READINESS OF INDUSTRY REVOLUTION 4.0 (IR4.0) IMPLEMENTATION IN ASSET INTEGRITY MANAGEMENT (AIM)

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A project report submitted in partial fulfilment of the requirements for the award of Master of Project Management

Faculty of Engineering and Science
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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and in the same time submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I hereby certify that this project report entitled **"READINESS OF INDUSTRY REVOLUTION 4.0 (IR4.0) IMPLEMENTATION IN ASSET INTEGRITY MANAGEMENT (AIM)"** was fully prepared by **SHAHRIL FITRI BIN MUSTAPHA** has fulfilled the required standard for submission in partial fulfilment of the requirements for the award of Masters in Master of Project Management at Universiti Tunku Abdul Rahman.

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Date : 03/04/2021

Specially dedicated to my beloved wife and family.

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In the name of Allah, the Most Gracious and the Most Merciful.

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May God shower the above cited person with success and honour in their life.

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ABSTRACT

The current mega trend of IR4.0 revolution is the game changing technology for Malaysian business ecosystem. Enterprises of different scales are currently defining the implementation strategies for the inevitable transformation to IR4.0. As the manufacturing sector leading in the transformation process, the other sectors are slowly picking up the inevitable revolution inclusive of the building maintenance related services. Ensuring the integrity of assets and building through the adoption IR4.0 technologies is the pillar to a better building maintenance initiative however the needs of understanding the current state of affairs is crucial in narrowing the gap for the anticipated transformation. In this research, the study will gauge the readiness level of Malaysian's Asset Integrity Management stakeholders in adopting IR4.0 by analyzing three key components i.e. people, technology and process. The objectives of this research are to identify the benchmarking methodology for the IR4.0 readiness level within asset integrity management and to analyse the readiness IR4.0 transformation of AIM within Malaysian building maintenance stakeholders The methodology of analysis will be adopted from proven model by established research institution within the country. The project looks at reviewing the current offering of IR4.0 technologies related to facilities management, identifying the methodology of benchmarking the IR4.0 readiness level within asset integrity management and analyse the IR4.0 transformation readiness level of Malaysian Facilities Management. A questionnaire survey was carried out and 111 out of 150 sets of questionnaires were collected from the targeted respondent to understand the readiness of IR4.0 implementation in Asset Integrity Management (AIM). A comprehensive analysis was carried out to further understand the data collected. It was found out, from the preliminary study, that the current level for Malaysian AIM in embracing the IR4.0 is barely a beginner.

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INTRODUCTION

1.1 Introduction

In the real estate industry, complex building structure and utilities system are exposed to various loads and conditions throughout the lifetime. The cost of these infrastructures can reach millions of dollars hence breakdown or disaster can be very costly as well as fatal (Chandima Ratnayake & Markeset 2012). In the United State (US) alone, the property damage within the period of 1986-2003 was over than USD850M a year. Flaws or defects building must be constantly investigated with accurate interpretation from any evidence gathered during examination to allow the prediction of future failure.

In modern engineering, Asset Integrity Management (AIM) is a widely recognised method for determining and evaluating the properties of material, component, or system without causing any damage to the assets, and later plan for a systematic maintenance procedure in preserving the asset to its desired standards (CFI, 2018).

The recent policy of the government and the latest trend in technology shifted towards the implementation of Industry Revolution 4.0 as the tools for AIM. There is a need to measure the readiness of Malaysian building owner in implementing the digitalisation strategies such as for a comprehensive improvement to buildings and assets related (MPC, 2018, SIRIM, 2019).

1.2 Importance of the Research

This study is to find out the awareness of IR4.0 among the asset integrity managers and the readiness of the institutions in adopting the transformation. Outcome of the study can help in further understanding of the stakeholders' conscious and reasons why they are not aware of it and the gaps in achieving the desired output of an IR4.0 ready institution.

Most of the research is to discover the importance of IR4.0 and the benefit of adopting the technologies (Seif, Toro, and Akhtar, 2019). However, without understanding the current state of affairs for AIM in Malaysian building management, a clear strategy of transformation will not be derived correctly, and this study could help to understand the gap thoroughly.

1.3 Problem Statement

Globally, common practice within AIM are working on experimental and field data to provide the references for best fit methodology of improvement in AIM (Lutchman 2018). As most of the work are being done in the west, there is a great need to look for probable implementation for local scenario.

Rapid development due to urbanization over the last decade have reach its maturity and currently at its maintenance level. The integrity of all these assets are of great important in ensuring the sustainability and safe of inhabitant. With the current technology trends, the maintenance or asset integrity management must be executed at its optimized potential using Internet of Thing (IoT) and reliable analytics.

Understanding the ground zero for the transformation must be made in order to plan for the seamless leap to desired Industry Revolution 4.0 level (CFI 2018; MPC 2018). Therefore, the research will look at identifying solutions to the two-main problem statement:

1. Finding the right tools for assessment through the understanding of IR4.0 technology.
2. The current level of technology readiness and the gaps towards achieving IR4.0 status.

1.4 Report Aims and Objectives

1.4.1 Report Aims

This research proposed a measure of determining the readiness of Asset Integrity Management entities in implementing the IR4.0 technology in managing facilities of building in the country (Bjerke and Renger 2017). In this research, through reviews of publications and common practices, 2 core objectives of the project were identified.

1.4.2 Research Objectives

The objectives of the research are:

1. To identify the benchmarking methodology for the IR4.0 readiness level within asset integrity management
2. To analyse the readiness IR4.0 transformation of AIM within Malaysian building maintenance organization.

1.4 Scope and Limitation

The activities considered in the survey are asset integrity management for buildings in Malaysia. The analysis of the system efficiency was based on the current data from companies registered under BOVAEA (Board of Valuers, Appraisers, Estate Agents and Property Managers). Measurements of available and parameters from BOVAEA were used to evaluate the readiness of asset managers in adopting IR4.0, limited to the data made available via the survey.

1.5 Contribution of the Research

Output from this study could be used as a guideline for future study of IR4.0 related issues within the asset management domain. The assessment will allow researchers to gauge the current level of awareness of IR4.0 within asset management.

In preparing the strategic transformation plan for organisation, the methodology used in this work will be crucial in identifying the gap of knowledge and competency along the vertical, hence the implementation in asset management strategy provides data reference to better understanding of current conscious towards IR4.0 (Dastbaz 2019).

Although the methodology of assessment is well established within other sectors of economy such as manufacturing, this work is paving its way for researcher to understand the condition within building management that often disconnected to the core technologies movement.

The respondents are the core people within the asset management society locally and therefore it shall be specific to the needs related to the stakeholders. Lastly, this research could provide a guideline to the related stakeholder on encouraging and assist them to promote the transformation of current conventional management to IR4.0 solution.

1.6 Research Methodology

The purpose of the research methodology is to provide a guideline for this study to achieve the research objectives that are identified in the earlier stage. The flowchart in Figure 1.1 shows the steps taken in the research methodology.

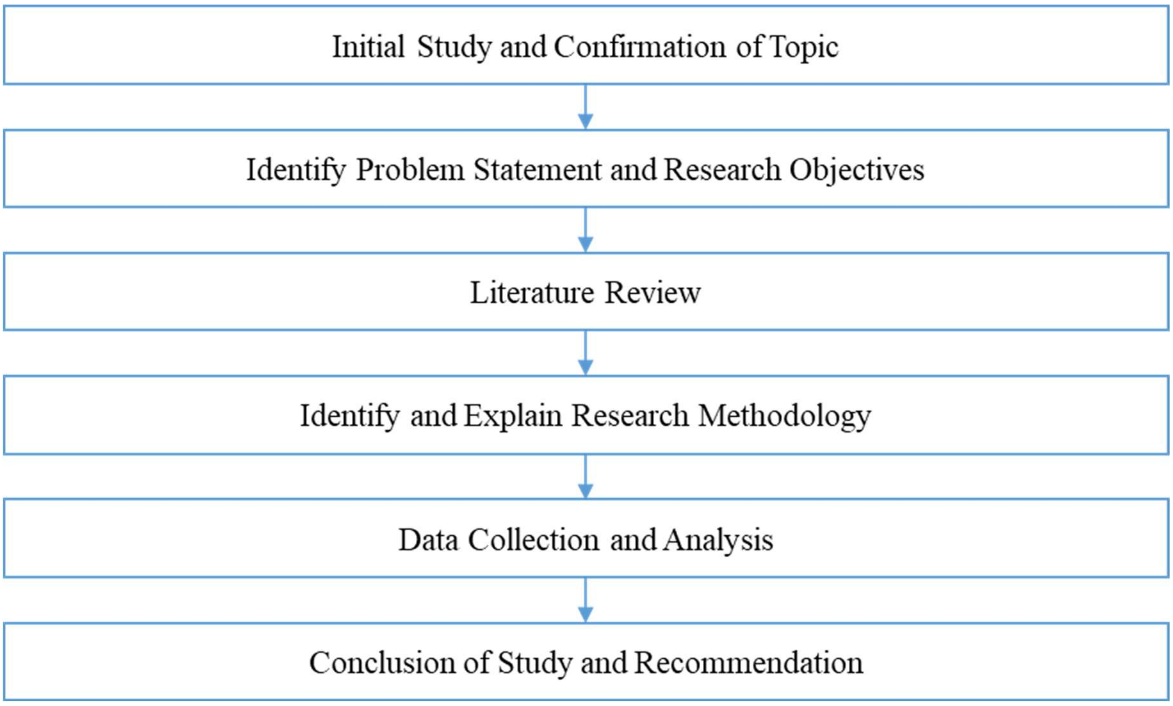

Figure 1.1: Research Methodology Flowchart

In the beginning stage of the research methodology, an initial study was carried out to understand the research topic before selecting it. The reason for an initial study to be carried out is to research and to narrow the scope so that the objectives of the research topic can be identified.

The following stage is to identify the problem statement and research objectives. This chapter provides an outline of the limitation and scope of study the research topic.

Upon identifying the problem statements and confirming the research objectives, the next stage is to summarize a literature review of pass research that have been carried out in regard to the research topic. Journals and books are the main sources that assist in preparing the literature review and will be classified as secondary data and help to prepare the questionnaire survey's questions.

The subsequent stage is to identify and to explain the research method being used. This stage will explain the purpose of a questionnaire survey. The questionnaire survey will be adapted for this research topic and to be sent to targeted groups so that the results will be based on people's direct involvement or experience towards the research topic.

In the next stage, data from the questionnaire replies are collected and analysed. Relative Importance Index will be used to convert the qualitative data to quantitative data.

In the final stage, a conclusion and recommendation will be identified based on the research carried out. In this stage, it explains the major outcome of this research and recommends suggestions for future research development.

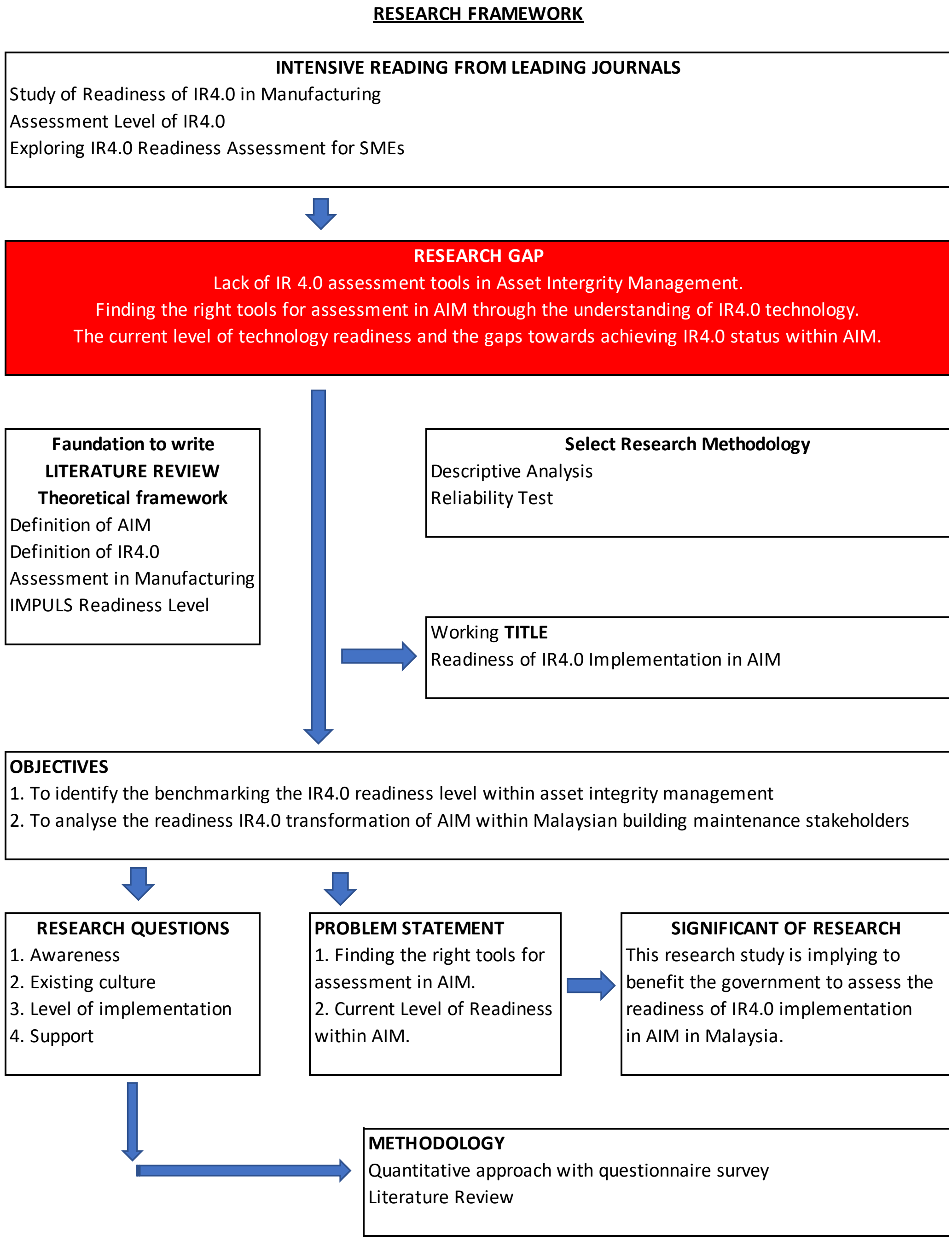

Figure 1.2: Research Methodology framework.

1.7 Research Gap

There is a dearth of focused research on readiness assessments, particularly on rectifying strategies in the country; hence the purpose of this research carried out to add to the body of literature and to fill the research gap. There has been a variety of research about IR4.0 readiness level, but most studies have focused manufacturing industry. The studies overlooked level of readiness from the perspective of building management and AIM as well as the benefits and method to assess the readiness level. Also, very minimal studies have conducted within Malaysia. Therefore, more comprehensive research is required to explore the current level of technology readiness and gaps towards IR4.0 status within AIM.

Figure 1.2 above highlight the research gap of this study which based on the research on the net, there are limited assessment tools in AIM. It is difficult to find a right tool to measure readiness in AIM towards the understanding of IR4.0. There is limited study with regards to the current level of technology readiness and the gaps towards IR4.0 status within AIM.

1.8 Report Structure

The structure of this report is as presented below:

Chapter 1: Introduction

This chapter included brief introduction, importance of research, problem statement, research aims, research objectives, scope, limitation and contribution of this research. This is for the readers to understand the intention of this research and the expectation at the end of the research.

Chapter 2: Literature Review

This chapter provided the review of other related and relevant research works or studies on the similar topic. The outcome of the literature review from published journals, articles, book and others presented in here. This chapter is critical as it helps toward the formation of the research methodology.

Chapter 3: Research Methodology

This chapter spelled out the research methodology that applied in this research to achieve the research aims and objectives set in Chapter 1. The data collection method and techniques used for data analyses detailed in this chapter. Justification provided for selection of the method and techniques.

Chapter 4: Results

This chapter of the research presented the analysis and discussion on the collected data through the method stated in Chapter 3. The results derived from data analysis were discussed here to confirm whether the research aim, and objectives are achieved.

Chapter 5: Discussion

Discussion on the data collected and obtained generated in chapter 4 will be discussed in chapter 5.

Chapter 6: Conclusion and Recommendation

The conclusion of the research stated in this chapter after the evaluation on the achievement of the objectives. Recommendations were provided for future researcher for further research on this topic.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This study explores the readiness level of Industry Revolution 4.0 within Assets Integrity Management (AIM). A readiness level assessment is an evaluation tool used to analyse and determine the level of the company's preparedness needed to achieve its goals (Mittal et al, 2018).

Building Management and Maintenance is an organized and effective system of maintenance operations, which is set up to deal with problems related to the upkeep of a building. The main aim of maintenance is to protect a building at its preliminary stage and to retain the value of investments in the property. Keeping a building in a condition in which it continues to fulfil its purpose and making sure it presents an attractive exterior are also important factors made possible through proper building maintenance. Building maintenance is an expensive process both from financial aspects (operational costs, real estate management, administration, job with debtors, legal services etc.) and environmental aspects (climate change, greenhouse emissions, and energy efficiency measures). Businesses aim to reduce the costs of buildings transforming them into a more efficient and sustainable infrastructure. Maintenance is often defined as the series of activities undertaken to take care of the building structure and services to ensure the intended functions and optimal performance of a building life cycle. The management department of a building is usually responsible for the enhancement of the indoor environment quality by service delivery and for boosting occupant productivity and satisfaction (Noorsidi and Chris (2010).

Industry 4.0 is a concept that emerged for the first time in 2011 with the objective of characterizing highly digitized manufacturing processes where information flows among machines in a controlled environment so that human intervention is reduced to a minimum (Qin, Liu and Grosvenor, 2016). The concept was generated and developed by German Industrial and Academic communities with the support of the German Government with the intention of framing and developing the country's industrial competencies that have been powered by digitization of the production processes in several industrial sectors (Kagerman, Washler and Helbig, 2013).

2.2 Asset Integrity Management (AIM)

Asset Integrity Management or also known as AIM is currently applied to multiple engineering activities. It is a term used to describe the practice of managing an asset or assets to ensure its ability to perform its function effectively and efficiently is maintained. Well run AIM strategies ensure that the people, systems, processes and resources that enable an asset to deliver its function are in place over the life cycle of the asset, while simultaneously maintaining health and safety and environmental legislation (Rahim, Refsdal, and Kenett 2010). AIM applies to the entirety of an asset's operation, from its design phase to its decommissioning and replacement. However due to its expensive set-up procedures, AIM is a system of choice to larger cooperation than small-medium industries.

According to Milar (2015), Asset intergrity is same as Asset Integrity Management has same definition. Therefore AIM can be defined as capability of an asset for premis or building's perform its required function effectively and efficienlty in order to protect health, safety and environemnt. This is to ensuring the people, process and technology are able to delivery in place, in use and perform as needed in lifecyle of the asset.

2.2.1 The function of Asset Integrity Management (AIM)

Woodward (1997) has mentioned that to determine the overall successful for some organization, it is significance to know the function of asset management for the organization. Therefore, AIM is required to function effectively and efficiently whilst protecting health, safety and the environment and the means of ensuring that the people, systems, processes, and resources that deliver integrity are in place, in use and will perform when required over the whole life-cycle of the asset. AIM executes its functions as:-

i. The management tools of ensuring asset perform effectively
ii. Ensure the safety of personnel and protect the environment by mitigating risk of failure and hazards
iii. Extend the life of asset by analytical approach of determining period of service

iv. Maintain a fit for service asset condition

v. Applications of methodology related to diagnosis, assessment, and predictive maintenance.

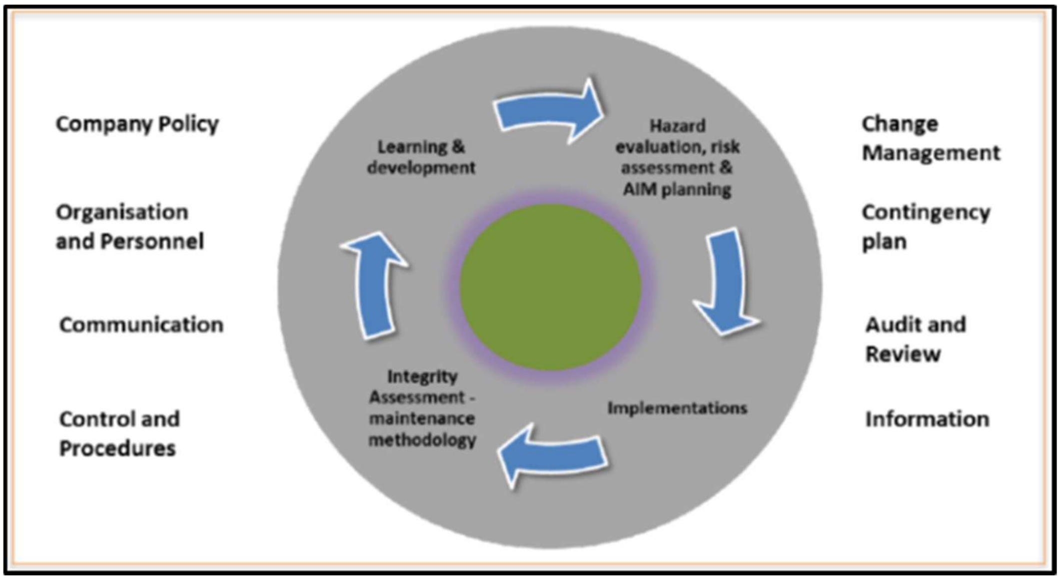

Figure 2.1: Typical Asset Integrity Management Framework (Drozdz 2008).

Based on research by As Drozdz (2008), as depicted in Figure 2.1, the typical AIM framework within establish organisation is able to identify through all phases of the Asset Lifecycle. In order to achieve targets for Health, Safety, Environmental and operational performance, it may be adopted by comprehensive management system and activities such as:

- Promote visible asset integrity leadership commitment through the company policy such that strategic asset plans are suitable to the risk level, adequately resourced, communicated and monitored to completion.
- Provide a governance framework for asset integrity management activities, including compliance with regulatory, classification, contractual requirements and business processes.
- Provide reliable and optimized asset designs to meet project and operational objectives, with the most efficient and effective input of resources to maximize overall financial performance.
- Provide suitable design, technical, and operational asset integrity in order that major accident and occupational risks are As Low As is Reasonably Practicable (ALARP).

- Provide the necessary resources, systems, training, and competency to maintain asset integrity performance.
- Investigate all asset non-conformance reports and integrity incidents such that to identify and implement effective corrective and preventive actions.
- Monitor and report throughout asset performance against Key Performance Indicators, KPIs, as a means of ensuring continual improvement.

2.2.2 Scope of AIM

The building operations and maintenance stage is typically the longest and most stage of building's lifecycle, eventually exceeding the total cost of initial design and construction. Various organizations have reassessed the contributions of Facilities Management and Building Operations Maintenance regarding the profitability of their business objective (Baaki et al., 2016; Kamaruzzaman et al., 2017; Awuzie & Isa, 2017). Aiming these operations and maintenance costs and the aggregate sustainment and renewal costs can take a significant effect in decreasing total cost of ownership.

In AIM operations describe as the effort required to supply the property with heating, water, and electricity (utilities) as well as preserving both the outside and inside of the building (Milar, 2015). In the current years the operation governance raises beyond the physical as the internet of things emerge in the mainstream needs.

Maintenance however described as the work needed to preserve the purpose of the building, the technical and aesthetical standard and the importance or value of the building. Normally, there are two parts of maintenance implementation strategies for example the routine and preventive maintenance. The former is considering at the schedule repair activities meanwhile the later focusses on the activity that decrease or eliminate any repair obligations.

Corrective maintenance involves the replacement or repair of equipment after it fails (Micheal, 2016). Corrective Maintenance is the oldest and most traditional method followed to correct defective items. It is the routine or day to day repair or replacement of malfunctioning or defective items. Preventive Maintenance is the planned and controlled schedule or programme of continuous inspections and corrective actions engaged to ensure peak efficiency and reduce deterioration. A successful preventive maintenance program involves constant performance reports that signified the percentage of preventive work orders accomplished in the scheduled time frame.

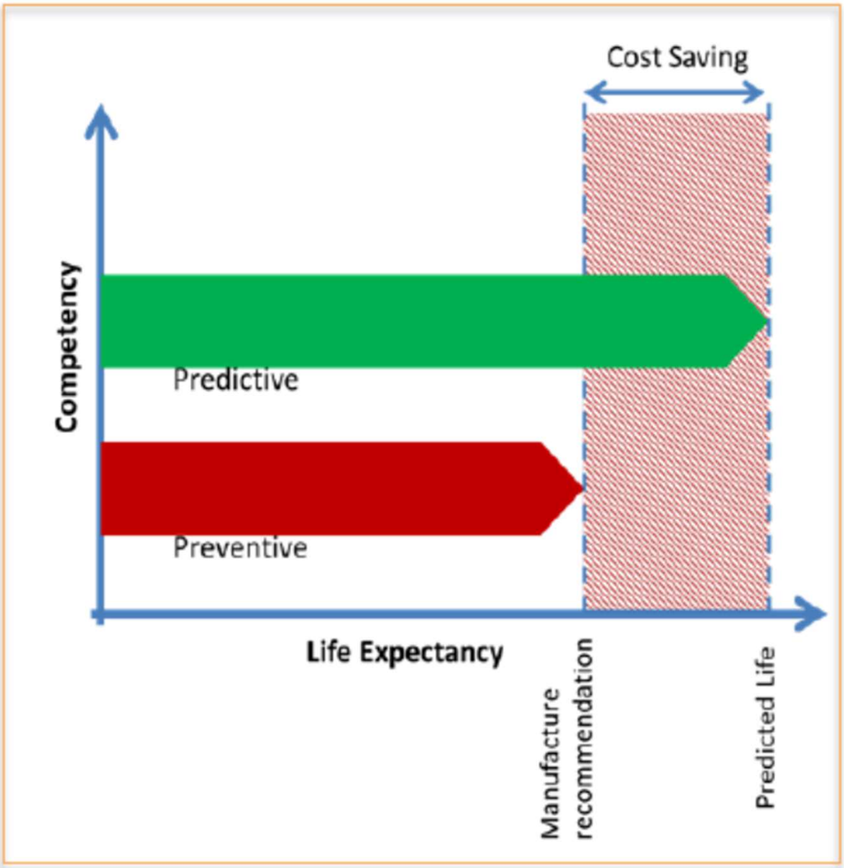

Figure 2.2: Predictive maintenance advantages in AIM

The newest maintenance strategy is the current predictive maintenance methodology which focusses on the fundamental idea of prolonging the life of assets with the optimized cost. Figure 2.2 described the concept of maximizing the serviceability of asset to its real potential, hence reducing the needs to spend on maintaining effort based completely on the recommendation by suppliers or manufacturers.

Maintenance actions throughout the life cycle are particularly important to avoid or elude any delay in facility use. The ongoing efforts to find ways to advance or improve staffing, operational efficiency and productivity are the other significant elements. Good management practices have an effect related to that of quality assurance during construction; to improve the likelihood that performance will indeed correspond or conform to design intent. This accountability for good practices rests mainly with the facility manager and maintenance staff.

Training of maintenance staff, use of suitable material, and the application of a new computerized facility management system will help condition monitoring, documentation management, reduce or decrease cost and time, and make it possible or probable for 28 maintenance scheduling to be connected with other building systems. Facilities must accommodate or familiarised anticipated new communication, building automation, and energy saving technologies. Consideration must be given to the changing patterns of space (Gursev, 2018) .

2.3 Systematic Building Management

Although it is natural human process to ensure the best condition of living condition such as maintaining a comfortable house in the premise of private ownership, the systematic building management system was introduced only in the last decade prior to the second millennium. It was developed there over 30 years in some developed countries such as the United States and the United Kingdom (CFI 2018).

As the Asian country developed, it grew up in several Asian countries such as Japan, Hong Kong and Singapore. In general, the management of various disciplines involved in building and activities that can be adopted by all organizations whether public or private sector. Building management system is an important component in the fields of civil engineering and building now.

AIM in the context of a building is a form system used in the management of maintenance of a building. Building maintenance is an activity damage restoration and maintenance of building in ensuring it is in good condition. Thus, the construction of a good management system will be able to influence the quality of work, cost, time, and staff satisfaction Maintenance is an activity to conserve, preserve, manage, and regulate buildings, facilities, equipment, services and its surrounding buildings to meet current standards, the usefulness security of the institution’s facilities.

As time take its toll, every structure is inseparable from defect or damage despite various preventive measures taken during the design and construction. Very often, as the repair element is getting, many resolves to the idea of building new structure to replace the abandoned buildings repair and maintenance. Contrary to the west, this condition is actually common in developing countries. Many provisions of the cutting and extended for a further building maintenance account without realizing that each new building was added burden of maintenance. As a result, more and more buildings must be evacuated well ahead of time that should be. This means that the country has lost its history and adhere to the capital expenditure wasting public or private funding made earlier (Kana 2018).

2.4 The Function of AIM in Building Management

As the significance of the building management system during the life cycle of any building was made very clear in the last section and indicates the need to manage this stage in a cost-efficient manner. Traditionally, building management has been considered primarily to comprise facility maintenance and operation tasks. The mission is to improve and add value to a business by ensuring and improving the quality of all the environment processes for the maintenance of a facility (Nurogly, 2018).

AIM offers a rather engineering oriented solutions to the building management system. As most of the assets in a building governs by the engineering characteristic during the construction, the continuation of engineering-based maintenance strategy will ensure a better decision making in preserving the assets.

The North American Facilities Management Domain Committee of the International Alliance for Interoperability (IAI) has developed a Facility Management Function hierarchy as a guideline for developing AIM projects. It is defined as function of “a set of related and on-going activities of the business.

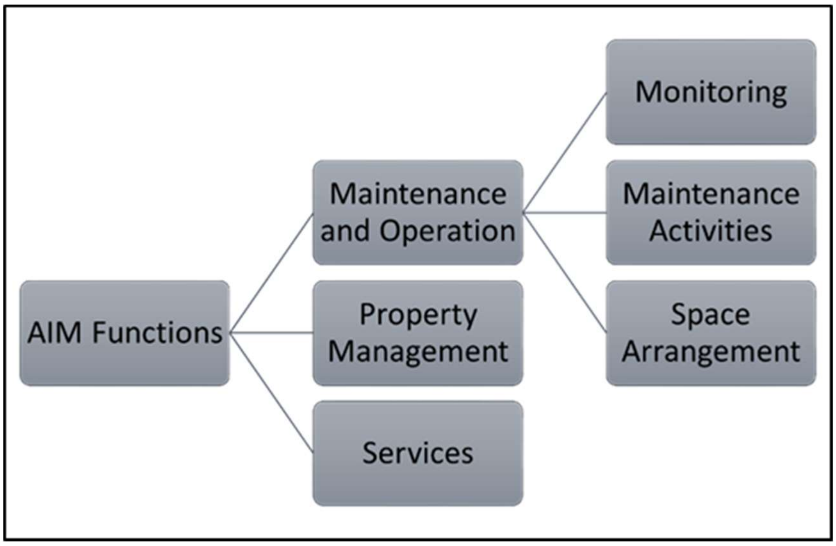

Figure 2.3: AIM Functions Structure in An Organisation
(Petchrompo and Parlikad 2019)

There is no start or end for a function; it continuously performs the work as needed. For example, the FM system includes the following functions (sub-systems): Operation & Maintenance Management (O&MM), Property Management, and Services. Each of these functions may consist of dozens or hundreds of discrete processes to support specific activities and tasks (Petchrompo and Parlikad 2019).

2.5 The Fourth Industrial Revolution (IR4.0)

Digital transformation has been affecting business models, production processes, and corporate governance. Improvements in information and communication technologies (ICT) infrastructure, and in analytical capabilities during the past decade have fueled a stream of innovation at all levels of business models, and corporate organization and the ability of companies to master them has become an element of competitive advantage in almost all economic sectors (Bleicher and Stanley, 2016). Within the various dimensions of digital transformation, one has been gathering the attention of policymakers, academics and managers: the possibilities that arise from the application of digitization to manufacturing processes, what is now being commonly called Industry 4.0. (Smit, Kreutzer, Moeller and Carlberg, 2016).

This section of the study, the first step, aims at specifying a complete summary of revolutions in the industrial history as well as the explanations of Industry 4.0 and related terms. Successively, the fundamentals of Industry 4.0 are treated in detail. In particular, the narrative of concepts or technologies like Cyber Physical System (CPS), Internet of Things, (IOT) Big Data, Smart Products, Connectivity, Additive Manufacturing, Automation, Digitalization, Work 4.0 as well as Safety and Security are presented. The creation of a compact knowledge base allows to pass to the determination of strengths, weaknesses, opportunities and threats belonging to fourth industrial revolution. To complete the part dedicated to the state of the art an outline of current assessment models and maturity stages models is presented.

2.5.1 The Definition and Core Technologies of IR4.0

In this introductory paragraph, some previously stated terms, are defined to assure the presence of a common knowledge base that serves as foundation for the entire work. The legitimacy of the presented definitions is ensured through the credibility of the selected foundation, which are represented by renowned institutions, state-of-the-art enterprises or experts in the treated field. The theories or concept that are specified are Cyber Physical System, IoT, Big Data and conclusively Smart Factory.

The oldest reference to IR4.0 goes back to the year 2011, in which at the Hannover Fair in Germany a pool of professionals first created the term. The management board of the International Organization for Standardization (ISO) announced in the year 2015 to produce an interdisciplinary strategic consultative line-up focusing on Industry 4.0 that collaborates tightly with the International Electro-Technical Commission (IEC) and the International Telecommunication Union (ITU) in order to produce a concise a description or definition of Industry 4.0. The work is still under way. For the American National Standards Institute (ANSI) IR4.0 “refers to the fourth industrial revolution, a new level of organization and control of the entire value chain and over the life of the cycle of products”.

2.5.2 The Pillars of Technologies

The I4.0 is being reinforced or supported with pillars of technologies that guarantee the transformation strategies achieved. Trusting on the introduction of ten elementary concepts or technologies, the pillar on which Industry 4.0 and the Smart Factory lean, is successively recognised. The mentioned fundamentals are represented by Cyber Physical System, IoT, Big Data, Smart Products, Connectivity, Additive

Manufacturing, Automation, Digitalization, Work 4.0 and to conclude Safety and Security.

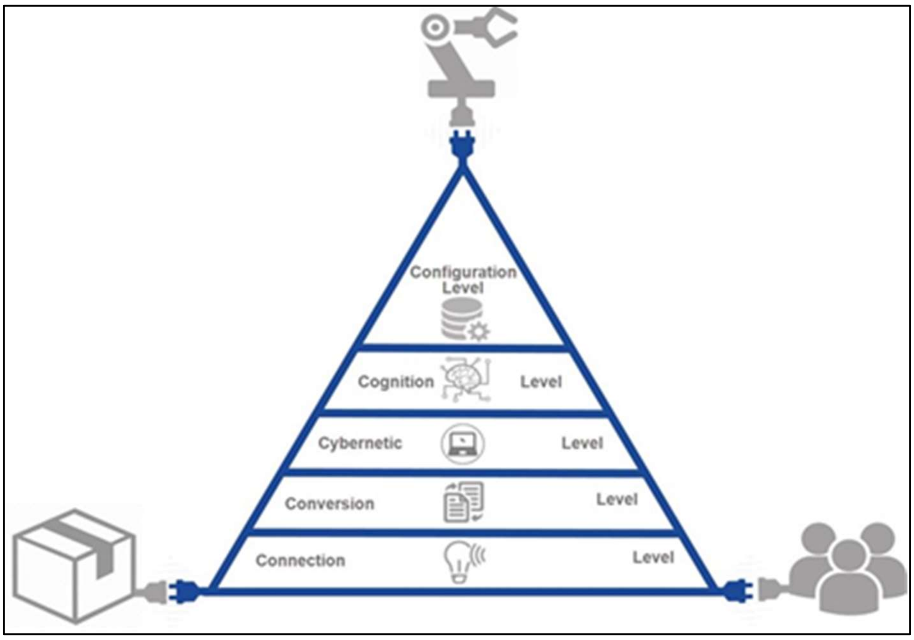

Figure 2.4: Cyber-physical system 5C-architecture

2.6 Benchmarking Readiness of AIM

Benchmarking as a technique has been attracting considerable attention for its effectiveness (Yasin, 2002; Sisson et al., 2003; Rohlfer, 2004; Anderson and McAdam, 2004; Huq *et al.,* 2008; Likierman,2009). Benchmarking is a tool commonly used while firms compete with each other. In this research, they study used benchmarking to do readiness assessment.

2.6.1 National Policy on IR4.0 (Industry 4WARD)

The Industry 4WRD is Malaysia's response is required for digital transformation of the manufacturing sector and related services by facilitating companies to embrace Industry 4.0 in a systematic and comprehensive manner. This is also can bring the services be smarter and stronger driven by people, process and technology.

2.6.2 Analysis of People, Technology and Process

This Policy, in essence, outlines 13 broad strategies for Malaysia to embark on a journey that will transform the manufacturing industry landscape over the next decade. Ministry of International Trade and Industry (MITI) believes that this journey towards

Industry 4.0 adoption is anchored on three shift factors: People, Process and Technology (SIRIM, 2019) .

People: putting people and the entire organisation as a priority. This Policy focuses on strategies towards creating differentiated talent acquisition, developing the required human capital and retaining our existing talents by providing them with the right support.

Process: improving the manufacturing and the whole business processes by encouraging smart and strategic public-private partnerships. We remain committed to ensuring the manufacturing sector continues to contribute significantly to the nation's economic prosperity. To propel this further, we are working towards improving the business environment to reform unfavourable or overly bureaucratic policies, attracting high value investments for greater economic development and strengthening the overall infrastructure for the manufacturing sector, while seeking greater partnerships with the industry (SIRIM, 2019).

Technology: advancement and convergence of technologies are increasingly underpinning global manufacturing competitiveness. We acknowledge that many leading manufacturing firms have started to adopt and implement smart manufacturing solutions where advanced hardware are now combined with advanced software, sensors as well as data analytics. The adoption of Technology in AIM is inevitable for the required transformation.

2.6.3 Background Adoption of Assessment Model

The core part of the entire master thesis is entailed in the fourth chapter. Factually, the development of a deployable assessment tool for Industry 4.0 implementation is executed grounded on a step-by-step procedure. Commencing with the (Nurogly, 2018)previously exposed Industry 4.0 elements, the determination of straightforward concepts is executed.

With regard to the introduced Industry 4.0 concepts, specific maturity levels, which consists of five distinct stages, are established. While the concepts and maturity levels form the content-related framework of the assessment tool, the specification of the quantitative assessment approach delineates the calculation scheme. In order to enhance the ease of use of the assessment tool, the capability of visualization tools including graphs and diagrams is exploited.

2.6.4 Available Assessment Model

The current assessment model calls for a guided implementation approach that requires the guidance of an Industry 4.0 expert and the participation of a company representative. As of now, for Malaysia, the available assessment tool is Industry4ward readiness assessment looking at a comprehensive programme to help firms assess their capabilities and readiness to adopt Industry 4.0 technologies and processes. The assessment uses a pre-determined set of indicators to understand their present capabilities and gaps, from which will enable firms to prepare feasible strategies and plans to move towards Industry 4.0.

This model can be adopted to our study as it defines the preliminary stage of adoption for the key parameters below;

- Determine their state of readiness in the adoption of Industry 4.0 technologies
- Identify the gaps and areas of improvement for Industry 4.0 adoption as well as opportunities for productivity improvement and growth; and
- Develop feasible strategies and plans to perform outcome-based intervention projects

2.6.5 IMPULS Original Process

As studied by Lichtblau et al., (2015), The IMPULS model process is conducted by assessing the readiness level of a company by using the dimensions and fields. Each dimension and its associated fields are assessed and a level for each field is determined. The first step is to look at the dimensions in the inner circle and identify which dimension is applicable from the model. The purpose of this step is to go through the inner circle of IMPULS in order to identify which of the dimensions of industry 4.0 is applicable to a company. It could be all or just a few, depending on the company. The input for this step is the information about the company, which could be retrieved in numerous ways such as questionnaires or literature reviews. The output is the identified dimensions for the company (Nurogly, 2018) .

The next step is to determine the fields for each dimension which will be measuring industry 4.0 readiness level for the company. The fields will be analysed in a similar manner as dimensions, with the purpose to find applicable fields in the identified dimension. The input is derived from the previous step and the output is the suitable fields. The IMPULS framework applied in the study "IMPULS - industry 4.0 readiness" by Lichtblau et al (2015) is used as reference. This benchmark the IMPULS Readiness Level. The levels are divided into three groups consisting of newcomers (L0-L1), Learners (L2-L3) and Leader (L4) respective to the cumulative points. Table 2.1 and figure 2.5 show the benchmarking of readiness level with explanation of each level. The reason to determine the dimension is to derive the importance of the company in implementation of industry revolution 4.0.

Table 2.1: Benchmarking Readiness Level (Lichtblau et al, 2015)

Level		Indicator	Group
Level (L0)	0	Indicates that a company either does not know of industry 4.0, thinks it is irrelevant or has not taken any steps towards an implementation.	Newcomer
Level (L1)	1	Involves some steps taken towards industry 4.0, such as doing pilot studies and having some system compatibility for industry 4.0, along with very little competence in the organization and only planned IT security.	
Level (L2)	2	Companies that have implemented industry 4.0 to some extent into their strategies, some investments are being made, the infrastructure is to some extent using industry 4.0, inhouse sharing of information, there are competencies in the company and sufficient IT security.	Learner
Level (L3)	3	Companies that have an industry 4.0 strategy, makes investments in more than a few areas, promotes industry 4.0 via the innovation department, have information sharing inhouse and partly external and have connected infrastructure with future expansion in mind that collects data automatically. Also, necessary IT security is implemented, cloud is used for future expansions and major steps are taken to make sure competencies for all this already exists in the company or making efforts to achieve it.	
Level (L4)	4	Companies that already using and monitoring industry 4.0, makes investments in almost all areas, supported by interdepartmental innovation, IT-systems supports almost all production and collects vast amounts of data also used for optimization. Here, future expansions can easily be made due to already supporting systems, information sharing is on both internal and business level, IT security is applied, and scalability is not a problem, data-driven	Leader

	services are used, and the company has all necessary skills inhouse.

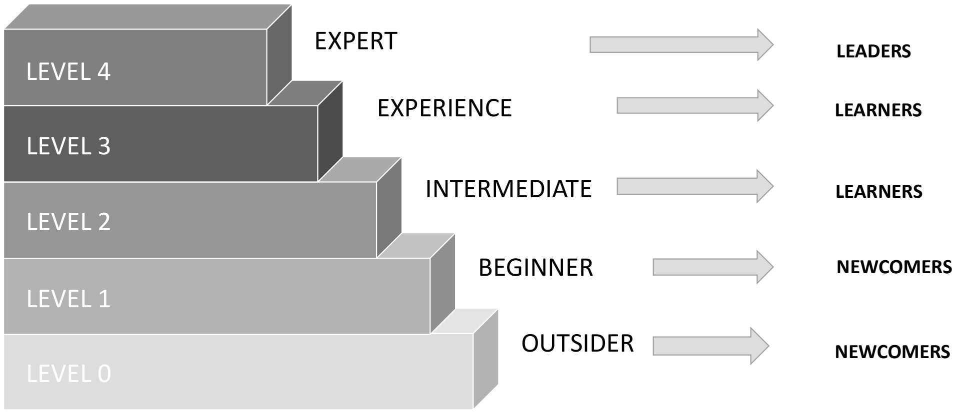

Figure 2.5: IMPULS Levels (Lichtblau et al, 2015)

Referring to figure 2.5 of the IMPLUS level made by Lichtblau et al (2015), it is show each of points were calculated the readiness score for a company with different at level and each of the level is a measurement of readiness that need to meet a minimum requirement for the specific dimension given (Lyons, 2020).

2.7 IR4.0 Assessment Framework

The 3 pillars of assessment of IR4.0 adopted in current practice for manufacturing scope are people, technology and process. In quantifying the analysis, the 3 pillars are expanded into dimensions that determine the questionnaire structure and the weightage of every dimensions were determined according to the degree of importance related to implementation (Nurogly, 2018) .

Table 2.2: Dimensions of Assessment for Company's Horizontal

IR4.0 Readiness Assessment					
People		Process		Technology	
Transformation Initiatives	Human Capital Development	Operations Management	Maintenance Management	Enterprise	Facilities
Leadership	Personnel IR4.0 Competency	Production Management	Lifecycle Management	Data Management	Assets Automation
Collaboration Structure and Governance	Top Management Technology Savviness	Technology Management	Supply Chain Management	Data Connectivity	Assets Connectivity
IR4.0 Strategy		Performance Management		Data Security	Assets Intelligence

In Table 2.2, the clear correlation of parameters within an IR4.0 assessment model from the literature search offers comprehensive method of determining the rating of readiness an organisation (Milar, 2015).

2.8 Summary

Early in this chapter, this report reviewed relevant definition to asset integrity management and the early work on building maintenance fundamentals. The research later underpins the importance of AIM in making sure assets within organization operates at its optimised potential.

The chapter later derived the latest technology pillars of IR4.0 and its crucial transformation strategies within an organization. Leveraging on the knowledge of IR4.0 technology, the chapter zoomed into the fundamental research question of determining the readiness of an organisation in embracing the technology of IR4.0.

Assessment methodology availability is limited in the case of IR4.0 and therefore the key strategy of this research is to adopt and available model outside the scope of this study. For that, a detail discussion on the existing readiness assessment model by the manufacturing sector was done by understanding the dimension of assessment. With the knowledge gained through the review, the assessment methodology is carefully crafted and will be discussed in the next chapter.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodology followed to address the research objectives set in the Chapter 1. The concepts, process and techniques applied to complete this research are detailed in this chapter. The following are the contents will be discussed in subsequent sections:

i. Research framework and design;
ii. Population and sampling;
iii. Data collection; and
iv. Analysis of Data.

3.2 Research Framework and Design

To outline the research method, a framework is needed where the technique for data collection and analysis is used to confirm the research objectives is able to be achieved. Therefore, a research framework as illustrated in Figure 3-1 is adopted and use as a guideline for this research. The research techniques for the framework is based around the research techniques describe in Creswell (2014).

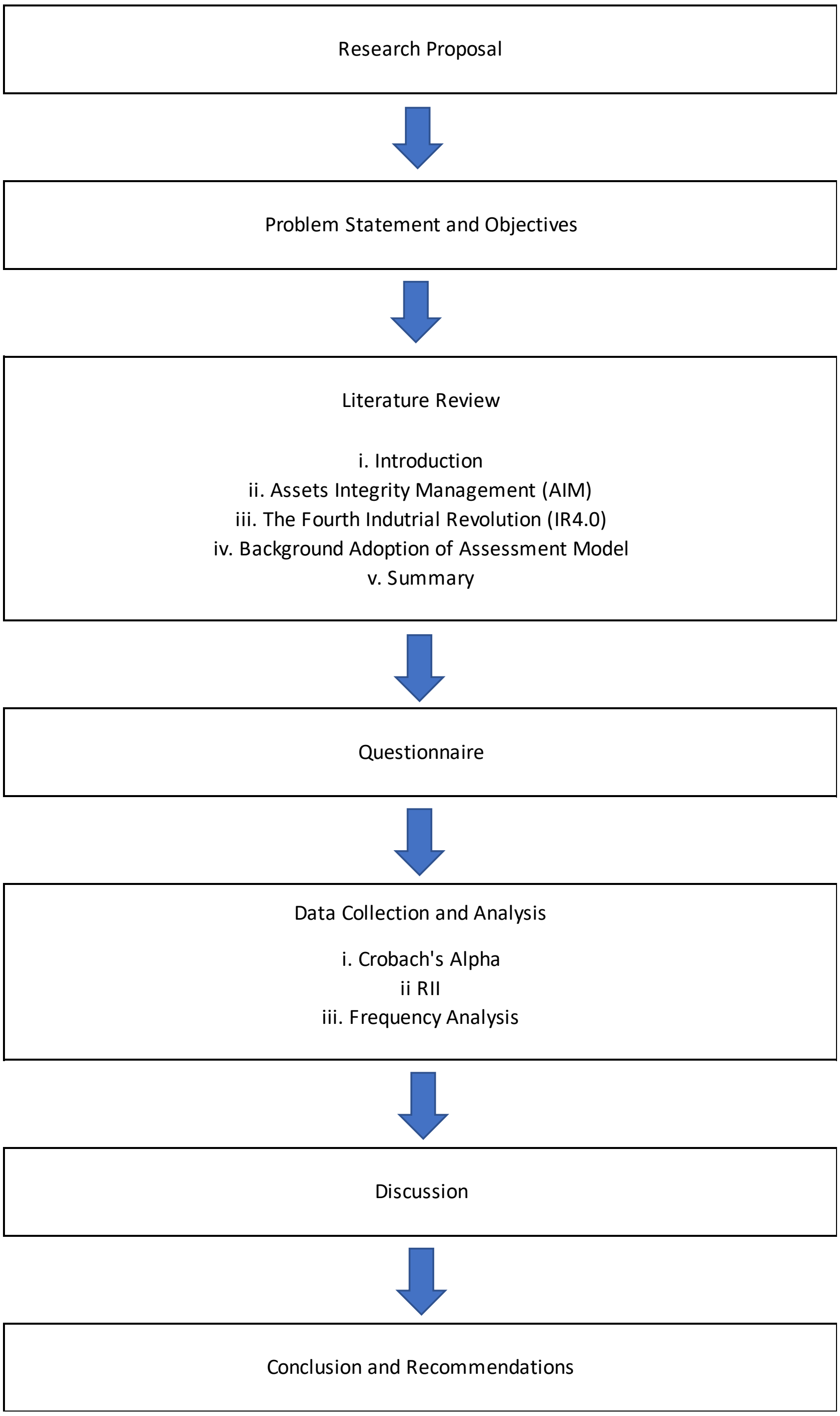

Figure 3.1: Research Framework Guideline (Creswell, 2014)

3.2.1 Research Design

The aim of research methodology is to provide a work plan of research (Chinnathambi, 2013). Research is referred to as a study that is carried out by any individual or a group of people (C.R. Kothari, 2004). It is mentioned in the oxford dictionary that the purpose of research is to create certain facts and to reach new conclusions through carrying out studies based on existing sources and to follow a systematic investigation approach.

There are various research methods that can be used in order to conduct a research. The various research methods are all bound to their own specific procedures and systematic ways in order how the research is to be carried out. According to Chinnathambi (2013), research methods are used in order to assist the researcher to gather information, data, and samples and to find a possible solution to a specific problem. There are three research method that can be adopted which are quantitative, qualitative and mixed method. A quantitative research includes a systematic investigation through the process of collecting, analysing and interpreting the collected data to obtain the outcome of the research (Creswell, 2014). A qualitative research method involves collecting and analysing non-numerical data to understand concepts, opinions or experiences. Qualitative studies are used to gather in-depth studies of an issue or to produce new research ideas. According to Creswell (2014), mixed mode research integrates both quantitative and qualitative method into one research.

In this paper, quantitative research method is used as it is suitable for the research topic. The main purpose of using the quantitative research is so that a large research sample size can be collected in a short amount of time frame though an organized survey via questionnaire.

3.3 Population and Sampling

3.3.1 Sampling Design

Sampling is a technique used in order to gather information from a controllable group size. Sampling technique is choosing as it fits best and gives the researcher the ability to estimate and to obtain the required information from a specific target group. In order to ensure that the data obtained is good, restriction of time and location were enforced.

There are two types of sampling according to Saunders et al, (2008), the first is probability sampling and the other is called non-probability sampling. In order to reduce cost, money and effort, non-probability sampling was adopted in this research. Further to acquire the data needed, convenience sampling was chosen due to the short time frame. Convenience sampling method allowed the researcher to obtain data based on the chosen proximity and accessibility to the researcher. This technique was adopted as it is inexpensive and provides data fast as the respondents are either colleagues or knew the researcher.

3.3.2 Sampling Size

Kumar Ranjit (2019) has mentioned that, the sampling is the process to select some portion from the great number of populations as a foundation for estimating the prevalence of information which related to the research topic. An appropriate sample size according to pervious researchers such as Roscoe (1975), Gorsuch (1983), Kline (1984) and MacCallum et al. (1999) is between a range of 30 to 500 numbers. This is supported by Fellows & Liu (2008), where a sample size greater than 30 and less than 500 is adequate and factor analysis needs at least 100 numbers. However, according to Meng (2013), it was found out that the simple random sampling is defined as sampling model, where x dissimilar items was selected from the y in population item. It is believed that each of possible union of x item is equivalent to the selected sample. This is to show that the simple random sampling is allowed to choose for each sample given.

3.3.3 Target Population

In this research, the respondents will be selected from BOVAEA consisting of valuers, appraisers, estate agents and property managers. The questionnaire was distributed through email to the respective respond in order to answer the questions in google form provided.

3.3.4 Data Collection

The objective of collecting data is to allow the researcher to collect enough evidence and to later proceed to come up with an inference that is required to make decisions about the findings generated (Vian Ahmed, 1997; Syed Muhammad, 2016). In quantitative research methodology, there is a couple of research data-collection methods that can be adopted, but for this research a questionnaire approach was adopted. According to Vian Ahmed (1997) and Nigel Mathers et al., (2009), the questionnaire method is good because it provides flexibility, has low cost and is easy to administrate. In this research, the questionnaire was generated via Google forms that is readily available on the internet. The generated online Google form questionnaire then was distributed to specific personnel that is related to the Building Management Industry via the share link from the Google form.

3.4 Questionnaires Design

In this research, the questionnaire generated in Google forms, was developed based on close-ended questions. The respondents were required to address all questions that were in the questionnaire.

The development of questionnaire consists of four main sections i.e. the classification of organisation, the people, the technologies and the process within the organisation related to asset integrity management.

3.4.1 Section 1: Classification of organization and Demographics

In this section of questionnaire, the main objective is to understand the nature of the organization. Key parameters of interest are the nature of the business unit within the organisation, size of or population within the organisation, maturity of establishment and the location of organisation. These data will distinguish polarities of the survey population.

3.4.2 Section 2: People

For this section of questionnaire, in understanding the readiness of the overall people factor to the readiness, the survey is divided into few sub-sections;

Transformation Initiative

The process of developing human capital requires creating the necessary environments in which employees can learn better and apply innovative ideas, acquire new competencies, develop skills, behaviours and attitudes. This section understands the readiness of leadership, governance structure and the strategic planning of the top management.

Human Capital Development

This section explores the competencies across the horizontals and the savviness of top management in riding the IR4.0 transformation.

3.4.3 Section 3: Process

In section 3, a deeper understanding of the business process of the organisation will be established through inquiries of these subsections.

Productivity Management

Productivity management is a set of skills that help people and teams improve productivity. It's a key aspect of people management, where leaders use incentives, goals, development and communication techniques to help employees and teams increase their productivity.

Technology Management

technology management is about getting people and technologies working together to do what people are expecting, which is a collection of systematic methods for managing the process of applying knowledge to extend the human activities and produce defined products.

Performance Management

Performance management is an ongoing process of communication between a supervisor and an employee that occurs throughout the year, in support of accomplishing the strategic objectives of the organization. The communication process includes clarifying expectations, setting objectives, identifying goals, providing feedback, and reviewing results.

3.4.4 Section 3: Technology

Technology is the creation, usage and knowledge of tools, techniques, crafts, systems, or methods of organization, to solve a problem or serve some purpose or end. In this section the underlying technology available within the organisation will be established through inquiries of these subsections.

Enterprise technology

In the enterprise technology sub-section, the survey will investigate the data management within the organisation. Connectivity of all the relevant data and the underlying security level are the key parameters in rating the readiness of convergence.

Facilities

In this subsection the survey will be zooming into the vertical of facilities management with technology readiness based on IR4.0 technology pillars acting as the denominator. Through this set of question, the research will identify maturity of technology use for the asset management activities.

3.5 Rating of Readiness Level

For this research the rating scale were refer to Level Readiness as per explain in chapter 2.6.5. This rating strategy based on the maturity of knowledge is used as indicator and the input will be obtained from the survey. The cumulative rating from section 2,3 and 4 on the questionnaire will indicate the level of readiness. Refer to table 3.1, the levels were divided into three groups consisting of newcomers (L0-L1), Learners (L2-L3) and Leader (L4) (Lichtblau et al, 2015) respective to the cumulative points. However, each of assessment were based size of company to evaluate each level for different size of company.

Table 3.1: Rating Level of Readiness

Level	Group	Size of Company
Level 0 (L0)	Newcomer	
Level 1 (L1)		Small
Level 2 (L2)	Learner	Medium
Level 3 (L3)		Big
Level 4 (L4)	Leader	

3.6 Analysis of Data

A software tool called Statistical Package for Social Science (SPSS) is used to analyse the data collected via the questionnaire survey. The analysis carried out on the data is to achieve the objective of this research via the help of the SPSS software. The tests used were Cronbach's Alpha, Ranking Test and Frequency Analysis.

3.6.1 Frequency Analysis

Frequency analysis is descriptive statistical method to display the frequency of each response selected by the respondent in this research through the questionnaire survey. The results were tabulated in order to provide a clearer understanding. Frequency analysis shows the number of occurrences of each response chosen by the respondents. When using frequency analysis, SPSS Statistics can also calculate the mean, median, and mode to help users analyze the results and draw conclusions.

3.6.2 Cronbach's Alpha Test

The Cronbach's Alpha reliability test was selected to measure internal consistency reliability from the keyed in data. The main purpose the Cronbach's Alpha test is conducted is to determine the reliability of the scale used in the questionnaire. The Cronbach's Alpha coefficient ranges from a scale of 0.00 to 1.00. The higher the alpha value states that the internal data obtained is more consistent. According to (Pallant, 2011), Cronbach's Alpha coefficient above 0.70 is acceptable.

Table 3.2: Cronbach's Alpha Value (Pallant, 2011)

Cronbach's Alpha	Level of Internal Consistency
$\alpha \geqslant 0.9$	Excellent
$0.9 > \alpha \geqslant 0.8$	Preferable
$0.8 > \alpha \geqslant 0.7$	Acceptable
$0.7 > \alpha$	Poor

3.7 Summary

In a nutshell, Chapter 3 presents the research methodology that acts a guideline for both data collection and data analysis. The quantitative research method was adopted in carrying out this research. This chapter explains in detail the formulation of questionnaire design and means of questionnaire distribution via Google Form, Email, and WhatsApp method. The preferred choice of data analysis software was also highlighted, including the use of Microsoft Excel 2013 and IBM SPSS Statistics 25 to conduct statistical analyses on the primary data collected from targeted groups of respondents. At the end of the chapter, frequency analysis and the Cronbach's alpha test are explained one by one at great length. The results obtained from the questionnaire and from data analysis is state in Chapter 4. The discussion of the results is provided in Chapter 5.

CHAPTER 4
4 RESULTS AND FINDINGS

4.1 Introduction

As stated in Chapter 3, a minimum of 100 responses to the questionnaire survey is necessary for this research. The questionnaire was sent out to 150 targeted respondents. All 150 questionnaires were share to respondent via Google form link. A total number of 111 sets of responded questionnaire received at the end of data collection activity with a response rate of 74%. Table 4.1 below states the number of targeted respondents and the number of replies obtained.

Table 4.1: Data Collection from Targeted Respondent

Distributed to Respondents	150
Questionnaire Replies Obtained (n)	111
Respond rate (%)	74%

4.2 Respondent Background

The respondent's background data obtained from the questionnaire was analysed using frequency analysis and is summarised in Figure based on 111 respondents. Table 4.2 below shows the respondent information and demographics.

Table 4.2: Respondents Information and Demographics

General Information	Frequency (n)	Percentage (%)
Position in Firm/ Organisation		
Executive	47	42.3
Senior Manager	35	31.5
Manager	22	19.8
Assistant Manager	7	6.3
Years Of Working Experience		
< 2 year	23	20.7
≥ 2 - 5	9	8.1

≥ 5 - 10	25	22.5
≥ 10 - 15	17	15.3
> 15	37	33.3
Region of Operation		
Northern Region	16	14.4
Central Region	83	74.8
Southern Region	7	6.3
East Coast	3	2.7
East Malaysia	2	1.8
Size of Company		
Small (Less than 20)	27	24.3
Medium (≥ 20 to 50)	22	19.8
Large (More than 50)	62	55.9
Understanding Awareness of IR4.0		
Yes	73	65.8
No	21	18.9
Maybe	17	15.3
Familiar with AIM Terminology		
Yes	35	31.5
No	53	47.7
Maybe	23	20.7

From the table 4.2 above, it can be observed that the largest group of respondents are coming from the combination of two management level groups. As the questionnaire requires input from decision maker in the company, the demographic allows better reliability.

20.7% (n=23) of the respondents are newcomers to the institution. 33.3% (n=37) of the source of information have been employed more than 15 years. Coherent to the above, the data offers the desired understanding of the subject matter experts.

Results from the findings draws a conclusion to the nature of real estate development variances between central region and other region outside. Most of the companies operates within the capital business centre and mostly in Central Region. The size of companies within the population skewed towards large organisation with number of staff exceeding 50. Only 24.3% of the respondents classified as small institution.

In measuring the awareness of mega trend of IR4.0, the respondents were requested their input on the overall understanding of the concept. It was observed that 65.8% of respondents admitted that they are aware of the key definitions of IR4.0 meanwhile 16.3% is unsure and another 18.9% are not aware of the revolution. On the awareness of AIM terminology, the respondents were requested to gauge their understanding of AIM. Only 31.5% is in the know, while 20.7% is unsure of their understanding. A staggering number of 47.7% answered no to the question.

Although there is 20.7% is unsure of their understanding towards AIM, 16.3% is unsure and another 18.9% are not aware of the Industry Revolution 4.0, the study include the respective respondent in the analysis to assess their level of understanding and how far is there level of awareness in details according to the questionnaires given.

4.3 Analysis for People Readiness in AIM

In the people readiness rating, 5 core competencies were measured through the survey. Rating system from chapter 3 were used as the guiding in the quantifying survey questions. The questions concentrated at management strategies in adapting changes.

4.3.1 Code for Benchmarking of IR 4.0 Readiness Assessment Dimension for People in AIM

Table 4.3: Coding for Benchmarking of IR 4.0 Readiness Assessment Dimension for People In AIM

Code	Description
	MANAGEMENT ABILITY TO DRIVE
Pe1	Does your management have the ability to drive and transform towards IR4.0?

Pe2	Do you make use of interdisciplinary teams (internally and/or externally) to lead and transform your organization towards IR4.0 readiness)
	COLLABORATION MODEL
Pe3	How do the management collaborate internally and externally with regards to IR4.0?
Pe4	If you have collaborated with external partners, what are the areas?
Pe5	Which of these challenges prevent you from collaborating with others?
	DEVELOPMENT OF STRATEGIES
Pe6	Have you developed a dedicated IR4.0 strategy? How would you describe the implementation stage of the strategy? (Note: normally IR4.0 strategy map is subset of technology roadmap)
Pe7	How successful is the implementation of your IR4.0 strategy?
Pe8	How do you communicate your IR4.0 strategy to your employees?
	HUMAN CAPITAL MANAGEMENT
Pe9	How do you manage human capital development within your company? (Note: Do you conduct Training Needs Analysis)
	MANAGEMENT KNOWLEDGE
Pe10	What is the level of knowledge and experience of the top management about the current technological advancement on IR4.0?

Table 4.3 above shows a coding and grouping for Benchmarking of IR 4.0 Readiness Assessment Dimension for People in Asset Integrity Management. Pe1 and Pe2 is under Management Ability to Drive, Pe3 to Pe5 is under Collaboration Model, Pe6 to Pe8 under Development of Strategies, Pe9 and Pe10 is under Human Capital Management and Management Knowledge respectively.

Table 4.4: Level of Readiness for Dimension People In AIM

Code	Level	Description	Group
Pe1	L0	Management is unfamiliar with the concept of the Fourth Industrial Revolution	Newcomer
	L1	Management is aware of the changes brought by the Fourth Industrial Revolution but adopts a wait and see approach of peers before responding or depend on external parties before developing initiatives.	
	L2	Managements have strategic perspective and critical analysis of opportunities and threats posed by the Fourth Industrial Revolution	Learner
	L3	Management understands application of latest technology and trends. Management has a sustainable plan	

	L4	Management can independently adapt and apply its organizational transformation framework based on changing needs and technology trends, with a clear vision for Industry 4.0.	Leader
Pe2	-	Yes or no	Newcomer, Learner & Leader
Pe3	L0	Information sharing between individuals and/or teams are done informally	Newcomer
	L1	Information sharing between selected individuals and/or teams across the supply or value chain are secure and established through a formal structure	
	L2	Selected individuals and/or teams across the supply or value chain function within an interoperable environment and are empowered to adjust certain structural	Learner
	L3	Selected individuals and/or teams across the supply or value chain function within an interoperable environment are empowered to undertake joint tasks and projects, real time.	
	L4	Formal channel is established within the supply or chain partner to enable flexibility and agility to address any problem identified. Targeted risks, responsibilities and key-performance-indicators are also shared.	Leader
Pe4		Areas of collaboration. (Refer table 4.5)	
Pe5		Challenges that prevent collaboration. (Refer table 4.5)	
Pe6	L0	Enterprise has no strategies for Industry 4.0. Organization has no current or future intention of upgrading to a smart factory.	Newcomer
	L1	Enterprise has strategies but not up to Industry 4.0. Organization has plans to establish a smart factory as strategic focus.	
	L2	Enterprise has a transformative strategy for Industry 4.0. A sustainable able to plan for a smart factory is being developed or has been developed using forward thinking approach. The plan is implemented at least at one functional area.	Learner
	L3	Enterprise has a transformative strategy for Industry 4.0. A sustainable plan with sufficiently allocated resources for smart factory has been implements. Business activities have achieved sustainable growth and profitability through implementation plan.	
	L4	The implemented transformative strategies and sustainable plan for smart factory is constantly reviewed and improved to account for latest technology, business model and practices advancements.	Leader
Pe7	L0	We do not track the success of our strategy	Newcomer
	L1	Unstructured and ad-hoc tracking	

	L2	We regularly check to meet the strategic goals	Learner
	L3	We have a set of indicators to meet strategic goals	
	L4	We manage to achieve our strategic goals	Leader
Pe8	L0	No communication	Newcomer
	L1	Someone in the company is responsible for the task	
	L2	Do it in an unstructured, informal way	Learner
	L3	Record of communication and strategies are regularly maintained	
	L4	All employees are constantly informed and well-versed with the strategies and implementation plan	Leader
Pe9	L0	No gap analysis or competency requirement established	Newcomer
	L1	Partial competency requirement and learning and development (L&D) plan was established based on necessary skillsets for Industry 4.0 activities.	
	L2	Full competency requirement and Industry 4.0 L&D plan was established and embedded in its governance process. Training needs analysis also undertaken.	Learner
	L3	Industry 4.0 L&D plan is a part of the value chain life cycle and effectiveness is measured. Training syllabus was developed with or without external assistance. Training plan to upgrade personnel competencies for career development progression was established with clear commencement and conclusion points.	
	L4	Active efforts are made to identify and incorporate Industry 4.0 L&D programme for future skillset requirements. Training syllabus is constantly reviewed based on feedback received on current technology advancement and needs. Training is conducted continuously with evaluation on its effectiveness.	Leader
Pe10	L0	Management is unfamiliar with the Fourth Industrial Revolution and/or Industry 4.0 product requirements, and/or technology trends.	Newcomer
	L1	Management has limited knowledge and awareness of recent technological trends. However, able to partially recognize and/or describe the Fourth Industry	
	L2	Management is well-informed and able to distinguish and explain the concept of the Fourth Industry Revolution and/or Industry 4.0 product requirements, and/or technology trends through formal platform	Learner
	L3	Management is able to accurately explain conceptual application of Industry 4.0 technology and/or concepts with or without external assistance	
	L4	Management is able to correctly illustrate financial relationship and benefits anticipated from the application of Industry 4.0 technology and/or concepts without external assistance.	Leader

In Table 4.4 show to identify each of coding according to the ratings for example Pe1, L0 means the Management is unfamiliar with the concept of the Fourth Industrial Revolution, L1 means Management is aware of the changes brought by the Fourth

Industrial Revolution but adopts a wait and see approach of peers before responding or depend on external parties before developing initiatives. L2 means the Managements have strategic perspective and critical analysis of opportunities and threats posed by the Fourth Industrial Revolution and L3 state that Management understands application of latest technology and trends. Management has a sustainable plan. L4 shows that Management can independently adapt and apply its organizational transformation framework based on changing needs and technology trends, with a clear vision for Industry 4.0. We further group L0 and L1 under Newcomer. L2 and L3 we group it under Learner and L4 we group it under Leader.

4.3.2 Reliability Test for IR 4.0 Readiness Assessment Dimension for People in AIM

The Cronbach's Alpha reliability test revealed the value of 0.934 based on the 7 items in benchmarking readiness assessment dimension for people by BOVEO member as presented in Table 4.5. The data collected for Cronbach's Alpha value was 0.943, that means the collected data are considered very reliable (Stephanie, 2014) to be used for analysis purpose in this research.

Table 4.5: Cronbach's Alpha for readiness assessment

Reliability Statistics	
Cronbach's Alpha	N of Items
.934	7

4.3.3 Analysis Benchmarking Readiness IR 4.0 For Dimension of People In AIM

Table 4.6: Analysis Descriptive of Benchmarking of Readiness IR 4.0 for Dimension of People In AIM

Code	Group	Size of Company	Frequency (n)	Mean	SD
Pe1	Newcomer	Small	21	0.631	6.3
		Medium	17		
		Large	32		
	Learner	Small	4	0.243	7.1
		Medium	4		
		Large	19		
	Leader	Small	2	0.126	4.5
		Medium	1		

		Large	11		
Pe2	Yes	Small	15	0.667	11.0
		Medium	19		
		Large	40		
	No	Small	12	0.333	7.8
		Medium	3		
		Large	22		
Pe3	Newcomer	Small	18	0.559	10.0
		Medium	10		
		Large	34		
	Learner	Small	5	0.243	5.0
		Medium	6		
		Large	16		
	Leader	Small	4	0.198	3.4
		Medium	6		
		Large	12		
Pe4	Technology Development	Small	2	0.243	10.6
		Medium	1		
		Large	24		
	Joint Venture	Small	7	0.207	2.5
		Medium	11		
		Large	5		
	Product Development	Small	6	0.153	2.9
		Medium	2		
		Large	9		
	Sharing of Equipment and/or Resources	Small	4	0.090	1.7
		Medium	5		
		Large	1		
	Collaborate in R&D Projects	Small	3	0.090	2.9
		Medium	0		
		Large	7		
	Participate in Seminars/ Trainings	Small	4	0.189	5.0
		Medium	3		
		Large	14		
	Never	Small	1	0.027	0.8
		Medium	0		
		Large	2		
Pe5	Appropriate partners could not be found	Small	5	0.297	4.5
		Medium	12		
		Large	16		
	Unavailability of funds	Small	20	0.387	7.3
		Medium	4		
		Large	19		
	Non-disclosure agreement	Small	2	0.270	8.6
		Medium	6		
		Large	22		
	Not Available	Small	0	0.027	1.4
		Medium	0		
		Large	3		

	No intention	Small Medium Large	0 0 1	0.009	0.5
	Not relevant in organisation	Small Medium Large	0 0 1	0.009	0.5
Pe6	Newcomer	Small Medium Large	20 16 43	0.712	11.9
	Learner	Small Medium Large	7 5 8	0.180	1.2
	Leader	Small Medium Large	0 1 11	0.108	5.0
Pe7	Newcomer	Small Medium Large	23 21 38	0.739	7.6
	Learner	Small Medium Large	4 1 21	0.234	8.8
	Leader	Small Medium Large	0 0 3	0.027	1.4
Pe8	Newcomer	Small Medium Large	19 11 37	0.604	10.9
	Learner	Small Medium Large	6 10 18	0.306	5.0
	Leader	Small Medium Large	2 1 7	0.090	2.6
Pe9	Newcomer	Small Medium Large	21 21 37	0.712	7.5
	Learner	Small Medium Large	6 1 17	0.216	6.7
	Leader	Small Medium Large	0 0 8	0.072	3.8
Pe10	Newcomer	Small Medium Large	21 18 35	0.667	7.4
	Learner	Small Medium Large	6 1 17	0.216	6.7
	Leader	Small Medium Large	0 3 10	0.117	4.2

Table 4.6 show an analysis of findings of Frequency and Mean from the survey. Under the group Management Ability to Drive which is Pe1 and Pe2, Pe1 has the highest mean of 0.631 under newcomer and most of the respondent are from the large companies with 32 frequency and the rest are 21 from small companies and 17 from medium size companies. As for Pe2, 66.7% make use of make use of interdisciplinary teams (internally and/or externally) to lead and transform your organization towards IR4.0 readiness) with a frequency of 40 from large companies, 19 from medium and 15 from small size companies. The rest of 33.3% do not make use of the interdisciplinary teams. This means that only a few companies have a management that can independently adapt and apply its organizational transformation.

Under the grouping of Collaboration Model, Pe3 has mean of 0.559 under the newcomer and leader only have a mean of 0.198. Most of the respondent are from the large companies with 62 frequency and the rest are 27 from small companies and 22 from medium size companies. Pe4 questions if the respondent has any collaboration with a partner. The highest is 24.3% which is under Technology Development and 20.7% under Joint Venture. 18.9% participate in seminars and 15.3% collaborated under product development. 9% of the respondent has shared resources and collaborate in R&D Projects and 2.7% has never collaborated with any partner. For Pe5, questions the challenges faced by the respondent in collaborating with others. From the findings, 29.7% said an appropriate partner could not be found, 38.7% has issues with unavailability of funds and 27% answers they have issues with Non-Disclosure agreement. The results once again showed that respondents skewed towards low rating to the question on IR4.0 collaboration be it internal or external.

Pe6, Pe7 and Pe8 are under the Development of Strategies grouping. Pe6 has the highest mean of 0.712 under newcomer and most of the respondent are from the large companies with 43 frequency and the rest are 20 from small companies and 16 from medium size companies. Only 10.8% are leaders and 18% are learners. Pe7 which shows a slightly similar result of 73.9% newcomer, 23.4% learners and 2.7% leaders while Pe8 shows 60.4% newcomer, 30.6% learners and 9% leaders. This shows that in determining the existence of dedicated strategy of IR4.0 by the management, more than 50% of the respondents responded by admitting that there is no clear strategy.

Human Capital Management is the next grouping which have Pe9 questions about how the company manage the human capital especially in area of training relating to IR4.0. The results shows that 71.2% is newcomer, 21.6% learners and 7.2% a leader. This shows that most of the respondents agreeing that the management is not ready with the human capital requirement for transformation.

Management Knowledge is under the last grouping of Benchmarking of Readiness IR 4.0 for Dimension of People In AIM. Pe10 enquire about the readiness of top management on the knowledge and experience in handling the transformation program in the company. Pe10 has the highest mean of 0.667 under newcomer and most of the respondent are from the large companies with 35 frequency and the rest are 35 from small companies and 18 from medium size companies. This also shows that the level of readiness from top management is low.

4.4 Analysis for Process Readiness IR4.0 in AIM

In the process readiness rating, 5 core competencies were measured through the findings. Rating system from chapter 3 were used as the guiding in the quantifying survey questions.

4.4.1 Code for Benchmarking of IR 4.0 Readiness Assessment Dimension for Process in AIM

Table 4.7: Coding for Benchmarking of IR 4.0 Readiness Assessment Dimension for Process In AIM

Code	Description
	ASSET MANAGEMENT AUTOMATION
Pr1	Can you describe your production / operation system?
	MACHINE CONTROL
Pr2	What is main method of machines control used in the production process / operation?
	UPDATING TECHNOLOGY TRENDS
Pr3	Does your company follow the technology trends of Industry 4.0?

Pr4	Do you have any technology management plan that is aligned to IR4.0
MAINTENANCE PERFORMANCE	
Pr5	How do you carry out production performance management in your company?
Pr6	How do you perform your supply chain management (SCM)
CYBER-SECURITY IMPLEMENTATION	
Pr8	What is the extent of your cyber-security implementation?

Table 4.7 above shows a coding and grouping for Benchmarking of IR 4.0 Readiness Assessment Dimension for Process in Asset Integrity Management. Pr1 is under Asset Management Automation and Pr2 is under machine Control. Pr3 and Pr4 is under Updating Technology Trends, Pr5 and Pr6 under Maintenance Performance and Pr7 is under Cyber Security Implementation.

Table 4.8: Level of Readiness for Dimension Process In AIM

Code	Level	Description	Group
Pr1	L0	Production / Operation processes are done manually. No dedicated machine or equipment to run production process. No operation management system in place.	Newcomer
	L1	Dedicated machine or equipment are allocated to run production process / operation, but manufacturing/quality parameters are unstructured.	
	L2	Dedicated machine or equipment are allowed to run production process / operation and manufacturing/quality parameters are controlled.	Learner
	L3	Dedicated manufacturing cells with predetermined reconfigurable machines or equipment are allocated to run continuous production process / operation,	
	L4	Manufacturing cells capable of utilizing predetermined machine/ equipment for continuous production; flexible; integrated every floors and levels. Management systems analytical and adaptive	Leader
Pr2	L0	Application of Hardwired control system	Newcomer
	L1	Application of the computer-based systems	
	L2	Application of computer-based systems with local networking	Learner
	L3	Application of computer based operational and control network - manage production workflow.	
	L4	Application of a fully integrated computer-based systems capable to react, impact changes and converged with enterprise management systems.	Leader
Pr3	L0	No	Newcomer
	L1	Follow in ad-hoc manner	

	L2	Follow some trends but information not kept in structured manner	Learner
	L3	Follow trends and information are kept systematically by dedicated personnel	
	L4	Disseminate trends information to relevant personnel in the company	Leader
Pr4	L0	Enterprise does not have any technology management roadmap or plan in place	Newcomer
	L1	Enterprise has some technology related study	
	L2	Enterprise has developed a technology management plan that is compatible with the enterprise's sustainable plan, considering Industry 4.0 requirements.	Learner
	L3	Enterprise develops a comprehensive technology management plan taking into consideration technology and market trends through various sources.	
	L4	The technology management plan well optimized and integrated overall value chain of the enterprise. Able to address the future trends of Industry 4.0 technology needs.	Leader
Pr5	L0	There is no monitoring and measuring system for performance. Performance information is not observed.	Newcomer
	L1	Basic monitoring and measuring system for performance. Performance indicators are organized manually or partial application of electronic/ digital management system.	
	L2	Performance indicators are managed by electronic/ digital management system. Utilization of performance information is specifically towards achieving organizational goals.	Learner
	L3	Well-integrated performance and information management system. Performance management process interoperability is achieving from different systems, but accessibility is limited	
	L4	High quality of information and robust system accessible internally and externally supports the decision making.	Leader
Pr6	L0	Each organization in the supply chain manages its processes separately using its own management system.	Newcomer
	L1	Supply chain processes are defined and executed by humans, with the support of manually and paper-based tools	
	L2	Define supply chain integration processes are completed by human with the support of digital tools	Learner
	L3	Digitalized supply chain processes and systems are securely integrated across business partners and clients	
	L4	Automated supply chain processes and systems are actively analyzing and reacting to available information.	Leader
Pr7	L0	Cybersecurity is not available	Newcomer
	L1	Cybersecurity initiative is minimal and limited physical security, security practices, access control, asset inventory and device management.	
	L2	Cybersecurity framework is in place as zone and device firewalls, unidirectional gateways, anti-malware, and application whitelisting.	Learner
	L3	Review of policy of risk assessment with breaches anticipated and confronted.	

L4	Cybersecurity framework is dynamic with threat intelligence and incident management. Ongoing review of policy or risk assessment, current breaches confronted and inevitability of future breaches	Leader

In Table 4.8 we break and identify each Coding according to the ratings for example Pr1, L0 means the Production / Operation processes are done manually. No dedicated machine or equipment to run production process. No operation management system in place. L1 means Dedicated machine or equipment are allocated to run production process / operation, but manufacturing/quality parameters are unstructured. L2 means the Dedicated machine or equipment are allowed to run production process / operation and manufacturing/quality parameters are controlled and L3 state that Dedicated manufacturing cells with predetermined reconfigurable machines or equipment are allocated to run continuous production process / operation. L4 shows that Manufacturing cells capable of utilizing predetermined machine/ equipment for continuous production; flexible; integrated every floors and levels. Management systems analytical and adaptive. Again, we further group L0 and L1 under Newcomer. L2 and L3 we group it under Learner and L4 we group it under Leader.

4.4.2 Analysis Benchmarking Readiness IR 4.0 For Dimension of Process In AIM

Table 4.9: Analysis Frequency of Benchmarking of Readiness IR 4.0 for Dimension of Process In AIM

Code	Group	Size of Company	Frequency (n)	Mean	SD
Pr1	Newcomer	Small	23	0.757	10.0
		Medium	19		
		Large	42		
	Learner	Small	4	0.207	5.9
		Medium	3		
		Large	16		
	Leader	Small	0	0.036	1.9
		Medium	0		
		Large	4		
Pr2	Newcomer	Small	24	0.676	6.2
		Medium	18		
		Large	33		
	Learner	Small	3	0.207	5.9
		Medium	4		
		Large	16		

	Leader	Small Medium Large	0 0 13	0.117	6.1
Pr3	Newcomer	Small Medium Large	23 16 28	0.604	4.9
	Learner	Small Medium Large	2 5 25	0.288	10.2
	Leader	Small Medium Large	2 1 9	0.108	3.6
Pr4	Newcomer	Small Medium Large	25 15 37	0.694	9.0
	Learner	Small Medium Large	2 7 21	0.270	8.0
	Leader	Small Medium Large	0 0 4	0.036	1.9
Pr5	Newcomer	Small Medium Large	22 16 42	0.721	11.1
	Learner	Small Medium Large	5 6 17	0.252	5.4
	Leader	Small Medium Large	0 0 5	0.045	2.4
Pr6	Newcomer	Small Medium Large	17 13 29	0.532	6.8
	Learner	Small Medium Large	10 9 30	0.441	9.7
	Leader	Small Medium Large	0 0 3	0.027	1.4
Pr7	Newcomer	Small Medium Large	22 17 21	0.541	2.2
	Learner	Small Medium Large	5 5 19	0.261	6.6
	Leader	Small Medium Large	0 0 22	0.198	10.4

Table 4.9 show an analysis of findings of Frequency and Mean from the survey. Under the group Asset Management Automation, Pr1 has the highest mean of 0.757 under newcomer and most of the respondent are from the large companies with 42 frequency and the rest are 23 from small companies and 19 from medium size companies. For the maintenance operation system, the automation of process was identified, the selection distribution is towards L0 with gradual decrease with only 4 large companies admitting to L4. For Machine Control group, Pr2 has mean of 0.676 under the newcomer and leader only have a mean of 0.117. Most of the respondent are from the large companies with a frequency of 62 and the rest are 27 from small companies and 22 from medium size companies.

Pr3 and Pr4 is under the grouping of Updating Technology Trend, Pr3 has mean of 0.604 under the newcomer and leader only have a mean of 0.108. Most of the respondent are from the large companies with 62 frequency and the rest are 27 from small companies and 22 from medium size companies. Pr4 questions if the respondent has any technology management plan that is aligned to IR4.0. 69.4% respondents are newcomer who answers L0 and L1, 27% are learners and only 3.6% are leaders who mainly from large companies. This shows that most of the respondent are not up to date with the technology trends in IR4.0.

Under the Maintenance Performance grouping, Pr5 has the highest mean of 0.721 under newcomer and most of the respondent are from the large companies with 42 frequency and the rest are 22 from small companies and 16 from medium size companies. Pr6 has a different result which show slightly higher mean under Newcomer and Learner which is 0.532 and 0.441 respectively. Only 3 large company is under Leader which have a mean of 0.027. Looking at the result, this means that the respondent is a newcomer but in the learning zone within the Maintenance Performance grouping especially in the Supply Chain Management.

Pr7 is under the Cyber Security Implementation grouping. Pr7 has the highest mean of 0.541 under newcomer. 22 respondents were from small companies, 17 from medium and 21 are from large companies. 26.1% are considered learners in cyber security implementation and apparently 19.8% are leaders. This shows that almost all respondents are aware of the cyber security treats in the industry.

4.4.3 Reliability Test for IR 4.0 Readiness Assessment Dimension for Process in AIM

Table 4.10 show the value readiness assessment dimension for process in AIM was 0.734 collected from 11 items benchmarking readiness assessment and this value indicated that the consistency measure under this readiness dimension. As stipulated Pallant (2011), Cronbach's Alpha coefficient above 0.70 is under acceptable category.

Table 4.10: Cronbach's Alpha for readiness assessment

Reliability Statistics	
Cronbach's Alpha	N of Items
.734	11

4.5 Analysis for Technology Readiness in AIM

It can be acknowledging that many leading manufacturing firms have started to adopt and implement smart manufacturing solutions where advanced hardware are now combined with advanced software, sensors as well as data analytics. The adoption of Technology in AIM is inevitable for the required transformation.

4.5.1 Code for Benchmarking of IR 4.0 Readiness Assessment Dimension for Technology in AIM

Table 4.11: Coding for Benchmarking of IR 4.0 Readiness Assessment Dimension for Technology In AIM

Code	Description
Te1	How comprehensive is the ICT infrastructure in the company?
Te2	What is the level of connectivity of the IT system?
Te3	What is the level of intelligence of the IT system?
Te4	How do you monitor and control the facility management systems?

Te5	What is the level of connectivity of the facility management system?
Te6	What is the method of interaction between workers and machines?
Te7	What is the level of intelligence of the facility management systems?
Te8	What is the level of production automation practiced in your company?
Te9	How do you manage your production data?
Te10	How your equipment / facilities are connected, communicated, and controlled?
Te11	What is the level of intelligent of the assets?

Table 4.12: Grouping of Coding for Benchmarking of IR 4.0 Readiness Assessment Dimension for Technology In AIM

Technology Readiness	**Code**
Facility Management	Te6 and Te8
ICT Infrastructure	Te1 and Te9
Connectivity	Te2 and Te5
Artificial Intelligence	Te3, Te7 and Te11
Monitoring of Facilities	Te4 and Te10

Table 4.12 and Table 4.13 above shows a coding and grouping for Benchmarking of IR4.0 Readiness Assessment Dimension for Technology in Asset Integrity Management. Te1 and Te9 is under ICT Infrastructure, Te3, Te7 and Te11 is under Artificial Intelligence, Te6 and Te8 under Facilities Management, Te4 and Te10 is under Monitoring of Facilities and Te2 and Te5 is under Connectivity.

Table 4.13: Level of Readiness for Dimension Technology In AIM

Code	**Level**	**Description**	**Group**
Te1	L0	Basic ICT infrastructure (e.g., email & internet)	Newcomer
	L1	Local Network-based data sharing by means of interlinking between individual PC with a data serve (e.g., use of wired LAN)	
	L2	Internet-based data sharing with central data servers. Intranet mobile information access (e.g., use of wired LAN)	Learner

	L3	Internet-based data sharing with central and cloud data servers. Full mobile information access using cloud solutions.	
	L4	Fully integrated and inter-operable connected infrastructures with the shop floor and the facility systems	Leader
Te2	L0	No connectivity between enterprise IT equipment and computer-based systems	Newcomer
	L1	Existence of formal network that links a single enterprise IT system	
	L2	Connectivity and interoperability exist between various enterprise IT systems	Learner
	L3	Uninterrupted real time and information exchange enterprise IT system	
	L4	Existing network is flexible and scalable to accommodate future changes in an enterprise IT system	Leader
Te3	L0	Enterprise assets are not on any electronic or digital system	Newcomer
	L1	Enterprise assets apply pre-programmed logic to perform tasks on its equipment, machinery and computer-based system	
	L2	Plug and play enterprise assets are connected with network sensors which allows the integrated system to notify critical problem and inform possible causes.	Learner
	L3	Enterprise assets can predict and notify critical problem and inform possible causes	
	L4	Enterprise assets can predict and notify critical problem, and independently execute decision to optimized performance and resource efficiency.	Leader
Te4	L0	Facility operation are done by humans	Newcomer
	L1	Assistance of equipment, machinery and computer-based systems are used in the facility and human intervention is required	
	L2	Facility processes are fully automated and human intervention is required for unplanned circumstances	Learner
	L3	Modification, re-configuration and re-tasking of equipment, machinery and computer-based systems can be done quickly and easily	
	L4	Equipment, machinery, and computer-based systems are flexible and integrated with floor and enterprise systems	Leader
Te5	L0	No connectivity between facility's equipment and system.	Newcomer
	L1	Existence of formal network that links the facilities and computer-based system	
	L2	Connectivity and interoperability exist between various facility equipment and computer-based systems of different technology platforms	Learner
	L3	Uninterrupted real time interaction and information exchange between facility's equipment and computer-based systems	
	L4	Existing network is flexible and scalable to accommodate future changes in facility equipment and computer-based systems	Leader

Te6	L0	Machines with manual input and digital display for feedback	Newcomer
	L1	Machines with manual input and digital and physical buttons for interaction with the machine	
	L2	Machines with manual input and touch screen (GUI) for interaction with the machine	Learner
	L3	Machines are controlled remotely by mobile devices provided with the machine or apps on mobile devices	
	L4	Machines are controlled via augmented reality, realized via mobile devices or other AR-devices and gesture recognition and control	Leader
Te7	L0	Facilities assets are not on any electronic or digital system	Newcomer
	L1	Facilities assets apply pre-programmed logic to perform tasks on its equipment, machinery and computer-based system.	
	L2	Plug and play facilities assets are connected with network sensors to allows the integrated system to identify and notify critical problem and inform possible causes.	Learner
	L3	Facilities assets can predict and notify critical problem and provide information on possible causes.	
	L4	Assets are able to make correction based on pre-determined corrective measures.	Leader
Te8	L0	Production processes are done manually	Newcomer
	L1	Assistance of equipment, machinery and computer-based systems are used in the production process and human intervention is required to start and finish the process	
	L2	Production process is fully automated and human intervention is required for unplanned events	Learner
	L3	Modification, re-configuration and re-tasking of equipment, machinery and computer-based systems are easily done quickly	
	L4	Equipment, machinery and computer-based systems are flexible and integrated with enterprise and facility systems to allow for dynamic, cross-domain interactions	Leader
Te9	L0	There is no monitoring system for production data. Information is not being managed	Newcomer
	L1	There is no basic monitoring system (e.g., manually stored, paper based). Data are used for process monitoring, visualization and analysis.	
	L2	Data are collected and stored in a digital form and used for production planning and control	Learner
	L3	There is a well-integrated production data management system with comprehensive set of data standards & policies in used and limited access.	
	L4	Production data are collected in real time and embedded that aligned with autonomous rule-based decision making, cyber-physical system and digital process mappings	Leader
Te10	L0	No connectivity and interaction between equipment and system.	Newcomer

	L1	One to one equipment connection but limited to specific task or process.	
	L2	Multiple equipment is connected via network.	Learner
	L3	Physical connection is imbued with multiple networking technologies and protocols.	
	L4	Existing network is flexible and scalable to accommodate future changes in equipment, machinery and computer-based systems.	Leader
Te11	L0	Assets are not on any electronic of digital system.	Newcomer
	L1	Assets apply pre-programmed logic to perform task on its equipment, machinery, and computer-based systems.	
	L2	Plug and Play assets are connected with network sensors which allows the integrated system to identify and notify critical problem and inform possible cause.	Learner
	L3	Assets can predict and notify critical problem and inform possible cause.	
	L4	Assets are able to undertake corrective measures.	Leader

In Table 4.12 we break and identify each Coding according to the ratings for example in Te1, the question is how comprehensive is the ICT infrastructure in the company? The L0 means only the Basic ICT infrastructure in the company (e.g., email & internet). L1 means Local Network-based data sharing by means of interlinking between individual PC with a data serve (e.g., use of wired LAN). L2 means the Internet-based data sharing with central data servers. Intranet mobile information access (e.g., use of wired LAN) and L3 state that Internet-based data sharing with central and cloud data servers. Full mobile information access using cloud solutions. L4 shows that Fully integrated and inter-operable connected infrastructures with the shop floor and the facility systems. This is done throughout the questions from Te1 to Te11. Again, we further group L0 and L1 under Newcomer. L2 and L3 we group it under Learner and L4 we group it under Leader.

4.5.2 Analysis Benchmarking Readiness IR 4.0 For Dimension of Technology In AIM

Table 4.14: Analysis Frequency of Benchmarking of Readiness IR 4.0 for Dimension of Process In AIM

Code	Group	Size of Company	Frequency (n)	Mean	SD
Te1	Newcomer	Small	25	0.514	5.9
		Medium	21		

		Large	11		
	Learner	Small	2	0.342	15.8
		Medium	1		
		Large	35		
	Leader	Small	0	0.144	7.5
		Medium	0		
		Large	16		
Te2	Newcomer	Small	25	0.523	4.0
		Medium	16		
		Large	17		
	Learner	Small	2	0.315	11.0
		Medium	6		
		Large	27		
	Leader	Small	0	0.162	8.5
		Medium	0		
		Large	18		
Te3	Newcomer	Small	25	0.550	4.6
		Medium	14		
		Large	22		
	Learner	Small	0	0.315	11.3
		Medium	8		
		Large	27		
	Leader	Small	2	0.135	5.7
		Medium	0		
		Large	13		
Te4	Newcomer	Small	25	0.694	6.5
		Medium	18		
		Large	34		
	Learner	Small	2	0.243	8.5
		Medium	4		
		Large	21		
	Leader	Small	0	0.063	3.3
		Medium	0		
		Large	7		
Te5	Newcomer	Small	23	0.586	5.0
		Medium	15		
		Large	27		
	Learner	Small	2	0.297	9.4
		Medium	7		
		Large	24		
	Leader	Small	2	0.117	4.8
		Medium	0		
		Large	11		
Te6	Newcomer	Small	25	0.604	3.8
		Medium	17		
		Large	25		
	Learner	Small	2	0.360	14.0
		Medium	5		
		Large	33		

	Leader	Small Medium Large	0 0 4	0.036	1.9
Te7	Newcomer	Small Medium Large	24 15 29	0.613	5.8
	Learner	Small Medium Large	2 5 24	0.279	9.7
	Leader	Small Medium Large	1 2 9	0.108	3.6
Te8	Newcomer	Small Medium Large	25 15 31	0.640	6.6
	Learner	Small Medium Large	0 6 21	0.243	8.8
	Leader	Small Medium Large	2 1 10	0.117	4.0
Te9	Newcomer	Small Medium Large	14 12 14	0.360	0.9
	Learner	Small Medium Large	12 6 37	0.495	13.4
	Leader	Small Medium Large	2 4 11	0.153	3.9
Te10	Newcomer	Small Medium Large	25 17 20	0.559	3.3
	Learner	Small Medium Large	3 4 28	0.315	11.6
	Leader	Small Medium Large	0 1 14	0.135	6.4
Te11	Newcomer	Small Medium Large	25 18 30	0.658	4.9
	Learner	Small Medium Large	2 4 25	0.279	10.4
	Leader	Small Medium Large	0 0 7	0.063	3.3

Table 4.13 show an analysis of findings of Frequency and Mean from the survey. Zooming to the facility management level, the entity must be able to connect into the framework of IR4.0. Facility management connectivity will ensure the advancement of the vertical i.e. the management of asset integrity to the IR4.0 level. Under the group Facility Management, which is Te6 and Te8, Te6 has the highest mean of 0.604 under newcomer and the highest respondent are from the large and small companies with 25 frequency each and the rest are from medium size companies with a frequency of 17. Only 3.6% are from Leader rating which is the respondent are from 4 large company. As for Te8, 64.0% basically has manual process and assistance of equipment, machinery and computer-based systems are used in the production process and human intervention is required to start and finish the process which is under newcomer rating with a frequency of 31 from large companies, 15 from medium and 25 from small size companies.

Without a comprehensive ICT infrastructure, the transformation to IR4.0 cannot be materialised. To analyse this, under the grouping of ICT Infrastructure, Te1 has mean of 0.514 under the newcomer and leader only have a mean of 0.144. Most of the respondent are from the large companies with 62 frequency and the rest are 27 from small companies and 22 from medium size companies. Te9 questions how the company manage production data. The results shows that most of the companies' data are collected and stored in a digital form and used for production planning and control and also there is a well-integrated production data management system with comprehensive set of data standards & policies in used and limited access. The mean for Te9 is 0.495 showing most of the companies are Learners and 36% are newcomers. The remaining are from Leader with a mean of 0.153.

The Internet connection will ensure the convergence of information within the IR4.0 infrastructure, hence the measure of connectivity was weighted into the readiness survey. Connectivity is the next grouping which have Te2 and Te5 questions about what the level of connectivity of the IT system and facility management system is. For Te2, the results shows that 52.3 % is newcomer, 31.5% learners and 16.2% a leader while for Te5 the result shows 58.6 % is newcomer, 29.7% learners and 11.7% a leader. This shows that most of the respondents have limited connectivity of the IT systems and facility management.

Independent decision is the trademark of artificial intelligence where decision making can automatically made for the organisation. Te3, Te7 and Te11 are under the Artificial Intelligence grouping. Te3 has the highest mean of 0.550 under newcomer and most of the respondent are from the small companies with 25 frequency and the rest are 22 from large companies and 14 from medium size companies. Only 13.5% are leaders and 31.5% are learners. Te7 which shows a slightly different result of 61.3% newcomer, 27.9% learners and 10.8% leaders while Te11 shows 65.8% newcomer, 27.9% learners and 6.3% leaders. This shows that there is not much decision making using artificial intelligence made for the respondent organisation.

The usage of resources at the facilities will ensure better maintenance/management of assets. This foundation must be ready for a smoother transition to IR4.0. Monitoring of Facilities is under the last grouping of Benchmarking of Readiness IR 4.0 for Dimension of Technology In AIM. Te4 and Te10 enquire about how do the respondent monitor and control the facility management system and how it is connected, communicated and controlled. Te4 has the highest mean of 0.694 under newcomer and most of the respondent are from the large companies with 34 frequency and the rest are 25 from small companies and 18 from medium size companies. Te10 has the result of 55.9% newcomer, 31.5% Learner and 13.5% Leader. This also shows that the level of readiness in terms of monitoring using the technology is limited and there is no connectivity and interaction between equipment and system. All are monitoring are done by human.

4.5.3 Reliability Test for IR 4.0 Readiness Assessment Dimension for Technology in AIM

Table 4.15 show the value readiness assessment dimension for technology in AIM was 0.881 collected from 13 items benchmarking readiness assessment. The value obtains showed that the level of internal consistency was preferable. Pallant (2011), mentioned in the previous research, that value between $0.9 > \alpha \geq 0.8$ is good.

Table 4.15: Cronbach’s Alpha for Readiness Assessment for Technology

Reliability Statistics	
Cronbach's Alpha	N of Items
.881	13

CHAPTER 5
5 DISCUSSIONS

5.1 Introduction

This chapter will discuss the findings from the data tabulated in Chapter 4. It will be explained from the multiple plots presented.

5.2 Cronbach alpha

In the questionnaire, 15 outcomes for the determination of readiness level respondents were prepared for them to provide their inputs. Cronbach's Alpha Test was carried out on the scale using the SPSS software. It was deduced that the coefficient alpha value is more than 0.80. Hence, this value is within the acceptable range of 0.70 to 1.00, which clearly states that the scale has a good internal consistency as stated by (Pallant, 2011).

5.3 People, Process and Technology Dimensions

Data populated in the table above presents the opinions of the respondents on what is the rating of the organisation for the pillars of technology and knowledge related to IR4.0. The Relative Importance Index (RII) is used to calculate the importance of the factors and to find out the ranking of the factors among them.

With 111 respondents answering the survey, it won't be conclusive without proper interview in understanding the exact condition of the inputs, however for this FYP activity, these responses shall provide the foundation for the understanding of knowledge intended.

5.3.1 People Readiness

Table 5.1: People Readiness Findings Summary

Dimensions	Average
Management ability to drive	1.119
Collaboration model	0.844
Development of strategy	0.587
Human capital management	1.211
Management knowledge	0.862

According to the findings it is evident that respondents are choosing indicator between L0 to L1. The readiness of management to adopt IR4.0 is very low with the mode is at L1 with the lowest being the development of strategic planning. It is accurate to sums up the weakness being a lack of planning at the management level with regards to a specific strategy of IR4.0 as a whole and this derives to specific obstacle of accepting within the focused area of AIM. Some steps are taken towards industry 4.0, such as but the people in the organisation is very early in the stage beginning.

5.3.2 Overall readiness for people.

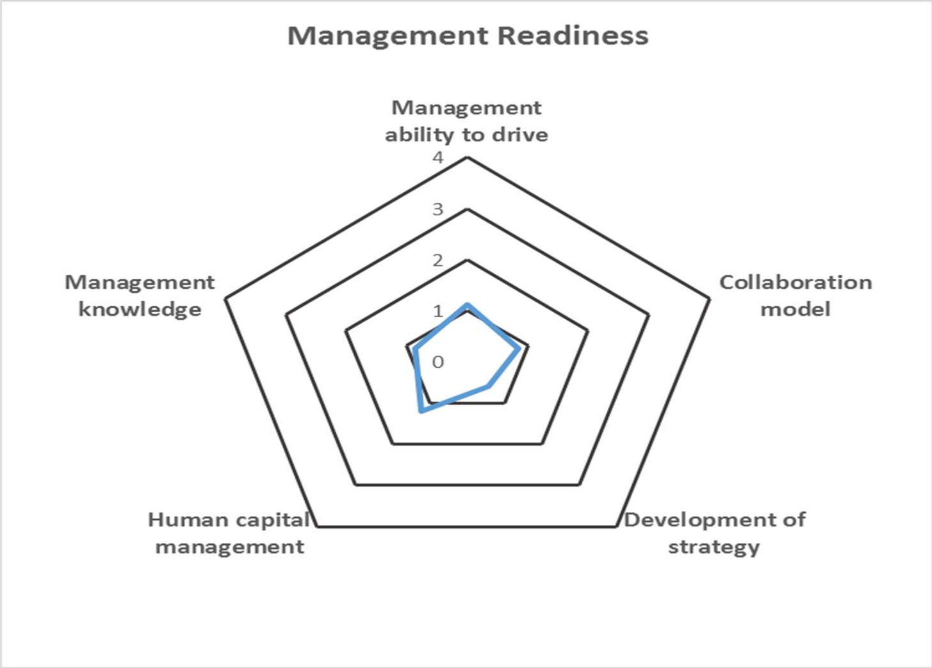

Figure 5.1: Spider Chart for Overall Readiness for People

As described in under 3.5 (Chapter 3), the benchmarking for readiness level which refer to IMPULS Readiness Level. The levels are divided into three groups consisting of newcomers (L0-L1), Learners (L2-L3) and Leader (L4) (Lichtblau et al, 2015) respective to the cumulative points. From the Figure 5.1 above, the average level of readiness for people is ranging from L0 and L1 which means mostly are newcomer.

5.3.3 Process Readiness

Table 5.2: Process Readiness Findings Summary

Dimensions	Average
Cyber-security implementation	0.678
Maintenance performance	1.146
Updating technology trends	0.954
Machine control	0.752
Asset Management automation	0.862

The next dimension of concern is the readiness in term of process. For cyber security protection, the average score is 0.67 and approaching L0 level of readiness. The other

3 scores are approaching L1 meanwhile maintenance performance is at the higher L1 level. Therefore, the overall mean for process readiness is at 0.88. Once again, coherent to the previous dimension, the respondents are generally a beginner in the transformation spectrum.

5.3.4 Analysis of overall readiness for process.

The average of process readiness level based on the responses can be seen in Figure 4.2 below. It is evident that the rating is at the lower range which means the average level of readiness for process is ranging from L0 and L1 and rate as a newcomer.

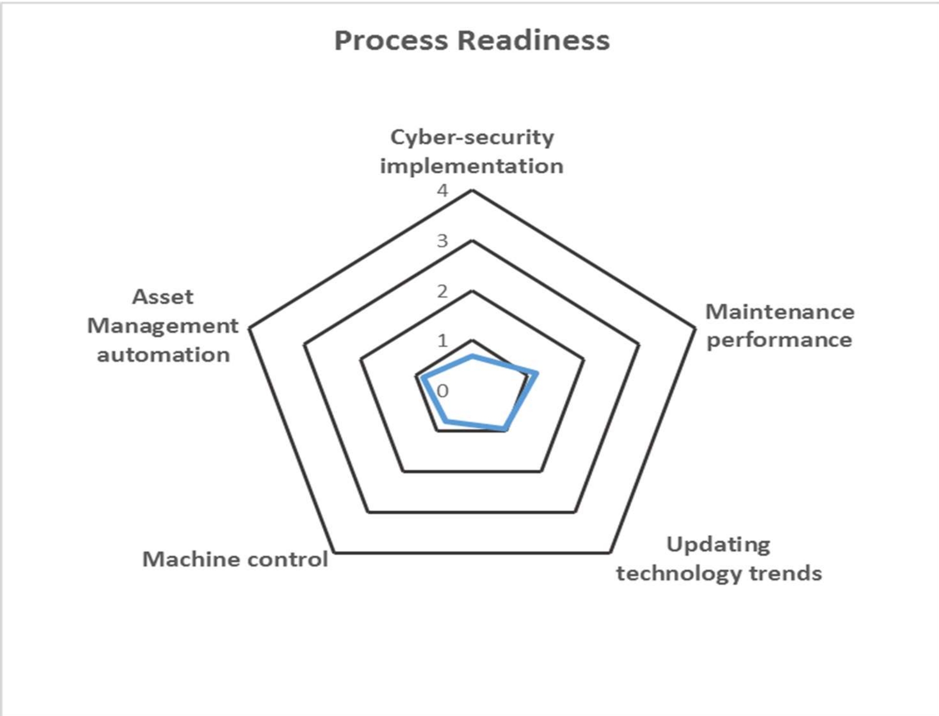

Figure 5.2: Spider Chart for Overall Readiness for Process

By referring to IMPULS Readiness Level as explained in chapter 3, the levels under process were divided into three group consisting of newcomers (L0-L1), Learners (L2-L3) and Leader (L4) (Lichtblau et al, 2015) respective to the cumulative points. Figure 5.2 above, the average level of readiness for process is ranging from L0 and L1 which means mostly are newcomer.

5.3.5 Technology Readiness

Table 5.3 show technology dimension results. Among all three, these dimensions yield a better rating overall. The lowest at 0.9 is the facility management technology which is approaching the absolute beginner classification. Mean rating for overall is nearly 1.80, a borderline L2 mode level. At L2 companies that have implemented Industry 4.0 to some extent into their technology set-up, some investments are being made, the infrastructure is to some extent using Industry 4.0, in-house sharing of information, there are competencies in the company.

Table 5.3: Technology Readiness Findings Summary

Dimensions	Average
Facility Management	0.954
ICT Infra	1.981
Connectivity	1.908
Artificial Intelligence	1.688
Monitoring of facilities	2.458

5.3.6 Overall Technology readiness rating

Finally, within this subsection, the overall readiness level can be observed in Figure 5.3 below.

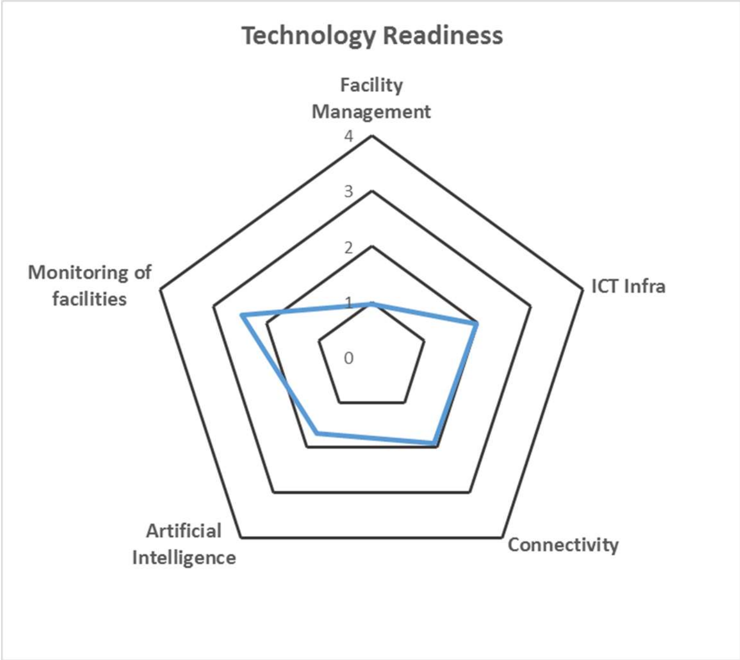

Figure 5.3: Spider Chart for Overall Readiness for Technology

Figure 5.3 show the spider chart for overall readiness for process by referring to IMPULS Readiness Level. Which the level readiness for technology were divided into three groups consisting of newcomers (L0-L1), Learners (L2-L3) and Leader (L4) (Lichtblau et al, 2015) respective to the cumulative points. From the chart it is show that the average level of readiness for people is ranging from L0 and L1 is the highest and most respondents were from newcomer group.

5.4 Summary

To recap Chapter 5, a total of 111 responses to the set of distributed questionnaires were analysed. Every question in the three sections of the questionnaire was thoroughly investigated. Frequency analysis was used to analyse the demographic of the respondents' background and projects' information. The reliability of the collected data was assured and confirmed with Cronbach's Alpha Test. The scales used in questionnaire were found to be statistically reliable as the alpha value, α of at least more than 0.7. The 2nd objective of this project which was to identify the readiness level, and the summary are given below.

Table 5.1: Overall Readiness Findings Summary

Dimension	Mean	Rating
People	0.924	L1
Process	0.878	L1
Technology	1.798	L2
Overall	1.200	L1

From the discussion and table 5.4 above, the study shows that the average level of readiness for people and process dimension is L1 with a mean of 0.924 and 0.878 respectively which means mostly are newcomer whilst for technology dimension the readiness level is L2 which indicate mostly are learners. Overall mean for the study above is 1.200 and it conclude that most of the respondent in the research are newcomers to the Industry 4.0 transformation within Asset Integrity Management.

6 CHAPTER 6
RECOMMENDATIONS AND CONCLUSIONS

6.1 Introduction

Chapter 6 is to conclude the findings from the questionnaire survey that was used for this research. It was beneficial and useful to understand the level of readiness for AIM in facility management nationwide. The stakeholders play a major role in this part to encourage feasible transformation to improve the existing asset integrity management system.

6.2 Conclusion

The primary objective of this project was to propose a measure of determining the true readiness of Malaysian Building Management entities in implementing the IR4.0 technology in managing facilities of building in the country. The 2 objectives of the research were defined the identification of the benchmarking methodology for the IR4.0 readiness level within asset integrity management and to obtain a preliminary result on gauging the IR4.0 transformation readiness of AIM within Malaysian building maintenance stakeholders.

Throughout this project, the readiness assessment model of manufacturing sector provided by Ministry of International Trade and Industry (MITI) through the national policy of IR4.0 were adopted by some modifications made to suit the implementation in building maintenance scenario. A set of rating were established and discussed in the methodology chapter, with level of readiness established i.e. L0, L1, L2, L3 and L4 in its ascending hierarchy of readiness.

A survey was conducted with the goal of having at least 100 respondents of which the final number of responses obtained for the survey is 111. Database of BOEVA, the building owner association of Malaysia was chosen as the channel for such survey. After a window of 3 weeks, the analysis was done to the acquired data using all the necessary tools. The results were evident in chapter 4, with underlying analysis of both qualitative and quantitative data.

In chapter 5, the report discussed findings of the survey thoroughly for all 3 dimensions identified, people, process and technology. It was found that the outcome is worrying for the first two dimensions, as the rating is on the lower side of L1(beginner). Although in the dimension of technology the rating is approaching L2(intermediate), it is a dimension that grows with general technology improvement globally and therefore it could not be directly related to the internal process itself.

IR4.0 is a revolution that encompass the entire spectrum of humanity and it is a revolution that one might not be able to have option rather that riding it. It is crucial to use the knowledge that we have gained throughout this project exercise in planning for a better future.

6.3 Limitations of Research

Time constraint was the primary limitation of this research. Convenience sampling of non-probability technique was adopted for this study due to the limited time frame. Due to time constraint, the data obtained was from respondents involved in projects across Malaysia only and was more focused towards Klang Valley.

Data for the entire Malaysia projects was unable to be obtained and the data obtained through the questionnaire survey hardly represents all the projects being carried out in Malaysia. As it is, the element of validating the respondent's credibility is limited due to the limited channel of communication. Therefore, the findings in Chapter 4 may not represent the overall Malaysian building management society, its implications towards the true readiness could have been compensated.

6.4 Implications of Research

From this research, although preliminary, it was able to identify the baseline rating of readiness to embrace IR4.0 for the building management sector and asset integrity management. By enforcing better policies based on best improvement would be guaranteed. Therefore, this research promotes the use of benchmarking tool for the determination of baseline level of readiness.

6.5 Recommendations

Urbanization exponential over the last decade have reach its maturity and currently at its maintenance level. Understanding the ground zero for the transformation must be made in order to plan for the seamless leap to desired IR4.0 level. Therefore, the AIM stakeholders are in need for the right tools of assessment through the understanding of IR4.0 technology.

From the companies' perspective, it is best if the company involving in AIM takes the preparation seriously to reduce the burden transformation cost. The best way is to enforce sustainable policies of IR4.0 so that the entire company works towards the similar goal. The company has to take charge and to guide its employees to better the plaining. Companies can also provide training to employee's and to get everyone on board maybe companies could introduce an incentive measure or an appreciation for employees that adhere best to the IR4.0 policies.

From the policy maker's perspective, should be a systematic way of identifying the current gap of knowledge within the building management sector and organise awareness activities to reduce the timing on this learning curve.

6.6 Recommendation for Future Work

The changes of the building management industry will be very rapid however the guidance will always be coming from first world nation. World moves towards IR4.0 every single day, and if these changes are not being address locally, we as a nation will be left behind. Implications will always look from a negative perspective and not a positive one. It will be too late if we were to look at the impact few years from now.

Therefore, the limited study discussed within this short-term project reports should be expanded. It shall cover the entire horizontals within the construction vertical in making sure that building maintenance will not remain to be the conservative process perceived by many other technology players.

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