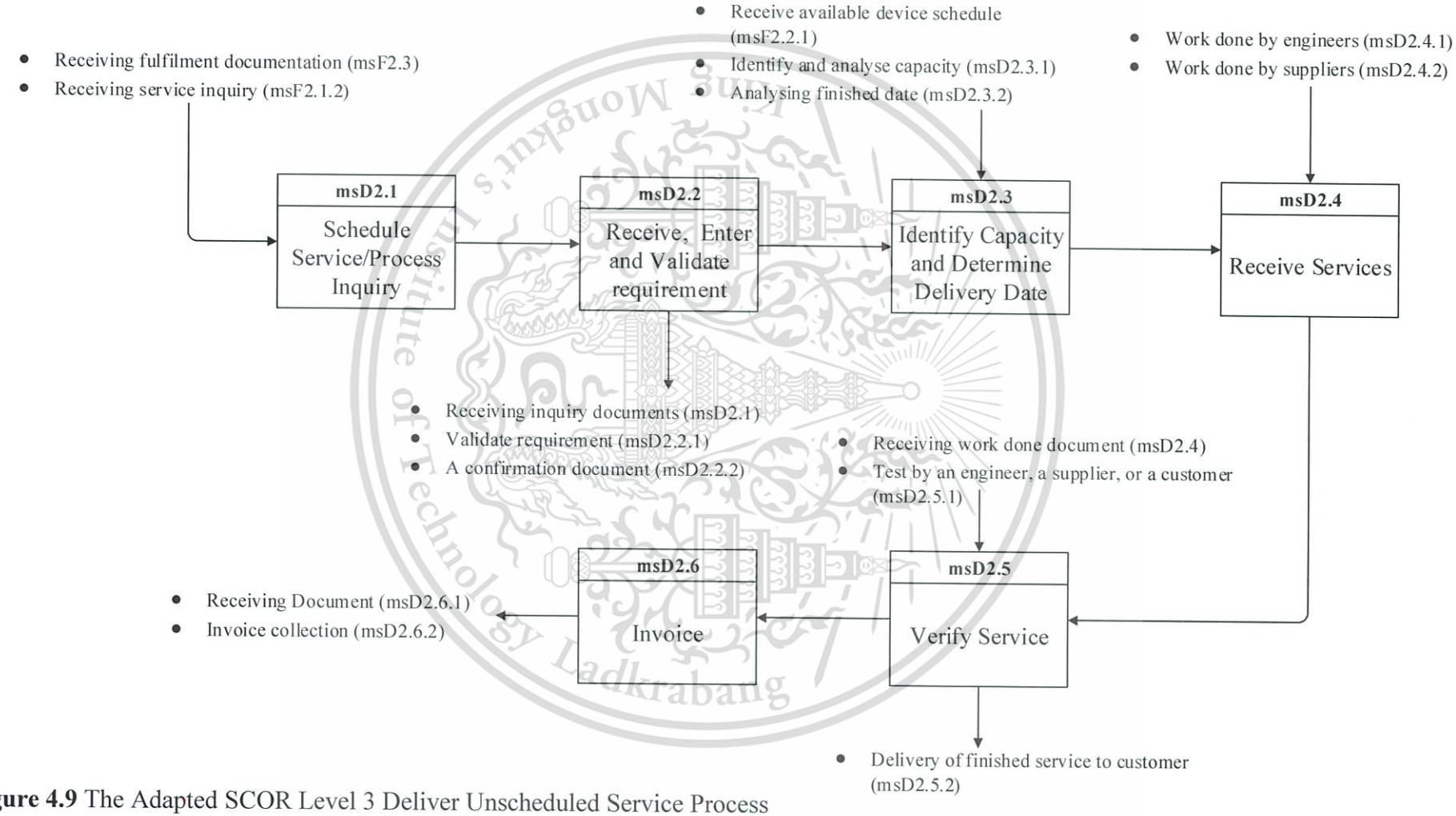



**Figure 4.9** The Adapted SCOR Level 3 Deliver Unscheduled Service Process

**Deliver Engineer Service**

The Deliver Engineer Service process provides a qualified engineer for an appropriate job for getting high performances. Due to maintenance service has several levels of issues, the experiences and skills are needed. The Deliver Engineer Service consists of 5 processes include:

**Obtain and Respond to requirements (msD3.1):** The identified of receiving details of requirements and conditions of fixing and cost.

**Negotiate and Receive Confirmation (msD3.2):** The activities of negotiating to a customer in case of the requirement not meet their demand and give alternative ways. Receive and validate the information.

**Schedule Execution (msD3.3):** This process identified an available source and time of qualified engineers after that expect finishing date.

**Receive Services from Source or Fulfil (msD3.4):** The activities of receiving the confirmation document from source and fulfil process.

**Execute Service (msD3.5):** The process describes work done by engineers or suppliers and verifying that the execution was fixed complete and the service meet customer requirements. The execution can be verified by a user or higher level's engineer.

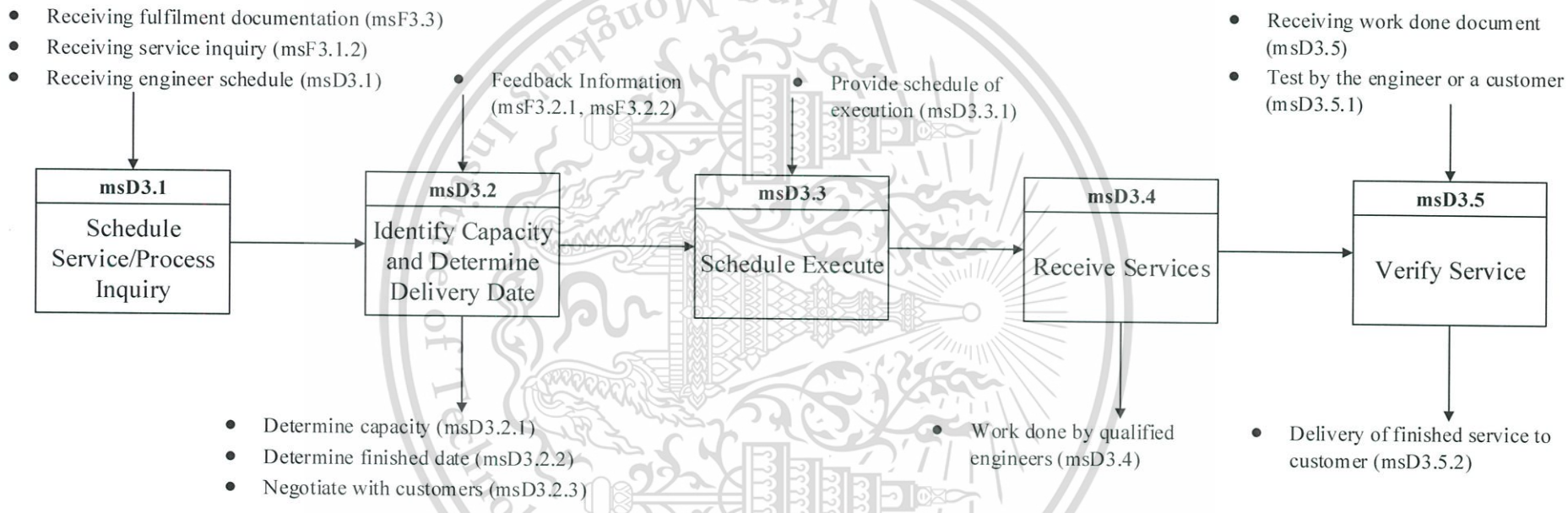



**Figure 4.10** The Adapted SCOR Level 3 Deliver Engineer Service Process

**Return Process**

The Return process determines a defective part and service which it will be returned due to work incomplete or unstable. The defective part will be returned to MROs or suppliers because the function does not work appropriately. The Return process consists of two processes consist of Source Return Defective Service (msR1) and Delivery Return Defective Service (msR2).

**Source Return Defective Service**

Source Return Defective Service associate finding a cause of problems activity and return the issue to Fulfil or Deliver process.

**Identify Defective Service Condition (msR1.1):** The activity of identification of defective service, this sometimes can be identified by a user.

**Disposition Defective Service (msR1.2):** This process concerns the management of defectives after receiving the document from the Source and Fulfil department.

**Return Defective Service (msR1.3):** The activity of sending defective part including unserviceable part from fixing to MRO or suppliers.

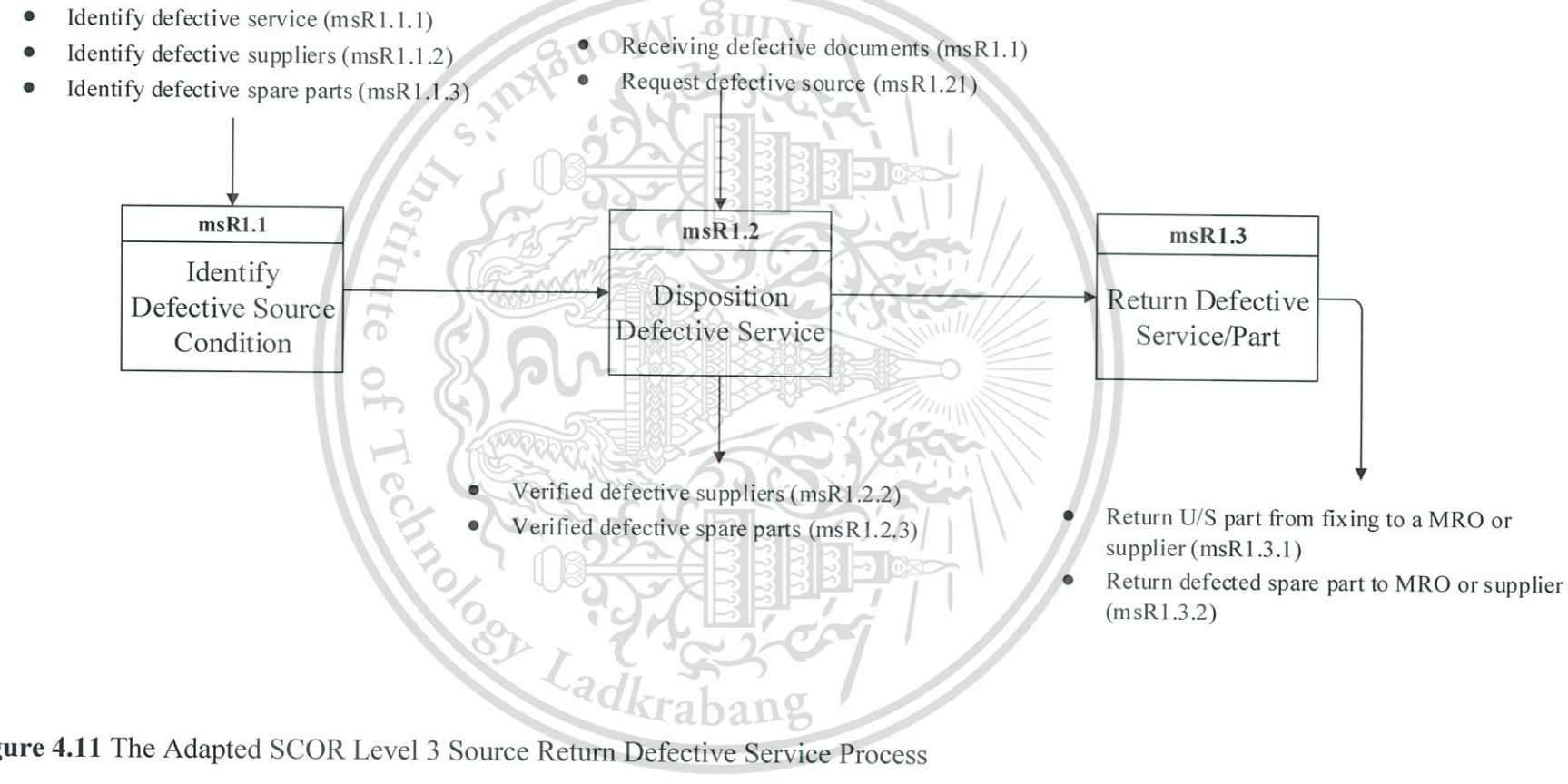



**Figure 4.11** The Adapted SCOR Level 3 Source Return Defective Service Process

**Delivery Return Defective Service**

The Delivery Return Defective Service associates with the activity of returning defective service from customer to engineer because the work does not complete. And the returning completed service form engineer to customer or user after implementation.

**Authorize Defective Service Return (msR2.1):** This process concern the activity of defective service return authorisation whether the service was implemented correctly and have no defects. This activity can be identified by engineers or suppliers.

**Receive Defective Service (includes verify) (msR2.2):** Receiving document and feedback from a customer. The engineer will be verified defective service and monitored that service or send the defective to concerning suppliers.

**Transfer Defective Service (msR2.3):** This process determines the transferring defective service from sources or spare parts to concerning suppliers. And send the feedback information to the Deliver process.

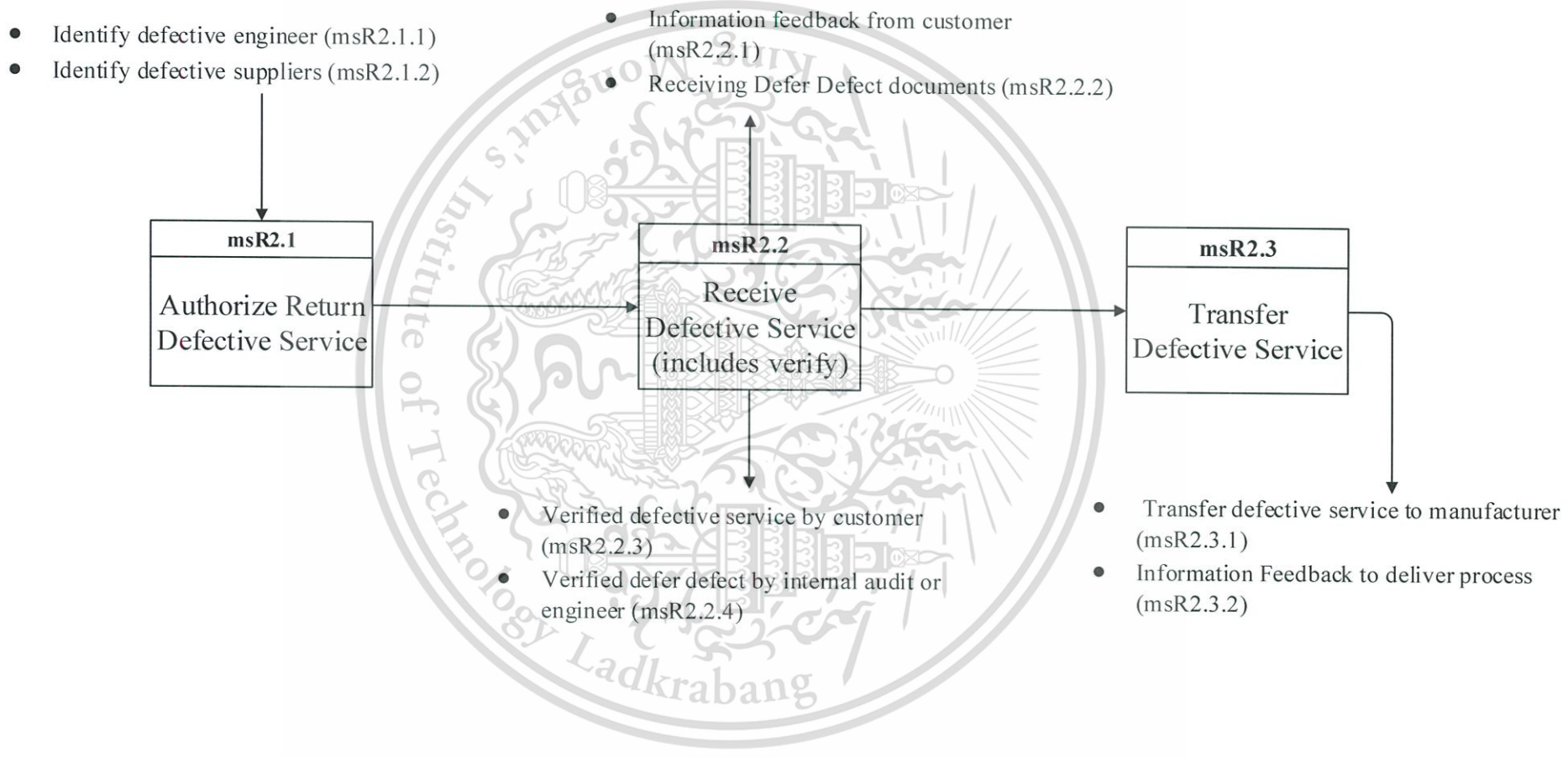



**Figure 4.12** The Adapted SCOR Level 3 Source Return Defective Service Process

### 4.2 Maintenance Service Process through BPMN

The last process, the designing of the adapted maintenance service process models were illustrated through BPMN base on the SCOR model as shown in **Figure 4.13** and **Figure 4.14**. The models through BPMN will give a business the ability to communicate and understand implementation and communication between levels and suppliers as it is standard communication. In conclusion, the designing of the adapted maintenance service process model can create a standardised maintenance services process model base on the SCOR model. The study has reached its objectives and shown that the model can be improved service level and reduced the breakdown. Moreover, the models through BPMN can be useful for business management level for implementation and communication between levels and suppliers.

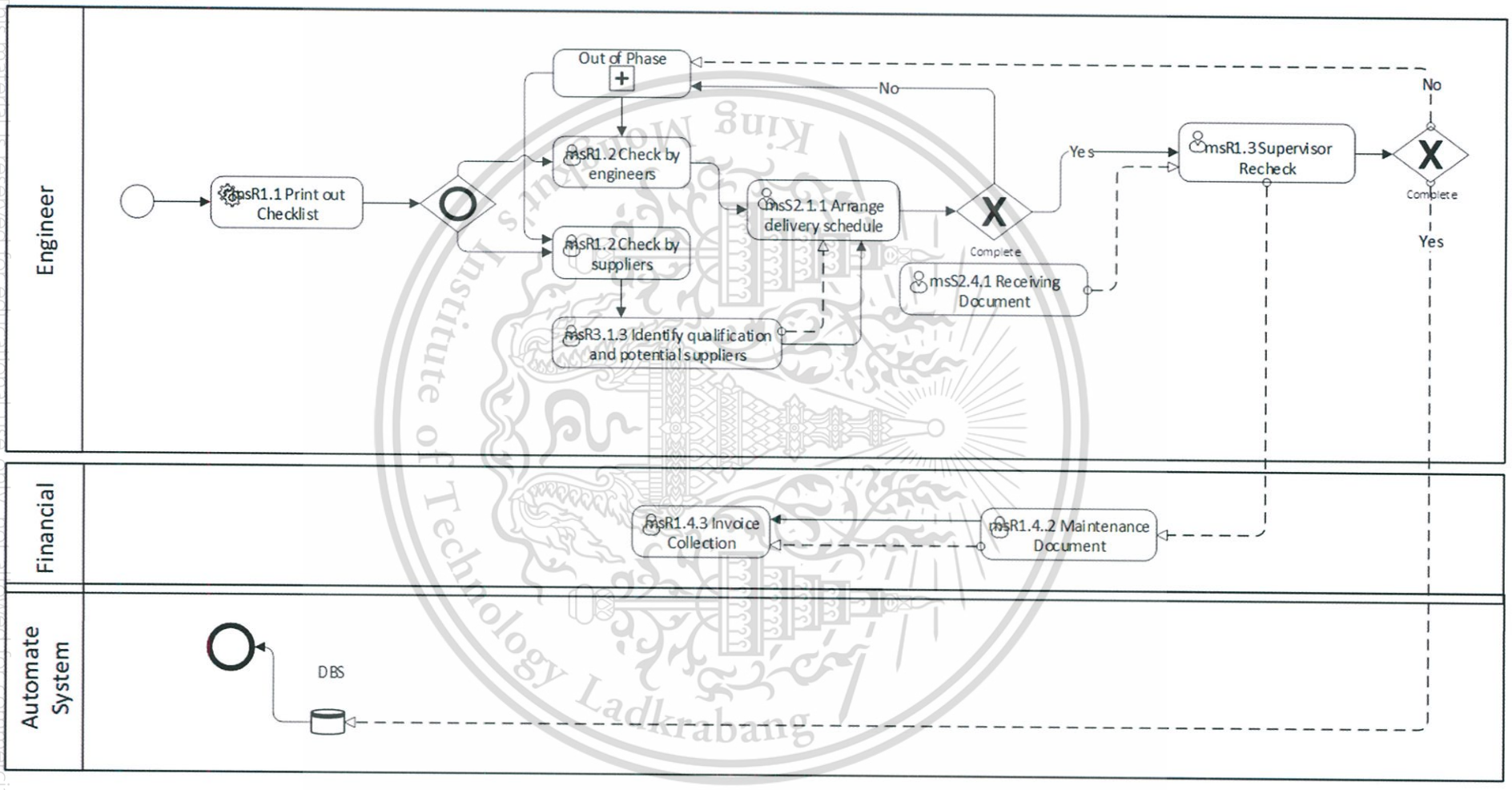



**Figure 4.13** Preventive Maintenance Process through BPMN

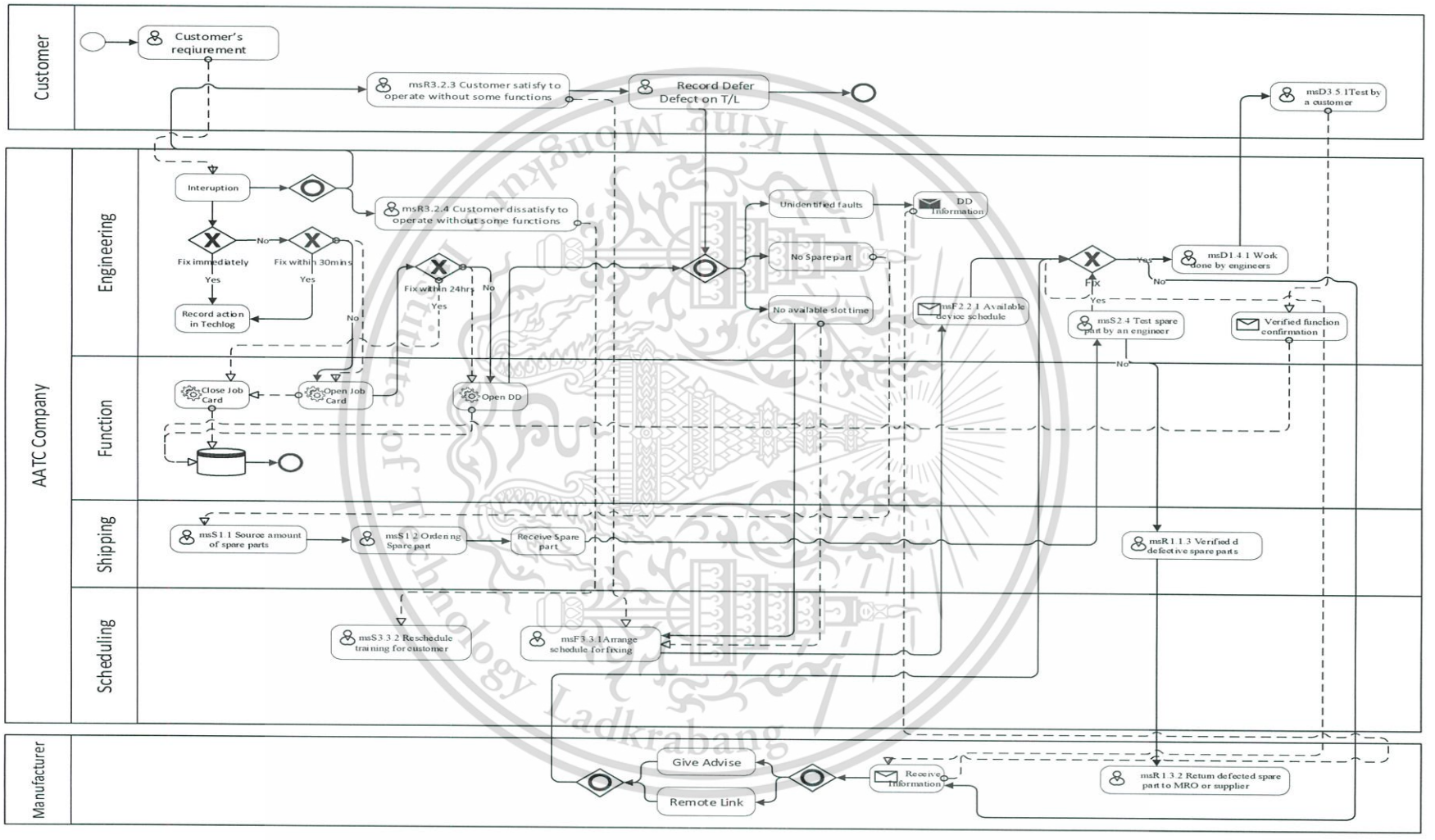



**Figure 4.14** Corrective Maintenance Process through BPMN

### 4.3 Model Validation

The questionnaire will be adopted in model validation phase two. The question naires were separated in two rounds; Pre and Post round. The first round will ask the p articipant with the unseen questionnaire, after that, the participant will be attended the workshop course together with the authors. The discussion for finding the best outco me of the model will occur in this process.

First of all, all participants have given an adopted SCOR maintenance process model (Figure 4.13 and 4.14) without any clarifying. The participants allowed to discuss with others in their round. The work period averages of the participants are about 9 years, and most of the participants have no idea in supply-chain term observed from questions number two. The answers from the first round questions can summary as usefulness regarding the participants claimed that the adapted model helped in the understanding the standardise processes (17 people), the model helped understand the strategy linked to the service (17 people), and the model helped understand the end to end service supply chain (16 people). The suggestion from the participants from open-questions number 15 and 16 can be concluded that the participant needs more time to work through the model and need some SCOR model explanations. As well as Discussion on how to implement the adapted model is required.

After the workshop, all of the participants more understand about supply chain, even they never worked with supply chain but they have ideas on how to apply it in the work area. The questionnaire form post-round shown the model usefulness, observed from the summary of the answer: the adapted model helped in the understanding the standardise processes (20 people) and the model helped understand the strategy linked to the service (20 people)

**Table 4.1** The Pre-Questionnaire (Round1)

| Questionnaire Analysis (Round 1) | | | |
|---|---|---|---|
| | | | |
| 1 | How many years have you worked in the maintenance services industry? | 9 | |
| | | Yes | No |
| 2 | Have you ever worked with supply-chain or used a supply-chain? (any capacity) | 6 | 14 |
| 3 | Did the model improve your understanding of your business and how you fit into the overall service to the customer? | 20 | 0 |
| 4 | Did the model help you in understanding how to analyse your business? | 20 | 0 |
| 5 | From your analysis, could you come up with ideas of how you could change the overall business? | 16 | 4 |
| 6 | Were the descriptions in the model accurate in what must be done? | 18 | 2 |
| 7 | Were the Level 1 performance metrics useful in giving ideas of what you should measure? | 18 | 2 |
| 8 | In looking at the HR process, did it give you an idea of what is expected of you in terms of the HR processes? | 20 | 0 |
| 9 | Did the use of the SOURCE and FULFIL processes make sense in analysing the costs and time associated with these processes in your supply-chain | 18 | 2 |
| 10 | Was the model easy to understand and use? | 20 | 0 |
| 11 | Did the use of a Scheduled and Unscheduled services (e.g. msF1 or msF2) make sense? | 20 | 0 |
| 12 | Did you find the adapted service SCOR glossary with the process definitions useful? | 20 | 0 |
| 13 | Where the descriptions of the various process elements useful? | 18 | 2 |
| 14 | Do you think this model could be used for other services as well? | 20 | 0 |
| 15 | Do you have any suggestions or improvements to the model? | | |
| 16 | What was the biggest learning for you personally? | | |

**Table 4.2** The Post-Questionnaire (Round 2)

| Questionnaire Analysis (Round 2) | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| 1 | How many years have you worked in the services industry? | 9 | | | |
| | | Not at all | No much | Some What | Very |
| 2 | Have you ever worked with supply-chain or used a supply-chain? (any capacity) | 0 | 9 | 6 | 5 |
| 3 | Did the model improve your understanding of your business and how you fit into the overall service to the customer? | 0 | 0 | 0 | 20 |
| 4 | Did the model help you in understanding how to analyse your business? | 0 | 0 | 2 | 18 |
| 5 | From your analysis, could you come up with ideas of how you could change the overall business? | 0 | 1 | 3 | 17 |
| 6 | Were the descriptions in the model accurate in what must be done? | 0 | 0 | 2 | 18 |
| 7 | Were the Level 1 performance metrics useful in giving ideas of what you should measure? | 0 | 0 | 5 | 15 |
| 8 | In looking at the HR process, did it give you an idea of what is expected of you in terms of the HR processes? | 0 | 0 | 0 | 20 |
| 9 | Did the use of the REQUEST and DELIVER processes make sense in analysing the costs and time associated with these processes in your supply-chain | 0 | 0 | 2 | 18 |
| 10 | Was the model easy to understand and use? | 0 | 0 | 0 | 20 |
| 11 | Did the use of a Scheduled and Unscheduled services (e.g. msF1 or msF2) make sense? | 0 | 0 | 0 | 20 |
| 12 | Did you find the adapted service SCOR glossary with the process definitions useful? | 0 | 0 | 5 | 15 |
| 13 | Where the descriptions of the various process elements useful? | 0 | 0 | 0 | 20 |
| 14 | Do you think this model could be used for other services as well? | 0 | 0 | 0 | 20 |
| 15 | Do you have any suggestions or improvements to the model? | | | | |
| 16 | What was the biggest learning for you personally? | | | | |

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

Evaluation results base on the description of feasibility, usability, and usefulness, the conclusions were shown that the company would benefit from being developed designed model. The process of flight simulator maintenance service process was defined in 3 levels and 5 process elements included Plan, Source, Fulfil, Deliver, and Return as follow:

Level 1 devised for the top level of the supply chain. At this level, the adapted SCOR using establishes basic strategic objectives regarding the case study company operations areas. Therefore, the process of level 1 shows the overall plan processes with managements, suppliers, and customer throughout the engineering department.

Level 2 is configuration level which breaks down from level 1. The key level 2 processes are defined by the relationship between a Process and a Process Type. These process activities have a letter and number which the letter represents the initial of the process (msP, msF, or msD). The numbers identify the scenario or configuration (1, 2, or 3). For example, msP1 stands for a maintenance service plan or msF1 stands for maintenance service fulfil.

Level 3 is detailed process elements that use to determine and identify the relevant process for each level 2 processes. Any processes in level 2 will be elaborated in level3, the example shows the breakdown of the level 2 process maintenance service fulfil into its level 3 components identified from msF1.1 to msF1.1.1.

In addition, the engineering team was a part of designing their procedures base on the SCOR model, maintenance service process improvement was developed through the feedback from the expert of the field. Therefore, the maintenance service model processes earn more effectively and efficiently. In conclusion, the designing of the adapted maintenance service process model can create a standardised maintenance services process model base on the SCOR model. The study has reached its objectives and shown that the model can be improved service level and reduced the breakdown. Moreover, the models through BPMN can be useful for business management level for implementation and communication between levels and suppliers.

## 5.2 Recommendations

According to this research is based on the assumption of services business which different from manufacturing, thus the results is shown that the designed model is a specific model of a services business. As well as the case study is a specific unit; this may mean the maintenance service process model does not apply to general businesses. Nonetheless, the knowledge from the study can apply to other business areas such as manufacturing, logistics and transportation, military, and IT business through designing the process and measure the performance by the using SCOR model.

This research is limited to an action project while future studies are suggested to apply or adapt the proposed technique in various industries and projects, particularly a set of structural case studies to generalise the applicability. In this study, a major limitation is a time-limited, thus, the models were applied only on the management level. The designed model was tested on the expert of flight simulator

maintenance services. This procedure was done to test the feasibility, usability, and usefulness of the model. Even the experts were part of the model validation, but these experts do not explicitly identify. Further research suggests conducting the test of the model by process specialist and proper methodology. An important suggestion for future work is to gather more data and take more time to design the performance measurement system. This could increase the reliability of the maintenance service.

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## APPENDIX A

### The Pre-Questionnaire Analysis

| Questionnaire Analysis (Round 1) | | | |
|---|---|---|---|
| | | | |
| 1 | How many years have you worked in the maintenance services industry? | | |
| | | Yes | No |
| 2 | Have you ever worked with supply-chain or used a supply-chain? (any capacity) | | |
| 3 | Did the model improve your understanding of your business and how you fit into the overall service to the customer? | | |
| 4 | Did the model help you in understanding how to analyse your business? | | |
| 5 | From your analysis, could you come up with ideas of how you could change the overall business? | | |
| 6 | Were the descriptions in the model accurate in what must be done? | | |
| 7 | Were the Level 1 performance metrics useful in giving ideas of what you should measure? | | |
| 8 | In looking at the HR process, did it give you an idea of what is expected of you in terms of the HR processes? | | |
| 9 | Did the use of the SOURCE and FULFIL processes make sense in analysing the costs and time associated with these processes in your supply-chain | | |
| 10 | Was the model easy to understand and use? | | |
| 11 | Did the use of a Scheduled and Unscheduled services (e.g. msF1 or msF2) make sense? | | |
| 12 | Did you find the adapted service SCOR glossary with the process definitions useful? | | |
| 13 | Where the descriptions of the various process elements useful? | | |
| 14 | Do you think this model could be used for other services as well? | | |
| 15 | Do you have any suggestions or improvements to the model? | | |
| 16 | What was the biggest learning for you personally? | | |

## APPENDIX B

### The Post-Questionnaire Analysis

| Questionnaire Analysis (Round 2) | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| 1 | How many years have you worked in the services industry? | | | | | |
| | | Not at all | No much | Some What | Very | |
| 2 | Have you ever worked with supply-chain or used a supply-chain? (any capacity) | | | | | |
| 3 | Did the model improve your understanding of your business and how you fit into the overall service to the customer? | | | | | |
| 4 | Did the model help you in understanding how to analyse your business? | | | | | |
| 5 | From your analysis, could you come up with ideas of how you could change the overall business? | | | | | |
| 6 | Were the descriptions in the model accurate in what must be done? | | | | | |
| 7 | Were the Level 1 performance metrics useful in giving ideas of what you should measure? | | | | | |
| 8 | In looking at the HR process, did it give you an idea of what is expected of you in terms of the HR processes? | | | | | |
| 9 | Did the use of the REQUEST and DELIVER processes make sense in analysing the costs and time associated with these processes in your supply-chain | | | | | |
| 10 | Was the model easy to understand and use? | | | | | |
| 11 | Did the use of a Scheduled and Unscheduled services (e.g. msF1 or msF2) make sense? | | | | | |
| 12 | Did you find the adapted service SCOR glossary with the process definitions useful? | | | | | |
| 13 | Where the descriptions of the various process elements useful? | | | | | |
| 14 | Do you think this model could be used for other services as well? | | | | | |
| 15 | Do you have any suggestions or improvements to the model? | | | | | |
| 16 | What was the biggest learning for you personally? | | | | | |

# APPENDIX C

## 2019 International Conference on Management Science and Industrial Engineering

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### Welcome to MSIE 2019!


2019 International Conference on Management Science and Industrial Engineering will be held in Phuket, Thailand on May 24-26, 2019. MSIE 2019 is one of the principal events for experts from academia, industry, utilities, researchers and scientists across the globe to exchange ideas and experiences on Management Science and Industrial Engineering. The primary goal of the conference is to exchange, share and distribute the latest research and theories from our international community. Prospective authors are invited to submit original research papers which have not been submitted or published by other conferences or journals.

### Submission & Publication

After a peer review process, accepted papers presented in the conference will be published in **ACM conference proceedings(ISBN: 978-1-4503-6264-1)**, which will be indexed by **Ei Compendex and Scopus** and submitted to be reviewed by Thomson Reuters Conference Proceedings Citation Index (ISI Web of Science).

**Review Process:**

The peer-reviewing is a critical process for scientific paper publication. The reviewers are responsible to ensure the scientific equality verification and high standard.

All the submissions are divided into several chapters according to the topics, and removed the information of the authors, including name, affiliation, and email. Then the submissions will be sent to reviewers according to their research interests. Each submission should be reviewed by at least two reviewers. And the revised papers should go through the second peer-reviewing if it is necessary. Thus these review comments on the papers should be helpful to assist the authors to improve the paper content, structure, and language.

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This award recognizes three (3) best conference papers presented in the conference. The Conference Best Paper Award Chair will determine these papers with the help of session chairs and technical committee members.

### News

January 17, 2019 News! Requested by some authors, MSIE 2019 submission deadline extended to February 20.

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September 23, 2018 News! Welcome Shahron Rahman from University of Hawaii-Hilo, USA, Reggie Davidrajuh from University of Stavanger, Norway, Taesu Cheong from Korea University, Korea and Ramayah Thurasamy from Universiti Sains Malaysia, Malaysia to join in MSIE 2019 committees. (Click)

September 22, 2018 News! Welcome Prof. Maged M. Dessouky from University of Southern California, USA to to be a keynote speaker! (Click)

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### Important Dates

| | |
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| Conference Date | May 24-26, 2019 |

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# Supply Chain Operations Reference Model for the Flight Simulator Maintenance Service Process Model: A Case Study of Asian Aviation Training Centre

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## ABSTRACT

This study aims to present the flight simulator maintenance process model. To avoid failures of the system and mechanical, it is necessary to implement the maintenance processes. Moreover, flight simulator operator has to ensure that the performance of the devices qualified with the international regulations published by EASA, ICAO, and FAA. This paper demonstrates the maintenance process model and framework which is adapted to the supply chain operations reference (SCOR) model, to implement the flight simulator maintenance supply chain. The maintenance process model purposed with the most popular notation which called Business Process Model and Notation (BPMN) to support identification and visualisation of the processes as well as validate the effectiveness of models through the reviewing and analysing methodology with the experts in the field.

## CCS Concepts

• **Social and professional topics→ Systems planning • Social and professional topics→ Systems development**

## Keywords

Service supply chain; Maintenance; Flight simulator maintenance; SCOR model; BPMN

## 1. INTRODUCTION

Business aviation well-established in the 1920s, it is a part of general aviation focusing on the business use of airplanes and helicopters. The business aviation has been growing to be a substantial contributor because of the high level of its benefits. Flying is an exclusive experience; it becomes the alternative primary traveling. Allowing across vast distances with low-priced made the number of passengers handled by the airline industry globally from 2004 to 2018 is growing up. The growth of passenger and air cargo traffic rates from 2018-2037 are expected to grow by 4.7 percent [1] as shown in Figure 1. According to lower oil prices and the result of increasingly affordable flight rates, and growing up of low-cost airline, passenger and cargo air traffic, the growth passenger is estimated to grow importantly through 2037.

Additionally, Thailand's aviation business growth is also increasing; it is rising three times faster than the global market. The number of visitors to Thailand increase as well as the travelers in domestic routes, so the expansion of Thai Airlines is mainly driven by the demand for low-cost carriers. Thailand Board of Investment 2016 claimed that the market share of low-cost airlines currently contributes to only about 30% of the total market share, which showcases the vast growth opportunity in this sector.

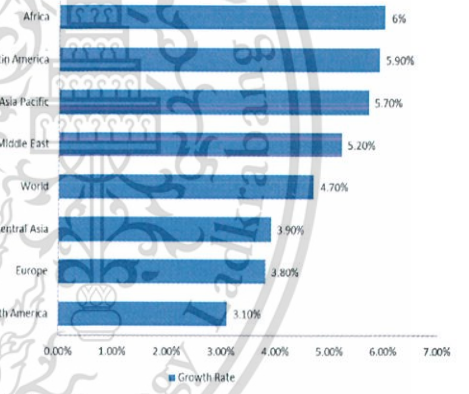


**Figure 1. Annual growth rates for passenger air traffic from 2018 to 2037.**

Growing of business of aviation is not just only the increasing of airlines revenue, but it included all components of aviation industry which growth with aviation's company such as aircraft manufacturer, energy, insurance, technology, and human resources. Human resources represent another critical consideration concerning growing aviation's business. In such a safety requirement from aviation standard, human resources expertise such as pilots, engineering maintenances, cabin crews, ground services, and air traffic controllers required for the aviation industry. Aviation industry jobs are specifically job which needs to attend competency training; thus, flight training academy is one of the businesses that has been growing in the aviation industry. At the moment, pilot and mechanics are the most demand in airline jobs. Right now, careers in aviation


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account for over $1.5 trillion in the U.S economy [2], there was no doubt about being new careers with new skills requirements would earn more pay raise.

Aircraft crashes are the most disastrous of all transport accidents, primarily because they often involve a catastrophic loss of life. Aircraft crashing can kill as many as four or five hundred times more people than a car accident. Therefore, global aviation organisations emphasise the standard of aviation training to meet aviation priorities and implement the specific instruction to develop human resources to achieve aviation safety's standard.

## 2. LITERATURE REVIEWS

### 2.1 Aviation Industry

It was over the past 50 year that the aviation industry had grown exponentially due to escalating global travel demand. The revenue of the civil aviation flight training market is expected to reach 8.3 billion dollars by 2023 [3]. Increasing demand for air travel and the needed for the pilot have significantly improved, observed from the statistic of demand for commercial airline pilots in 2016-2035 especially in Asia Pacific region; it has increased 40% of world total [4]. This qualified pilot demand also increased more and more the need for the flight simulation market.

Becoming a pilot in Thailand, a bachelor's degree in aircraft operations, aviation, aeronautical engineering, or a related field is required. The skills needed for this career include secure communication, problem-solving and observation skills, good depth perception and reaction time, and the ability to operate aircraft computer and navigation systems. The key to becoming a good pilot is getting a certified pilot license before operating an aircraft; therefore, global aviation needs an academy for developing qualified pilots. It is a very complicated process to be a pilot due to safety regulations as illustrated in Figure 2.1.


**Figure 2.1 Pilot Supply Chain**

Aspiring airline pilots and private pilots are required to complete a certain number of hours of flight training simulator to qualify for licensure. To obtain a commercial pilot's license, Civil Aviation Authorities of Thailand (CAAT) requires 32 hours of flight simulator training time for initial training, once became a pilot, the pilots are generally required to recurrent pilot's license six-monthly, by training in a flight simulator for 4 hours.

The flight training simulation is simulated real flying by using motion and visual systems; the majority of flight training devices are used for pilot training. The use of flight simulators is widely accepted around the world because one of the essential benefits of flight simulator training is training time in a simulator can replace training time in an aircraft. And these are the significant factors that drove the revenue of training simulation market include rising fuel prices and the growing international regulation of emissions and noise pollution.

The development of flight simulator began since World War I; it was developed and evolved to further technology continuously. The first known flight simulation device was the Antoinette monoplane, which helped the pilots to simulate the flight [5]. In 1927, Edwin Link built the flight simulation called the Link Trainer which provided a pneumatic motion platform driven by inflatable bellows. The Link Trainer gave the pilot cues as to original angular motion in pitch, roll, and yaw, consequently, the U.S. Army Air Corps purchased six Link Trainers [5], this is the start of the world flight simulation industry, and it finally was developed to a full flight simulator (FFS) nowadays.

Asian Aviation Training Centre (AATC) is Asia's leading independent Approved Training Organisation (EASA.ATO.0024) [6]. AATC provides approved training for pilots combining state-of-the-art Full Flight Simulation (see Figure 2.2) technology with enhanced Flat Panel Trainer technology and operates twenty-four hours a day, seven days a week. To provide quality service, to achieve the highest customer satisfaction and to prepare for the increase of flight training market, AATC would like to develop a new maintenance process, which is an integrated system for flight training reservation, maintenance management, shipping and store management. Operation and installation all the flight simulators must be provided under the current regulatory standards, criteria, and requirement of aviation regulation from ICAO and EASA.

**Figure 2.2 a Full Flight Simulator**

Although, the flight simulator training devices are always fully booked but each flight training device needs to be maintained and monitored regularly, especially, working twenty-four hours and seven days of the devices. Any technical issues of a flight simulator cause not only trouble to engineers but can also lead to serious problems for training centers. Therefore, engineers usually perform Daily, Weekly, Monthly, Quarterly, Six Monthly and Yearly routine maintenance of simulators to ensure uninterrupted operation and reduce the risk of any failures during pilot training [7].

In case of maintenance services, the item flowing toward the customer will be serviced, not physical products as illustrated in Figure 2.3. The concept of introducing the customer in the actual chain should be where the customer takes an active part in adding value to the service [8].

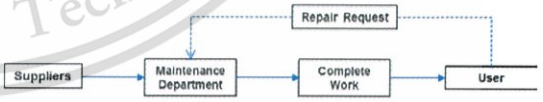
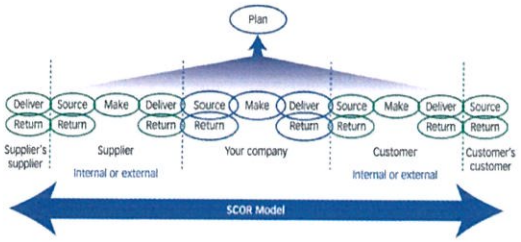



**Figure 2.3 Maintenance Service Supply Chain**

### 2.2 SCOR Model

The SCOR modeling framework is the standard implementation roadmap which has been created and developed by the Supply Chain Council (SCC) for the supply chain standardisation, measurement, and improvement. The SCOR model combines four essential elements including Process, Executions, Metrics, and

Best practice. The structure of the SCOR model is classified to




five basic processes, called: Plan (P), Source (S), Make (M), Deliver (D) and Return (R) as illustrated in Figure 2.4.

**Figure 2.4 SCOR Model**

The SCOR model mainly contains three levels of process details. Level 1 is the top level that deals with process types which define a scope of a supply chain. Level 2 is the configuration level which deals with process categories. The lowest level in the SCOR model is Level 3 which is the processing element or executes.

In SCOR, each process has its performance metrics to monitor overall supply chain performance which attributes: Reliability, Responsiveness, Agility, Cost, and Assets management efficiency. Each process is measured against these performance attributes; it has been widely used in the global organisation and commonly accepted.

Although the SCOR model was designed and applied for manufacturing industries, based on identified limits and weaknesses, researches and results from different practitioners and academicians such as Weyers and Ellram proved that SCOR model could be extended and increasing its proven practical relevance. Therefore, Weyers' approach model was adapted by using semantics, removal of elements and limited addition of elements that relate to services. The study claimed that the SCOR model could be created for services business and the model was useful to participants that work with back office services.

## 2.3 Business Process Modeling Notation

BPMN stands for Business Process Modeling Notation which is a graphical representation for specifying business processes. The purpose of BPMN is to facilitate communication and understanding business processes, and the BPMN is a language which can be easy to understand for the business industry. It is an effective and useful methodology to use in crisis time because the BPM can help an organisation to look at and control the processes that represented in the organisation, it will show a better and more cost efficient organisation. The simplest way of business process management is workflow which is known as routing. Workflow is more than telling moving things from process A to process B to process C to process D or combine all tasks because it also carries out functions in parallel, increase productivity and save time. It is reasonable to say that BPMN is one of the most popular business process languages.

## 2.4 Semantics Changed

The SCOR model adaptation will be adapting the model through the changing of words, using a direct translation or similar concepts. An example of the semantics changed is the definition and use of the "Make" process. Semantically, the "Make" definition in SCOR is the process where the value added to the product. Translating this "Make" concept to the service sector creates a situation where some of the intent and concepts, specific to manufacturing, may be lost in the translation to a new concept. Thus, there is no translation of "Make" relate in the service business.

In this procedure will analyse the original SCOR process name each elements which comprised of Plan, Source, Make, Deliver, and Return through Weyers' approach, each descriptions examined with the decision of the adaptation approach options, any process elements not relevant with maintenance service process will be removed or changed the title of the processing element. An example of adapted maintenance service process elements through SCOR model is derived with the new process elements illustrated in Table 1.1 and Table 1.2 respectively.

## 2.5 Adapted SCOR Model

The previous section changed the name of elements processes, based on the above changes; the new process references are msP (maintenance process Plan), msS (maintenance service Source), msF (maintenance service Fulfil), msD (maintenance service Deliver), and msR (maintenance service Return) respectively. Besides the new process elements, the maintenance services classified into Scheduled and Unscheduled follow preventive and corrective maintenance; thus Figure 2.5 summarises the adapted maintenance service SCOR model.

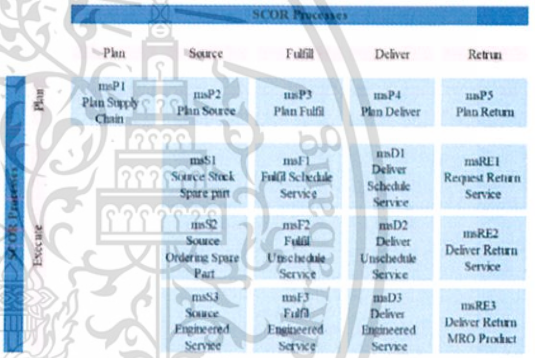



**Figure 2.5 Adapted Service SCOR Process Elements**

After the adapted process elements in the scope of the SCOR model have been generated. The next step will elaborate on the SCOR Level 1 and 2; the adapting methods in the process of maintenance service supply chain have followed the design of the SCOR model in total five process elements (Plan, Source, Fulfil, Deliver, and Return) as shown in Figure 2.6.

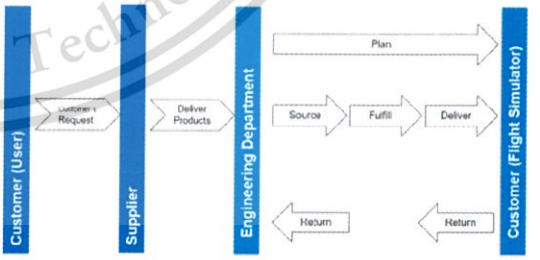



**Figure 2.6 an Overview Adapted SCOR Model Process Elements**

**Table 1.1 Plan Process Approach**

| Process Reference | Original Process Name | Process Removed | New Process Reference | New Process Name | No Title Change | Semantic |
|---|---|---|---|---|---|---|
| sP1 | Plan Supply Chain | | msP1 | Plan Maintenance Service Supply Chain | | x |
| sP1.1 | Identify, Prioritize and Aggregate Supply Chain Require... | | msP1.1 | Identify, Prioritize and Aggregate MS Supply Chain... | x | |
| sP1.2 | Identify, Prioritize and Aggregate Supply Chain Resources | | msP1.2 | Identify, Prioritize and Aggregate MS Supply Chain... | x | |
| sP1.3 | Balance Supply Chain Resources with Supply Chain... | | msP1.3 | Balance MS Supply Chain Resources with MS Supply... | | x |
| sP1.4 | Establish and Communicate Supply Chain Plans | | msP1.4 | Establish and Communicate MS Supply Chain Plans | | x |
| sP2 | Plan Source | | msP2 | Plan Source | x | |
| sP2.1 | Identify, Prioritize and Aggregate Product Requirement | | msP2.1 | Identify, Prioritize and Aggregate Source Services... | | x |
| sP2.2 | Identify, Assess and Aggregate Product Resources | | msP2.2 | Identify, Assess and Aggregate Services Resources | | x |
| sP2.3 | Balance Product Resources with Product Requirements | | msP2.3 | Balance Service Resources with Service Requirements | | x |
| sP2.4 | Establish Sourcing Plans | | msP2.4 | Establish and Communicate Sourcing Plans | | x |
| sP3 | Plan Make | | msP3 | Plan Fulfil | x | |
| sP3.1 | Identify, Prioritize and Aggregate Production Requirement | | msP3.1 | Identify, Prioritize and Aggregate Fulfil Requirement | | x |
| sP3.2 | Identify, Assess and Aggregate Production Resources | | msP3.2 | Identify, Assess and Aggregate Fulfil Resources | | x |
| sP3.3 | Balance Production Resources with Production | | msP3.3 | Balance Fulfilment Resources with Fulfilment | | x |
| sP3.4 | Establish Production Plans | | msP3.4 | Establish and Communicate Fulfil Plans | | x |
| sP4 | Plan Deliver | | msP4 | Plan Deliver | x | |
| sP4.1 | Identify, Prioritize and Aggregate Delivery Requirement | | msP4.1 | Identify, Prioritize and Aggregate Delivery Requirement | x | |
| sP4.2 | Identify, Assess and Aggregate Delivery Resources | | msP4.2 | Identify, Assess and Aggregate Delivery Resources | x | |
| sP4.3 | Balance Delivery Resources and Capabilities | | msP4.3 | Balance Delivery Resources and Capabilities | x | |
| sP4.4 | Establish Delivery Plans | | msP4.4 | Establish and Communicate Delivery Plans | | x |
| sP5 | Plan Return | | msP5 | Plan Return | | |
| sP5.1 | Assess and Aggregate Return Requirements | | msP5.1 | Assess and Aggregate Return Requirements | x | |
| sP5.2 | Identify, Assess and Aggregate Return Resources | | msP5.2 | Identify, Assess and Aggregate Return Resources | x | |
| sP5.3 | Balance Return Resources with Return Requirement | | msP5.3 | Balance Return Resources with Return Requirement | x | |
| sP5.4 | Establish and Communicate Return Plans | | msP5.4 | Establish and Communicate Return Plans | x | |

**Table 1.2 Return Process Approach**

| Process Reference | Original Process Name | Process Removed | New Process Reference | New Process Name | No Title Change | Semantic |
|---|---|---|---|---|---|---|
| sSR1 | Source Return Defective Product | | msR1 | Source Return Defective Service | | x |
| sSR1.1 | Identify Defective Product Condition | | msR1.1 | Identify Defective Service Condition | | x |
| sSR1.2 | Disposition Defective Product | | msR1.2 | Disposition Defective Service | | x |
| sSR1.3 | Request Defective Product Return Authorization | x | | | | |
| sSR1.4 | Schedule Defective Product Shipment | x | | | | |
| sSR1.5 | Return Defective Product | | msR1.3 | Return Defective Service | | x |
| sDR1 | Deliver Return Defective Product | | msR2 | Deliver Return Service | | x |
| sDR1.1 | Authorize Defective Product Return | | msR2.1 | Authorize Defective Service Return | | x |
| sDR1.2 | Schedule Defective Return Receipt | | | | | |
| sDR1.3 | Receive Defective Product (includes verify) | | msR2.2 | Receive Defective Service (includes verify) | | x |
| sDR1.4 | Transfer Defective Product | | msR2.3 | Transfer Defective Service | | x |
| sSR2 | Return MRO Product | x | | | | |
| sDR2 | Deliver Return MRO Product | | | | | |
| sSR3 | Source Return Excess Product | x | | | | |
| sDR3 | Deliver Return Excess Product | x | | | | |

## 3. APPLICATION SCOR IN FLIGHT SIMULATOR MAINTENANCE SERVICE

As the AATC never organised the maintenance service model before, the maintenance workflows both of preventive and corrective maintenance has conducted by interviewed the Engineering management teams and Supervisor Engineers, then analyse maintenance service workflow to maintenance service process model. The maintenance workflow was generated from the discussion and interviews the staffs in the company as summaries in Figure 3.1, the workflow divided into two categories: Corrective maintenance service and Preventive maintenance service. The maintenance process "As-Is" analysis started with the original maintenance workflow then the model would be adapted to SCOR model level 1, level 2, and level3 respectively.

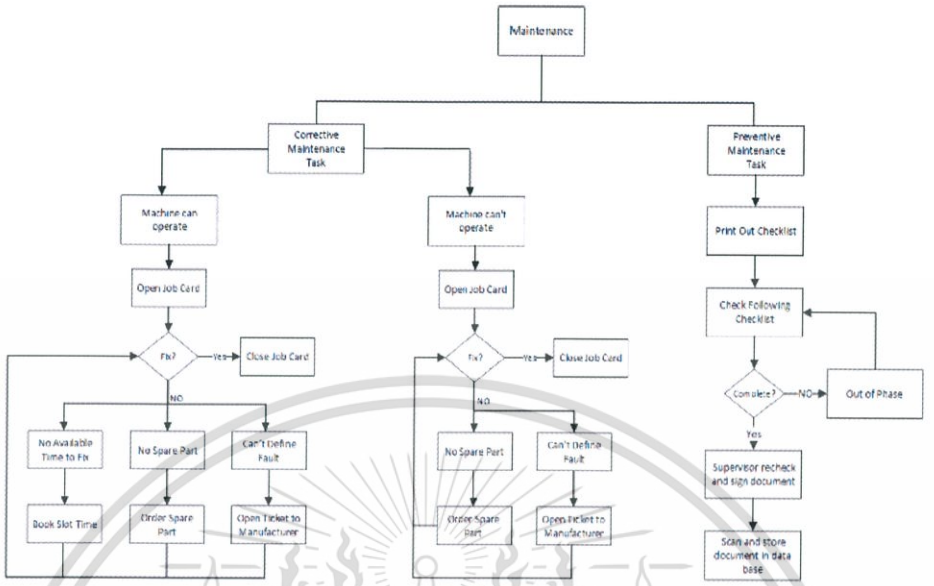



**Figure 3.1 Maintenance Workflow**

Corrective maintenance generally starts from receiving a call from the customer to report faults, then categories into two cases: the FFS can operate and cannot operate. After that the engineer will discuss and inform a problem to customers and sourcing a spare part as well as an application engineer for preparing. And then the engineer will go to solve the problem or in some cases, the suppliers will in charge of the problem.

On the other hand, preventive maintenance starts from print maintenance checklist out, then checking to follow the activities on the list. The preventive maintenance activities should be finished on time follow the cycle such as weekly, monthly, or even annually. The significant factors which effect on preventive maintenance activities are a weak schedule, spare part shortage, and uncontrollable issues such as an electric power system down. The engineering supervisor will in charge of out of phase tasks.

The SCOR Level 1 as shown in Figure 3.2 corresponds the overall of plan processes which concern with management or top level. The process described the maintenance service flow and information flow between the engineer and suppliers and the engineer and user.

The SCOR Level 2 break down from level 1, the process in level 2 integrate all participates and activities together. The integration along the maintenance service supply chain generated both information flow and physical flow is shown in Figure 3.3. The level 2 process classified in 5 processes:

- Plan (msP): the process relevant to the integrated maintenance service supplies chain.
- Source (msS): the process is verifying suppliers, spare parts, and user's requirements.
- Fulfil (msF): the process adds value to fulfill user requirements before transferring the tasks to Deliver.
- Deliver (msD): the process that consists of fixing, testing and delivering fulfilled services to the user.
- Return (msR): the process to determine the defective sources and the services that do not meet the requirements.

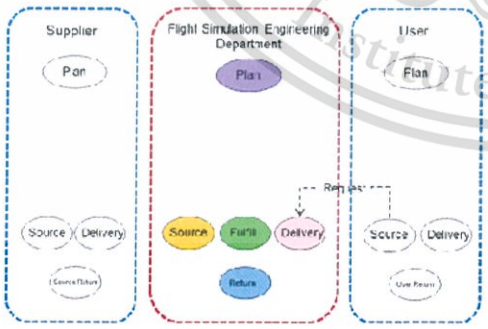



**Figure 3.2 the SCOR Level 1 Maintenance Service Process**

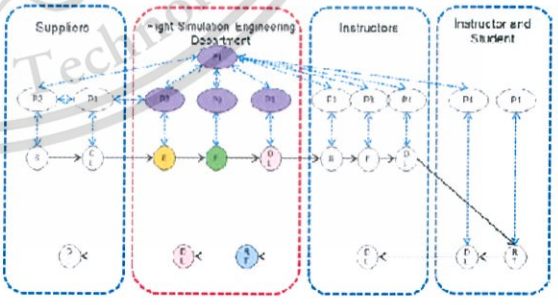



**Figure 3.3 the SCOR Level 2 Maintenance Service Process**

The model validation and testing base on the review from 20 expertise in a case study company through an evaluation methodology for the business process [11] designed by S. Adesola and T. Bainese. Testing methodology was refined to applicable with maintenance service model testing then the questionnaire was set out to determine the following [11]:

- Could the methodology be used in practice?
- Are there any problems and difficulties with the model?
- Are the designed models worth the effort and are they useful to the host organisation?

To assess whether the methodology was working, a procedural approach of evaluating process research was adopted Platts (1990) [12]. The subsequent assessment procedure consisted of three categories of measurement and were [11]:

- Feasibility: Can the adapted model be followed?
- Usability: Is the adapted model workable? Are the steps and techniques easy to use and apply?
- Usefulness: Is the adopted model worth following? Does the model produce results that the business finds helpful?

Evaluation results base on the description above of feasibility, usability, and usefulness, the conclusions were shown that the company would benefit from being developed designed model. In addition, the engineering team can be a part of designing their procedures base on the SCOR model. Maintenance service process improvement was developed through the feedback from expertise so that the maintenance service model processes earn more effectively and efficiently.

## 4. CONCLUSIONS

In conclusion, the designing of the adapted maintenance service process model can create a standardised maintenance services process model base on the SCOR model. The study has reached its objectives and shown that the model can be improved service level and reduced the breakdown. Moreover, the models through BPMN can be useful for business management level for implementation and communication between levels and suppliers.

In this study, a major limitation is a time-limited, thus, the models were applied only on the management level. As well as the case study is a specific unit; this may mean the maintenance service process model does not apply to general businesses. An important suggestion for future work is to gather more data and take more time to design the performance measurement system. This could increase the reliability of the maintenance service.

## 5. ACKNOWLEDGMENTS

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