Deployment Maintenance Strategy for the Development of Maintenance Personnel in Irish and Malaysian Automated Manufacturing Industries

By

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DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Abstract

In order to ensure that a manufacturing company is able to achieve the optimum productivity and equipment reliability, an effective maintenance system must be implemented. However it is very important to realize that the maintenance employee involvement is a critical factor in the maintenance implementation stage. An effective maintenance requires an understanding of the link between the maintenance and maintenance employee involvement. As such, there is a need for empirical research on the deployment strategy for the development of maintenance personnel incorporated within the company's maintenance strategy.

This study is a research programme based on the Irish and Malaysian automated manufacturing industries. The primary objective of this research is to formulate the maintenance strategy which leads to the deployment strategy for the development of maintenance personnel in Malaysian automated manufacturing companies. In order to achieve this primary objective, it is necessary to understand the current maintenance practice in manufacturing industries and to establish the extent to which Irish and also Malaysian companies invest in developing its maintenance teams through employee development. It involved carrying out a postal-survey questionnaire which examined and analyzed the maintenance implementation and the nature of problems and difficulties faced by the maintenance personnel in performing their tasks and activities. A comparative study has also been carried out between both countries, as well as the correlation between variables measured which relate to the performance of the company.

The key findings are as follow: the commitment of top management plays very important role in the implementation of maintenance strategy; most of the problems encountered in maintaining the automated system are closely related to the human aspects, i.e. maintenance personnel; higher the utilization of proactive and aggressive maintenance, better the improvement of equipment availability that could be expected; by conducting an appropriate and good training implementation, a better improvement of equipment availability could be achieved; in Malaysia, there is higher improvement of equipment availability in the company which uses in-house maintenance.

Based on the theoretical understanding of current research in the literature and the results of empirical data found in this study, the author proposes a deployment strategy for the development of maintenance personnel to be incorporated within the company's maintenance strategy in Malaysia, from the maintenance employee perspective and participation for self reliance and improved reliability and performance.

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LIST OF ABBREVIATIONS

AMS	Automated Manufacturing System
BPR	Business Process Re-engineering
BS	British Standard
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Production Planning
CIM	Computer Integrated Manufacturing
CMMS	Computerized Maintenance Management System
CMW	Control Maintenance Workstation
CNC	Computer Numerical Controller
DBMS	Database Management System
D-IAL	Diagnosis Intelligent Automation Language
DNC	Digital Numerical Controller
DCS	Distributed Control System
ED	Employee Development
EPRI	Electrical Power Research Institute
EU	European Union
FAA	Federal Aviation Administration
FDI	Foreign Direct Investment
FMEA	Failure Mode Effects Analysis
FMECA	Failure Mode Effects and Criticality Analysis
FMM	The Federation of Malaysian Manufactures
FMS	Flexible Manufacturing System
FPA	Flexible Production Automation
FTA	Fault Tree Analysis
GDP	Gross Domestic Product
HRM	Human Resource Management
IBEC	Irish Business and Employers Confederation

IMD	Institute of Management Development
ISO	International Standard Organization
JIT	Just In Time
LAN	Local Area Network
MARA	Majlis Amanah Rakyat (Malaysia)
MRP	Material Requirement Procedure
MTBF	Mean Time Before Failure
MTTR	Mean Time To Repair
NC	Numerical Control
NCC	National Competitive Council
OEE	Overall Equipment Effectiveness
OECD	Organization for Economic Co-Operation and Development
OM	Operation Management
OPT	Optimized Production Technology
PDM	Predictive Maintenance
PLC	Programmable Logic Controller
PM	Preventive Maintenance
POM	Production Operation Management
QC	Quality Control
RCM	Reliability Centered Maintenance
R&D	Research and Development
SADT	System Analysis Design Technique
SFC	Shop Floor Control
SME	Small and Medium Enterprise
TNA	Training Need Analysis
TPM	Total Productive Maintenance
TQC	Total Quality Control

Chapter 1

INTRODUCTION

1.0. Introduction

The main objective of this chapter is to introduce the research topic area and explain the aims of the work, which is based on a study of Irish and Malaysian automated manufacturing industries.

A general introduction to the background of the research addressed in this study is followed by an explanation of the research questions and aims of the research. An explanation on why Irish and Malaysian manufacturing industries are selected as a comparison study is also presented. To this end, this chapter describes the research approach used in this study and the link between theory and practice. An outline of the significance and contribution of this study is then provided, followed by the outline structure of the thesis.

1.1. Background to the Research

The genesis of this research lies indirectly with the author's professional experience as a lecturer in a Malaysian University. As a lecturer in maintenance management and other engineering subjects, he has the opportunities to meet the industrial personnel, especially from the engineering and maintenance department. From various meetings and discussions, the most frequent issue that has been highlighted was the problem of developing competent maintenance personnel so that they are able to perform their maintenance tasks. This issue can be translated into a generic question: "*How to develop maintenance personnel so that they are able to perform their maintenance tasks involving highly complex and sophisticated equipment in the automated manufacturing environment*". This anomaly sets the scene for the research presented in the thesis.

Manufacturing systems are considered essential by most nations for creation and propagation of wealth, and for improving standard of living of people. As the global competition has increased significantly, the ability to compete is vital for contemporary manufacturing in all aspects of product manufacture. With the competition increasing from the market, demands on products with higher quality, faster delivery and competitive prices have led to the development of manufacturing system combining automation, integration and flexibility.

However, in order to ensure that the company is able to achieve the optimum productivity and equipment reliability, an effective maintenance system must be implemented. Indeed, the maintenance function plays a critical role in a company's ability to compete on the basis of cost, quality and delivery performance [1].

It is very important to realize that maintenance adds value to the finished products, that it is a contributor to a reliable production capacity, and that it should be used to achieve business goals. Maintenance must operate in a proactive mode to become more valuable to the profitability of the plant.

An effective maintenance requires an understanding of the link between the maintenance function and maintenance employee involvement. Unfortunately, human issues, including the aspects of maintenance employee involvement have not typically been examined rigorously as often as technical issues. As such, this study has an objective to examine the aspect of human i.e. maintenance personnel, so that it can provide answers to the generic question as mentioned above.

1.2. The Importance of Maintenance

Over a period of time, there have been a significant developments in the field of manufacturing and maintenance. These developments are in the areas of technology, concepts, methodologies, and philosophies. Some examples of direct influence of the developments are advanced manufacturing technologies (AMT), Just in Time (JIT) and Total Productive Maintenance (TPM) [2].

In response to market pressure, many companies are striving for lower costs, higher quality and improvement in logistical performance. Concepts such as Just-In-Time (JIT), Optimized Production Technology (OPT), Total Quality Control (TQC) and Flexible Production Automation (FPA), have one thing in common, namely that the availability of the production lines is a critical success factor. To that end, the effectiveness of maintenance needs to be increased [3].

The evolution of automation technology has made it possible for factories to employ automated manufacturing systems to successfully adapt to dynamic changes in product and process designs [4]. A highly integrated automated manufacturing system is a combination of very complex machinery integrated with an equally complex computer system. Each machine is a combination of many sub-assemblies, where each sub-assembly is itself complex and consists of many dissimilar interdependent components.

However, in order to ensure that the targeted service level is achieved and to minimize the cost of lost productivity, efficient, effective and systematic maintenance system must be installed and implemented.

In relation to the maintenance aspects, traditional maintenance policies deal with stand-alone machinery comprised of mechanically similar components with similar failure distributions. However automated manufacturing system maintenance policies must deal with a complex system comprised of many dissimilar components. A typical system will not only have mechanical components, but also electronic, hydraulic, electro-mechanical, software, and human elements, each having different failure rate distributions. In this respect, maintenance strategy for automated manufacturing system must focus on understanding the entire system instead of individual units or components because of the integrated nature of the units. Without a doubt, these more complex devices and systems seem to require much greater levels of technical support than previously [1]. The details of maintenance aspects in automated manufacturing environment for the context of this study will be elaborated further in section 2.3 (chapter two).

Pintelon et al [5] stated that a few decades ago, the maintenance function was regarded as an unavoidable part of the production function and difficult to manage. This view has only changed gradually and maintenance became a separate, fully recognized and essential business function. According to Aigner et al [6], it was illustrated that ever more complex automation is leading to large changes in the scope and tasks of plant maintenance work. The qualifications of the personnel and the organization and techniques have to be suitably adapted.

In order to accomplish these tasks, it requires special attention to the career development of automation professionals, more leverage of existing automated facilities and partners, and development of best practices in delivery and maintenance [7].

1.3. Human Resource and Role of Maintenance Employee

In relation to this aspect, studies that had been carried out by Power and Sohal [8] in the manufacturing environment indicated that the ability to tap into and maximize the human potential of the organization will be a major determinant of success.

McLachlin [9] found that employee involvement was a critical factor in the implementation stage and that promotion of employee responsibility, provision of training, promotion of teamwork and demonstration of visible commitment were "necessary conditions". Furthermore it was also found that the overall job satisfaction and organizational commitment were significantly associated with prior participation in required training courses and work-based development activity [10]. In relation to the relationship between business and maintenance strategies, an investigation conducted by Pinjala and Pintelon [2] concluded that human resource is considered as one of the decision elements in maintenance strategy.

The evaluation of advanced manufacturing technology has change the nature of maintenance function [11]. Maintenance personnel in the automated system have a major responsibility they perhaps did not previously possess in a traditional facility. In their new role, they must have a thorough understanding of the functional design of the computerized automated equipment system and how information flows in and out. They must be competent in the hardware involved with the automated systems, as well as possess an understanding of the associated computerized control systems. In other words, the skills of maintenance personnel will determine the effectiveness and the efficiency of the functionality of maintenance department. Therefore, a comprehensive employee development through on-going training programme for the maintenance personnel is a basic ingredient for success in supporting system automation. This issue concerning human resource and maintenance personnel involvement will be elaborated further in section 2.2 and 2.5 (chapter two).

1.4. Research Questions

The research questions are used as a starting point for analysis [12][13]. In general, these questions are developed in order to address the issue raised from the research objectives in the following section 1.5. As a result of the generic question stated at the beginning of this chapter, more specific research questions have evolved as stated below:

1. What are the linkages between the level of production technology used and the maintenance system implemented in the automated manufacturing company?

2. What are the maintenance problems and obstacles faced by the maintenance department in carrying out their function?

3. What are the maintenance approaches used in terms of maintenance types, tools and strategies employed by the maintenance department in carrying out their function?

4. What are the decision elements or dimension to be considered in formulating the maintenance strategy in order to improve and enhance the maintenance function?

5. How important is the human factor (i.e. maintenance employee involvement) and how does it affects the overall performance of maintenance function?

6. What is the deployment strategy to be used in the development of maintenance personnel?

7. Are there any commons (and/or differences) between Ireland and Malaysia in terms of trends of production technology and maintenance practice in their automated manufacturing industries?

In the context of this study, seven hypotheses are formulated, for the purpose of offering a clear framework and direction to this research, as well as to guide when collecting, analyzing and interpreting the data [14]. The seven hypotheses that will be presented in chapter two will examine in detail the issues involved.

1.5. Aims of the Research

The primary objective of this research is to formulate the maintenance strategy which leads to the deployment strategies for the development of maintenance personnel in Malaysian automated manufacturing companies. This will be based on the theoretical understanding of current research in the literature and the result of empirical data found in this study.

In order to achieve this primary objective, it is necessary to understand the current maintenance practice in manufacturing industries and to establish the extent to which Irish and also Malaysian automated manufacturing companies invest in developing its maintenance teams through employee development. Hence, the research objectives will be addressed using findings from both countries.

The followings are the specific research objectives which correspond to the research questions:

- To discuss the relevance of the research topic by achieving a theoretical understanding of current research on maintenance and maintenance personnel issues, which leads to identifying the potential gaps in the literature.

- To examine and analyze the maintenance implementation, as well as the level of automation applied in the automated manufacturing companies. This study will also examine the relationship between automation complexity, maintenance organization and practice, maintenance personnel competencies and maintenance training programme, which relate to the performance of equipment reliability.

- To examine and analyze the issues of human factor (i.e. maintenance personnel) in performing their tasks and duties. The effects of maintenance employee involvement in determining the overall performance of maintenance function will also be examined.

- To carry out a comparative study in order to analyze the common as well as the differences between the practices in both countries in the aspect of maintenance of the automated manufacturing industry. Malaysia as a developing industrialized country could learn and emulate the good practice in the Irish manufacturing industries as Ireland has gone through the experience in terms of sustained rapid growth of economic development over a longer period of time which is more than forty years.

To this end, a comprehensive literature review will be conducted and feedback will be solicited through an appropriately designed research instrument to establish the current practice of maintenance in both countries and finalised the detailed objective of this study. This should assist to formulate the maintenance strategy which leads to the deployment strategies for the development of maintenance personnel in Malaysian automated manufacturing companies incorporated within the company's maintenance strategy. The improvement of equipment reliability and performance could be expected due to the high competent and self reliant maintenance personnel. This will be dealt thoroughly in chapter four and five.

1.6. Comparison between Irish and Malaysian Manufacturing Environment

In Production Operation Management (POM) literature, there are quite a number of cross-country or country comparison studies that had been conducted. For instance, Zanakis et al [15] have listed a number of studies that had attempted to compare the relative competitiveness of countries for a specific industry.

In general, cross-country studies have a specific aim. As Sundqvist et al [16] put it: "Factors explaining cross-country may be grouped into three: country effect (wealth, trade, mobility and cosmopolitanism), cultural effect (cultural indices) and time effect (lead-lag)".

To give some examples, Calantone et al [17] studied in three-country comparison: the United States, Korea, and Japan, on the basis of cultural and economic differences. Wunder [18] studied five-country comparison between Gabon, Cameroon, Papua New Guinea (PNG), Venezuela, and Ecuador, based on the background of middle-income countries with strongly expanding domestic markets. Based on the differences between two industrialised countries and one developing country, Bruek et al [19] studied three-country comparison between Nicaragua, Ireland and the Netherlands. Another example, Hobday et all [20] studied cross country comparison on governance of technology in the electronics industries of East and South-East Asia.

Regarding the country comparative analysis in this study, two countries were chosen: an industrialized country, Ireland and a developing industrialized country, Malaysia. One of the resemblances, apart from the many differences between Ireland and Malaysia, is in their relentless effort to diversify and transform their respective economies from a traditionally agricultural-based to an industrial economy. Both had faced persistent problems in the transfer of technology programmes from large foreign-based companies [21] [22].

With a relatively small domestic market, both countries have traditionally agriculture-based economy. The government of both countries had been playing major roles in diversifying and changing their agriculture-based to industrial-based economy. In short, the government is intensifying effort through financial, research institutions, and technology support to welcome all the technology change and evolution into the manufacturing industry. Both countries have enjoyed consistently rapid growth in their Growth Domestic Product (GDP) and incoming foreign investment in technology and manufacturing industry.

The choice of countries was based on two comparative elements: first, both countries have consistent rapid growth in their GDP, and second, through foreign investment, both countries have similar products and process technologies, as much as possible, a similar pattern of production.

Thus, this comparative study will contribute to analyze the common as well as the differences between both countries in the aspect of maintenance of the automated manufacturing industry. Furthermore, Malaysia as a developing industrialized country could learn and emulate the good practice in the Irish manufacturing industries as Ireland has become the main European centre for the high-technology sectors of manufacturing and has achieved a global status as a highly successful business environment and centre of excellence for manufacturing [23]. From the technological innovation and achievement perspective, the report provided by The United Nation Human Development [24] stated that Ireland and Malaysia falls under category of '*technology leader*' and '*potential leader of technology*' respectively (*refer to appendix F*). The information about Irish and Malaysian manufacturing industry perspective in terms of industry evolution and economic growth will be provided in section 2.6 (chapter two).

1.7. Research approach used in this study

According to Selltiz et al [25], the purpose of research is to discover answers to questions through the application of scientific procedures. These procedures have been developed in order to increase the likelihood that the information gathered will be relevant to the question asked and will be reliable and unbiased.

A research is an activity that is difficult to define as it encompasses many areas including beliefs, choices, aspects and dimensions. Wolcott [26] believed that research should be thought about as "problem setting rather than problem solving". This is a reasonable argument as so much of a research's efforts have to go into designing the research hypothesis, proposition, outlines and methods of data collection before even one piece of field work takes place.

The meaning of research is also important to be examined. Preece [27] for instant placed a particular emphasis on academic research and believes that: "Such research is conducted within a system of knowledge or understanding, but it should always be probing or testing that system. It aims towards increasing a common heritage or knowledge, though sometimes it will fail. The increase of knowledge maybe something entirely new or original or, more commonly, it may consist of checking, testing, expanding and refining ideas which are themselves still provisional. In particular, a research should continually question the nature of knowledge itself, what it is and how it is known".

Creswell [28] however, supplied a more pragmatic view and states that the definition of a research study is "one that advances a research question and reports data to answer the question". The most important issue here is the development of the research questions or the description of research objectives, as without a concrete set of propositions to examine, any study undertaken will lack a coherent focus.

Thus, the research hypotheses guiding this study are developed in chapter two. In chapter three, an overview of research in general and a description of research philosophies is elaborated further, as it is an integral part of any research work. This is followed by explicit description and presentation of the research methodology chosen.

According to Flynn et al [29] who have written on empirical research methods in operations management, "theory provides the foundation for all scientific research". They also believed that there are two ways in which the theoretical foundation can be established, and they are by 'theory verification' or 'theory building'.

Theory verification is the approach used where the focus is on testing the hypotheses rather than analysing its origin. Using this approach the hypotheses are constructed before the research starts and then tested when the data are obtained. On the other hand, *theory building* studies, use information in different ways and the starting point is based on propositions, assumptions or problems rather than definite hypotheses. Information is collected in order to define the propositions, and thus they are grounded in data even before the actual theory building begins [29].

This study utilizes the theory verification approach, as the research hypotheses were set down following literature review. The information collected during this research period was used to clearly define the research hypotheses and address the issue raised from the research objectives in section 1.5, in order to answer the research questions. The research hypotheses developed and presented in chapter two will examine and evaluate in detail the issues involved.

Adams and Schvaneveldt [30] provided another way of looking at the research process. They believe that "research in any field seeks to generate new information or knowledge that, in turn, can be applied to solve problems, improve the quality of life and provide a better understanding of conditions in a field". This means that the results of a well conducted study can provide useful information for both academics and practitioners and build on the work that has already been carried out.

This is a pertinent point, since one of the objectives of this research is to try and forge a link between theory and practice. The aim here is to provide useful information and guidance for the maintenance department as far as Irish and Malaysian manufacturing industries are concerned.

This aim is shared by Lawler et al [31], who stated that there are two standards that any research project must meet: "the project must help practitioners understand organizations in a way that will improve practice, and it must contribute to a theoretically and scientifically useful body of knowledge about organizations".

In line with this, a proposed solution is expected as the outcome of this study to contribute and solve the issues that have been presented in the aim of this study. This will be presented in chapter five.

1.8. Significance and contribution of this study

There has been little or no substantial research carried out in Ireland and Malaysia in the aspect of maintenance in the automated manufacturing environment. This is therefore important as it addresses the need for this kind of research in the Irish and Malaysian context.

In general, there are four main areas where the work presented in this thesis provides a significant addition to knowledge in the following manner:

1. The literature review addresses the gaps in the maintenance and related operation management literature, focusing in the aspects of human resource and maintenance personnel development.

2. The study investigates possible linkages between production technology, maintenance and maintenance personnel in the automated manufacturing environment.

3. The study examines and carries out a comparative study on the aspects of maintenance implementation between Irish and Malaysian automated manufacturing companies. Since there has been little or no research carried out (in a large scale in terms of number of participants), the work presented here fills a large gap in the Irish and Malaysian contexts. These are up-to-date information to the body of knowledge and can provide new insight to current situation and guideline for the maintenance department as far as Malaysian and Irish automated manufacturing industries are concerned.

4. The study offers a proposed solution in providing a deployment strategy for the development of maintenance personnel incorporated within the company's maintenance strategy in the Irish and Malaysian contexts.

1.9. Structure of the Thesis

The structure of the thesis is outlined as follows:

■ Chapter 1 – Introduction

Chapter 1 introduces the research topic area and explains the aims of the work. A general introduction to the background to the research addressed in this study is followed by an explanation of the research questions and aims of the research. An explanation on why Irish and Malaysian manufacturing industries are selected as a comparison study is also presented. This chapter also describes the research approach used in this study and the link between theory and practice.

■ Chapter 2 – Literature Review

Chapter 2 presents a review of existing literature on the subjects in accordance to the aims of this research that have been outlined in the previous chapter. A critical evaluation of the maintenance literature and other related area is undertaken to determine the research works that had been done, as well as to identify gaps in the literature that will provide the framework for this research study and direction for the empirical research. This literature review chapter is divided into five sections with the specific purposes. In the context of this study, seven hypotheses are formulated, for the purpose of offering a clear framework and direction to this research, as well as to guide when collecting, analyzing and interpreting the data.

■ Chapter 3 – Research Methodology

Chapter 3 provides an overview of research methodologies and justification for the selection of appropriate methodologies used in this study to address the objectives of the research. The chapter starts with an overview of research in general and a description of research philosophies and certain terms related to the research methodology. The chapter then presents the research methodology chosen i.e. questionnaire survey research, in elaborating the survey questionnaire design and process, as well as the statistical analytical tools and tests used in this study.

■ Chapter 4 – Results and Discussions

Chapter 4 presents the results of the research survey carried out. It reports the survey findings on the current level of automation and maintenance practices in the Irish and Malaysian automated manufacturing companies. The results of seven hypotheses testing are then provided. In the second section, discussions take place that further demonstrates critical thought and evaluation of the empirical findings gathered from the survey.

- Chapter 5 – Proposed Deployment Strategy

As a proposed solution to the research questions, chapter 5 outlines the proposed deployment strategy for the development of maintenance personnel incorporated within the company's maintenance strategy in Malaysian automated manufacturing companies.

- Chapter 6 – Conclusion

Chapter 6 summarizes the principal findings of the research followed by the thesis contribution and the recommendations for future work.

1.10. Chapter Summary

This chapter introduced the research topic area and explained the aims of the work. It provided general introduction to the background of the research addressed in this study. The introduction was followed by an explanation of the research questions and aims of the research. A brief introduction on the importance in ensuring the equipment reliability in the manufacturing industries was presented and followed by the explanation of role of maintenance employee as an important factor in determining the effectiveness and the efficiency of the maintenance function. An explanation on why the Irish and Malaysian manufacturing industries were selected as a comparison study was also presented. This chapter also described the research approach used in this study and the link between theory and practice.

Chapter 2

LITERATURE REVIEW

2.0. Introduction

The reviewing of existing literature relating to the topic is an essential first step and foundation when undertaking a research project [32]. According to Jancowics [33], "literature review is a critical search for an analytical framework, or frameworks, which you can put to work to test a hypothesis (if adopting a positivist approach), or proposition, or to systematically investigate a set of issues".

By contrast with the amount of advice available on the subject of writing a research proposal, much more has been written about the task of writing a literature review. According to Hart [34], the author of "Doing a literature review", the literature review has at least the following purposes in research: distinguishing what has been done from what needs to be done; discovering important variables relevant to the topics; synthesising and gaining a new perspective; identifying relationships between ideas and practice; establishing the context of the topic or problem; rationalising the significance of the problem; enhancing and acquiring the subject vocabulary; understanding the structure of the subject; relating ideas and theory to applications; identifying of the main methodologies and research techniques that have been used; and placing the research in a historical context to show familiarity with state the art developments."

2.1. Purposes of Literature Review

In line with the purposes of literature review that has been mentioned above, this chapter presents a review of existing literature in developing the theoretical understanding on the following topics with the specific purposes, in accordance to the aims of this research that has been outlined in the previous chapter: Human factors in manufacturing environment; Maintenance strategy in the automated manufacturing environment; Current trend of maintenance practice; Human resource and employee development in maintenance; and Irish and Malaysian manufacturing perspective. A critical evaluation of the maintenance literature and other related area is undertaken to determine the research works that had been done, as well as to identify gaps in the literature that will provide direction for the empirical research. In the context of this study, seven hypotheses are formulated, for the purpose of offering a clear framework and direction to this research, as well as to guide when collecting, analyzing and interpreting the data.

This literature review chapter is divided into five sections with the specific purposes:

a) Human factors in manufacturing environment

The issue of human factors in manufacturing and maintenance environment is firstly introduced in this section. As the main objective of this research is very much related to human aspects, i.e. the development of maintenance personnel in automated manufacturing environment, this section reviews the importance of human factors and employee involvement, including the issue of employee resistance to technology change in manufacturing and maintenance contexts. The literature also discusses the existing research that had been carried out which leads to the identification of the gap of knowledge in the human factors. Consequently, the first hypothesis concerning the human factors in relation to the maintenance function (*H1*) is formulated in this section.

b) Maintenance strategy in the automated manufacturing environment

This section discusses the link of maintenance from the context of operation management which explores the relationship between organisation strategies within the context of the implementation of maintenance practices. In this section, the concept of maintenance is presented. It presents the role and other relevant issues in maintenance related to manufacturing industry, and examines the challenges, top management commitment, technology complexity as well as the relationship between maintenance and production technology in the context of automated manufacturing environment. In this section, two hypotheses in relation to the role of top management (*H2*) and production technology used (*H3*) are then formulated.

c) Current trend of maintenance practice

This section presents the literature of maintenance practices in the automated manufacturing industry, which will be used in examining and understanding the current trend of maintenance practice in both countries. This information will be used as a guideline in establishing the questionnaire content in the aspect of maintenance practice. Two inter-related hypotheses in relation to the maintenance practice (*H4-i, H4-ii and H4-iii*) and maintenance outsourcing (*H5*) are then formulated in this section.

d) Human resource and employee development in maintenance

This section presents the issue of human resource and employee development for maintenance personnel, as a continuation from the issue of human factors and employee involvement in the previous section. Two inter-related hypothesis in relation to the maintenance employee development (*H6-i and H6- ii*) are then formulated in this section.

e) Irish and Malaysian manufacturing perspective

This section presents information about Irish and Malaysian manufacturing industry perspective in terms of industry evolution and economic growth. The information discusses in this section will be useful in conducting the comparative study between both countries which analyze the common as well as the differences between both countries in the aspect of maintenance in the automated manufacturing industry. The last hypothesis in relation to the Irish and Malaysian maintenance practice trend (*H7*) is then formulated in this section.

2.2. Human factor in manufacturing environment

In this section the issue of human factors in manufacturing environment is presented to provide a context for the later discussions. This is a continuation from the chapter one, as the main objective of this research is very much related to human aspects, i.e. the development of maintenance personnel in automated manufacturing environment. It reviews the importance of human factors and employee involvement, including the issues of employee resistance to technology change in manufacturing and maintenance contexts. The first hypothesis concerning the human factors in relation to the maintenance function (*H1*) is formulated in this section.

When discussing about human aspects, it is important to differentiate between human factors and the actions that influences them. Kelly [35] defined "human factors" as the characteristics, which defines the way in which an individual, or group behaves or acts in an industrial setting. He categorised these factors into two: those that can affect individual behaviour (i.e. motivation, goodwill, equipment ownership, morale, resentment, protectionism and parochialism) and those that can affect the behaviour of industrial grouping of people (i.e. culture, esprit de corps, horizontal and vertical polarization).

2.2.1. Technical versus human issues

In modern manufacturing, automated equipment and computer applications are increasingly sharing the work environment with humans [36]. Functions routinely performed by humans in the past are now assigned to machines. It is important that for the successful manufacturing implementation, one focuses both on technical issues (cell formation and design) and human issues. Unfortunately, human issues have not typically been examined as rigorously as often as technical issues. A cursory study of published articles shows that while cellular manufacturing is a popular research area, there is a singular absence of articles that deal with the human element in cellular manufacturing [37].

In general, it is necessary to understand the four basic components of manufacturing cells: people, equipment, operating rules, and material [38]. Of these four components, Bidanda et al [38] noted the primary variable that is most difficult to control is people or the human element. In the integration of these four components, it is essential to focus both on technical issues (cell formation and design) and human issues since each can greatly affect the design, implementation and operation of cells.

In addition to this, Bidanda et al [37] stated that consideration of technical issues alone cannot guarantee that an organization can develop and implement an optimal cell manufacturing design. Furthermore, they found that for successful implementation of cells, people who will eventually operate, manage, support and maintain the manufacturing cells should actively participate in their design and development [38].

Hopkins [39] also shared this observation and added that "it is a common practice for companies to focus on the technical issues at the outset of a cellular manufacturing project implementation and to overlook the human resource preparation". It is not surprising therefore that most research on manufacturing also tends to be focused on the technical rather than the human aspects. This observation has earlier been made by Huber and Brown [40] who suggested that empirical research is needed to investigate the impact of sociological variables on implementation of advanced manufacturing technology.

In relation to the issue of lacking of human element in research, maintenance is no exception to this. For example, Wei Zeng [41] presented a case study of robotics car assembly line on maintenance strategy, policy and corresponding maintenance system. He stated that it is technically possible and economically necessary to maintain the manufacturing system in a preventive and predictive way by development of maintenance system, with the trend towards automation integration and openness. However, despite of admitting the high involvement of human in maintenance activity, there is no significant discussion or suggestion been done in relation to the maintenance employee aspects.

2.2.2. The importance of human factors and employee involvement

Human factor plays an important role and contributes toward the success of technology implementation in manufacturing industries. Power and Sohall [8] examined current human resource management practice in three Australian companies that have been operating the JIT methodology for some years. The cases focus on practice in the areas of levels of participation, multi-skilled and flexibility, communication, employee development programs, teams, and empowerment. The research indicates that the ability to tap into and maximize the human potential of the organization will be a major determinant of the success.

In relation to this, McLachlin [9] found that employee involvement was a critical factor in the implementation of JIT and that promotion of employee responsibility, provision of training, promotion of teamwork and demonstration of visible commitment were "necessary conditions for both JIT flow and quality".

Bidanda et al [37] completed a comprehensive evaluation of relevant human issues that are applicable to cellular manufacturing and the general area of technology implementation by studying the existing literatures. Results from this review of the literature identify eight broad areas of human issues: worker assignment strategies, skill identification, training, communication, autonomy, reward or compensation system, teamwork and conflict management. Followed by the review, a survey was conducted to determine the importance of human issues in manufacturing. The overall survey results showed that the three major human issues in manufacturing are communication, teamwork and training. It has been shown that to make an impact on the shop floor, all stakeholders (especially the shop floor worker) must be considered and involved both in the design and implementation process

In the aspect of job satisfaction, Birdi et al [10] conducted a study of four different types of development activity in a sample of manufacturing employees. They found that the overall job satisfaction and organizational commitment were significantly associated with prior participation in required training courses and work-based development activity.

Vineyard et al [42] who studied on the machine failure and maintenance decisions in advanced manufacturing technology environment reported that there are six types of failure identified and categorized them as mechanical, electrical, electronic, hydraulic, human and software. Interestingly, the result of this study revealed that human failures accounted for 40% of all the failures, more than any other failure type. This is followed by software (19%), electrical (16%), mechanical (13%), hydraulic (8%) and electronic (5%). Because many failures result in mechanical damage, there is a tendency for software and particularly human failures to be blamed on the damaged mechanical components. It was noted as well in the study that several of the failures in this human failures category were caused by maintenance personnel while performing unrelated maintenance tasks [42].

Another study on implementation of advanced manufacturing technology conducted by Ghani and Jayabalan [43] also found that the main reasons attributed to lower performance are human factors.

The above review of the relevant literature, naturally leads to the development of the first hypothesis. This will help to examine the problems or obstacles faced by the maintenance function. Firstly, it will seek the answer of "what and where" the problems are. Later on, the information sought will be used to examine how important the human factor i.e. maintenance personnel affect the overall function of maintenance department.

The following hypothesis concerning the human factors in relation to the maintenance function (*H1*) is thus formulated:

Hypothesis H1: Human factor i.e. maintenance personnel is among the major problems faced by the maintenance department in carrying out their maintenance tasks.

This hypothesis will be tested and addressed in chapter four to determine whether the effect of human factor in maintenance is confirmed in practice by referring to the empirical finding. As the issues of maintenance personnel are among the major problems, further information will be sought on the reason behind them.

Jengkinson [44] who studied the issue of industrial culture in the advanced manufacturing industries found that there are many organisations that reviewed and implemented improvement manufacturing techniques, programmes and philosophies such as BS5750, ISO9000, JIT, TQM and many others, but unfortunately in many cases these have not achieved the transition required to enable strategic objectives to be effectively met. In order to manufacturing operations to be more efficient and effective in meeting needs, the companies need to utilise their workforce more effectively by creating a suitable culture which will allow the management team to channel employee commitment along pre-planned routes towards specified goals and objectives.

From the literature, it is generally widely accepted that employees should be involved from the beginning by being updated about plans for new technology and the reasons why this new technology is needed. They should be aware of the impact the new technology will have on their job security, working conditions, promotion opportunities, job classifications and training requirements. Special emphasis should be given to the involvement of the workforce to the maximum possible extent in the selection and implementation of the new technology [45]. Tippett [46] suggested that companies seeking to achieve successful technology implementation found it necessary to introduce some changes in basic Human Resource Management (HRM) areas, and in the overall role HRM professionals play in the implementation process.

2.2.3. Employee resistance to technology change

In the past, the implementation of new conventional equipment resulted in little change to the human infrastructure. The installation of new equipment only slightly modified direct labour jobs or training activities.

However, change is inevitable in the history of any organisation. The adoption of new technologies affects any organisation when they are implemented. The change forces the organisations to cope with the environment to become more adaptive otherwise they become extinct [47]. What makes the technology adoption becomes a complex process is that new technology changes faster than people's behaviour. Any attempt to change the organisation to meet changes in technology generally takes place before the majority of people are ready for it. Thus, while the process of organisational change is going on, a parallel process of preparing employees to accept the change is necessary. In many ways the introduction of AMT is as painful for traditional management as it is for traditional employees [48].

The major reason for a decline in employee commitment is due to employee resistance to technological change. Gupta [49] described that in the organisations under review, three groups evolved in the early stages of implementing advanced manufacturing technology, although the size of these groups varied among organisations. First, there are the early adapters who subscribed to the new philosophy and eagerly awaited change. Conversely, there are the resisters who resisted change from the very beginning. Finally, there are the fence sitters who waited to see which way the organisation was going before committing themselves. It is important to focus early management development efforts on obtaining a critical mass of capable, skilled and influential people from the early adapters group. These persons need to be educated in AMT implementation techniques, should show an ability to take responsibility, and be used as examples of success. These examples will serve to influence undecided or resistant members of an organisation.

According to Wilkinson [50], employees defy technological change fearing that new technology would diminish or eliminate the need for their particular skills. He stated that new technology has the potential to isolate and deskill the worker to diminish the power from the worker. Most of the employees want to have some benefits out of the new technology. There are operators who are more comfortable with existing technology. They feel powerless and are detached from new technology. Some feel that they should retire at an early age. Some are alienated from new technology. New technology creates phobia among operators. The anxiety and emotional fear towards new technology lead to committing mistakes that would cost heavily in advanced manufacturing technology [50]. Bamane [51] added that change of technology threatens most personnel in terms of their job security.

Larsen [52] has indicated that the introduction of new technology has marked effect on individuals as well as the organisation as a whole, and is itself contingent upon the social dynamics of the workplace. Technological change induces stress among operators, which is caused by anxiety and tension associated with technological change [53]. In several organisations, the new equipment lies idle for quite some time because the employees refuse to operate them. The productivity of a firm, at first, drops because of resistance to accept new technology [43].

Adler [54] stated that of all the implementation issues regarding advanced manufacturing technology, labour requirements are often the least well managed. Then, effort should be made so as to minimise the negative impact of technology on human beings in order to achieve successful technology implementation [55] [56]. Barton [57] believed that resistance to change is rational and it should be eliminated to achieve better performance of the firm. Ghani and Jayabalan [43] suggested that superior performance of advanced manufacturing technology can be achieved when there is a positive change in work attitudes as a result of elimination of psychological barriers to technological change and change in organisational structure compatible with new technology by a planned change process.

2.2.4. Needs of human resource and employee development

There is no doubt that the human resource issues are the greatest asset for any organisation, without which the use and development of technology will not happen. Many implementation efforts fail because some underestimate the scope or importance of preparation or involvement of employees. Abundant resources have been invested in the purchase of new technology equipment, but very little has been done on its implementation. Davids [58] estimated that firms introducing new technology spend more than ninety percent of resources on technology while less than ten percent is attributed to human resource development for training and educating the work force.

In facts, several studies reported that advanced manufacturing technology implementation is more likely to be successful when the technology, organisation, and employees' issues have been designed to complement and integrate with each other. For instance, Kochan [59] identified that poor productivity and quality performance are found in plants that underestimate human resource management dimensions. Others agreed that disappointed outcomes and higher failure rate could be derived from unawareness of organisational and human resource changes that should be performed with advanced manufacturing technology implementation [60][61][62]. Thus, changes in company structure and human resource management must be adjusted in compatible with changes in advanced manufacturing technology projects.

Bamane [51] reported a number of important factors related to human resource issues that restrict the effective implementation of advanced manufacturing technology projects. Among others: change in skills of traditional craft workers, lack of teamwork and advance planning, less development of new sources and procedures, poor coordination of training programmes, inadequate training arrangements, no attention or weight paid to the need for skills and training programmes (which are essential) in the new manufacturing activities, and ultimately reluctance of the people to take responsibility in the new system. Sohal [63] stressed that lack of in-house programming skills is a major problem for companies to achieve the competitive advantage of advanced manufacturing technology implementation.

Gupta [49] emphasised that one of the major problems associated with advanced manufacturing technology is that organisations' operations require skills that are unrelated to existing skills. Since advanced manufacturing technology involves an extensive use of computers, preparation programmes should be directed towards the continual improvement of computer skills. Other researchers recommended that extensive preparation programmes should be conducted to increase the standard and competence of workers, to produce multi-skilled workers, and to develop analytical abilities for evaluating and using information and improve group interaction skills [39][40][65][66][67]. Therefore, the employees' skills and abilities to perform a variety of tasks is an important factor, related to human resource issues, in determining the degree of success in the adoption of advanced manufacturing technology projects. Furthermore, Fallik [60] recommended that effective implementation of advanced manufacturing technology requires adequate advanced planning so that job redesign and consequent training of workers in conjunction with the technological change rather than after implementation.

Most of the research findings that have been presented in the above literature agree that the issue of human factor plays an important role and contribution towards the success of technology implementation in automated manufacturing plant, including in the aspect of maintenance. However there is a lack of emphasize on the aspect of how the development of maintenance personnel can be implemented. Therefore, this study will help to examine and analyze this aspect in line with the aims of this research.

2.3. Maintenance Strategy in Automated Manufacturing Environment

This section discusses the link of maintenance from the context of operation management which explores the relationship between organisation strategies within the context of the implementation of maintenance practices. This is a logical progression from the previous section 2.2, as the literature has shown that the issues of human factors in manufacturing are by their very nature related to the overall strategy of an organisation. As Otley [68] put it: "the process of performance management begins with the establishment of strategy". In the later part of this section, the concept of maintenance is presented. It presents the role and other relevant issues in maintenance related to manufacturing industry, and examines the challenges, top management commitment, technology complexity as well as the relationship between maintenance and production technology in the context of automated manufacturing environment. Two hypotheses in relation to the role of top management (*H2*) and production technology used (*H3*) are then formulated in this section that will provide direction for the empirical research. To this end, maintenance strategy and the relation with business strategy will be presented.

2.3.1. Definition of strategy in the context of operations management

In the literature, a number of authors have produced definitions relating to operations management, though differing in details and emphasis, present a consistent picture of the key organizational function. Harrison [69] quoted several forms of definition of operation management:

> "Operations are the process by which people, capital and materials (inputs) are combined to produced the services and goods consumed by the public (output)" –Vonderembse and White [70].

> "The operation function is performed by that group of persons in a business who are responsible for producing the goods or providing the services that the business offers the public" – Dilworth [71].

"Operation management is that function of an organization which is concerned with the design, planning and control of resources for the production of goods and the provision of services" – Benneth et all [72].

Thus to summarize, according to Harrison [69], operations may be defined as a transformational process which adds value, while operation management is the decision making and control function associated with it.

Strategy can have various definitions depending upon different contexts. However the elements within it can provide more insight in understanding the type of strategy and its contents.

According to Hax and Majluf [73], "strategy is a coherent, unifying and integrative pattern of decisions; determines and reveals the organizational purpose; selects the businesses the organization is in or is to be in; attempts to achieve a long term sustainable advantage in each of its businesses, engages all the hierarchical levels (corporate, business and functional) of the firm; and defines the nature of the economic and non-economic contributions it intends to make." As Moody [74] put it, "strategy" is a competitive approach toward winning a market niche, being best in quality or lower in price.

Another author, Drucker [75] stated that "strategy" is the theory of the organization. It reflects the organization's conception of its intended long-term goal and the approach to achieving it. As it is often formulated at senior management level, the espoused strategy is usually too abstract to line management personnel. As such, it becomes difficult to relate departmental and individual activities to the attainment of the strategic goal.

In manufacturing strategy perspective, Hayes and Wheelwright [76] explored in detail how corporate and operational strategies are linked. They defined a company philosophy as "the set of guiding principles, driving forces and ingrained attitudes that help communicate goals, plans and policies to all employees and that reinforced through conscious and subconscious behaviour at all levels of the organization". Furthermore, they defined three level of strategy:

corporate strategy (highest level), business strategy (second level) and manufacturing strategy (third level).

Corporate strategy specifies all areas of overall interest to the organization: the definition of the business in which the corporation will participate and the acquisition and allocation of key corporate resources to each of these businesses. As for business strategy, it specifies the scope of that business (product, market, service sub segments) and the basis on which that business unit will achieve and maintain a competitive advantage. On the other hand, manufacturing strategy consists of a sequence of decisions that enable a business unit to achieve a desired manufacturing structure, infrastructure and set of specific capabilities [76].

As for development of strategies, Garvin [77] suggested a range of basic approaches in operations strategy which are more likely to be successful, based on the following: competition on quality, productivity, new products and processes; development on performance measurement systems; exploiting technological opportunities; using appropriate organizational forms; developing people; sending appropriate leadership signals; and employing an appropriate working culture.

2.3.2. Business and manufacturing strategy

Hax and Majluf [73] defined business strategy in terms of three elements: the mission of the business, the attractiveness of the industry in which the business belongs, and the competitive position of the business unit within that industry. In fact, according to Hayes and Wheelwright [76], the business strategy choice elements like cost (or price), quality, customization, or flexibility were termed as competitive priorities – the ways in which a company chooses to compete in the market place and the types of markets it pursues.

As for manufacturing strategy, Dangayacha and Deshmukhb [78] stated it as a plan that describes the way to produce and distribute the product. It describes the contribution that manufacturing makes to the cost, quality, availability and future objectives of the business. They proposed that in order to be most effective, the manufacturing strategy should act in support of the overall strategic directions of the business and provide for competitive advantages [78].

Hill [79] in his book "Manufacturing strategy: text and cases" described that manufacturing strategy comprises a series of decisions concerning process and infrastructure investment, which, over time, provide the necessary support for the relevant orders-winners and qualifiers of the different market segment of a company. He elaborated that there are two important roles which manufacturing can offer as part of the strategic strength of a company. The first is to provide manufacturing processes which will give the business a distinct advantage in the market place. The second is to provide coordinated manufacturing support for the essential ways in which products win orders in the market place at a level which is better than its competitors are able to do.

2.3.3. Frame work of manufacturing strategy

Harrison [69] introduced a framework for manufacturing strategy based on Hill's model [79] which emphasizes the importance of financial and corporate and human resource issues as shown in figure 2.1. One key to Hill's approach is the idea of qualifying and order-winning criteria which Hill uses to provide a link between market and manufacturing strategy.

In order to help a company reestablish manufacturing position as a critical contributor to the success of the company 's business strategy, Beckman et al [80] proposed a methodology which combines academic theory and real-world applications on a five step strategic manufacturing planning process, as follows: The first step is to start with the business strategy. The second step is to create a manufacturing strategy that is linked to the business strategy. The third step is to identify manufacturing tactics to execute the strategy. The fourth step is to organize for manufacturing success. Finally, the fifth step is to measure the result and initiate further change. In these five steps of planning strategy, they emphasized that the process must begin at the top. The highest levels of the management must commit the corporation to a strategic direction that is clearly defined and well communicated throughout and conduct periodic reviews to ensure that its direction is being followed [80].

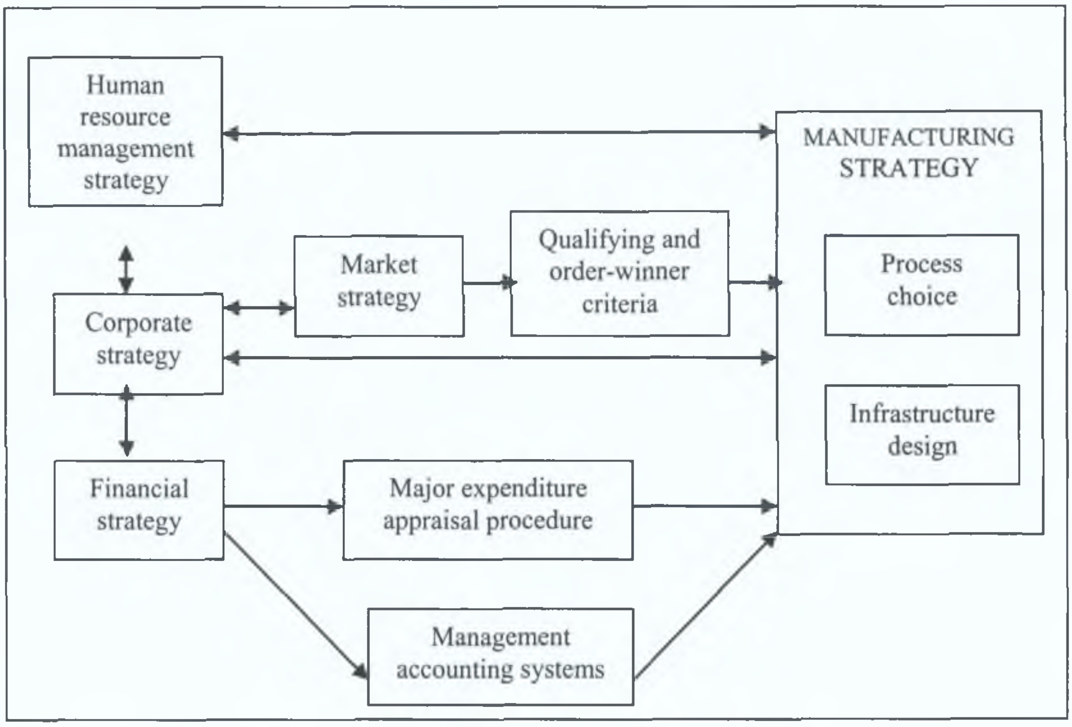


Figure 2.1 – Manufacturing strategy framework [69]

2.3.4. Top management role

One of critical factor to the success of any project implementation is the role of the top management. According to Pinto and Slevin [81], top management commitment and contribution are evident if support is provided in defining and/or establishing project vision, resources, monitoring, and feedback.

In relation to this, Olorunniwo and Udo [82] in their study on the impact of management and employees on cellular manufacturing implementation, found among other things, that cellular implementation seems to be more successful if top management initiates the project, and if employees are cross-trained to run various machines.

Maintenance implementation, like any project, requires top management support. Research and experience support the fact that the degree of management support of a project will lead to significant variations in the degree of acceptance or resistance to the project, and by extension, to the degree of success [83].

In line with this requirement, several authors [40] [81] have proposed various ways in which top management support can be provided. These ways include, among other things: creating project mission (project goals clearly outlined and understood by everyone); providing management support; installing project schedule/planning mechanisms; instituting a monitoring and feedback system; communication (including project vision); and trouble-shooting.

In their interviews with several companies, which had implemented MRP, Sum et al. [84] cited three main facets of top management support. These facets are: first, showing interest such as participating in team meetings, willingness to spend time with people and listen to feedback, willingness to help resolve problems; second, providing necessary resources including training and other critical resources; and third, providing leadership in helping to translate plans into actions, regular review of project progress, and official commissioning of project leader and project team. The authors [84] also found out that top management is expected to set the overall direction of the project by formally forming an executive steering committee to track, review, and monitor the project's progress.

2.3.5. Roles of Maintenance

Maintenance, as an important support function in businesses with significant investments in physical assets, plays a very important role in enhancing a company's capability to create value to customers and improve the cost effectiveness of their operations [11]. As Draycott [85] put it, in a modern manufacturing business, maintenance function plays a vital role in supporting the changing needs.

These maintenance roles are also supported by Swanson [86] who stated that maintenance function is critical to a manufacturing organization's ability to maintain its competitiveness. Properly maintained equipment will have higher availability and longer life. In fact, without well-maintained equipment, a plant will be at a disadvantage in a market that requires low-cost products of high quality to be delivered quickly. Additionally, poorly maintained equipment is less likely to produce products of consistent quality [86].

In literature publications, there have been a number of key objectives stated by the researcher on the roles of maintenance related to manufacturing industries. For instant, O'Dodoghue and Prendergast [87] stated that the objective of maintenance is to try to maximize the performance of equipment by ensuring that, items of equipment function regularly and efficiently, by attempting to prevent breakdowns or failures. The potential cost savings that can be achieved as a result of optimising the maintenance function in the manufacturing sector is very significant.

The above definition is in line with the "Maintenance" definition is defined by the German Industrial Standard DIN 31051 as: "The totally of measures to preserve or restore an item or system to a required condition and to establish and judge the actual condition of that item or system if necessary" [88]. Wei Zeng [41] linked maintenance with availability and cost, and stated that the maintenance objective as "to provide production with the long and short term manufacturing system availability requirement at a minimum resource cost.

Sivalingam [89] discussed the importance of maintenance within the broader area of industrial management. He stated "an integrated maintenance management when properly implemented can lessen emergencies by seventy five percent, cut purchasing by twenty five percent, increase warehouse accuracy by ninety five percent and improve preventive maintenance by two hundred percent". He went on to say that "with maintenance costs rising between nine percent to eleven percent per annum, the potential of savings is very high in the short and long term.

Good management of maintenance can reduce costs by as much as thirty five percent".

All the above objectives cited are in line with the goal of any well-run maintenance organisation which is to have the lowest cost of the sum of two quantities, i.e. maintenance labour and material, and production loss reduction resulting from an inadequate maintenance program (which includes lack of ability to produce, and value added material that is lost as a result of a break down) [90].

Maintenance itself can result in excessive downtime and costs. This results from the requirement to take the machinery off-line to carry out (possibly unnecessary and invasive) maintenance. The danger of infant mortality after it has been put back on line again and also the cost of the maintenance action itself contributes to costs. As such, companies should be able to put a cost to their loss of production resulting from equipment down time.

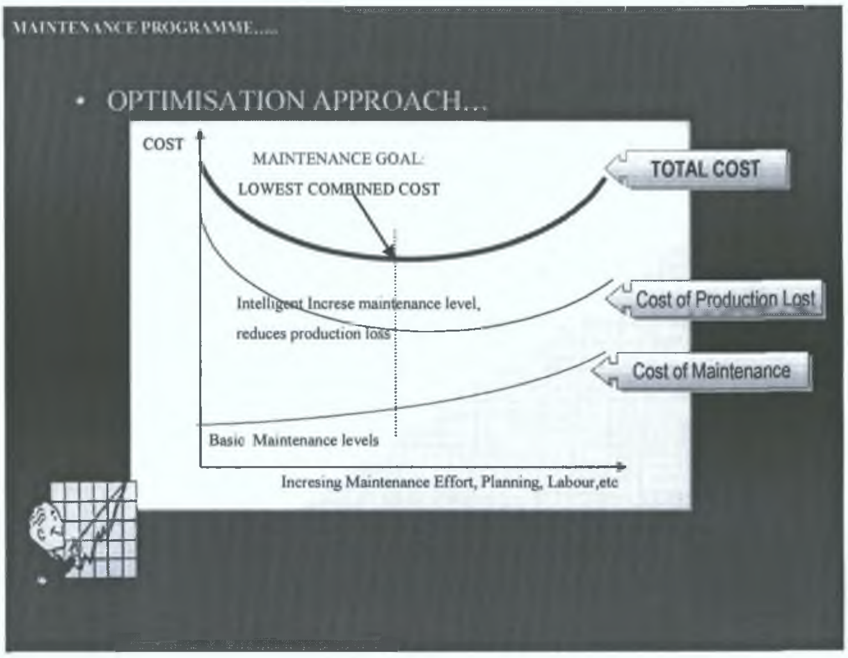


Figure 2.2 - Maintenance cost optimization technique [90]

In order to achieve the lowest cost in maintenance, an optimisation technique can be applied [90]. As shown in figure 2.2, when maintenance costs are at a minimum the cost of lost production is at its highest. As maintenance effort and costs are intelligently increased the production loss gradually decreased until the lowest combined cost is achieved. This is the maintenance goal. Maintenance effort applied beyond this point, increases costs. Maintenance can increase costs because of the need to take equipment off line to carry out maintenance, infant mortality after being put back in service, etc. [90].

2.3.6. Maintenance challenges

There have been various issues and challenges related to the maintenances that had been discussed which relate to the effect of maintenance practice in manufacturing industries. However, before it goes further, the issues of underestimation (or "negative perception") towards maintenance will be highlighted, as it becomes one of the challenges in the maintenance aspects.

Willmott [91] stated that one of the main reasons for the companies having poor availabilities is that, maintenance is not usually considered at executive level. He added that most companies do not know the cost of downtime – especially in terms of lost sales opportunities. In consequence, these companies do not have a realistic plan and start point to determine their maintenance strategy and policies.

The above statement has also been mentioned by other authors. De Groote [92] highlighted that since maintenance has always been underestimated (and often unaccepted) as a major component of profitability, maintenance is relegated to an inferior hierarchical level in many companies.

In relation to this issue, with regards to how the maintenance is regarded in the hierarchical of the company, one study had been conducted by Cooke [93]. He examined the maintenance practice of four large and medium-sized manufacturing and processing companies in the United Kingdom. It identifies the strengths and weaknesses of each of these plants in terms of their plant maintenance function at both the strategic level and the operational level. This study found that, on the whole, the maintenance functions of all four companies shared similar characteristics. However, the evidence shows that none of the four companies investigated placed their maintenance function in a sufficiently important position in relation to their business and production strategies. In other words, maintenance function remains a low priority. Furthermore, this study also found limited connection (if any) between maintenance strategy and business strategy.

In order to rectify or at least to minimise this problem, Draycott [85] proposed that the most important characteristic, which will need to be developed, is "the alignment of company's business strategy with all the people involved". He cited further that there are serious barriers to this alignment, however, and it is important to recognise the difference between the wished-for picture and reality.

On the other aspect, in terms of cost optimization, Kessel [3] mentioned that many maintenance managers feel that they are trapped between two conflicting pressures. On one hand there is a never-ending pressure to lower costs. On the other hand, maintenance is confronted by increasing demands from production to raise plant performance.

Following the above review leads to the development of the following hypothesis. This information will be used to examine the importance of top management commitment in maintenance implementation and in relation to the business strategy. The following hypothesis states that in order to ensure that the maintenance can be implemented effectively, full commitment from the top management is required and should be regarded as an important function. The following formulated hypothesis is as follows:

Hypotheses 2: The maintenance function should be regarded as a sufficiently important function to the business strategy and get full commitment from the top management

This hypothesis will be tested and addressed in chapter four to determine whether the maintenance function and the position in the company is confirmed in practice by referring to the empirical finding.

In discussing further, the issue of maintenance challenge, De Groote [92] elaborated that maintenance is facing a major challenge because it must deal with complex influences, which are often opposed to it, i.e.: physical (natural degradation of equipment), technical (production technology), human resource, Organisational and managerial, economic and financial, and market (constantly changing requirements). In human aspects, the major challenges are related to the development of human resources, systems to motivate personnel, social and cultural evolution.

In relation to this Tsang [11] identified four issues of developments that have made the performance demanded of maintenance ever more challenging: emerging trends of operation strategies, toughening societal expectations, technological changes and changes in the people and organizational systems. He elaborated that the deployment of these new technologies is instrumental to enhancing system availability, improving cost effectiveness of operations and delivering better or innovative services to customers. The move presents new challenges to maintenance. New knowledge has to be acquired to specify and design the new systems, taking advantage of these emerging technologies. Obviously, installing the right equipment and facilities, optimizing the maintenance of these assets and effective deployment of manpower to perform the maintenance activities are crucial factors to support these emerging trends of operation strategies [11].

As equipment and system automation increases, it becomes increasingly difficult for decision makers to allocate funds and resources for technical support and maintenance of individual devices and subsystems. However, unlimited technical support costs are not acceptable, just as poorly performing automated systems are also not acceptable [94].

2.3.7. Complexity of maintenance in automated manufacturing environment

In today's competitive global market, for the survival of any industry, manufacturing companies need to be flexible, adaptive, responsive to changes, proactive and be able to produce a variety of products in a short time at a lower cost [95]. Furthermore, non-price factors, such as quality, product design, innovation and delivery services are the primary determinants of product success in today's global arena [96].

Changes in technology, competition and economic condition have happened more rapidly that ever before. Implementation of advanced manufacturing technologies provides opportunities to achieve competitive advantage in an intermediate to long-term time frame [97]. Changes in technology are forcing shorter product life: i.e. obsolescence. In turn, the time to develop new products is being forced to be reduced. Forecasters predict that theses changes will continue even faster in the future [98].

Automation is a technology concerned with the application of mechanical, electronic, and computer based systems to operate and control production. It is a dynamic technology that represents a continuous evolutionary process that began many decades ago [99]. This includes the use of Computer-integrated manufacturing (CIM) which is frequently considered as a technology enabling companies to compete in today's market that requires great flexibility and responsiveness.

There are a number of important aims of implementing automation stated in the literature. For instant, Morriss [100] stated that automation is a technique that can be used to reduce costs and/or to improve quality. Automation can increase manufacturing speed, while reducing cost. Automation can lead to products having consistent quality, perhaps even consistently good quality. Indeed, since all manufacturing companies choose to compete in the market based on some competitive priorities like cost, quality, flexibility and other priorities - depending upon their manufacturing capabilities, automation provides the opportunity to improve returns by improving quality, increasing production, and reducing costs [4].

According to Adler et al [7], automation aims to maximize value-cycle opportunities by blending together knowledge and automation technologies. This will extend the company's capabilities and promote global collaboration by providing continuous access to information. As for the CIM, it is a management philosophy in which engineering design, manufacturing, planning purchasing, production, sales and support functions are integrated in a computer-coordinated system [101]. Some of the benefits realized from successful implementation of CIM technology include: Improved quality, greater flexibility and responsiveness, improved competitiveness, reduced lead time, increase productivity and decreased work-in-process [99].

A highly integrated manufacturing system such as a Flexible Manufacturing System (FMS) or Computer Integrated Manufacturing system (CIM) is a combination of very complex machinery integrated through an equally complex computer system. Each machine is a combination of many sub-assemblies, where each sub-assembly is itself complex and consists of many dissimilar interdependent components. Traditional maintenance policies deal with stand-alone machinery comprised of mechanically similar components. However, a typical AMT deals with a complex system which not only have mechanical components, but also electronic, hydraulic, electro-mechanical, software, and human elements, each having different failure rate distributions.

As new technology continues to enter the factory, the proportion of effort being shifted to maintenance increases each day. However, according to Willmott [91], largely overlooked at present is a companion requirement to keep the automated systems themselves maintained so that they perform reliably and continuously at peak level. In this era of Computer Integrated Manufacturing, a company's production is becoming progressively more reliant on availability of fewer but more sophisticated machines and processes. The point is that the significance and impact of maintenance are changing dramatically. A properly formulated and managed maintenance policy and practice can make a substantial contribution to profitability.

Following the above review literature, leads to the development of the following hypothesis. This information will be used to examine the level of automation and integration of the company as well as to understand the complexity of production and process technology used in the company. Further more, the data will be used to find if there is any correlation between the level of automation and maintenance practice as well as with other variables measured. The following formulated hypothesis is as follows:

Hypotheses 3: The use of complexes machineries (in terms of integration and production technology) will be higher for the company reporting high level of automation.

This hypothesis will be tested and addressed in chapter four to determine whether the level of automated manufacturing company is confirmed in practice by reference to the empirical finding in this aspect.

In this respect, according to Cho and Parlar [102] maintenance approach for advanced manufacturing technology must focus on understanding the entire system instead of individual units or components because of the integrated nature of the units. Swanson [86] stated that along with the intricacies associated with technologies, the maintenance function often has to cope with managing many different maintenance craft classifications and increasingly complex organizational structures. All of this complexity makes the decisions about allocating resources and scheduling work more difficult for maintenance. Based on the responses from the previous survey [1], the analysis shows a strong relationship between technical complexity and maintenance practices.

According to Collins and Hull [103], the high level of capital intensity associated with automated equipment also places greater pressure on the maintenance function to rapidly repair equipment and to prevent failures from occurring. Paz and Leigh [104] added that higher levels of automation and changes in the production environment can make diagnosis and repair of equipment more difficult and increasingly complex.

Pintelon et al. [105] also noted that the complexity and stochastic nature of maintenance requirements in such environments make deciding on an appropriate maintenance policy a very difficult task.

From the above literature, the complexity of the maintenance of the automated manufacturing environment can be categorized into three aspects: First, the production technology used, which describes the diversity of equipment that the maintenance function is expected to maintain, the extent of use of advanced manufacturing technology in the plant and the mass output orientation which describe the process technology. The second aspect is maintenance approaches, which can be described by the type of maintenance program use, maintenance department size, based on the log of the number of hourly maintenance workers in the plant and use of area maintenance employed. Third, from the organizational structure aspects of the company that describes the number of levels in the organization and the total number of maintenance staff classifications in the plant.

2.3.8. Relationship between maintenance strategy and business / manufacturing strategy

In the past few years, there has been an increase of research in investigating new theoretical concepts, frameworks and models both related to manufacturing and maintenance.

Demeter [106] studied manufacturing strategy and its competitiveness. He explained that a smoothly running production system will have a positive influence on business performance. However, smooth running mainly depends on equipment performance, hence maintenance.

Several other studies mainly focus on the connection between business and manufacturing strategies. Some of the recent studies like Waeyenbergh and L. Pintelon [107] and Al-Najjar and I. Alsyouf [108] emphasized the importance of maintenance and its role in contributing to positive business performance.

Swanson [86] studied the relationship between the complexity of the production environment and the use of maintenance practices that assist in managing the information processing requirements brought on by such complexity. Taken together, the findings seem to indicate that the maintenance function responds to complexity in the production environment by undertaking different maintenance practices and approaches.

The investigation on the relationship between business and maintenance strategies was also carried out by Pinjala and L. Pintelon [2]. The maintenance strategy elements that are investigated constitute outsourcing, organization structure, maintenance policies, planning and control systems and finally, human resource policies. The results indicate that there is a relationship between business and maintenance strategies. Interestingly, in terms of human aspect, in most of the companies teamwork is still only at a medium level. This can be due to many reasons like workers attitude, training level of operators and management philosophy. To implement people-oriented maintenance concepts like TPM, improving teamwork is an important factor. They recommended for further research on the area of maintenance related to the issue of training, technical complexity and teamwork [2].

Concerning the optimisation of manufacturing system performances, Gadhi et al [109] stated that an appropriate maintenance strategy leads to an optimal availability of equipments. Since the design step, an appropriate strategy of maintenance must be defined, particularly for systems concerned by wear and ageing. Swanson [110] added that while maintenance strategy requires increased commitments to efforts, resources and integration, it also promises to improve performance.

2.3.9. Maintenance strategy and its decision elements

Maintenance being an integral part of manufacturing can influence the business and manufacturing strategies directly in a negative or positive way. Maintenance, though closely related to manufacturing is an operation function of its own. Its role is to provide dependable service to manufacturing. Maintenance strategy is a long-term plan, covering all aspects of maintenance management which sets the direction for maintenance management, and contains firm action plans for achieving a desired future state for the maintenance function [111].

In the literature, the term maintenance strategy is generally viewed from the perspective of maintenance policies and concepts. For instance, Cooke [93] and Swanson [110] defined maintenance strategy in terms of reactive or breakdown maintenance, preventive and predictive maintenance which consists of three types of maintenance strategies: reactive strategy (breakdown maintenance), proactive strategy (preventive and predictive maintenance), and aggressive strategy (TPM).

However, according to Pinjala and Pintelon [2], these maintenance policies and concepts form only one of several elements of maintenance strategy. Based on the strategy definition given by Hax and Majluf [73], they defined maintenance strategy at a functional hierarchy level and can be defined as "coherent, unifying and integrative pattern of decisions in different maintenance strategy elements in congruence with manufacturing, corporate and business level strategies".

In order to develop an operation strategy, elements and dimensions have to be identified [79]. Several authors have described the decision elements and dimensions in developing maintenance strategy.

Visser [112] modeled maintenance as a transformation process encapsulated in an enterprise system as shown in figure 2.3. In the input-output model, the resources deployed to maintenance include labour, materials, spares, tools, information and money. The way maintenance is performed will influence the availability of production facilities, the volume, quality and cost of production, as well as safety of the operation. These, in turn will determine the profitability of the enterprise.

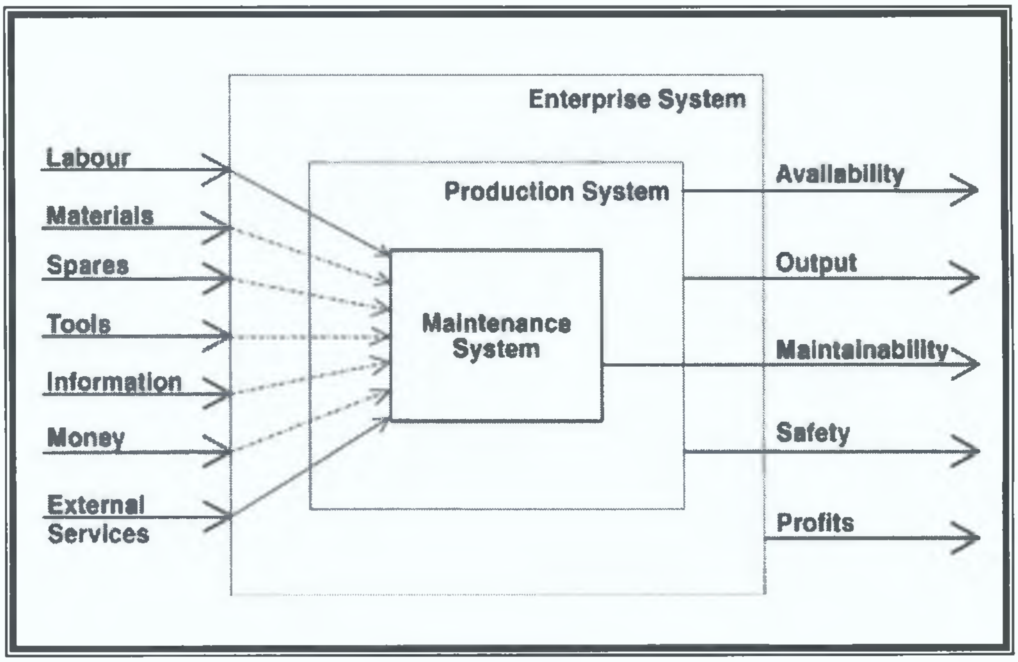


Figure 2.3 - Input-output model for the enterprise system [112]

Based on Visser's input–output model, Tsang [11] identified four strategic dimensions of critical decision elements in maintenance, as listed below. The first relates to the inputs, the next two are concerned with the design of the maintenance process itself, and the fourth one is about the support systems. First, service-delivery options which is the choice between in-house capability and outsourced service. Second, organization of the maintenance function and the way maintenance tasks are structured. It covers the maintenance work structure, plant specialization, workforce location and specialization and interface with operation. Third, maintenance methodology: the selection of maintenance policies. It consists of type of maintenance used (run to failure, preventive, preventive, RCM and TPM, troubleshooting methodology. Lastly, design of the infrastructure that supports maintenance which covers hierarchy and communication, education and training, management information systems and e-maintenance.

Table 2.1 -The summary of maintenance strategy decision elements [2]

a) Structural decision elements	
Maintenance capacity	Capacity in terms of work force, supervisory and management staff. Shift patterns of work force, temporary hiring of work force.
Maintenance facilities	Tools, equipment, spares, workforce specialization (mechanics, electricians, etc.), location of workforce.
Maintenance technology	Predictive maintenance, or condition monitoring technology, expert systems, e/i maintenance technology (intelligent maintenance).
Vertical Integration	In-house maintenance versus outsourcing and relationship with suppliers.
b) Infrastructure decision elements	
Maintenance organization	Organization structure (centralized, de-centralized, or mixed), responsibilities.
Maintenance policy and concepts	Policies like corrective, preventive and predictive maintenance. Concepts like Total Productive Maintenance (TPM), Reliability Centered Maintenance (RCM).
Maintenance planning and control systems	Maintenance activity planning, scheduling. Control of spares, costs etc. Computerized Maintenance Management Systems (CMMS).
Human resources	Recruitment policies, training and development of workforce and staff. Culture and management style.
Maintenance modifications	Maintenance modifications, equipment design improvements, new equipment installations and new machine design support.
Maintenance performance measurement and reward systems	Performance recognition, reporting and reward systems.

Other authors Pinjala and Pintelon [2] proposed maintenance strategy in the form of structural and infrastructure decision elements, as presented in table 2.1. The first four decision elements consume a majority of the maintenance budget. They are structural in nature because decisions made in these areas are generally assumed to be fixed. The last six infrastructure decision elements are generally linked with specific operating aspects of a company like production process, size, degree of automation and other related aspects. However, according to them it should be emphasized that both structural and infrastructure elements are closely interrelated [2].

From a system perspective, the elements provided by Pinjala and Pintelon [2], as shown in table 2.1, cover most of the elements of a maintenance system.

2.3.10. Deployment strategy

The topics of strategic management came originally from the corporate planning literature in the 1960s and moved through strategy development and organizational performance in the 1970s [113]. Consequently, in the 1990s, most people writing in the filed are in agreement that most important task faced by top management is actually the implementation of strategy [114] and [115]. Researchers are now "not so much concerned about the "what" of strategy, as the "how" of strategic management [113]. However, work that has been done in this area is still at the exploratory stage, and there is no single theory that encapsulates the research findings [113].

In any discussion of strategy, it is important to consider how the strategy will be controlled. Equally important as the strategies are the means by which they are deployed into organizational activity. As Mannix and Pelham [116] described it: a strategic plan is a valuable management tool that provides an organization with long term direction. Planning is not an end in itself; rather, it is a means of providing direction of implantation.

Deployment of strategy refers to translating the strategy formulated by the organization into organizational activity. A number of terms are used today to describe this planning tool such as strategic policy and deployment, strategy planning and deployment, management by policy and Hoshin Kanri (the Japanese term for management by policy) are used synonymously in the context of planning [116]. Collins and Huge [117] defined it as "a management process to help the company achieve dramatic improvement that supports the corporate vision". Regardless of the term used, Mannix and Pelham [116] specified that what is key is to understand the power of the tool i.e deployment strategy, and to develop a method of applying it to the organization.

The key elements of the strategic deployment tool are vision, objectives, indicators and targets, and means and methods [116]. Thus a strategic plan should combine the vision (long term direction) and objectives that support achievement of the strategy. Ideally, the objectives should be measured by indicators and targets that demonstrate progress or closure of the gap between the organization's current state and its desired objective. Finally, the specific means and methods to be used to achieve the objective should be identified. The strategic deployment combines all these strategic planning enhancements. When the tool is used effectively, it contributes to an outcome that can measurably improve organizational performance and help achieve a predefined vision [116].

2.4. Current Trend of Maintenance Practice

This section presents the literature of maintenance practices in the automated manufacturing industry, which will be used in understanding the current trend of maintenance practice. This information will be used as a guideline in establishing the questionnaire content in the aspect of maintenance practice. Two hypotheses in relation to the maintenance practice (*H4-i, ii and iii*) and maintenance outsourcing (*H5*) are then formulated in this section.

Traditional maintenance plans are often based on a combination of recommendations from manufacturers, legislation and company standards, and to a minor extent maintenance models and data [118], as shown in figure 2.4. Many companies are faced with laws and regulations related to personnel safety and environmental protection that set requirements to their maintenance strategies. As Tsang [11] stated it: "keeping facilities in optimal conditions and preventing failures are an effective means to meet the ever more demanding societal challenge of pollution control and accident prevention".

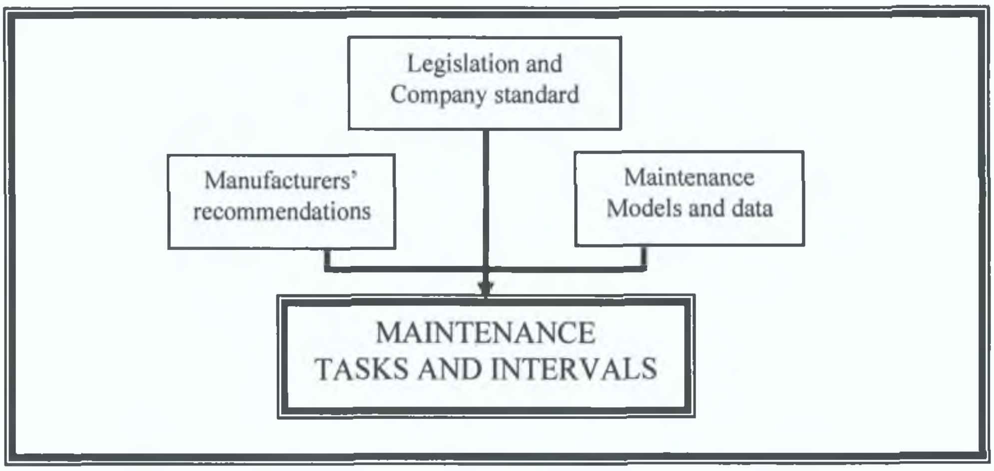


Figure 2.4 - Traditional development of maintenance plans [118]

In terms of maintenance evolution, Moubray [119] categorised the evolution of maintenance philosophies over the past 60 years into three generations starting from the first generation – 1930s, second generation – late 1970s and followed by third generation - 1980s. The background, equipment characteristics and maintenance technique used are summarised in table 2.2.

In relation to this continuous development, Tsang [11] elaborated that the emerging trends of operation strategies and technological changes highlight a shift of emphasis from volume to quick response, elimination of waste and defect prevention. On top of that there is a growing body of knowledge about people at work, about organization, about social and demographic changes and about management with new attitudes towards work. This leads to the appearance of variety of innovative and highly successful organizational forms, which could be the appropriate options in providing excellent maintenance service to organisations [11].

Table 2.2 - The evolution of maintenance philosophies [119]

Generation	Time	Background and characteristics of equipment	Maintenance techniques and philosophy
First generation	Before the Second World War	Equipment simple, over-designed, easy to repair	- Basic and routine maintenance - Reactive breakdown service ("fix it when it is broke")
Second generation	Second World War – late 1970s	- More complex, greater dependence of industry on machinery - Higher maintenance cost relative to other operating cost	- Planned preventive maintenance - Time-based approach
Third generation	1980s	- Continued growth in plant complexity and accelerating use of automation - Downtime very costly - Just-in-time systems more common - Rising demand for standard of product and service quality - Tightening legislation on safety	- Condition monitoring, hazard studies, failure modes and effect analysis - Reliability-centred maintenance (RCM) as corner stone - Computer-aided maintenance management information system - Workforce multi-skilling and teamworking - Emphasis on reliability and availability - Proactive and strategic

2.4.1. Reliability, maintainability and availability of equipment

A reliable piece of equipment is understood to be basically sound, to be able to meet its design specifications, and to give trouble-free performance in a given environment. However, it is necessary to have an understanding of the technical engineering use of the term 'reliability' as specified for equipment [90]. The following section describes some of the relevant technical definitions used in this study, in order to make meaningful comparisons between the reliability of alternative plant and equipment.

- Reliability

Reliability is the probability that a plant or component will not fail to perform within specified limits in a given time while working in a stated environment [90].

The definition of reliability includes a number of variables that are external to the artefact being analysed. Identical equipments may have very different duty requirements such as frequent stop-starts or continuous running. Environmental conditions such as fine dust can also affect a machine. It is thus necessary to understand completely the operating conditions under which an artefact is expected to operate [90].

- Maintainability

Once a piece of equipment has failed it must be possible to get it back into an operating condition as soon as possible, this is known as *maintainability* [90]. By definition, maintainability is the probability that a failed system will be restored to specific performance within a stated period of time when maintained under specified conditions [120].

Maintainability is "an inherent design characteristic of a system or product and it pertains to the ease, accuracy, safety and economic in the performance of maintenance action" [121].

- Availability

The *availability* of a system is the probability that the system is functioning at time t. The Availability for a single machine is: A = MTBF/(MTBF+MTTR)

The implication of this formula is that high availability can be obtained either by increasing the Mean Time Before Failure (MTBF), and hence the reliability, or improving the maintainability by decreasing the Mean Time To Repair (MTTR) [90].

- Repairable and non-repairable system

In reliability engineering, repairable and non repairable systems are treated differently [90]. A *non-repairable* item is replaced with a new item that will be as good as the item replaced. Over time as items are replaced with identical new items the failure rate will remain constant. In a *repairable* system the repaired item following a breakdown will not be as good as when it was first installed (as good as new). General wear and errors in the repair carried out will result in the failure rate increasing over time.

In a study within British manufacturing industry carried out by Willmott [91], it was found that with good maintenance management, the costs of maintenance could be reduced and at the same time, plant availability could be improved, to the extent that a thirty percent increase in profitability.

2.4.2. Type of maintenance programme

Many authors have described different types of maintenance programmes. Bateman [122] described three basic types of maintenance programmes, including reactive (or corrective), proactive maintenance (preventive and predictive) and aggressive maintenance. Preventive and predictive maintenance represent two proactive strategies by which companies can avoid equipment breakdown.

Some elaborated further that there are many ways to accomplish maintenance, and some formal maintenance strategies currently in vogue include the following: preventive, routine, periodic, corrective, breakdown, opportunistic, operator attention, emergency, project (or upgrading), predictive, Reliability Centered maintenance and Total Productive maintenance. There are three basic approaches to maintenance: reactive, proactive and aggressive maintenance. The brief descriptions of these approaches are as follow:

a) Reactive and Corrective maintenance

Reactive maintenance may be described as a fire-fighting approach to maintenance. Equipment is allowed to run until failure. Then the failed equipment is repaired or replaced. Under reactive maintenance, temporary repairs may be made in order to return equipment to operation, with permanent repairs put off until a later time [104].

Reactive maintenance allows a plant to minimize the amount maintenance manpower and money spent to keep equipment running. However, the disadvantages of this approach include unpredictable and fluctuating production capacity, higher levels of out-of-tolerance and scrap output, and increased overall maintenance costs to repair catastrophic failures [123].

b) Proactive maintenance

Proactive maintenance is a strategy for maintenance whereby breakdowns are avoided through activities that monitor equipment deterioration and undertake minor repairs to restore equipment to proper condition. These activities, including preventive and predictive maintenance, reduce the probability of unexpected equipment failures [110].

Preventive maintenance is often referred to as use-based maintenance. It is comprised of maintenance activities that are undertaken after a specified period of time or amount of machine use [124]. The work undertaken may include equipment lubrication, parts replacement, cleaning and adjustment. Production equipment may also be inspected for signs of deterioration during preventive maintenance work [125].

Predictive maintenance is often referred to as condition-based maintenance. Specifically, maintenance is initiated in response to a specific equipment condition [124]. Under predictive maintenance, diagnostic equipment is used to measure the physical condition of equipment such as temperature, vibration, noise, lubrication and corrosion [126] [127].

In relation to the proactive approach used, Swanson [110] reported a study on the relationship between maintenance strategies and performance. In this study, the result found that there is a strong positive relationship between proactive maintenance strategies and performance [110].

c) Aggressive maintenance

An aggressive maintenance strategy goes beyond efforts to avoid equipment failures. Two examples of aggressive maintenance which are commonly used are Total Productive Maintenance (TPM) and Reliability Centred Maintenance (RCM). RCM is an asset-centred methodology with a primary focus on making decisions on the type of maintenance tasks to be used. TPM, on the other hand, is a methodology with a very different orientation which focuses on people and is an integral part of total quality management (TQM) [11].

- Total Productive Maintenance

TPM seeks to improve overall equipment operation. Maintenance may participate in these improvements through involvement in efforts to improve the design of new and existing equipment [110].

Macaulay [128] stated TPM is a philosophy of maintenance management developed in Japanese manufacturing plants to support the implementation of just-in-time manufacturing, advanced manufacturing technologies and to support efforts at improving product quality. TPM activities focus on eliminating the "six major losses". These losses include equipment failure, set-up and adjustment time, idling and minor stoppages, reduced speed, defects in process and reduced yield.

According to Maggard et al [129], TPM has been described as a partnership approach to maintenance. Under TPM, small groups or teams create a cooperative relationship between maintenance and production that helps in the accomplishment of maintenance work. Additionally, production workers become involved in performing maintenance work allowing them to play a role in equipment monitoring and upkeep. This raises the skill of production workers and allows them to be more effective in maintaining equipment in good condition.

- Reliability Centered Maintenance

Reliability Centered Maintenance (RCM) is a technique for developing a preventive maintenance programme. It is based on the assumption that the inherent reliability of the equipment is a function of the design and the build quality. An effective preventive maintenance program will ensure that the inherent reliability is realized. It cannot, however, improve the reliability of the system. This is only possible through redesign or modification [118].

According to the Electric Power Research Institute (EPRI), RCM is:
"A systematic consideration of system functions, the way functions can fail, and a priority-based consideration of safety and economics that identifies applicable and effective PM tasks" [118].

The main focus of RCM is therefore on the system function, and not on the system hardware. The main objective of RCM is to reduce the maintenance cost, by focusing on the most important functions of the system, and avoiding or removing maintenance actions that are not strictly necessary. If a maintenance program already exists, the result of an RCM analysis will often be to eliminate inefficient preventive maintenance tasks [118].

RCM and TPM approaches are however complementary. According to Briggs [130], RCM can be linked into a TPM environment to enhance the latter's drive for improved Overall Equipment Effectiveness (OEE). TPM is essentially an operating philosophy aimed – in pursuit of the business objectives of quality and delivery at low cost – at minimizing the hidden costs of impaired operation, where as RCM is a maintenance management strategy aimed at improving the efficiency of maintenance by identifying the type and quantity which is appropriate to the consequence of failure [130].

In addition to the three basic approaches to maintenance as been described above, Tsang [11] added another approach – design improvement. In this approach, the design is modified to achieve one or more of these objectives: improve reliability, enhance maintainability, minimize maintenance resource requirements and eliminate the need for routine servicing.

2.4.3. Computerized Maintenance Management System

In maintenance, there has been an increasing movement toward Computerized Maintenance Management system (CMMS) [86]. CMMS assists in managing a wide range of information on the maintenance workforce, spare-parts inventories, repair schedules and equipment histories. It can also be used to automate the preventive maintenance function, and to assist in the control of maintenance inventories and the purchase of materials. CMMS may also be used to plan and schedule work orders and to manage the overall maintenance workload. Another capability offered by CMMS is the potential to strengthen reporting and analysis capabilities. Finally, CMMS has been described as a tool for coordination and communication with production [86].

There are many factors, which influence management on installing CMMS software and using it within their plants. Trunk put forward the following reasons for adopting CMMS software [131]. First, customers demand compliance with ISO 9000. Second, the authorization bodies require maintenance management systems for plants that handle pharmaceuticals. Third, insurance companies demand to know cost and condition of material handling assets.

The variety of tasks associated with the organization of maintenance management lens itself to the utilisation of computer systems. It is in this area including planning, organisation and administration of maintenance management that CMMS have proved to be very beneficial [87]. Lamendola [132] emphasised the need to eliminate non-value added activities especially with respect to documentation of work within maintenance. He stated that “this philosophy has long been the essence of CMMS” [132].

2.4.4. Maintenance tools and troubleshooting methodology

According to Wireman [133], quality equipment maintenance, preventive maintenance, labour planning, inventory control and automation are the key elements for optimising the maintenance departments to meet its goals. Each of these areas is supposed to be tracked closely with clearly defined matrices that allows for quick problem spotting and resolution.

There are numerous techniques and troubleshooting methodologies have been developed and are currently available to the maintenance function in the automated manufacturing factory. Some of the techniques includes: the diagrams, flowcharts, simulation systems, maintenance software and experts systems, include:

- Failure Modes Effects and (Criticality) Analysis (FMEA)

It is the tasks of finding possible faults in a system and evaluating the consequence of the fault on the operational status of the system [134].

- Fault Tree Analysis (FTA)

It is potentially one of the most powerful techniques of risk analysis as it estimates the probability/frequency of accidents [135]. It complements FMEA in that it is a "top-down" analysis, starting with a system fault (the top event) and analyzing this fault in terms of sub-system faults [90].

• System or Structured Analysis and Design Technique (SADT).

It is a standard tool used in design of computer integrated manufacturing systems, including flexible manufacturing systems [136].

• Cause and Effect Diagram

It is also called Ishikawa diagram (after its creator, Kaoru Ishikawa of Japan), or the fishbone diagram. It was created so that all possible causes of a result could be listed in such a way as to allow a user to graphically show these possible causes [137].

• Pareto Analysis

The Pareto Principle [138] stated that only a "vital few" factors are responsible for producing most of the problems. This principle can be applied to quality improvement to the extent that a great majority of problems (80%) are produced by a few key causes (20%). The purpose is to have a quick focus and efforts on the key causes of a problem.

Langan et al [139] proposed that the management must realize that maintenance adds value to the finished products, that it is a contributor to a reliable production capacity, and that it should be used to achieve business goals. Maintenance must operate in a proactive mode to become more valuable to the profitability of the plant. In addition, computerized maintenance management systems and other automation tools can be put in place to further enhance maintenance effectiveness.

The above literature discussions on the maintenance practice in the aspects of maintenance programmes and approaches lead to the development of the following three hypotheses. This information will be used to examine the current practice of maintenance approaches and programme used as well as to find if there is any correlation between the maintenance approaches used and the improvement of performance as well as with other variables measured. The relationship between maintenance approaches and programme used and the improvement of performance is thus examined by means of the following three inter-related hypotheses:

Hypothesis H4-(i): The use of specific type of maintenance practices and strategy will contribute to the improvement of equipment availability.
Hypothesis H4-(ii): The use of communication and coordination support (such as CMMS) will contribute to the improvement of equipment availability.
Hypothesis H4-(iii): The use of appropriate maintenance troubleshooting tools will contribute to the improvement of equipment availability.

These hypotheses will be tested and addressed in chapter four to determine whether the maintenance programmes and approaches given in the literature can be confirmed in practice by referring to the empirical findings in this area. Furthermore, this information will be used to find if there is any correlation between the maintenance approaches used and the improvement of performance as well as with other variables measured.

2.4.5. In-house maintenance versus maintenance outsourcing

Conventional wisdom regarding the outsourcing decision states that the company should outsource the "non-core" business activities. The difficulty with this approach, however, is that it provides no guidance for deciding which activities is "non-core". Ultimately, in many organisations adopting this approach, the discussion about what is "core" and what is "non-core" end up being highly subjective, and in the end, one person's opinion ends up prevailing over another's [140].

Some organizations purchase maintenance support from equipment manufacturers or supplier, by way warranties, service contracts, or paid field service calls for a period of time. A variation of this approach is a "buy-install-operate-turnover" concept that seemingly offers the purchaser assurance that the new device or system is up and running correctly before custody is taken [141].

Ildhammar [141] has elaborated that various aspects need to be considered in discussing should or should not be contracted out and the reasons for choosing either option: variability in workload, temporary scheduled increase in workload, core business philosophy and lack of skills and expertise. Other reason stated by Tsang [11] is the expected volume of maintenance work was too small and the variety of maintenance-related specialist skills too wide to justify a specialist on standby.

Through a survey, Bettis et al [142] reported that approximately forty percent of hi-tech industries (communications, computers, and semiconductors) rely on outsourcing and believed that this reliance will continue to grow. Loh and Venkatraman [143] reported that some industries have gained but others have declined, a few even severely. However, some companies have canceled outsourcing contracts and have rebuilt their internal capabilities [143].

Tsang [11] said that the selection of whether the maintenance should or should not be outsourced, should be made in the context of the company's overall business strategy. He added that when companies consider outsourcing of their maintenance activities as a strategic option, they need to answer three key questions: what should not be outsourced, what type of relationship with the external service supplier should be adopted, and how should the risks of outsourcing be managed. According to Ngwenyama and Bryson [144] poor outsourcing decisions can lead to drain of strengths, exposure to unknown risks and eventually business failure.

The above literature discussions on the maintenance outsourcing practice lead to the development of the following hypothesis. This information will be used to examine the current involvement of in house maintenance as well as the outsourcing maintenance. In addition, the data will be used as well to find if there is any correlation between the option of in-house / outsourcing maintenance and the improvement of performance as well as with other variables measured. The following formulated hypothesis is as follows:

Hypothesis H5: Higher improvement of equipment availability can be expected for the company that uses in-house maintenance in their plant.

This hypothesis will be tested and addressed in chapter four to determine whether the maintenance programmes and approaches given in the literature can be confirmed in practice by reference to the empirical findings in this area.

The strategic initiatives discussed above in terms of the best maintenance approaches to be used leads to another aspect which is the implementation stage. In order to achieve the maintenance objectives, it is very important to realize that whatever maintenance programmes or approaches are used, maintenance personnel is the main factor for its successful implementation. In the maintenance implementation stage, people who will eventually operate, manage, support and maintain the operation. The human aspects in relation to the maintenance employee development will be addressed further in following section 2.5.

2.5. Human Resource and Employee Development in Maintenance

This section presents the issue of human resource and employee development for maintenance personnel, as a continuation from the human factors and employee involvement in manufacturing environment presented in the previous section. One hypothesis in relation to the maintenance employee development (*H6-i and ii*) is then formulated in this section.

2.5.1. Lacking of maintenance competencies

In determining the cause of major breakdowns, Robertson [145] conducted a study using root cause failure analyses. In this study human factor was found to be the direct contributor. This often happens because a maintenance personnel has been told to do the job but has had no formal training on how to do it.

In relation to this issue, Smith [146] has assessed the skill level of thousands of maintenance personnel in the U.S. and Canada manufacturing industries. He found that eighty percent of the people scored less than fifty percent of where they need to be in the basic technical skills to perform their jobs. The skill level of the maintenance personnel in most companies is well below what industry would say is acceptable.

Furthermore, it is reported that a number of surveys conducted in industries throughout the United States have found that seventy percent of equipment failures are self-induced [94]. Between thirty and fifty percent of the self-induced failures are the results of maintenance personnel not knowing the basics of maintenance. Maintenance personnel, who although skilled, choose not to follow best maintenance repair practices, potentially cause another twenty to thirty percent of those failures.

According to Robertson's observation [145], maintenance personnel really do have a good attitude towards their chosen profession, but they are often frustrated when they lack the proper tools and training needed to produce professional results. Groote [147] added that apart from the lack of motivation and attitude towards the job, the technical qualification of the local workers is generally low, particularly among the craftsmen and foremen. A complete lack of technical schooling, and above all the absence of an industrial tradition and experience, mean that any maintenance which is carried out, is in a word, a catastrophe.

2.5.2. Importance of training and development

Most publications on human resource management stress the importance of training and development for individual and organizational growth and success. In reviewing manufacturing improvement strategies as a whole, Samson et al [148] stated as a result of case study research state: "...in all cases, it was found that the new systems cannot simply be placed into an organisation without carefully attending to a number of human resource issues such as training and skills, cooperation and involvement and overall work culture".

Bowey [149] defined "manpower planning" as "the activity of management which is aimed at coordinating the requirements for and the availability of different types of employee". Keep [150] stress that human resource development is "a vital component" in HRM, an integral, part of wider employment strategies and a "useful litmus test" of the reality of human resource management.

Laird [151] summarized the importance of training and development this way: Training is the acquisition of the technology, which permits employees to perform to standard. They must master the special technology used by their organization before they can perform their tasks properly. As Storey et al [152] put it, a high investment in training and development can lead to the more effective utilization of high technology, higher skill levels, higher wages and lower unit labour cost, leading ultimately to competitive advantage.

2.5.3. Means used in acquiring knowledge and competency

This study will examine the various means use by the maintenance personnel to acquire and increase their knowledge and competencies in performing the maintenance job.

According to Marchington and Wilkinson [153], traditionally, organizations used to employ specialists whose job was merely to "instruct and teach" people how to do tasks more efficiently. Nowadays, the emphasis is on "learning" – both from the standpoint of the individual and from that of the organization. "Man power planning" is seen to be at the junction of a number of disciplines – economics, statistics, operational research, organization studies, and politics – and to be highly relevant for employers who are confronted with skill shortages as well as problems of how to plan careers for their managerial staff [153].

In fact, there are various means use by the maintenance personnel to acquire and increase their knowledge and competencies in performing the maintenance job such as learning, education, training and development.

Learning is the "process by which a new capability is attained" [154]. Although all the learning approach terms such education, training, and development are often used interchangeably, there is a need to be aware of the major distinctions between them, at least in their pure form [153]. *Education* has been defined as "activities which aim at developing the knowledge, skills, moral values and understanding required in all aspects of life. Its purpose is to provide the conditions essential to young people and adults to develop and understanding of the traditions and ideas influencing the society in which they live" [154].

On the other hand, *training* is a much narrower concept than education, referring to a "planned process to modify attitudes, knowledge or skill behaviour through learning experience to achieve effective performance in an activity or range of activities" [154]. The notion of predetermined standards is important here, as too is the rather more limited purpose and coverage of training [155] and more explicit reference to instruction [156].

There is less agreement among authors about the definition of *development*. Collin [157] viewed development as a broader term of learning, in terms of its complexity and elaboration, as well as its continuity, but nevertheless saw it as rooted in the individual. Reid et al [154] defined it as "the planning and management of people's learning", while Harrison [155] refers to employee development as "the skillful provision of learning experiences in the workplace in order that performance can be improved".

Truelove [158] defined development as "a process whereby individuals learn through experience to be more effective. It aims to help people utilize the skills and knowledge that education and training have given them – not only in their current job, but also in future posts. It embodies concepts such as psychological growth, greater maturity and increase confidence". According to Truelove, opportunities for learning may be put into three categories [158]: First, learning deliberately initiated by someone else includes 'formal' development interventions, such as coaching, mentoring, counselling, planned experience, projects and committees. Second, learning that occurs as a consequence of the demands the job makes includes covering, crisis and organizational growth. And third, learning initiated by the individual includes volunteering, reading, outside activities.

In relation to this aspect, this study will examine the means used and practiced by the maintenance personnel in acquiring knowledge and competency. This includes the participation of maintenance personnel in maintenance conference, seminar or workshop, and the subscription of maintenance journal or technical publication. This will further examine the information about development of maintenance personnel, which is related to the testing of hypotheses H6-i and H6-ii.

2.5.4. Nature of training needs

According to Harrison [155] and Moorby [159], contemporary treatments of employee development continue to relate the concept of training need to the existence and achievement of organisation objectives. Thus the exact nature of organization objectives will determine, to some extent, the nature of training needs existing in a particular organization at any given time [160]. The link between organization objectives and training needs, leads to the characterisation of a training need as a 'gap' [158]. As Steward [161] put it: a training need is the same as a gap between existing capability and that required to achieve performance objectives.

Based on the way of conceptualising a training need, Boydell [162] produced a three interrelated level framework of training needs: the organization, the job or occupation, and the individual employee. Harrison [155] described that identifying individual training needs follows from the job/occupation level. Establishing training needs at this level requires a detailed examination of the selected job or occupation. The purpose of the examination is to produce a "job training specification". This specification describes and details both the nature of the job, and the knowledge, skills and attitude necessary for the effective performance at the defined standard [155].

The above literature discussions on the maintenance employee development lead to the development of the following hypothesis. This information will be used to examine the implementation of training in the companies as well as to find if there is any correlation between implementation of training and the improvement of performance. The relationship between maintenance employee development and the efficiency of the maintenance function is thus examined by means of the following two inter-related hypotheses:

Hypothesis H6-(i): The maintenance employee development and training are better implemented for companies using training need analysis.
Hypothesis H6-(ii): The maintenance employee development and training will contribute towards a better performance of improvement in equipment availability.

As conclusion, depending on the empirical data results, taking these and the previous hypotheses together can lead to the conclusion that association between the maintenance employee development and the efficiency of the maintenance function. The outcome of this study would be interesting in proposing a deployment strategy for the development of maintenance personnel. This issue will be addressed further in chapter four and five.

2.6. Irish and Malaysian Manufacturing Perspective

In this section, the discussions on the Irish and Malaysian manufacturing industries perspective take place for the purpose in establishing the context of research topic undertaken. It presents the information about Irish and Malaysian manufacturing industry perspective in terms of industry evolution and economic growth. The information discussed in this section will be useful in conducting the comparative study between both countries which analyze the common as well as the differences between both countries in the aspect of maintenance of the automated manufacturing industry. The last hypothesis in relation to the Irish and Malaysian maintenance practice trend (*H7*) is then formulated in this section.

2.6.1. Review of the evolution of Irish economy

Manufacturing industrial sectors play an important role in both the industrialized country and developing industrialized country. Over the past decades, the traditional focus of Irish economic activity has shifted from agriculture to industry. Following a period of recession, the Irish economy has enjoyed significant growth over the past decade, earning Ireland its “Celtic Tiger” nickname. This growth, both in employment and output terms, is most marked in the manufacturing sector [163].

Since independence in 1922 the evolution of the Irish economy falls broadly into two main periods [21]: The first period is the era of Protectionism and Economic Nationalism (1922-1955). During the earlier period, there was a decisive shift towards economic nationalism and protectionism based on "infant-industry" arguments. At the time those working in agriculture accounted for over 50% of the labour-force and agri-based exports accounted for almost 90% of exports. The second period is the outward orientation of Ireland's economy (1955 to date). Starting in the 1950s economic development policies in Ireland became increasingly focused on export generation and the opening up of the Irish economy to embrace international developments.

The orientation of policies can conveniently be broken into four phases as follows [21]:

i) 1955-1973: The shift from Protectionism to Internationalism. The full impact of the overall relative failure of the economic policies pursued since independence became clear with the 1961 Census of Population. These developments helped to generate policy changes in the 1950's which laid the foundations for, what turned out to be, unprecedented high rates of economic growth achieved in the 1960's and early 1970's.

ii) 1973-1983: The impact of the international oil crises. With membership of the EEC in 1973 and following a period of unprecedented economic growth over the previous 10 years expectations of significant advance in economic development and living standards in Ireland over the following decade and beyond were high. In the event these expectations were not realised during the 1970s and 1980s due largely to the impact of the major increases in oil prices in 1973 and 1979, the attendant world economic recession and, what turned out to be, inappropriate economic policies pursued by successive governments. However, while the population, labour-force and employment increase achieved during the 1970's were significant, they depended, to a considerable extent, on an unsustainable stimulus of the economy through high public sector borrowing and spending.

iii) 1983-1993: Crisis driven adjustment. The economic crisis of the mid-1980's led to the negotiation of a three-year national programme (1987-1990: published under the title of Programme for National Recovery). The relative success of this national programme has led to the further negotiation of a series of three-year social partnership programmes subsequently. The process has also been increasingly extended, on a voluntary basis, from the national level to the level of local communities and individual enterprises.

iv) 1993 - present: period of exceptional economic growth. The process of economic adjustment initiated in the mid-1980's together with other factors relating to demography and policy initiatives introduced in earlier decades, but which bore fruit in the 1990's, has led to a period of exceptional economic growth in Ireland in the 1990's until present.

2.6.2. Phenomenon of Irish economic growth

Since the mid-1950s the country's industrial base has expanded, and now mining, manufacturing, construction, and public utilities account for approximately thirty four percent of the GDP, while agriculture accounts for only about four percent. Private enterprise operates in most sectors of the economy [164].

Over 1,050 overseas companies have chosen Ireland as their European base and are involved in a wide range of activities in sectors as diverse as e-Business, engineering, information communications technologies, pharmaceuticals, medical technologies, financial and international services. Ireland has achieved a global status as a highly successful business environment and centre of excellence for manufacturing in defining Ireland's new era of competitive advantage which will be driven by the availability of the people with the right skills, quality infrastructure, waste management and telecommunications [23].

Ireland has become the main European centre for the high-technology sectors of manufacturing while other major industries include fishing, pharmaceutical and financial services. It is also the second largest exporter of software in the world behind the US. High-profile companies such as Microsoft, Oracle, and Sun Microsystems have established their European headquarters in Ireland, while blue-chip hardware manufacturers such as Dell, IBM, and Intel all have major bases in Ireland. The tertiary or services sector has in the last decade been increasing steadily in its importance to the Irish economy [164].

The rapid growth of the Irish economy over the past decade and the simultaneous increase in (i) the number of foreign-owned plants in the high-tech sectors and (ii) the research and development (R&D) activities of foreign-owned plants, have given rise to an increased interest in the relationship between foreign direct investment (FDI) and economic growth in Ireland [163]. Ireland is currently in a state of boom, boasting the fastest-growing economy in the European Union, which is one of the best-performing in the industrialised world [164].

Ideas and knowledge have transformed business and industry and have been crucial in the development of the Irish economy. The Irish Government's economic policies are directed towards the creation of a stable economic environment that is supportive of the needs of business [23].

Ireland's economic growth rates in recent years have consistently been among the highest of the Organization for Economic Co-operation and Development (OECD) countries [165], as shown in table 2.3. Between 1993 and 1997, the economy grew by an unprecedented 40 per cent, and the trend has continued, albeit it at a slower rate. Growth in 2004 was a healthy 5.6 per cent in real GDP [23].

Table 2.3 - GDP Growth among the OECD countries [165]

Country	2003	2004	2005
Ireland	3.7%	5.6%	5.7%
UK	2.2%	3.2%	2.6%
France	0.5%	2.1%	2.0%
Spain	2.5%	2.6%	2.7%
Germany	-0.1%	1.2%	1.4%
Netherlands	-0.9%	1.2%	1.2%
Portugal	-1.2%	1.5%	2.2%
Switzerland	-0.4%	1.9%	1.9%
USA	3.0%	4.4%	3.3%
Japan	2.5%	4.0%	2.1%
Euro Area	0.6%	1.8%	1.9%

The forces of growth are firmly rooted in Ireland's economy, through favourable demographics, increasing investments in education and a high rate of technology-oriented investments. This spectacular growth is due, in the main, to the competitive features of the Irish economy and its openness to international trade [23].

In terms of unemployment rate, according to The ESRI (Economic and Social Research Institute), Ireland's unemployment rate stood at around 4.4 per cent in

2004, which is the second lowest unemployment rate in the EU at less than half of the EU 25 average [164].

2.6.3. Success factors of Irish economy

It should be noted that the rate of increase in GDP per head in Ireland relative to the EU over the past 30 years has been driven by two principal factors [21]: The first factor is the strong productivity growth (output per head) particularly in an increasingly high-tech industrial sector. The second factor is the falling economic dependency ratio (i.e. the ratio of total population to the number of people employed) as employment and labour participation rates increased and unemployment and the proportion of the population outside the 15-64 year age groups fell.

In seeking to identify the underlying reasons for the economic success achieved by Ireland in recent years, it is useful to keep in mind the following eight factors [21]. These are among the most influential in explaining the success achieved in more recent years: i) macro-economic management; ii) EU membership; iii) social partnership agreements; iv) research and development investment; v) taxation reform; vi) demographics/skills/education; vii) public administration; and vii) industrial policy.

These economy and industrial policies and activities establish the fundamental parameters which support the promotional work of the agencies and determine their relative success. There has always been a wide range of public sector policies and activities behind the work of bodies like IDA Ireland (the body responsible for promotion of FDI in Ireland) and Enterprise Ireland (the body responsible for the promotion of indigenous industrial development and trade promotion) which set the framework within which these agencies carry out their work [21].

2.6.4. Continuous economic growth in Malaysia

For centuries, Malaysia's central position between the Indian Ocean and the South China Sea made her a meeting point for traders from the East and West. Over the last forty years, the structural change of Malaysia's economy has been spectacular. From a country dependent on agriculture and primary commodities in the sixties, Malaysia has today become an export-driven economy spurred on by high technology, knowledge-based and capital-intensive industries.

Malaysian economy has performed remarkably well over the years due to the country's political stability, the sound financial and economic policies adopted by the government, and the efficient management of its natural resources which include oil and gas. Even more impressive is the fact that economic growth in Malaysia was achieved within an environment of relatively low inflation [22].

With the recovery of the global recession in 1985-1986, the Malaysian economy grew rapidly from 1991-1995 at an average rate of 8.7% per annum. The growth momentum over the next five years from 1996-2000 was disrupted by the severe contraction in 1998 arising from the East Asian financial crisis. Malaysia's GDP had expanded at an average rate of 8.7% per annum during the period from 1996-1997 before registering a negative growth rate of 7.4% in 1998. Efforts by the government to resuscitate the economy starting from mid-1998 succeeded in generating an average growth rate of 7.2% during the period from 1999-2000. Overall, the economy grew better than expected at an average of 4.7 per cent per annum during the period [166].

In the last four years, the Malaysian economy recorded a creditable performance despite the unprecedented volatility in the global economy as well as uncertainties arising from international issues. Through fiscal stimulus and accommodative monetary policies, the government was able to sustain growth due to the expansion in domestic demand and promotion of domestic sources of growth. From a GDP growth rate of only 0.4% in 2001, the Malaysian economy recovered strongly to register growth rates of 4.2% and 5.2% in 2002 and 2003 respectively. With the outlook for the global economy becoming increasingly optimistic, the Malaysian economy is continuing to strengthen further in 2004 with the real GDP growth is 7.1% [167] [168] as shown in table 2.4.

Table 2.4. - Malaysia's Key Economic Indicators [167] [168]

Malaysia Key Economic Indicators		
Currency rate in June 2005: (US$1.00 = RM3.80)	2004	2005
Population	25.6 million	26.13 million
GDP	RM248.06 billion (*US$65.3 billion*)	RM262.6 billion (*US$69.1 billion*)
GDP Growth	7.1%	5%-6%
Per capita income	RM16,098 (*US$4,235*)	RM16,693 (*US$4,393*)
Inflation rate	1.4%	1.8%
Labour force	10.9 million	11.3 million
Unemployment	3.5%	3.4%
Total export (f.o.b.)	RM479.9 billion (*US$126.3 billion*)	RM514.05 billion (*US$135.3 billion*)
Total import (f.o.b.)	RM399.8 billion (*US$105.2 billion*)	RM427.6 billion (*US$112.5 billion*)
Major exports	Manufactured goods (electronic products, chemicals and plastic products, wood products, iron and steel products, metal products, and petroleum products).	
Major imports	Intermediate goods (thermionic valves and tubes, primary and processed industrial supplies, parts and accessories of capital goods, primary and processed fuel lubricants, and parts and accessories for transport equipment)	

During the last decade, Malaysia's trade expanded by 2.3 times to reach RM716.6 billion (US$188.6 billion), with exports increasing by 2.6 times to RM398.9 billion (US$104.9 billion) and imports doubling to RM317.7 billion (US$83.6 billion). In 2005, Malaysia is the world's 18th leading exporter and 20th leading importer [22].

The manufacturing sector now accounts for 31.6% of Malaysia's GDP while exports of manufactured goods make up 78.4% of the country's total exports. From being the world's largest producer of rubber and tin, Malaysia is today one of the world's leading exporters of semiconductor devices, computer hard disks, audio and video products and room air-conditioners [22].

Malaysia's rapid industrialization was the result of the country opening itself relatively early in the 1960s to foreign direct investments (FDI). Today, its market-oriented economy, combined with an educated multilingual workforce and a well-developed infrastructure, has made Malaysia one of the largest recipients of FDI among developing countries. The Institute for Management Development (IMD) in its 2004 World Competitiveness Yearbook ranked Malaysia as the fifth most competitive country in the world (for countries with a population of greater than 20 million), ahead of countries such as Germany, United Kingdom, Japan and Mainland China [22].

2.6.5. Comparative study between Irish and Malaysian maintenance practices

In this study, a comparative study between both countries – Ireland as an industrialized country and Malaysia as a developing industrialized country, will be carried out in order to analyze the common as well as the difference between the practices in both countries. The comparative study that will be carried out between both countries in the aspect of maintenance of the automated manufacturing industry, leads to the formulation of the last hypothesis in this study.

Hypothesis 7: As both countries, Ireland and Malaysia have similar trends of consistent rapid growth and pattern of production technology, the trend of its maintenance practices are more likely similar.

Malaysia as a new comer in the scene of developing industrialized country is prepared to emulate Ireland and other countries in order to continue to invest towards the development of technology, human resource and self reliant industrialization. With similar trends of consistent rapid growth and pattern of production technology, Malaysia could learn and emulate the good practice in the Irish manufacturing industries as Ireland has gone through the experience in terms of sustained rapid growth of economic development over a longer period of time.

2.7. Deployment Strategy for the Development of Maintenance Personnel

An effective maintenance requires an understanding of the link between the maintenance function and maintenance employee involvement. However, in practice these links are often forgotten or at least are not emphasized. Little empirical research exists to guide maintenance managers in understanding these links.

Through the literature review conducted, there are quite a number of researches which related to the maintenance aspects. On the aspect of maintenance strategy, human resource is considered as one of the decision elements [2]. The maintenance employee involvement is a critical factor in the implementation stage and the overall job satisfaction and organizational commitment were significantly associated with their involvement. In other words, the skills of maintenance workforce will determine the effectiveness and the efficiency of the functionality of the maintenance department.

However from the above literature review, there are no direct or very few studies emphasizing on the understanding of the links between the maintenance functions and maintenance employee involvement as well as on the deployment strategy for the development of maintenance personnel especially in the context of Malaysian manufacturing industries. Hence, there is a need for empirical research on deployment strategies for the development of maintenance employee incorporated within the company's maintenance strategy.

As such, based on the theoretical understanding found in the literature and the empirical findings in this study, in line with the stated objective of this research, the maintenance strategy will be reformulated. The decision elements in developing the maintenance strategy, as discussed in section 2.3.9, will be used as a guideline. This framework will lead to the proposed deployment strategy for the development of maintenance personnel in Malaysian automated manufacturing companies, where the findings from the empirical data of this study in each maintenance elements will be used accordingly.

2.8. Chapter Summary

This chapter provided a comprehensive and up-to-date literature review on the subject of human aspects of maintenance in automated manufacturing environment. In line with the purposes of literature review, this chapter presented a review of existing literature in developing the theoretical understanding on the following topics with the specific purposes, in accordance to the aims of this research: Human factors in manufacturing environment; Maintenance strategy in the automated manufacturing environment; Current trend of maintenance practice; Human resource and employee development in maintenance; and Irish and Malaysian manufacturing perspective. In the context of this study, seven hypotheses are formulated, for the purpose of offering a clear framework and direction to this research, as well as to guide when collecting, analyzing and interpreting the data.

It has set out the primary objective of this study concerning the employee involvement in maintenance, relationship between maintenance and production technology, as well as the maintenance personnel training and development within the organisation of automated manufacturing environment in Malaysian companies with comparison to Irish companies' experiences.

Following the preliminary research effort and literature review, the next phase of the research work will be the selection of research methodology for collecting information, which will be addressed in chapter three.

Chapter 3
RESEARCH METHODOLOGY

3.0. Introduction

The preliminary research effort and literature review assist in determining the areas that need to be addressed in designing of the implementation framework. Following this, the most important phase of the research work comes next, the selection of research methodology for collecting information that will illuminate the topic. Therefore, it is essential to gain a good understanding of the issues surrounding the research methodology prior to going into the fieldwork.

The purpose of this chapter is to provide an overview of research methodologies and justification for the selection of appropriate methodologies used in this study to address the objectives of the research. The chapter starts with an overview of research in general and a description of research philosophies as it is an integral part of any research work. This follows by making explicit description of certain terms related to the research methodology that will be used frequently during the thesis. The chapter then presents the research methodology chosen i.e. questionnaire survey research, in elaborating the research instrument and process, as well as the statistical analytical tools and tests used in this study.

3.1. Research Process of This Study

The Research process is usually described as a sequential process which involves several clear defined steps. However, according to Blumberg [12] it does not necessarily require that each step is completed before going on to the next one. Despite these real life variations, the idea of a basic sequence is useful in developing a research project and in keeping things orderly as it unfolds.

Some methodologists (e.g. Berger et al., 1989) suggested that the use of research models [14]:

- offer a guide that directs the research action, helping to reduce time and costs to a minimum.
- help to introduce a systematic approach to the research operation, thereby guaranteeing that all the aspects of the study will be addressed and that they will be executed in the right sequence.
- encourage the introduction of an effective organization and coordination of the project.

Sarantakos [14] presented a research model in terms of steps and elements, as shown in Table 3.1.

Table 3.1 - The research model – Sarantakos [14]

STEPS	ELEMENTS
ONE: *RESEARCH PREPARATION*	▶Selection of research topic ▶Defining research objective ▶Formulation of hypothesis ▶Selection of research methodology
TWO: *RESEARCH DESIGN*	▶Selection of sampling procedures ▶Selection of methods of data collection ▶Selection of methods of data analysis ▶Arrangement of administrative procedure
THREE: *EXECUTION*	▶Data collection
FOUR: *PROCESSING*	▶Grouping and presentation of data ▶Analysis of interpretation of data
FIVE: *REPORTING*	▶Publication of the findings

Another author, Punch [13] presented another model of research which shows research questions with hypothesis as shown in figure 3.1. The research questions are the straightforward ones of '*what*' (what question is the research trying to answer? what is it trying to find out?) and '*how*' (how will the research answer these questions?). This model of research helps to organize the planning, execution and writing up of the research.

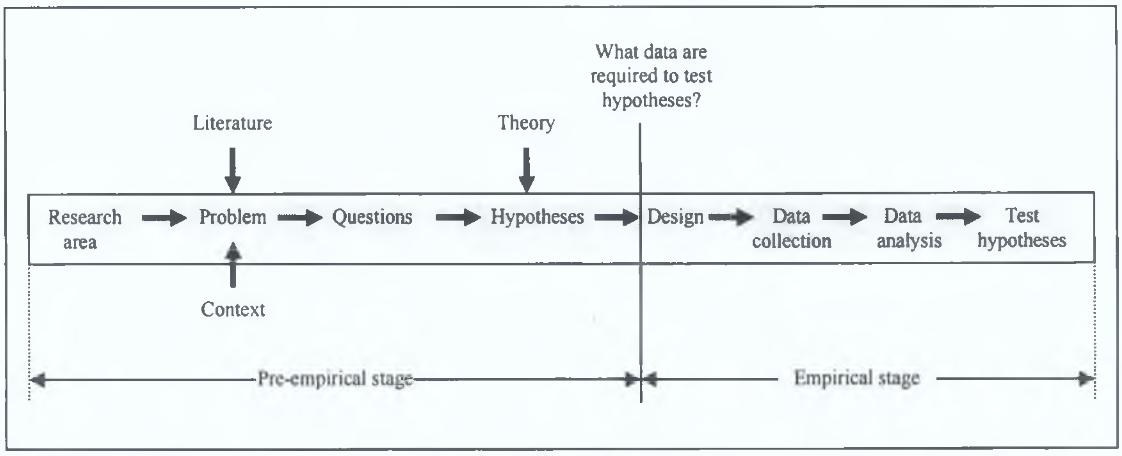


Figure 3.1 - The research model – Punch [13]

In adopting the two research models as described in table 3.1 and figure 3.1, figure 3.2 illustrates the research journey of this study. This provides a structured guidance to understand the link between each process and tasks at different stages of this research work. The details of research philosophies, research methodology and research design employed in this study are discussed in the following section.

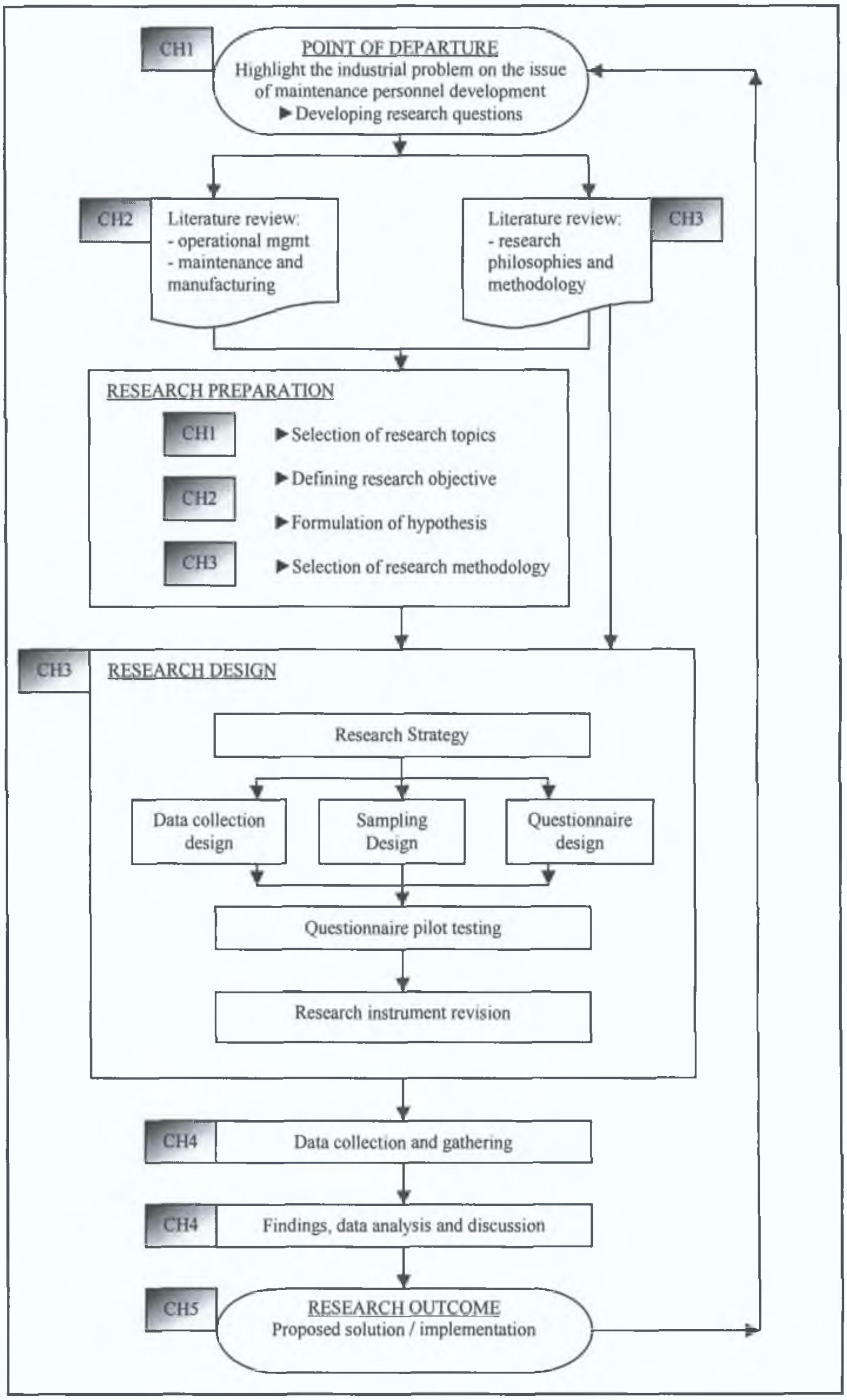


Figure 3.2 – Summary of research process

3.2. Overview of Research Philosophies

Science may be said to progress on its methods. The production of knowledge depends very much on the techniques for collecting, analyzing and interpreting data and on the way they are applied [169].

Nodoushani [170] quoted that throughout the short history of positivist epistemology research has been defined as the formal process of inquiry by an organized quest for principles, theory or even "laws of nature", as quoted from Spraque (1976) definition.

According to Blumberg et al [12], *research* is based on reasoning (theory) and observations (data or information). How observation and reasoning are related to each other is a still ongoing and old philosophical debate on the development of knowledge. Although many researchers conduct sound research without a thought for underlying philosophical considerations, some knowledge of research philosophies is beneficial for a researcher as it helps to clarify the research design and facilitates the choice of an appropriate one. Furthermore, Easterby-Smith et al [71] emphasized that by understanding the basic assumptions of research philosophies can enable researchers to reach beyond their past experiences.

There are two most distinguished research philosophies that are often been discussed in the literature, with clearly differentiates extremes: *positivism* and *interpretivism* (also called *phenomenological*). Different names have been used to identify both philosophies. The former is also known as *objectivist, traditional or main stream* while terms such as, *phenomenological, humanistic, hermeneutic and subjectivist* have been used when referring to the latter [12] [14] [171].

3.2.1. Positivism

Positivism is a research philosophy adopted from the natural science. Its three basic principles [12] are:

a. the social world exists externally and is viewed objectively

b. research is value-free

c. the research is independent, taking the role of an objective analyst.

According to positivism, knowledge develops by investigating the social reality through observing objective facts. This view is important implications for the relationship between theory and observation, as well as for how research is conducted. Theory development starts with hypothesizing fundamental laws and deducing what kind of observations support or rejects the theoretical predictions of the hypotheses.

Positivism implies the following assumptions: the social world is observed by collecting objective facts; and the social world consists of simple elements to which it can be reduced.

Scientists following this research tradition believe that observable facts are objective, because they are external, i.e. cannot be influenced, and research is conducted value-free.

3.2.2. Interpretivism

Unlike positivists, interpretivists hold the view that the social world cannot be understood by applying research principles adopted from the natural science and propose that social sciences require a different research philosophy. The basic principles of interpretivism [12] are:

a. the social world is constructed and is given meaning subjectively by people

b. research is part of what is observed

c. the research is driven by interest.

Interprevitists argue that simple fundamental laws are insufficient to understand the whole complexity of social phenomena. Knowledge is developed and theory built through developing ideas inducted from the observed and interpreted social constructions. Interprevitists attempt to understand subjective realities and to offer interpretative explanations, which are meaningful for the participants of the research [12].

3.2.3. Research implication of positivism and interpretivism.

The opposing stances taken by positivists and interpretivists are summarized in table 3.2 [12]. These differences in basic principles and assumptions have several implications for how researchers should conduct research.

Table 3.2 -The differences in basic principles and assumptions between positivism and interpretivism [12]

	Positivism	**Interpretivism**
Basic principles		
View of the world	The world is external and objective	The world is socially constructed and subjective
Involvement of researcher	Researcher is independent	Resewarchwer is part of what is observed and sometimes even actively collaborates
Researcher's influence	Research is value-free	Research is driven by human interest
Assumptions		
What is observed	Objective, often quantitative, Facts	Subjective interpretation of meanings
How is knowledge developed?	Reducing phenomena to simple elements representing general laws	Taking a broad and total view of phenomenon to detect explanations beyond the current knowledge.

Positivism starts from the idea that the world can be described by objective facts, which are then investigated. Therefore, one needs to assess whether observations are indeed objective facts. The constructs used are operationalized to ensure that observing the same phenomenon measure it in the same way. In practice, constructs are often operationalized in quantitative terms, as presenting facts using numbers facilitates comparisons. On the other hand, interpretivist is interested in subjective meanings and interpretations of phenomena to detect what is happening in a specific situation.

In the positivist side, Easterby-Smith et al [171] noted that the research methods used will focus on developing and testing hypothesis. This will be done by taking large samples and measuring the phenomena using objective method (i.e. quantitative) rather than subjective methods. Furthermore, as shown in table 3.3 Easterby-Smith et al [171] summarized the differences characteristics of these two research philosophies.

Table 3.3 - The differences in characteristics between positivism and interpretivism [171]

	Positivism	**Interpretivism**
Research should	Focus on facts Look for causality and fundamental laws Reduce phenomena to simplest elements Formulate hypotheses and then test them	Focus on meaning Try to understand what is happening Look at the totality of each situation (i.e. historical-contextual characteristics) Develop ideas through induction from data
Preferred methods includes	Operationalising concepts so that they can be measured Taking large samples Quantitative methods	Using multiple methods to establish different views of phenomena Small samples investigated in depth or over time Qualitative methods

3.3. Research Methodology

In the literature, it is found that there are differences between authors in the definition of research methodology. Different researchers offer different definitions according to their own personal views.

According to Sarantakos [14] research methodology seems to be defined in at least two ways. In one form, methodology is identical to a research model employed by a researcher in a particular project. Another definition relates the nature of methodology to a theoretical and more abstract context. Here, a methodology is supposed to offer research principles related closely to a distinct paradigm translated clearly and accurately.

In terms of prominent operational features of a research methodology, Easterby-Smith et al [171] described that a research methodology will explain and justify the particular research strategy and methods used in the study.

Flynn et al [29] outlined a methodology and recommended the following steps to be followed:

- Establish the theoretical foundation
- Select a research design
- Select and implement a data collection method
- Analyse data and present work

The process of the theoretical foundation establishment is discussed in the following section. Accordingly, the selection of the research methodology and description of the data collection method are described. The result and data analysis take place in chapter four.

3.3.1. Theory verification and theory building

Flynn et al [29] believed that there are two ways in which the theoretical foundation can be established, ie by 'theory verification' or 'theory building'. According to Wolcott [172] this is the distinction between "theory-first" and "theory-after". In theory-first research, it starts with a theory, deduce hypotheses from it, and design a study to test these hypotheses. This is theory verification. On the other hand, theory-after research, it does not start with a theory. Instead, the aim is to end up with a theory, developed systematically from the data that has been collected. This is theory building (or called theory generation).

A similar explanation was given by Flynn et al [29] in differentiating these two research purposes. Theory verification is the approach used where the focus is on testing the hypothesis rather than analyzing its origin. Using this approach the hypotheses are constructed before the research starts and then tested when the data are obtained. Theory building studies, however, use information in different ways and the starting point is based on propositions, assumptions or problems rather than definite hypotheses. Information is collected in order to define the propositions, and thus they are grounded in data even before the actual theory building begins. Flynn et al [29] added that "the actual of theory building lies in its permitting a wider range of observation and inquiry than the more traditional theory testing done".

Historically, there has been a correlation between the purpose of the research (whether it is aimed at theory verification or theory building) and the approach used in the research (qualitative or quantitative). Quantitative research has typically been more directed at theory verification, while qualitative research has typically been more concerned with theory building [13]. While that correlation is historically valid, it is by no means perfect, and there is no necessary connection between purpose and approach, as pointed out by various writers (for example, Hammersley [173] and Brewer and Hunter [174]). According to Punch [13], it depends on the topics, on the context and practical circumstances of the research, and especially on how much prior theorizing and knowledge exist in the area. He added that when an area has a lot of unverified theories, an emphasis on theory verification research seem a good thing. On the other hand, when an area is lacking in appropriate theories, it is time for the emphasis to shift to theory building [13].

3.3.2. Deduction versus Induction

According to Blumberg et al [12], characteristics of science research is the inclusion of theory. It may start with theory in order to test it or solve a theoretical contradiction, or may close with theoretical considerations drawn from the observation. The position or role of theory in the research is directly link to different reasoning approaches: deduction and induction.

In comparing between these two different approaches, Preece [27] explained that "induction provides ideas, whereas deduction is used to test and to confirm or reject ideas, wholly or impart". He added that the use of deductive methods is attractive because if the argument is all valid then the conclusion is certain. Induction methods on the other hand require a "creative leap". It means that new ideas are needed to reach the conclusion, and extra evidence can support the conclusion [27].

This study utilizes the theory verification approach (deductive approach), as the research hypotheses were set down as presented in chapter two, then test it in practice using the empirical data collected.

3.3.3. Descriptive and explanatory

Before designing the research, a decision has to be made about the overall strategy and what are the most useful data collection methods. According to Punch [13], descriptive and explanatory represent two different levels of understand. The distinction between them is particularly relevant to the purpose of a piece of research. Description is concerned with making complicated things understandable. Explanation, on the other hand involves finding the reasons for things, events and situations, showing why and how. A good way to make contrast is to say that description focuses on what is the case, whereas explanation focuses on why and how something is the case [13].

The descriptive element of the research is also important as description is the foundation of knowledge" [27]. As in this thesis, the descriptive work can then be used to construct an explanation or be fitted into an explanatory work [175]. Identifying relationship or correlation between different variables will also allow a certain level of prediction to take place, although care will be taken in this study not "to assume that all observed relationships are casual" [27].

Pinsonneault and Kraemer [176] differentiated between descriptive and explanatory in terms of purposes of survey research:

i) The purpose of survey research in description is used to find out what situations, events, attitudes or opinion are occurring in a population. It aims to describe a distribution or to make comparisons between distributions.

ii) The purpose of survey research in explanation is used to test theory and casual relations. It aims to ask about the relationships between variables.

This study use a combination of descriptive and explanatory approach in nature where the research will attempt to examine the aspect of maintenance and the linkage between the maintenance strategy, maintenance practices and the maintenance employee involvement in the companies examined.

3.4. Formulation of hypotheses

Sarantakos [14] defined hypotheses as an assumption about the status of events or about relations between variables. It is a tentative explanation of the research problem, a possible outcome of the research, or an educated guess about the research outcome. According to Blumberg [12], as a declarative statement, a hypothesis is of a tentative and conjectural nature.

In term of generating hypotheses, Sarantakos [14] quoted from Selltiz (1976) who stated that hypotheses are generally translation of research question and can be generated in many ways. They can be developed, for instance, through existing theories; they can be based on social policy, research findings of other studies, evidence, commonly held beliefs, intuition, and the findings from exploratory studies especially designed for this purpose.

Hypotheses can be formulated [12][14] in the form of:

- descriptive, which describe events. These are propositions that typically state the existence, size, form or distribution of some variable.

- relational, which establish relations between variables. This is divided into two: First, correlation hypotheses state merely that the variable occur together in some specified manner without implying that one causes the other. Second, explanatory (causal) hypotheses state that there is an implication that the existence of, or a change in, one variable causes or leads to a change in the other.

- directional, non-directional or null, depending on whether or not they make a concrete suggestion about the research question.

In the context of this study, seven hypotheses are formulated, for the purpose of offering a clear framework and direction to this research, as well as to guide when collecting, analyzing and interpreting the data [14]. The seven hypotheses that have been developed in chapter two are:

Hypothesis H1: Human factor i.e. maintenance personnel is among the major problems faced by the maintenance department in carrying out their maintenance tasks.

Hypothesis H2: The maintenance function should be regarded as a sufficiently important function to the business strategy and get full commitment from the top management

Hypothesis H3: The use of complex machineries (in terms of integration and production technology) will be higher for the company reporting high level of automation.

Hypothesis H4-(i): The use of specific type of maintenance practices and strategy will contribute to the improvement of equipment availability.
Hypothesis H4-(ii): The use of communication and coordination support (such as CMMS) will contribute to the improvement of equipment availability.
Hypothesis H4-(iii): The use of appropriate maintenance troubleshooting tools will contribute to the improvement of equipment availability.

Hypothesis H5: Higher improvement of equipment availability can be expected for the companies that use in-house maintenance in their plants.

Hypothesis H6-(i): The maintenance employee development and training are better implemented for companies using training need analysis.
Hypothesis H6-(ii): The maintenance employee development and training will contribute towards a better performance of improvement in equipment availability.

Hypothesis H7: As both countries, Ireland and Malaysia have similar trends of consistent rapid growth and pattern of production technology, the trend of their maintenance practices are more likely similar.

3.5. Research design

There are many definitions of research design offered by different researchers or authors. Kerlinger [177] defined research design as a plan and structure of investigation so conceived as to obtain answers to research questions. The plan is the overall scheme or program of the research. It includes an outline of what the investigator will do from writing hypotheses and their operational implications to the final analysis of data. A structure is the framework, organization, or configuration of.... the relations among variables of a study. A research design expresses both the structure of the research problem and the plan of investigation used to obtain empirical evidence on relations of the problem.

According to Blumberg [12], the essential of research design provides a guideline of the kind of answer the study is looking for, methods to be applied to find them, techniques to be used to gather data, kind of sampling to be used and how will time and cost constraints be dealt with [12].

According to Baker [178], there are three primary methods used in research: observation, experimentation and research survey:

3.5.1. Observation

An observation consists of the systematic gathering, recording and analysis of data in situations where the method is more appropriate – usually in terms of objectivity and reliability – and able to yield concrete results The major advantage and disadvantage of observation as a research method is that it is very largely a 'real time' activity [178].

While the participant observer role offers a degree of insight into a situation unlikely to be found in any other method (particularly when the researcher is also counted as an employee of the company under study), the role can be both physically and psychologically tiring, with issues of ethics and confidentiality to deal with as well. At the other end of the scale the pure observer is rather detached from the situation under study, and often looked upon with suspicion by those being observed. Therefore, the researcher is unlikely to understand truly what is happening in the situation and why things happen. In addition any form of observation entails (quite a difficult to secure) high level of cooperation by many members of an organisation and the organisation as a whole, (for political as well as practical reasons) [178].

Baker [178] discussed the advantages and disadvantages of observation as a research method. He explained that the observation method is predominately a real-time activity. With the advent of low cost video cameras it is true that one can record events for later analysis but this is certainly not possible for participant observation where the direct involvement of the observer is an essential part of the methodology. Participant observation is particularly suited to the gathering of qualitative data where one is seeking to establish the behaviour of the subjects in a particular context (family decision making, board meeting, etc). However, unless the observer is unknown to those they are observing, which is often difficult to achieve, there is always a danger of influencing the very behaviour one is seeking to monitor due to the control. Similarly, another danger is that by becoming a participant, the observer will change his own attitudes and/or behaviour and so introduce bias into his observation [178].

3.5.2. Experimentation

An experiment is usually a process of controlling all the variables so that by varying one while holding the others constant, can determine the effect of the input variable upon the output variable [178].

It follows that a basic requirement for the conduct of an experiment is that one must be able to specify all the relevant variables. Experiments are usually undertaken to determine if there is a causal relationship between the variables under investigation.

3.5.3. Survey research

Baker [178] describes a survey research as a systematic gathering of information from a sample of respondents for the purpose of understanding and/or predicting some aspects of the behaviour of the population of interest. Consideration of these definitions indicates that surveys are concerned with:

- Fact-finding
- By asking questions
- Of persons representative of the population of interest
- To determine attitudes and opinions; and
- To help understand and predict behaviour

Pinsonneault and Kraemer [176] defined survey research as "a quantitative method, requiring standardized information from and or about the subject being studied" It has three distinct characteristics. First, the purpose of the survey is to produce quantitative descriptions of some aspects of studied population. Second, the main way of collecting information is by asking people structured and predefined questions. Third, information is generally collected about a fraction of the study population, called a sample, but it is collected in such a way as to be able to generalize the findings to the population.

Hart [179] states that the survey research is the most usual form of primary research undertaken and attributes its popularity to the following factors:

i) Survey research provides the researcher with the means of gathering qualitative and quantitative data required to meet such objective.
ii) One of the greatest advantages of the research is its scope: a great deal of information can be collected from a large population, economically.
iii) Survey research confirms to the specification of scientific research: it is logical, deterministic, general and specific.

Alreck and Settle [180] considered that the main advantages of survey research are as follow: comprehensive, customised, versatile, flexible and efficient. Comprehensive means that the method is appropriate to almost all type of research, where as the other four advantages are closely interrelated and boil down to the fact that one can design surveys to suit all kinds of problems and budgets.

Of course survey research has the advantages and Hart [179] cited the following:
i) The willingness of respondents to provide the desired data
ii) The ability of respondents to provide data.
iii) The influence of the questioning process on the respondents.

3.5.4. Data collection methods

The choice of data collection method, such as postal questionnaire, email questionnaire, telephone interview and face to face interview, is significant because it affects the quality and cost of data collected [176].

The major methods associated with qualitative data collection are interviews, observation and diary methods, while the principal methods associated with quantitative data collection are postal questionnaire and online (web page-based) questionnaire surveys. Each method has a range of options, primarily linked to the objectives of the research, and each has its strengths and weaknesses. Table 3.4 summarizes the main range of the major methods [64].

Table 3.4 - Main Ranges for Qualitative and Quantitative Data Collection Methods [64]

Methods	Main Range	
Face-to-face Interviews	Highly formalized	Free-ranging conversation
Observation	Observation alone	Participant observation (Whether implicit or explicit)
Diary	Simple journal/record of events	Personal journal recording perceptions, feelings, reflecting, insights etc
Postal Questionnaire	Factual Closed (e.g. yes/no)	Opinion Open (e.g. List of things related to X)
Web page-based Survey	Factual Close-end	Opinion Open-end
Telephone Survey	Spontaneous	Scheduled appointment
Survey (both interview and questionnaire)	Stratified sample	Random sample

Moser and Kalton [181] described five methods of data collection as follows: documentary sources, observation survey, postal questionnaire survey, interviewing, combination of the above. According to Moser and Kalton [181] and Fowler [182], the choice of collection methods depends on the research topic, the sample frame, characteristics of the sample and resources. It is clearly one of the most important decisions in this study as it has implications for the rate of response, the survey instrument and the survey cost.

3.6. Selecting an Appropriate Research Method

Each of these methods has advantages and disadvantages. The choice will depend upon the purpose of the study, the type and size of the sample being studied, timeline, budget and staff availability [64].

Given the nature of this research study, i.e. to examine and analyze the maintenance implementation which is later on to be used as an information to develop the deployment of maintenance employee strategy incorporated within the company's maintenance strategy, it requires a decision in selecting the appropriate research methods and data collection.

Baker [178] believed that it is the propositions that will largely govern the approach taken to data collection and the precise questions asked, and of whom if the data cannot be obtained by observation alone. He suggested that in the social sciences, where the main focus of interest is usually human behaviour, it is rare that one is able to apply sufficient controls to make experimentation successful. Furthermore, one is usually concerned to know 'why' people behave in a particular way and inference from observed or experimental data is notoriously weak in doing this satisfactorily. Accordingly, having exhausted the possibilities of observation and experimentation, most researchers will wish to undertake some form of sample survey of the population in which they are interested.

With regards to the methods mentioned above, the deciding factor, in determining which the most appropriate method for this study is without doubt determined by two major factors. These two factors are firstly, the economics of the method and the geographical dispersion of the organisations and secondly, the nature of the study (i.e., availability of knowledge regarding the study and/or questions being investigated). The observation and experimentation methods are not applicable for this study because of the considerable time and arrangements they require.

In this research, the survey research using postal questionnaire data collection is selected because:

i) the fact-finding enquiry into the subject that is of close interest to survival of respondents.

ii) ability to reach widely dispersed respondents, one thousand companies in Ireland and Malaysia

iii) rapid data acquisition and straightforward processing

iv) low cost, very much lower compare to other data collection methods

The survey research using postal questionnaire approach of this thesis is presented, as shown in figure 3.3.

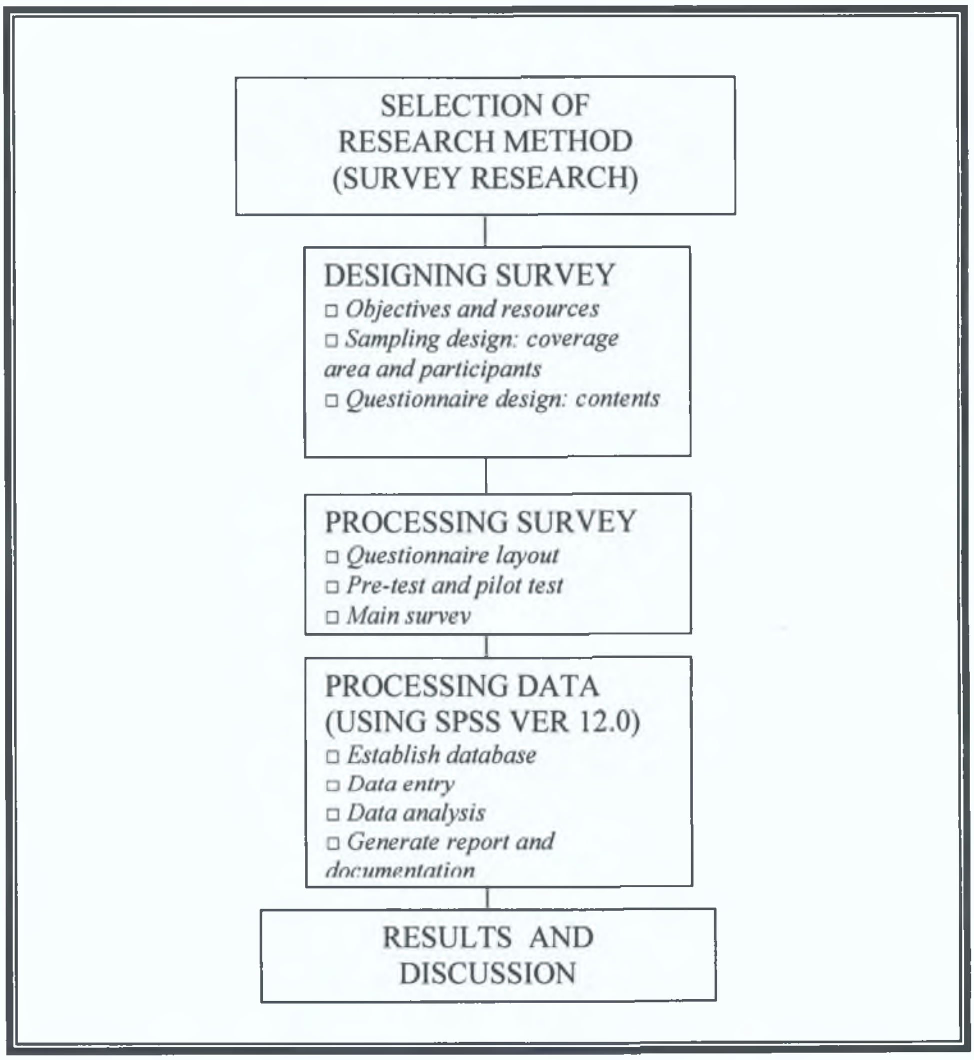


Figure 3.3 – Survey research using postal questionnaire approach

Survey research has often been used to collect data from business organizations. It has been used in the researches to develop explanations for some of the findings on a more comprehensive basis [178]. The same methodology has been also used to study the relationship between maintenance management and production technology by Swanson [1][86] and Ismail [194] in studying the implementation of quality management in the Irish manufacturing companies.

It is acknowledged that by its nature, the survey research method selected to carry out this fact-finding or collection of information is difficult to administer bearing in mind the many factors to be considered in carrying out a sound survey. Thus, in accordance with standard practice of professional survey bodies and due to its wide use in research surveys, this study would proceed with utmost care to ensure that the research survey will follow the well-established principles and guidelines. Details of this will be dealt with in the following section.

3.7. Designing the Survey Instrument

This survey which is the heart of this research study, is on maintenance of automated system. It includes a wide spectrum of maintenance practices, the level of automation implementations, training planning and the implementation, as well as the performance measures and indicator used in the industry.

A prerequisite in designing a good questionnaire is to decide what to measure. According to Fowler [182], this step seems simple and self evident but if overlooked may result in producing low quality questionnaires.

Thus, in accordance with standard practice of professional survey bodies, this study would proceed with utmost care to ensure that the survey questionnaire follows well-established principles and guidelines [182]:

- the procedure on survey design, survey process and selection of sampling frame are established,
- the quantitative as well as qualitative measures and indicators are put in place,
- data processing software / tools and analysis technique are employed accordingly, and
- other necessary steps are taken to ensure a sound and reliable survey

The survey questionnaire in this study was developed based on previous relevant empirical studies found in the literature. Where possible the study would make use of frequently used and tested measures and indicators as well as questions. These steps are necessary to address the issue of reliability and validity raised [182].

3.7.1. Objectives of survey

A survey is a systematic method used to collect data from more than one source to answer one or more questions typically arranged on a form of questionnaire [183].

Specifically, the objectives of the survey are: to gather information on the organizational characteristics, the level of automation employed, the maintenance practice, the problems encountered in maintenance, training planning and implementation, maintenance employee development and the correlation between various variables measured related to the equipment reliability.

3.7.2. Coverage of survey

Sampling is concerned with drawing individuals or entities from a population in such away as to permit generalization about the phenomena of interest from the sample to the population. The most critical element of the sampling procedure is the choice of the sample frame that constitutes a representative subset of the population from which the sample is drawn [176].

It this study, data has been collected from carefully selected manufacturing companies throughout Ireland and Malaysia with the intention of providing a representative snapshot of the current practice of maintenance in both countries.

a) Irish manufacturing companies

Data has been collected from carefully selected five hundred automated manufacturing companies within this sector of Irish manufacturing industry.

A sample of manufacturing companies was identified from the list of companies, which are available from:

i. Irish Times Top 1000 companies

- Total number of companies: 177 companies
- Description: "Irish Times Top 1000 companies" is a business information and an Irish company directory internet-based published by *The Irish Times.ireland.com.* It incorporates the online edition of The Irish Times newspaper. It is recognized as being the definitive brand of quality information and services for Ireland aimed at Irish Internet users and the rapidly expanding 'Irish interest' market [184].

ii. Ireland Enterprise

- Total number of companies: 221 companies
- Description: Enterprise Ireland is the government organization charged with assisting the development of Irish enterprise. Enterprise Ireland deals with indigenous firms engaged in manufacturing and internationally trading services. The aim is to accelerate Ireland's national and regional development by helping Irish companies to develop and compete so that they can grow in world markets. Their clients are mainly Irish

manufacturing and internationally traded services companies and overseas companies operating in Ireland. Enterprise Ireland also administers national and EU supports for building technological innovation capability and co-operation between industry and higher educational institutions. They provide a range of services to help international business access and evaluate appropriate and competitive source of supply in Ireland [185].

iii. Ireland Kompass directory

- Total number of companies: 102 companies
- Description: Kompass Ireland is an independent, Irish-owned company, which operates the Kompass System in Ireland. They offer specific services to buyers and sellers, covers the information on products, companies and key executives. The Kompass System is a marketplace for business and has served European business and industry for some fifty years. Its usefulness has caused it to grow continuously from its origin in Switzerland to its present coverage of more than sixty countries in all continents. The aim of the service is to enable better purchasing through the provision of reliable, timely, classified information [186][187].

The questionnaires were sent in October 2003, directly to the Maintenance or Engineering Manager in each plant. Eighty four of them responded the survey, representing a response rate of 16.8%. Even though the respond rate is considered quite low, comparison of responding plants to non-responding plants showed no significant differences for type of industry, size or age.

b) Malaysian manufacturing companies

Data has been collected from carefully selected five hundred automated manufacturing companies within this sector of Malaysian manufacturing industry.

A sample of manufacturing companies was identified from the list of companies, which are available from The Federation of Malaysian Manufacturers (FMM) company list:

- Total number of companies: 500 companies
- Description: FMM is Malaysia's premier economic organization and it was established in 1968. As the largest private sector economic organization in Malaysia representing over 2,000 manufacturing and industrial service companies of varying sizes, the FMM is the recognized and acknowledged voice of the industry [188].

The questionnaires were sent in October 2003, directly to the Maintenance or Engineering Manager in each plant. Eighty one of them responded the survey, representing a response rate of 15%. Using data available from the original FMM list, comparison of responding plants to non-responding plants showed no significant differences for type of industry, size or age.

3.7.3. Limitation of postal questionnaire survey method

Disadvantages of this method of information gathering include the low response rate and lack of interaction between researcher and respondents.

According to Moser and Kalton [181] there are limitations to the postal questionnaire method, as follow:

- non-response
- questions must be simple and straightforward
- no opportunity to check or clarify answers
- unsuitable where spontaneous answers are required
- questions cannot be made independent of each other as respondents can view all of them before answering
- someone else may answer the questions
- no opportunity to interact with the respondents

Following these limitations, several guidelines would be observed in the designing of the questionnaires in following section.

3.7.4. Questionnaire design

Since a questionnaire survey should be viewed, as in this case, as an important instrument of research and a tool for accurate data collection, an effective questionnaire has therefore to be carefully designed, to eliminate as far as possible the disadvantages involved, and to elicit a positive response from the respondents.

According to Walker [189], researcher should be clear about the reasons why each questions in a questionnaire is asked in justifying: i) the purpose of asking it; ii) its format; and iii) the manner in which data gathered will be analysed.

Whitman [183] and Czaja and Blair [190] identified several important factors and procedures any questionnaire design should take into careful consideration when designing questionnaires, which are:

- question is clear and unambiguous,
- wording of questions,
- formatting the questionnaire,
- length of the questionnaire.

These important factors are cited as well Sudman [191] and Fink [192].

As a general rule, experts recommend asking continuously "why am I asking this question" for every question and to be able to tie-in with the objectives of the survey. Apart from the above, the guidelines proposed by Sudman [191] and Fink [192] as outlined below were observed:

- draft questions that are related to survey's objectives
- avoid two edged questions (the use of the word "and")

- use tried questions from similar surveys
- ask specific and discriminating questions (requiring ordinal or numerical data)
- order the question in sequence
- format the questions
- pre-code and post-coding the responses
- draft questionnaires given to peers, supervisors and consultant group for comments and critical evaluation
- conduct pre-test and pilot test
- review, revise and eliminate problem questions

3.7.5. Steps in questionnaire construction

Questionnaires are constructed in a very sophisticated and systematic way. The process of construction goes through a number of interrelated steps, and offers the basis for the research stage to follow.

According to Sarantakos [14], the following are commonly mentioned steps of questionnaire construction:

Step 1: Preparation
In the first place, the researcher decides on the most suitable type of questionnaire and determines the way it will be administered. As well, a search of relevant questionnaires that might have already been developed by other investigator is undertaken. If suitable questionnaires are found they can either be adopted for the study or used as guides in the construction of a new questionnaire.

Step 2: Constructing the first draft
The research formulates a number of questions, usually a few more than necessary, which directly related to aspects of the research topic.

Step 3: Self-critique

These questions are tested for relevancy clarity and simplicity, as well as for complying with the basic rules of questionnaire construction.

Step 4: External scrutiny

The first draft is then given to experts or to persons with practical expertise in the area of investigation, for scrutiny and suggestion. The critique offered by the experts will be considered and eventual changes are implemented.

Step 5: Pilot test

In most cases, a pilot study is undertaken to check the suitability of the questionnaire. A small sample is selected for this purpose and the respondents requested to respond to the whole of the questionnaire. The results are then analysed and interpreted.

Step 6: Revision

The pilot test usually results in some minor or major changes. If the changes are minor, the researcher will proceed to Step 7. However if the changes are major, He/she will go back to Step 5 to run a "second pilot-test".

Step 7: Formulation of final draft

In this final draft, apart from implementing the suggestion derived from the pilot test, the researcher works on editing the text, checking for spelling mistakes, instructions, layout, space for response, pre-coding and general presentation of the questionnaire.

3.7.6. Scaling of response

The outcome of this fact-finding survey is to be able to understand and to measure various aspects of automation, maintenance practice, performance improvement and training implementation in the automated manufacturing companies.

Scales are techniques employed by social scientists in the area of attitude measurement. They consist of a number of statements or questions and a set of response categories, related to a score. They place respondents in a continuum between very low (or negative), over a neutral, to a very high (or positive) position. Most popular scales used in research are the Likert scale, Thurstone scales and Gutman scales [14].

Developed by Likert in 1932, the *Likert scale* consists of a set of items of equal value and a set of response categories to which subjects are asked to respond. It is very popular among social scientists, is relatively easy to construct, and is believed to be more reliable than the other scales [14].

In this survey, respondents were asked to rate two aspects on a five point Likert scale. First on the level or degree of importance placed, and secondly, the extent of use on each statement or question asked. An additional scale "0" was provided for both aspects to allow for those respondents who do not have or did not know the answer.

There are four main types of measurement scale that can be used for different types of data: nominal, ordinal, interval and ratio scale [193].

i) Nominal or categorical scale

Nominal or categorical scale is the lowest level of measurement and is most often used with variables that are qualitative in nature, rather than quantitative.

Example:
Question A3 - Is the firm a subsidiary or part of some larger organization?
Answer: ◘ *1. Yes* ◘ *2. No*

This type of question has limited application and has no numerical or preferential values.

ii) Ordinal scale

An *ordinal scale* represents the next higher level of measurement. It possesses a relatively low level of property of magnitude where the objects being measured are rank-ordered according to whether they possess more, less or the same amount of the variable being measured. Responses were recorded using five-point *Likert-type* scale.

Example:
Question B6: To what extent are each of the following advanced manufacturing technologies used?
Answer: NC - Numerical Controlled 0 □ 1 □ 2 □ 3 □ 4 □ 5 □
*[Scale: **0** - Do not have; **1** – Used Minimally; **3** - Use Moderately; **5** – Use Extensively]*

This type of question has a ranking of choice but without quantifying the magnitude of the difference.

iii) Interval or numerical scale

An *interval or numerical scale* represents the next higher level of measurement. It possesses the properties of magnitude and equal interval between adjacent units but does not have an absolute zero point.

Example:
Question E3. What percent of maintenance personnel received training last year?
Answer: ▫ *1. 0 % to 20 %* ▫ *2. 21 % to 40 %* ▫ *3. 41 % to 60 %*
▫ *4. 61 % to 80 %* ▫ *5. 81 % to 100 %*

iv) Ratio scale

A *ratio scale* represents the highest level of measurement. It has all the properties of interval scale and, in addition, has an absolute zero point. This makes it possible to compare both differences in scores and the relative magnitude of scores.

Example:

Question E4: On average, how many hours of training (related to maintenance) do each of the following maintenance personnel receive per year?

Answer: Management 0 □ 1 □ 2 □ 3 □ 4 □ 5 □

[Scale: 0:0 Hr 1:1-20 Hr 2:21 – 40 Hr 3:41 – 60 Hr 4:61 – 80 Hr 5:More than 81Hr]

As can be seen from the above measurement scales, all effort in designing questions must be directed to design specific and discriminating questions that can help in distinguishing clearly one respondent from the other.

3.7.7. Response errors and respond rates

This is a very important topic in any survey-based research that relates to reliability and validity. According to Sudman [191], the different types of errors fall into four factors:

i) Memory: material may be forgotten or may be not remembered clearly.

ii) Motivation: respondents may want to present their companies in a better light.

iii) Communication: inability to understand the questions asked.

iv) Knowledge: respondents may not know the answer.

Apart from the problem of response error that has a bearing on the reliability and validity of the survey and consequently the research study, the problem of low response rate has always been a major cause of concern to any researcher.

In general, it is believed that the factors that contributed to the relatively low response in this postal survey questionnaire are:

i) The length of the questionnaire which contained a list of specific and many closed-form questions

ii) The time pressures on the managers (i.e. a lack of available time)

iii) A lack of knowledge regarding the questions being asked

iv) Fearing that handing over such information may negatively impact on his/her company.

These reasons are similar to those often cited in the literature for similar studies [194][195][196][197].

According to Moser and Kalton [181], it is not the loss in sample numbers that is serious, but the likelihood that the non-respondents differ significantly from the respondents. There are various types of non-response and some will be mentioned below:

i) Companies outside the population

ii) Companies refusing to co-operate

iii) Change of address or wrong addresses

3.7.8. Questionnaire content

Basically, the questionnaire is a set of questions used to capture the experiences and the practices of the organization with respect to the maintenance of the automated system. Seen in this way, it is actually a measurement system, as a snapshot of the organization's practices.

According to Sarantakos [14] the content of the questions is obviously the most important element of the construction of a questionnaire, which will lead to the type of information sought in the study. It must be related to the research topic and each question should address one specific element or indicator of a research variable. However he added that questions not directly related to the topic may be asked only if they can be well justified and if they serve a certain purpose [14].

By taking the comments from the pre-test and pilot test into consideration, reviewing and eliminating problem questions was carried out. At the end, the final questionnaire was developed in such a way that all questions are clear, understandable in a logical sequence and nicely formatted. The length of time to answer the questionnaire was set to be approximately twenty minutes which was thought to be reasonable [194].

All questions are in multiple choices format and a number of them have allocated additional line to add additional information or related inputs. In order to facilitate the respondents in answering the questionnaire, the questionnaire has been categorized and ordered in logical sequence. A total of fifty four questions, which has been classified into five sections:

a) Section A: General Information

This section contains seven questions (Questions A1 to A7). It covers the information concerning company characteristics in terms of type of industry, ownership status, number of years in operation, number of employees, approximate turnover and achievement awarded. The industry or manufacturing group classification is similar as classified in KOMPASS [186][187], except the coding. The numbers 1-12 are used for coding of the responses in this survey.

The main purpose of these questions is to gather information about the company characteristics and background. The information from this section will be used to find if there is any correlation between company background and other variables measured such as level of production technology and maintenance practice in Irish and Malaysian automated manufacturing industry. Most of the questions in section A, follow the study conducted by Ismail [194] which has similarity in terms of purpose.

b) Section B: Level of Automation

This section contains twelve questions (Questions B1 to B12). It covers the information concerning the level of automation, the integration level, use of advanced manufacturing technologies and Computer Integrated Manufacturing, as well as the obstacle and the motivation of implementing automation in the production line.

The information from questions B1 (method of manufacturing system), B2 (level of automation), B3 (level of integration of automation used), B4 (level of automation varies by unit operation) and B10 (automation area) will be used to examine the level of automation and integration of the company. As for the questions B5 (type of work cell controller used), B6 (type of advanced manufacturing technologies used), B7 (application of Computer Integrated Manufacturing used), B8 (availability of communication networking) and B9 (type of communication networks used) will be used to understand the complexity of production and process technology used in the company. The data will be used to find if there is any correlation between the level of automation and maintenance practice as well as with other variables measured. This information is linked to the testing of hypothesis H3.

As for question B11 (obstacles of implementation of automated manufacturing system) and B12 (motivation factor of automation implementation), the data will be used to understand the issue of automation implementation and employee resistance to technology change, as has been presented in chapter two.

c) Section C: Maintenance

This section contains twenty questions (Questions C1 to C20). In the first part (Questions C1 to C12), it covers the information concerning the general plant maintenance practice in the production line such as maintenance organization, type of maintenance, maintenance responsibilities and the maintenance's strategy used. In the second part (Questions C13 to C20), all the questions are referred to the automated system and machineries. It investigates the issue of troubleshooting methodology used, major breakdown occurred according to the area, technology and implementation stages, as well as the availability of maintenance manual.

The questions C1 (person in charge in maintenance), C2 (to whom the person in charge of the maintenance of automated system normally reports to), C3 (number of employees in maintenance department) and C4 (number of maintenance personnel by categories) were specifically designed in order to know how important the maintenance function is regarded in the organisation. The information about specific designation and the ranking position in the organization's structure will help to indicate the recognition of the maintenance role. This information is related as well to the testing of hypothesis H2.

The questionnaire will go further to questions C5 (tasks and activities as responsibilities of the plant maintenance department), C7 (types of maintenance used), C8 (use of Total Productive Maintenance), C9 (use of Reliability Centered Maintenance). The information from these questions will be used to examine the current trend of maintenance practice in terms of type of maintenance used. In addition, the data will be used as well to find if there is any correlation between the type of maintenance used and the improvement of performance as well as with other variables measured. This information is linked to the testing of hypothesis H4-i.

This followed by questions C10 (use of Computerized Maintenance Management System), C11 (name or type of the CMMS used) and C12 (used of CMMS modules). The information from these questions will be used to examine the use of communication and coordination support, such as CMMS. The data will also be to find if there is any correlation between the use of CMMS and the improvement of performance as well as with other variables measured. This information is linked to the testing of hypotheses H4-ii. For question C6 (role of machine operator), the purpose was to identify whether the machine operators have been given the responsibility to maintain their own machines. Questions C5, C7, C8 and C9 were developed and adopted based from previous empirical study on maintenance and performance conducted by Swanson [110]. As for the questions concerning the CMMS system, i.e. questions C10, C11 and C12, they were developed and adopted based from previous study on "Benefits of CMMS implementation in manufacturing plants", conducted by O'Dodoghue and Prendergast [87].

The second part of section C starts with question C13 (how the respondent describes the degree of difficulty in maintenance task). In order to understand how, in general, the opinion of respondent about the maintenance task, as the questions about maintenance problems will follow next. The limitation of this question is that the answer will be described based on the respondents' opinion. Thus, this question could be very subjective and will be treated with caution [197].

In order to examine the problems or obstacles faced by the maintenance function, it starts first with the question C14 (major breakdown or problems occurred according to area and technology used). This question will answer the question of "what and where" the problems are. This will be followed by question C16 (major problems and obstacles in carrying out the maintenance tasks). In case if the respondent state "maintenance personnel" is among the major problems in C16, the respondent will be required to answer question C17 (major problems related to the maintenance personnel). The information from these questions will be used to examine problems or obstacles faced by the maintenance function. In addition, the data will be used to examine how important the human factor i.e. maintenance personnel in affecting the overall function of maintenance department. This information is linked to the testing of first hypothesis H1.

As for question C15 (methods used in maintenance troubleshooting tasks), the purpose is to identify the troubleshooting methodology used in maintenance. In addition, the information from this question will be used to find if there is any correlation between the troubleshooting technique used and the improvement of performance as well as with other variables measured. This information is linked to the testing of hypothesis H4-iii.

This study has also the intention to examine the involvement of in-house as well as the outsourcing maintenance. For that, question C18 (engagement of outsourcing maintenance compared to 'in-house maintenance") was designed. This is followed by question C19 (reason of appointing "external agencies" in maintenance). The information from these questions were used to find if there is any correlation between the involvement of in-house maintenance and the improvement of performance as well as with other variables measured. This information is linked to the testing of hypothesis H5.

The last question in section C is question C20 (availability of maintenance manual guidelines in the form of hardcopy and softcopy). This information will help to understand whether the maintenance department has an adequate supporting document in carrying out their maintenance function.

d) Section D: Productivity and Performance

This section contains six questions (Questions D1 to D6). It covers the information concerning the equipment performance measurement used, contribution of maintenance effort towards performance, as well as the top management commitment towards maintenance.

This section starts first with question D1 (method used in measuring the equipment performance). This is followed by question D2 (level of maintenance contribution to improvements in product quality, equipment availability and reduction in production costs). The information from these questions will be used to find if there is any correlation between the improvement of performance and the other variables measured, as described in the previous questions. These important questions were developed and adopted based from previous empirical study on maintenance and performance conducted by Swanson [110].

The questionnaire will go further to question D3 (level of satisfaction achieved in maintenance). It is a personal point of view of the respondent as a maintenance manager, in comparing the current achievement with the expectation to achieve. The limitation of this question is that the answer will be described based on the respondents' opinion. Thus, this question could be very subjective and will be treated with caution [197].

As presented in chapter two, top management commitment is very important in any project implementation. In order to examine this aspect in, question D4 (perception of top management towards the maintenance function) was designed. This is followed by questions D5 (review of the role of maintenance) and D6 (matters to be reviewed). The information from these questions will be used to examine the importance of top management commitment in maintenance implementation and in relation to the business strategy. This information is linked to the testing of hypothesis H2.

e) Section E: Training program

This section contains twelve questions (Questions E1 to E9). It covers the information concerning the training development, which sought the information on the training planning and implementation in organization.

This section starts first with question E1 (use of "Training Need Analysis"). This is followed by a series of questions related to the training implementation: E2 (number of maintenance training programmes attended), E3 (percentage of maintenance personnel who received training), E4 (number of training hours attended - related to maintenance, according to job category) and E5 (training approach used in conducting the maintenance training). The information from these questions will be used to find if there is any correlation between the training implementation and the improvement of performance as well as with other variables measured. This information is linked to the testing of hypotheses H6-i and H6-ii.

The questionnaire will be ended with questions related to learning approach that has been practiced by the company: E6 (how does the maintenance personnel get to increase their knowledge and competencies in performing their maintenance job), E7 (participation in maintenance conference, seminar or workshop), E8 (name of conference attended) and E9 (subscription and availability of maintenance journal or technical publication). This will further examine the information about development of maintenance personnel, which is related to the testing of hypotheses H6-i and H6-ii.

f) Re-contact

At the end of the questionnaire under "RE-CONTACT" section, the respondents were asked on their willingness to participate and be contacted again in case some further information is needed. The respondents are requested to specify the preferable mode of further conversation as well: through email, through questionnaire or through interview.

3.8. Processing the Survey

The questions included in the survey were reviewed to ensure that they were all linked to the objective of the study and are easy to understand. A cover letter (refer to Appendixes D1 and D2) was printed using the official letterhead of DCU Mechanical and Manufacturing Engineering School (for Ireland) and University of Kuala Lumpur-MFI (for Malaysia), and signed by the Head of School, cum the supervisor of this study. The letter was written to explain the purpose and the benefit of this study to the participants. This letter also informed the participants that the information will be treated strictly confidential. As a token of appreciation and to encourage better respond rate, a lucky draw was conducted for all the respondents who completed and returned the survey questionnaire (refer to Appendix D3).

3.8.1. Questionnaire layout

The postal questionnaire survey materials were printed in a booklet form, on A4 size paper (refer to Appendix A1). The questionnaire was nine pages, which was divided into five sections: general information, level of automation, maintenance programme, productivity and performance, and training programme. A cover letter, a reply paid envelope and description of lucky draw competition were also included in the envelope, which was delivered using ordinary mail.

3.8.2. Pre-test and pilot test

It is acknowledged that by its nature, the survey methodology selected to carry out this fact-finding or collection of information is difficult to administer bearing in mind the many factors to be considered in carrying out a sound survey. Thus, in accordance with standard practice of professional survey bodies and due to its wide use in research surveys, pre-test and pilot test surveys are carefully carried out in this research.

The purpose of conducting a pre-test pilot test was to test the questionnaire before embarking on the complete study. The aims of this pilot study were to test the approach used to solicit participants and to test the survey instrument itself. In fact, a pilot study was made to access content validity, where few questionnaires were administered to leading practitioners and academicians [78][194]. Based on their feedback, the final version of the questionnaire was sent to the participants.

In this study, pre-test of the survey questionnaire was conducted on a number of occasions. Sample questionnaires were given to peers and academic staff in Dublin City University who are familiar and have industrial experiences, and have been revised by the research supervisor. The purpose of this approach was to identify if any obvious issues had not been addressed within the survey or if there were any mistakes in the questionnaire. This ensured that the questions were easy to understand and simple to answer. Different opinions and comments of the respondents were used to determine whether the final draft of the postal questionnaire was acceptable.

As for the pilot test exercise, the survey questionnaire has been sent to selected companies (thirty companies in Ireland and thirty companies in Malaysia). The response rate was twenty percent. The main objective was to check the suitability and the relevancy of the questionnaire [14]. The respondents had also been asked to make their own comments on the design of the questionnaire.

In this pilot test, the comments received from two respondents were concerning about time taken to complete the questionnaire. It was also observed that almost all the participants did not fill the blank line provided which was allocated for them to fill other elements or items. In term of the relevancy of the questionnaire, there was one question concerning the communication method used in maintenance department was not answered by almost all respondents, which later on had been dropped out.

Once the amendment has been done and revised, the questionnaire had been sent to all companies that participate in the main survey.

3.8.3. Main survey

At the very heart of this research is the main survey. After all the questions have been revised, the survey questionnaires were sent directly to the Maintenance or Engineering Manager of each plant. It was sent to five hundred companies in Ireland and Malaysia respectively.

A reminder questionnaire (*refer to Appendix D4*) has been sent after about a month's time of the first questionnaire, to those who did not reply back the questionnaire. Returned replies were collected directly from the school office for data key-in and data processing.

3.9. Reliability and Validity

If a measuring instrument is developed or found in the literature, how do we assess its quality for use in research? For this question, according to Punch [13] there are two main technical criteria of *reliability* and *validity*, which are sometimes called psychometric characteristics of an instrument.

3.9.1. Reliability

Reliability is a central concept in measurement, and it basically means consistency. There are two main aspects to this consistency [13].

First, consistency over time means the stability of measurement over time, and it is usually expressed in the question: if the same instrument was given to the same people, under the same circumstances, but at a different time, to what extent would they get the same score? To the extent that they would, the measuring instrument is reliable, otherwise it is unreliable. Second, internal consistency reliability relates to the concept-indicator idea of measurement. Since multiple items are used, the question concerns the extent to which the items are consistent with each other, or all working in the same direction. This is the internal consistency of a measuring instrument. Various ways have been devised to assess the internal consistency. The best known are the Cronbach's coefficient alpha, the Kuder-Richardston formulas and split-half techniques [13].

In this study, the reliability test for the survey instruments (internal consistency analysis) was performed using the Cronbach's coefficient alpha, and will be reported in section 3.11.4.

3.9.2. Validity

A second central concept in measurement is validity. One view of its meaning is the question: how do we know that this instrument measures what we think (or wish) it measures? In this view, measurement validity means the extent to which and instruments measures what it is claimed to measure; an indicator is valid to the extent that it empirically represents the concept it purports to measure [13].

Among the various approaches to the validation of instruments, three of the main ones are content validity, criterion-related validity and construct validity [13].

Content validity focuses on whether the full content of a conceptual description is represented in the measure. Neuman [198] explained that a conceptual description is a space, holdings ideas and concepts, and the indicators in a measure should sample all ideas in the description. In this study, to access content validity, a pilot study was made and few questionnaires were administered to leading practitioners and academicians. Based on their feedback, the final version of the questionnaire was sent to the participants.

In criterion-related validity, an indicator is compared with another measure of the same construct in which the research has confidence. The third approach is construct validity which focuses on how well a measure conforms with theoretical expectations. Any measure exists in some theoretical context, and should therefore show relationship with other constructs which can be predicted within that context [13].

In this context, Zeller [199] believed that no foolproof procedure to establish validity, and the validation methods used should depend on the situation. He advocated a validation strategy: a valid inference occurs when there is no conflict between messages received as a result of the use of a variety of different methodological procedure. This is consistent with the view that relates validity to the interpretation of measurement [13].

In this study, the validity test for the survey instruments (construct validity) was performed using the Kaiser-Mayer-Olkin (KMO) measure and will be reported in section 3.11.5.

3.10. Data Processing

Once the responses start to trickle in, the process of editing and entering data into the computer is initiated. This task is made easy as most of the questions are pre-coded.

There are four main steps: establish database; data entry; data analysis and generate report and documentation.

The data is divided into two main files: Ireland and Malaysia, so that the data could be analyzed separately and independently.

The computer software used in the data entry and processing was SPSS (Statistical Package for the Social Sciences) for windows Release 12.0. SPSS is one of the most widely available and powerful statistical software packages.

SPSS is an integrated system of computer programmes designed for the analysis of social science data. The system provides a unified and comprehensive package that enables the user to perform many different types of data analysis in a simple and convenient manner. SPSS allows a great deal of flexibility in the format of data. It provides the user with a comprehensive set of procedures for data transformation and file manipulation, and it offers the researcher a large number of statistical routines commonly used in the social sciences [200].

In SPSS, data-management facilities can be used to modify a file of data permanently and can also be used in conjunction with any of the statistical procedures. These facilities enable the user to generate new variables, which are mathematical and/or logical combinations of existing variables, to record variables, and to sample, select, or weight specified cases. Furthermore, the user can add to or alter the data cases or the data-descriptional information in the file, such as labels, missing-value codes, etc [201].

SPSS enables the social scientist to perform an analysis through the use of natural language control statements. The text is a complete instructional guide to SPSS and is designed to make the system easily accessible to users with no prior computer experience. SPSS will do three basic things for the user [200]:

- It helps users to store and organise their data,
- It helps users to manipulate their data, and
- It allows users to analyse this data using statistical procedures.

It covers a broad range of statistical procedures that allow the users to summarize data (e.g., compute means and standard deviations), determine whether there are significant differences between groups, examine relationships among variables (e.g., correlation, multiple regression), and graph results (e.g., bar charts, line graphs).

3.11. Statistical Analytical Tools and Analysis

Quantitative research involves measurement, usually of a number of variables, and across a sample. In addition to the usual descriptive statistics, simple frequency distributions, and cross-tabulations, SPSS used in this study contains procedures for analytical tools and analysis. It covers a broad range of statistical procedures that allow to summarize data (e.g., compute means and standard deviations), test reliability and validity of the data, determine whether there are significant differences between groups, as well as to examine the relationships among variables (for both ordinal and interval data).

In presenting the statistical procedures contained in SPSS, the focus will particularly be on the statistical procedures and techniques that are used in this study.

3.11.1. Statistical terminology

In discussing this study throughout this report, certain technical terms and statistic terminologies will be used. Many of them are self-explanatory, and required no special consideration. However, there are terms or terminologies which are part of a somewhat specialized vocabulary of statistical research. They are discussed here, to clarify their usage. These terms and their short description will be given [13][193].

- Empirical

Empirical is a central term in this thesis. According to Ragin [202], *empirical* means that something (or its impacts) is observable, where '*observation*' is broadly interpreted. The essential idea is to use observable, real world experience, evidence and information as the way of developing and testing ideas. He referred

Empiricism as a philosophical position which sees observation as the foundation of scientific knowledge. Punch [13] preferred the general term "data" to describe this evidence and information in a research context.

- Data

The *data* is the measurements that are made on the subjects of an experiment.

- Statistic

A *statistic* is a number calculated on sample data that quantifies a characteristic of the sample.

- Population

A *population* is the complete set of individual, objects or scores that the investigator is interested in studying. In an actual experiment, the population is the larger group of individuals from which the subjects run in the experiment have been taken.

- Sample

A *sample* is a subset of the population. In an experiment, for economical reasons, the investigator usually collects data on a smaller group of subjects that the entire population.

- Parameter

A *parameter* is a number calculated on population data that quantifies the characteristics of the population.

- Variable

A *variable* is any property or characteristic of some event, object or person that may have different values at different times depending on the conditions.

• Independent variable

The *independent variable* in an experiment is the variable that is systematically manipulated by the investigator. In most experiments, the investigator is interested in determining the effect that one variable has on one or more variables.

• Dependent variable

The *dependent variable* in an experiment is the variable that the investigator measures to determine the effect of the independent variable.

3.11.2. Mean value, standard deviation and variance

The *mean* is the average score of any group on a test, as a common measures of central tendency. It is often of interest to compare the mean scores of different group on a test. The mean, *X*, is given by the sum of all scores on the test divided by the number of the sample [203].

As with central tendency, statisticians have developed several ways to measure the variance in a set of measurement. One of the common measure of variability is the *standard deviation.* It goes with the mean because the deviations involved are deviations of individual measurements from the mean of the distribution. It summarizes the variability in a set of data where the more spread out the scores, the larger the standard deviation. From the standard deviation, the *variance* is obtained. The variance is the square of the standard deviation, which can give a numerical estimate of the amount of spread in the data [13].

In this research study, the mean values were used for comparing the elements by using the SPSS Descriptive Statistics procedure.

3.11.3. Frequency distribution

In addition to the mean, standard deviation and variance, *frequency distributions* are a useful way to summarize and understand data [13]. The individual scores in the distribution are tabulated, where absolute numbers and / or percentages may be used. The results can be presented as frequency distribution tables or as graphs such as histograms, bar charts, frequency polygons, pie charts or other graph forms.

3.11.4. Reliability test for survey instrument

In this research study, an internal consistency reliability analysis was performed for the elements by using the SPSS Scale Reliability analysis procedure.

Reliability tests on the survey instruments were performed using the guidelines provided by Saraph et al [204]. *Cronbach's alpha* (α) is one of the most commonly used reliability coefficients, which ranges in value from 0 to 1 to estimate the value of internal consistency [197][205]. Alpha is measured on the same scale as a correlation coefficient. The closer the alpha is to 1.00, the greater the internal consistency of items in the instrument being assessed [206].

The α value can be calculated from any subset of the elements and it can provide the best illustration as regard to internal consistency. The coefficient α was calculated for each elements. Cronbach (1951), Nunnally (1967) and Scott (1981) as quoted by Saraph et al [204] held the same view that α value of 0.7 and above are considered to be adequate for testing the reliability of the elements. Thus, it can be concluded that on overall the survey instrument has high internal consistency and reliable.

Referring to table C.19 (*refer to appendix C*), the reliability coefficient α ranged from 0.707 to 0.944 which are more than 0.7. Thus, it can be concluded that on overall the survey instrument is reliable it has high internal consistency.

3.11.5. Validity test for survey instrument

The construct validity for each elements measured in this study was evaluated by factor analysing using SPSS Data Reduction and Factor Analysis procedure [207]. The steps used in performing this analysis were performed using the guidelines provided by Saraph et al [204].

Following this procedure, the items assigned to each elements were submitted to principal component factor analysis to determine the number of factors and factor loading extracted by the Kaiser criterion (with Eigenvalue greater that one). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was used to assess the suitability of the sample. The high values of KMO (close to 1.0) generally indicate that a factor analysis may be useful with the data. If the value is less than 0.50, the results of the factor analysis probably won't be very useful [207][208].

Referring to table C.20 (*refer to appendix C*), in general all the KMO values found are considered acceptable. All elements accounted for more than 0.50 of the variance. This suggests that on overall the survey instrument is valid and has high internal consistency.

3.11.6. Factor analysis

The SPSS Data Reduction and Factor Analysis procedure and steps were used in performing the analysis [207].

According to Kline [203], factor analysis consists of a number of statistical techniques the aim of which to simplify complex sets of data. As quoted in his book, Royce (1963) defined a factor is a construct operationally defined by its factor loadings. Factor loadings are defined as the correlations of a variable with a factor [203].

Factor analysis is a much more generalized procedure for locating and defining dimensional space among a relatively large group of variables. Because of the generality of factor analysis, it is difficult to present a capsule description of its functions and applications. The major use of factor analysis by social scientists is to locate a smaller number of valid dimensions, clusters, or factors contained in a larger set of independent items or variables. Factor analysis can help determine the degree to which a given variable or several variables are part of a common underlying phenomenon [201]. Kim and Mueller [208] also defined factor analysis as follows: factor analysis is a statistical technique used to discover which of the elements or variables in a sample population vary together and therefore may be candidates for grouping together into groups called components or factors.

Prior to the factor analysis, the Kaiser-Meyer-Olkin test (KMO) test will be performed. The KMO measures of sampling adequacy is a statistic which indicates the proportion of variance in the variables which is common variance, i.e. which might be caused by underlying factors. The value of KMO test indicates the suitability of the data for factor analysis. As mentioned earlier, the high values (close to 1.0) generally indicate that a factor analysis may be useful with the data. If the value is less than 0.50, the results of the factor analysis probably won't be very useful [207] [208].

Factor analysis is ideal to use where data are complex and it is uncertain what the most important variables in the field are. It is usual to regard factor loadings as high if they are greater than 0.6 and moderately high if they are above 0.3 [203].

3.11.7. Correlation analysis

Correlation analysis deals with the relationship between variables. If a relationship exists between two variables (a "predictor" and a "response") then it may be possible to estimate the value of the response, by using the value of predictor. It is about determining the magnitude and direction of the relationship [209].

It provides the researcher with a technique for measuring the linear relationship between two variables and produces a single summary statistic describing the strength of the association; this statistic is known as the correlation coefficient. SPSS has two programmes for computing correlations. Pearson Correlation produces zero-order or product-moment correlation coefficients (Pearson's *R*) that is best suited for normally distributed data with an interval scale. NONPAR CORR, suitable for ordinal data with a larger number of categories than would be appropriate for cross-tabulation tables, enables the user to compute either Spearman or Kendall rank-order correlation coefficients, or both. Both PEARSON CORR and NONPAR CORR can produce correlations for selected pairs or lists of variables as well as complete matrices of coefficients. The output from both sub-programmes provides the correlation coefficient, the number of observations upon which the correlation was based, and the level of statistical significance of the coefficient. In addition, each procedure provides for the output of correlation matrices that may be used when applying multivariate statistical techniques [201].

- Correlation coefficient

Correlation is a topic that studies the relationship between two variables. A correlation coefficient can vary from "+1" (means the correlation is perfectly positive, ie very strong relationship between the two variables) to "–1" (means the other way round - the correlation is perfectly negative between two variables) whereas the relationship is nonexistent if the correlation coefficient equals "0" [193][207].

The choice of correlation coefficient depends on the type of measuring scale underlying the data. The *Pearson* rank order linear correlation coefficient, r is employed for the data measured on an interval or ratio scale. As for the *Spearman* rank order correlation coefficient, *rho* is used when one or both of the variables are only of ordinal scaling [193].

- Level of significance

A correlation is said to be significant if it is greater than is likely to have arisen by chance. Two levels of significance are generally used: 0.05 or 5 per cent level and the 0.01 0r 1 per cent level. The more significant a correlation is, the more confident one can be that there truly is a relationship between the variables [203][207].

3.11.8. Multiple regressions analysis

Multiple regressions are an extension of the bivariate correlation coefficient to multivariate analysis. Multiple regression allows the researcher to study the linear relationship between a set of independent variables and a dependent variable while taking into account the interrelationships among the independent variables [13][201].

The basic objective of multiple regression is to produce a linear combination of independent variables, which will correlate as highly as possible with the dependent variable. This linear combination can then be used to "predict" values of the dependent variable, and the importance of each of the independent variables in that prediction can be assessed. A variety of multiple-regression calculations can be accomplished with the use of the regression procedure. This sub-programme can operate either on raw data or a matrix of correlation coefficients. The user can perform the regression upon a fixed number of variables or, using a forward-selection stepwise technique, allow the variables to be introduced into the computation sequentially depending upon their explanatory power [201].

The SPSS has the ability to transform variables, and allows the user to handle most polynomial and multiple-regression applications with relative ease [207]. Multiple R, R^2, and the significance of the regression equation are also computed at each stage. This statistical method provides three types of statistical models including R-Square, analysis of variance (ANOVA) and coefficients panel [210][211]:

• R is a multiple correlation coefficient between the observed and predicted values of the dependent variable. The values of R for models produced by the regression procedure range from 0 to 1. Larger values of R indicate stronger relationships. The R-Square (model summary) is used to define the proportion of variability in the dependent variable that can be explained by changes in the values of the independent variables. The values of R squared range from 0 to 1. Small values indicate that the model does not fit the data well. The sample R squared tends to optimistically estimate how well the models fits the population.

• The *analysis of variance (ANOVA)* indicates whether there is a significant linear relationship between the dependent variable and the combination of the independent variables (F-Test is used to test the null hypothesis that there is no linear relationship). The F statistic is the regression mean square (MSR) divided by the residual mean square (MSE). If the significance value of the F statistic is small (smaller than say 0.05) then the independent variables do a good job explaining the variation in the dependent variable. However, if the significance value of F is larger than say 0.05 then the independent variables do not explain the variation in the dependent variable.

• *Coefficients panel* provides t-test. Based on the results of t-test, any independent variable that did not exceed the significance level of 0.5% is used to explain the variability in the dependent variable. The t statistics can help to determine the relative importance of each variable in the model. As a guide regarding useful predictors, t values should be below -2 or above +2.

3.11.9. Pareto analysis

The Pareto Principle [138] stated that only a "vital few" factors are responsible for producing most of the problems.

Pareto analysis is a method of classifying items, events, or activities according to their relative importance. The purpose is to have a quick focus and efforts on the key causes of a problem [207].

3.11.10. Inference analysis

Inference or expectation is a probability statement which states the idea that science involves making decisions or drawing conclusions under conditions of uncertainty based on prior data experience or theory [212]. Fundamental to statistical inference is the fact that in research, as in all the science, one can never know the truth about something. All one can do is make an approximation or estimation or expectation [212].

Inference analysis is a kind of deductive reasoning approach. It is a process of analyzing the sample and assuming that the other data in the population, which have not been seen, are similar to the data in the population, which have been seen [209].

3.12. Chapter Summary

This chapter outlined the overview of research methodologies and justification for the selection of appropriate methodologies used in this study to address the objectives of the research. The chapter starts with an overview of research in general and a description of research philosophies and description of certain terms related to research methodology. The chapter then presented the research methodology chosen i.e. questionnaire survey research, in elaborating the survey questionnaire design and process, as well as the statistical analytical tools and tests used in this study.

It also described the justification of research method chosen in this study. This is followed by describing the survey instrument used which covers the survey coverage, method of data collection, questionnaire design, response scaling and questionnaire content and the survey process steps including pilot test and main survey. It also outlined the steps taken to ensure that the general principles and guidelines according to the standard practice of professional survey bodies are followed for administering a sound survey.

At the end, this chapter presented an overview of SPSS software package and the statistical procedures contained in SPSS as well as the test results which are used in this study. All the research approach and design discussed in this chapter then are employed to obtain the empirical data, which will be presented in the following chapter – results and discussion.

Chapter 4
RESULTS AND DISCUSSION

4.0. Introduction

This chapter presents the results of the survey carried out and their discussions in two main sections: survey results and discussions.

In the first section (section 4.1), it presents the results and analysis of the data from the survey findings on the current implementation of automation, maintenance practices and training implementation, both in Irish and Malaysian automated manufacturing companies. It consists of presentation of the descriptive statistics, frequency distributions, cross-tabulations, analysis as well as the comparison study between both countries.

In the second section (section 4.2), discussions take place that will further elaborate and evaluate the information from the findings of the results and analysis. The result of hypotheses testing is discussed in this section as well. For each hypothesis there is a discussion of the empirical findings in order to facilitate the analysis in relation to the aims of this study.

Note: *In this chapter, the tables which are numbered starting with letter B (example Table B.1.a, B.1.b, B.2.a, etc.) can be referred to in Appendix B.*

4.1. Results and Data Analysis of Survey Findings

The In Ireland, the total number of questionnaires sent out was 500, of which 84 were returned completed, a response rate of 16.8 %. As for Malaysia, the same number of questionnaire was sent out, 81 were returned completed, a response rate of 16.2 %.

4.1.1. Profile of the respondents

a) Type of industry or manufacturing group

Table B.1.a shows the distribution of product types manufactured by the respondent companies in Ireland. It can be seen that the companies belong to various types of industrial groups: Electrical and Electronic (22.6%), Food, Tobacco and Beverages (17.9%), Stationery, Paper and Printing (9.5%), Pharmaceutical (8.3%), Plastics and Rubber (8.3%), Chemical and Allied Products (6%), Metal and Mechanical. Engineering, Automotive and Transportation, Industrial equipment and others.

As for the Malaysian manufacturing companies, table B.1.b shows that the companies also belong to various types of industrial group: Electrical and Electronic (23.5%), Chemical and Allied Products (19.8%), Food, Tobacco and Beverages (9.9%), Metal and Mechanical Engineering (9.9%), Plastics and Rubber (8.6%), Automotive and Transportation, Clay and Building Industry Product, Stationery, Paper and Printing, Wood and furniture, Medical devices and others.

b) Company background

In both countries, as shown in tables B.2.a, B.2.b, B.3.a and B.3.b, the majority of the companies are "100% foreign owned company" and subsidiaries of larger organizations.

In terms of the number of years in operation, as shown in tables B.4.a and B.4.b, the majority of the respondents in Ireland have been in business for more than 30 years, whereas in Malaysia, the majority of them have only been in business for 11 to 20 years. Most of the companies in both countries have more than 100 employees as shown in tables B.5.a and B.5.b.

As shown in tables C.1.a and C.1.b, the correlation analysis indicates that in Ireland, a company with foreign ownership and being a subsidiary of larger organization has higher annual turnover. This correlation analysis also indicates that being a company of foreign ownership and being a subsidiary of larger organization with higher annual turnover has a characteristic of employing more employees in their operation.

A similar correlation was found in Malaysia, where a company being subsidiary of larger organization, has been long established in operation and has higher annual turnover, has a characteristic of employing more employees in their operation.

In terms of the award or certification received, both countries show a similar trend. As shown in tables B.7.a, B.7.b, B.8.a, B.8.b B.9.a and B.9.b, the majority of the respondents have gained the ISO 9000 certification. On the other hand, however, the majority of them have not yet gained the ISO 14000 and Total Quality Management (TQM) certification award.

4.1.2. Automation implementation

a) Automation level and integration level

Tables B.10a and B10.b show the different methods of production employed by the companies in their production line in both countries which consist of process, batch and mass production. In terms of the level of automation employed, the majority of them, as shown in tables B.11.a, B.11.b, B.12.a and B.12.b are semi automated, followed by mostly automated in their production. Most of the companies use stand alone machines, and automated machines linked with material handling. The variation of automation level by unit operation also is average, as shown in tables B.13.a and B.13.b.

On the other hand, the correlation analysis conducted in both countries, as shown in tables C.2.a and C.2.b, indicates that a company that has higher annual turnover has a characteristic of employing higher level of automation. Nevertheless, there is no significant relationship between the level of automation and the other company's characteristics. The result also demonstrates that, in both countries, the higher the level of automation, the higher the level of integration of automation, as shown in tables C.3.a and C.3.b.

b) Automation technology used

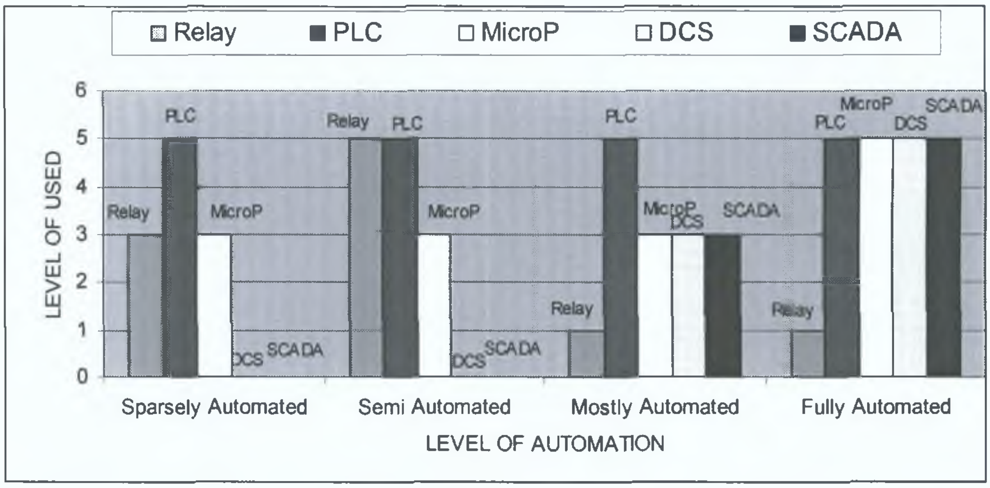
- Work cell controller

Tables B.14a and B.14.b show the types and to what extent work cell controllers are used in their automated systems. It can be seen that in both countries, Programmable Logic Controller (PLC) and Relay have the highest means values which are used extensively compared to the other type of controllers such as microprocessor controller, Distribution Controller System (DCS) and SCADA systems.

The results also reveal that the type of work cell controllers used depend on the level of automation employed as shown in table 4.1 and figure 4.1. While the PLC is used extensively in all levels of automated factory, the relay is found to be used extensively in the semi automated factory but very minimally used in the mostly and fully automated factory. As the latest state-of-art controller systems, DCS and SCADA systems are used extensively in the fully automated factory. On the other hand, the correlation analysis carried out between the level of automation and the type of work cell controllers shows that the higher the automation level, the more sophisticated type of controllers being used such as DCS and SCADA systems.

Table 4.1 - Level of automation and type of controller used

	Sparsely Automated	Semi Automated	Mostly Automated	Fully Automated
Relay	3-Moderate	5- Extensive	1- Minimal	1- Minimal
PLC	5- Extensive	5- Extensive	5- Extensive	5- Extensive
Microprocessor	3-Moderate	3-Moderate	3-Moderate	5- Extensive
DCS	0- N/A	0- N/A	3-Moderate	5- Extensive
SCADA	0- N/A	0- N/A	3-Moderate	5- Extensive



Scale Level of Used: 1- Minimal; 3-Moderate; 5-Extensive

Figure 4.1 - Level of automation and type of controller used

- Use of Advanced Manufacturing Technologies

Tables B.15.a and B.15.b show the use of advanced manufacturing technologies in their manufacturing plants. In both countries, the majority of them used automated system in their material load/unload, packaging / storage and inspection / testing work stations, which are most frequently rated as "used moderately". The findings also indicate that less than half of the respondents use AMT in Digital Numerical Controlled Machines (DNC), Numerical Controlled Machines (NC), and Computer Numerical Controlled Machines (CNC), as well as robots.

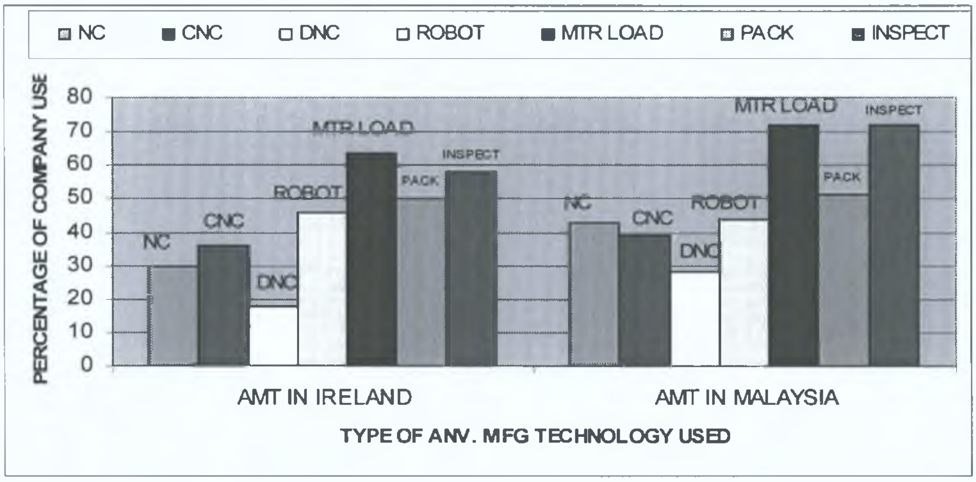


Figure 4.2 - Level of advanced manufacturing technology used

Figure 4.2 illustrates the result of comparison between both countries in the utilisation of Advanced Manufacturing Technologies (AMT) in their automated systems. In general, the findings indicate that the type and level of AMT used in both countries are of similar trend.

- Use of Computer Integrated Manufacturing applications

As for the Computer Integrated Manufacturing (CIM) applications, in both countries, as shown in tables B.16a and B.16.b, the findings reveal that Production Planning Control (PPC) and Computer Aided Design (CAD) have the highest means values compared to the other CIM applications. The findings also show that half of the companies use Computer Aided Quality (CAQ), Computer Aided Manufacturing (CAM), Computer Aided Planning Management (CAPM) or Computer Aided Process Planning (CAPP).

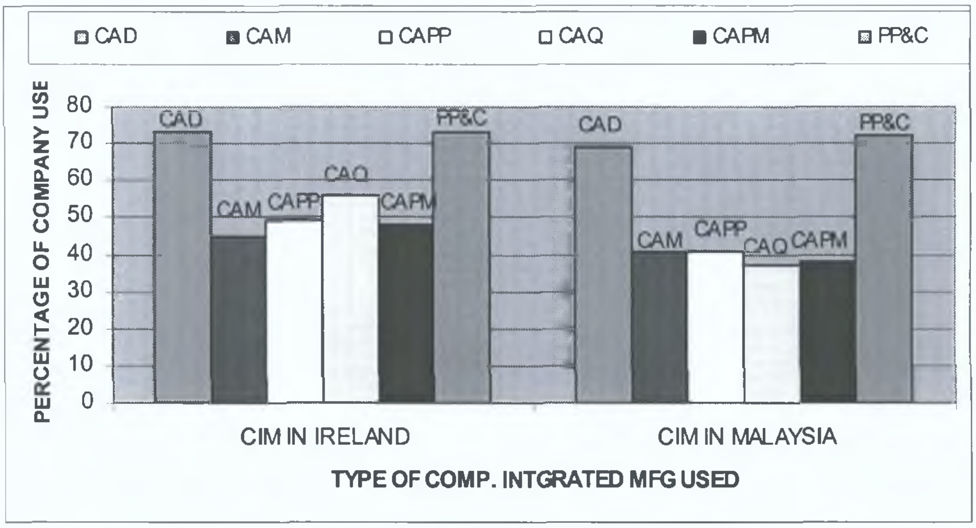


Figure 4.3 - Level of computer integrated manufacturing used

Figure 4.3 illustrates the result of comparison between both countries in the use of CIM applications in their automated systems. In general, the findings indicate that the percentage of respondents used CIM application in Ireland is slightly higher than in Malaysia. In terms of the degree of utilization, Planning Control (PPC) and Computer Aided Design (CAD) applications are used more extensively in Ireland compared to Malaysia.

On the other hand, the majority of the respondents also use communication networking, where most of them use Local Area Network (LAN) as their communication networking, as shown in tables B.17.a, B.17.b, B.18.a and B.18.b.

c) Obstacles and motivation factor in implementing the automated manufacturing system

Tables B.19a and B.19.b show the level of obstacles for implementation of automated manufacturing systems. It can be seen that in both countries, the factor of "cost" has the highest means value which is rated as major obstacle, followed by the factor of staff's technical skill and time.

As for the motivation factors in implementing the automated manufacturing systems, in both countries, as shown in tables B.20a and B.20.b, indicate that the factors of "lower production cost" and "better quality" have the highest means values which are rated as major factors.

All the other factors such as factor of improved personnel safety, improved product safety, access to process information and obsolescence of older technology are most frequently rated as an "average factor".

4.1.3. Maintenance practice

a) Responsibilities of the plant maintenance department

Tables B.22.a and B.22.b show the list of tasks and activities as responsibilities of the plant's maintenance department, and the level of emphasis in which has been placed on each activities.

Pareto Analysis technique has been used to identify the most important tasks in maintenance department. The tasks are ranked from the most important task to the least important according to the frequency distribution data and mean values. As shown in figure 4.4, the results demonstrate that in both countries, there are three tasks which are task D (*Maintaining equipment in operation*), task C (*Restoring equipment to operation*) and task E (*Performing preventive and predictive maintenance work)* have the highest means values and most frequently rated as "one of the most important tasks". The second three tasks which have higher mean values are task A (*Monitoring the production equipment status*), task B (*Analyzing equipment failure causes and effects*) and task G (*Helping to improve the production process*) and most frequently rated as "one of the most important tasks" or as an "important task". The other tasks (F, H and I), are most frequently rated as "somewhat important".

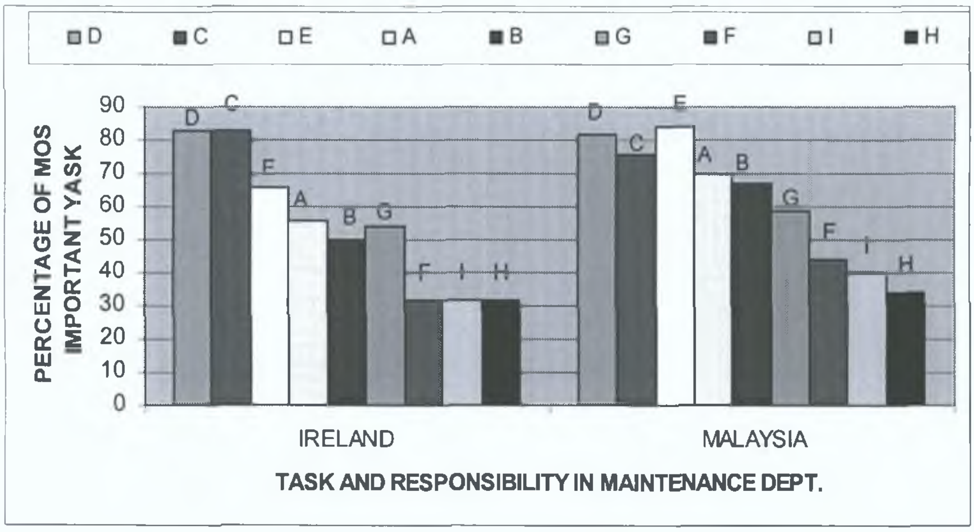


Figure 4.4 – Task and responsibility in maintenance department

In terms of the responsibility of machine operators, as shown in tables B.23.a and B.23.b, it is found that in both countries, fewer numbers of companies put the responsibilities to their machine operators for the maintenance task. On the other hand, apart from running the machine, majority of the companies put the responsibility to their machine operators for the material handling, machine set-up and gathering data and charts.

b) Maintenance programme employed

- Type of maintenance used

Tables B.24a and B.24.b show the types of maintenance used and to what extent each of them have been used. The results indicate that in both countries, preventive maintenance has the highest means values and most frequently rated as "used extensively or quite extensively", followed by breakdown maintenance and corrective maintenance. The results also show that more respondents have implement Total Productive Maintenance (TPM) compared to Reliability Centered Maintenance (RCM)

As shown in tables C.4.a and C.4.b, the correlation analysis indicates that the higher the level of automation, the higher the degree of utilization of preventive maintenance (in Ireland) and predictive maintenance (in Malaysia). Nevertheless, there is no significant relationship between the level of automation and the other types of maintenance.

On the other hand, in Ireland, the correlation analysis indicates that the higher the degree of preventive and predictive maintenance utilization, the better the improvement of equipment availability which could be expected, as shown in table C.6.a. The correlation analysis also indicates that the lesser the degree of utilization of breakdown maintenance, the better the improvement of equipment availability that could be expected. Furthermore, as shown in table C.7.a, in Ireland, the correlation analysis also indicates that the higher the degree of utilization of TPM, the better the improvement of equipment availability that could be expected.

- Link between maintenance responsibilities and the maintenance approaches used

In order to identify the link between maintenance responsibilities and the maintenance approaches used i.e. reactive, proactive and aggressive maintenance, it is necessary to see if there is a possibility to empirically derive constructs consistent with the three maintenance approaches used. To check for underlying dimensions, the nine variables concerning specific maintenance responsibilities were examined using exploratory factor analysis. This approach and analysis were performed using the guidelines provided by Swanson [110].

Prior to the factor analysis, the Kaiser-Meyer-Olkin test (KMO) was performed. High values (close to 1.0) generally indicate that a factor analysis may be useful with the data. As shown in table 4.2, the values of KMO test were 0.753 (Ireland) and 0.845 (Malaysia) which indicate the suitability of the data for factor analysis.

Table 4.2 - Factor analysis on the maintenance tasks and responsibilities

RESPONSIBILITIES IN MAINTENANCE DEPARTMENT	IRELAND			MALAYSIA		
	KMO value = 0.753			KMO value = 0.845		
	Fact 1	Fact 2	Fact 3	Fact 1	Fact 2	Fact 3
Task A		0.814			0.717	
Task B		0.847			0.741	
Task C	0.709			0.758		
Task D		0.703			0.701	
Task E		0.768			0.542	
Task F	0.691			0.900		
Task G			0.788			0.796
Task H			0.834			0.879
Task I			0.788			0.791

The relationships between the different maintenance responsibilities were analyzed using principal component factor analysis with varimax rotation. This procedure produced three factors representing different types of maintenance used.

The results show in both countries, as shown in table 4.2, all the responsibilities were classified in the same category of factors. The factors may be interpreted as representing the three different approaches of maintenance used.

Two tasks that load on factor 1, task C (restoring equipment to operation) and task F (installing new equipment), represent the traditional, reactive maintenance.

Another four tasks load on factor 2, include task A (monitoring production equipment status), task B (analyzing equipment failure causes and effects), task D (maintaining equipment in operation) and task E (performing preventive/predictive maintenance work). These factors are all consistent with an approach to maintenance that seeks to prevent breakdowns, a proactive maintenance.

Three other tasks load on factor 3, include task G (helping to improve the production process), task H (helping to design the production process) and task I (helping the purchasing department in OEM selection), represent an improvement-oriented approach to maintenance, which maybe described as an aggressive maintenance.

On the other hand, as shown in table C.6.c, in Ireland, the correlation analysis indicates that the higher the degree of proactive maintenance approach used, the better the improvement of performance in terms of product quality, equipment availability and reduction of production cost could be expected. The correlation also indicates the higher the degree of aggressive maintenance approach used such as TPM, the better the improvement of performance in terms of product quality.

c) Utilization of CMMS and modules used

In terms of the utilisation of Computerized Maintenance Management System (CMMS), as shown in tables 4.25.a and 4.25.b, 71.4 percent of the respondents in Ireland is using the CMMS, whereas in Malaysia there is only about 37 percent.

As for the degree of CMMS utilisation, as shown in tables 4.26.a and 4.26.b, from the sample of companies which have practiced CMMS, most of them use the system moderately or extensively.

Tables B.27.a and B.27.b show to what extent each of the CMMS modules are used. In identifying the level and the most extensive CMMS module used, the Pareto Analysis technique has been employed. The modules are ranked from the most extensively module used to the least module used according to the frequency distribution data and mean values.

As shown in figure 4.5, the results demonstrate that in both countries, four modules which are the module B (*Preventive maintenance planning and scheduling),* module E (*Equipment repair history*), module A (*Work order planning and scheduling*) and module F (*Equipment part list*) have the highest means values and have been used extensively. The second three modules which have higher mean values are the module J (*Material and spare parts purchasing*), module I (*Spare part requirement budgeting*) and module H (*Inventory control*) have been used quite extensively. The other tasks (C, D, K and G), are most frequently rated as "moderately used".

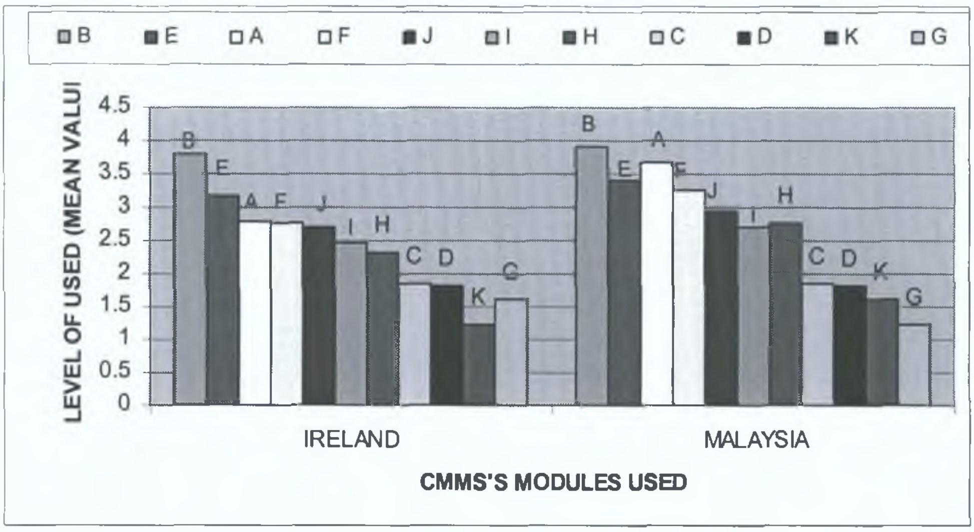


Figure 4.5 – CMMS modules used

On the other hand, as shown in table C.7.a, in Ireland, the correlation analysis also indicates that the higher the degree of utilization of CMMS, the better the improvement of equipment availability that could be expected.

d) Maintenance tools and support

• Troubleshooting methods used

Tables B.30a and B.30.b show the troubleshooting methods employed and to what extent each of the methods are used. The results show that in both countries, "Cause and Effect diagram" was the most frequently used compared to the other troubleshooting methods such as Pareto Analysis, Failure Mode Effectiveness Analysis (FMEA) and Fault Tree Analysis (FTA). On the other hand, System Analyse Design Technique (SADT) method was the least frequently method used.

As shown in tables C.8.a and C.8.b, in both countries, the correlation analysis indicates that the higher the degree of utilisation of FMEA, SDAT, FTA and Pareto Analysis (in Malaysia only) the better the improvement of equipment availability that could be expected.

• Availability of manual guideline

Tables B.35.a and B.35.b show the availability of manual guidelines in the form of hardcopy format. As shown in the results, in both countries, more than half of the respondents responded that the manual guidelines in the form of hardcopy format for each category has at least moderate content documentations. On the other hand, as shown in tables B.36.a and B.36.b, the availability of manual guidelines in softcopy format is much less available compared to the hardcopy format.

As shown in tables C.16.a, C.16.b, C.17.a and C.17.b, in both countries the correlation analysis indicates that the company that possesses a complete technical specification's hardcopy and softcopy manual, generally will also possess a complete set of maintenance guideline documents.

e) Engagement of external maintenance or outsourcing maintenance

Tables B.33.a and B.33.b show the involvement of "in-house maintenance" compared to the outsourcing in the maintenance department. The results show that in both countries, the majority of the respondents employ "in-house maintenance", out of which half of them rated as "full involvement". The majority of them also engage the outsourcing maintenance such as vendors and manufacturers which is rated as "moderate involvement". As for Consultants, the degree of involvement is quite low. The results also reveal that in both countries, as shown in tables B.34.a and B.34.b, the main reason of engaging the external maintenance is due to the unavailability of internal expertise in their maintenance department.

On the other hand, as shown in tables C.9.a and C.9.b, in Malaysia, the correlation indicates that there is higher improvement of equipment availability in the company which uses in-house maintenance. As for Ireland, there is no correlation found between the improvement of equipment availability and the involvement of "in-house and/or external" maintenance.

f) Problems encountered in maintenance

- Major breakdown according to the area and technology used

Tables B.29.a and B.29.b show the major breakdown and problems occurred according to the area and technology used. As shown, in both countries, most of the areas and the technology listed are frequently rated as "average" in terms of level of breakdown and problems. The results also show that, there are three areas which are mechanical, electrical and electronic parts have the highest means values, which indicate the most frequent areas or parts that the problems frequently occurred.

• Problems and obstacles encountered in maintaining of automated system

In terms of the major problems and obstacles encountered in maintaining automated systems, as shown in tables B.31.a and B.32.b, in both countries, most of the problems and the obstacles listed are frequently rated as "somewhat obstacle" The results also show that three aspects which are production disturbance, maintenance personnel and time consuming have the highest means values, which indicate the most frequent problems encountered in maintaining the automated system.

As a further investigation to the general problems, tables B.32.a and B.32.b show the problems of the maintenance personnel in maintaining automated systems. The results demonstrate that in both countries, three elements which are "lack of competencies / technical skill", "inadequate training" and "not enough manpower" have the highest means values. Most of the problems that have been highlighted as an obstacle are related to "hard skill" category such as "lack of competencies / technical skill", "inadequate training" and "not enough manpower". On the other hand, the "soft skill" category such as motivation, attitude and teamwork factors were considered as minor obstacles.

4.1.4. Training programme

a) Training planning and implementation

Tables B.43.a and B.43.b show the result of Training Need Analysis (TNA) utilization in identifying the need of maintenance training in the company.

The survey found that in both countries, the majority of the respondents which have TNA exercise, carried out their TNA once per year. On the other hand, the results also highlighted that one third of the respondents in Ireland do not conduct any TNA exercise in their company.

In terms of the number of different training programmes which related to maintenance, as shown in table B.44.a, the survey results show that in Ireland, the majority, 61.9 percent of the respondents have received less than two types of trainings. The results also indicate that more different types of trainings were conducted in Malaysia compared to Ireland. As shown in table B.44.b, the survey results show that in Malaysia, 40.7 percent of the respondents have received less than two types of trainings and 43.2 percent having two to four.

The survey results also reveal that the percentage of maintenance personnel who received training per year was quite low. As shown in tables B.45.a and B.45.b, about one third of the respondents in both countries could only provide training to less than 20 percent of their maintenance employees.

In terms of the number of hours does each of the maintenance personnel receive maintenance training annually as shown in tables B.46.a and B.46.b, engineer and technician have most frequently received 21-40 hours of training, whereas the management, specialist fitter and general worker have most frequently received 1 to 20 hours of training.

The survey results also indicate that in both countries, the majority of the respondents choose “in-house training” as their first option in conducting the maintenance training, where most of the trainings were conducted by their own staff, as shown in tables B.47.a and B.47.b.

On the other hand, in Ireland, as shown in table C.13.a, the correlation analysis indicates that by conducting an appropriate training needs analysis (once a year), a better training implementation in terms of the number of staff trained and percentage of participation can be expected. Furthermore, as shown in table C.14.a, in Ireland, the correlation analysis indicates that by conducting an appropriate training needs analysis and good training implementation, a better performance improvement in equipment availability can be expected.

b) Knowledge and competency learning approach

Tables B.48.a and B.48.b show the means by which the maintenance personnel get to increase their knowledge and competencies in performing the maintenance job. It can be seen that in both countries, the "on the job training" has the highest means value which is rated as an effective approach, followed by training from internal staff, self-learning approach and training from manufacturer or vendor.

In terms of the maintenance conference, the survey results in both countries, as shown in tables B.49.a and B.49.b, reveal that the majority of the maintenance personnel had never attended the maintenance conference, seminar or workshop.

On the other hand, in terms of the subscription to any maintenance journals and technical publications, as shown in tables B.50.a and B.50.b, the survey results reveal that 26.2 percent of the respondents in Ireland and 37.0 percent in Malaysia do not have any maintenance journal and technical publication in their maintenance department. Furthermore, even for those who subscribe it, the majority of them only receive a small number of publications.

4.1.5. Productivity and performance

a) Contribution of maintenance effort towards improvement of performance

Tables B.38.a and B.38.b show how much is the contribution of maintenance effort to the performance improvements. In both countries, the results of mean values show that the maintenance effort contributes the highest percentage in the improvement of equipment availability, followed by the improvement of production cost reduction and the improvement of product quality. Figure 4.6 illustrates the contributions of maintenance effort in both countries.

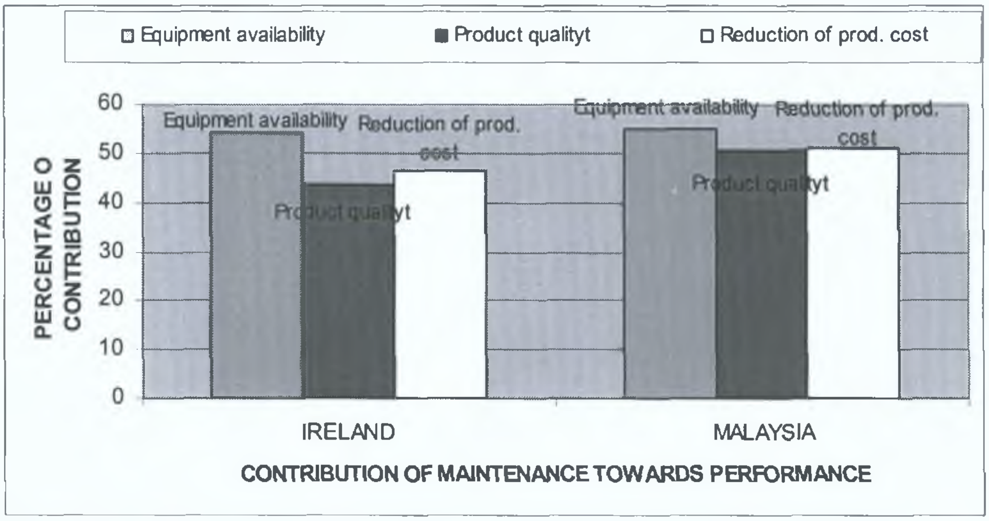


Figure 4.6 - Maintenance effort contributions towards improvement

In addition, in both countries, as shown in tables C.10.a and C.10, the correlation analysis indicates that the higher the improvement of equipment availability, the better the improvement on the product quality and the reduction of production cost. In other correlation analysis conducted, as shown in tables C.11.a and C.11.b, the result indicates that the higher the improvement of the performance, the higher level of satisfaction on the maintenance achievement.

b) Top management view on the maintenance function

Tables B.40.a and B.40.b show how the top management views the maintenance function. The results show that in both countries, most of the companies rated "agree and strongly agree" on the statement of the way top management regards the maintenance function as "an important supporting function" and "an overhead". On the other hand, fewer top management views the maintenance function as "an investment".

As shown in tables C12.a and C.12.b, the correlation analysis indicates that for those companies where top management do not regard the maintenance function as an investment and as an important supporting function should carry out a review of the maintenance role for the company.

Tables B.41.a and B.41.b show that the majority of the companies said that the management should review the role of maintenance in their company. As shown in tables B.42.a and B.42.b, the results of high mean value indicate that a review is required in the aspect of maintenance training programme, followed by maintenance methods and procedure and the review of maintenance organization.

4.2. Discussions

This section further elaborates and evaluates the information from the findings reported in the previous section. It consists of data interpretation and evaluation from the descriptive statistics, frequency distributions, cross-tabulations, analysis as well as the comparison from both countries. As for the hypotheses testing, for each hypothesis there is a discussion of the empirical findings in order to facilitate the analysis in relation to the aims of this study.

4.2.1. Profile of Irish and Malaysian manufacturing companies

In both countries, the results show that the majority of the respondents are the foreign owned companies and subsidiaries of larger organizations. On the other hand, the correlation analysis also indicates that being a company of foreign ownership and being a subsidiary of larger organization with higher annual turnover has a characteristic of employing more employees in their operation. These results demonstrate the phenomenon of rapid growth economy which produce and increase the number of foreign-owned plants, and the close relationship between foreign direct investment (FDI) and economic growth [163].

In terms of the number of years in operation, the comparison between two countries show that the majority of the respondents in Ireland have been in business for more than 30 years, where as in Malaysia, the majority of them have only been in business for 11 to 20 years. These results are very much related to the history of industrial evolution in both countries. Ireland has started its industrial development much earlier than Malaysia. Starting from the outward orientation of economy since 1960s, where the era of Protectionism has changed to Internationalism era followed by the membership of the EEC in 1973. Irish economic development policies became increasingly focused on export generation and the opening up of the Irish economy to embrace international developments. As for Malaysia, with the recovery of the global recession in 1985-1986, the Malaysian economy grew rapidly from 1991-1995, followed by the increase of foreign investment where new companies have started to relocate and operate their manufacturing plants in Malaysia.

4.2.2. Human factor in maintenance

In the research questions, there are two issues on human factors in maintenance have been highlighted. First, concerning the maintenance problems and obstacles faced by the maintenance department in carrying out their function. Second, about how does the human factor i.e. maintenance employee affects the overall function of maintenance department. For that, the first hypothesis (H1) was formulated to address this aspect, and will be tested as follows:

- Testing Hypothesis 1:

Hypothesis H1: Human factor i.e. maintenance personnel is among the major problems faced by the maintenance department in carrying out their maintenance tasks.

To test this hypothesis, a relationship between the maintenance personnel problem (C16) and the types of human problems (C17) was examined using the data distribution analysis.

As reported in 4.1.3.f, as shown in tables B.31.a and B.32.b, which indicate that, in both countries, maintenance personnel is among the most frequent problems encountered in maintaining the automated system. As a further investigation to the this problem, as shown in tables B.32.a and B.32.b, the results demonstrate that, in both countries, three elements which are related to the maintenance personnel were highlighted as the major obstacles are: lack of competencies / technical skill, inadequate training and have not enough manpower.

As conclusion, the above findings support this hypothesis (H1): human factor i.e. maintenance personnel is among the major problems faced by the maintenance department in carrying out their maintenance tasks. Therefore, the first hypothesis (H1) is accepted.

Apart from the maintenance personnel problem, the results also indicate that the most frequent problems encountered consist of other two aspects which are production disturbance and time consuming. It can be observed that most of the problems that have been highlighted as the obstacles are related to "hard skill" category, whereas the "soft skill" category such as motivation, attitude and teamwork factors were considered as minor obstacles.

4.2.3. Factor of top management commitment

As stated by Beckman et al [80], the highest levels of the management must commit the corporation to a strategic direction. This "top-down" approach in realizing the manufacturing strategy was also highlighted by Spraque [213] who described that strategic planning for manufacturing remains the missing link in corporate strategy. For that, the hypothesis (H2) was formulated to address this aspect and will be tested as follows:

■ Testing Hypothesis 2:

Hypothesis H2: The maintenance function should be regarded as a sufficiently important function to the business strategy and get full commitment from the top management.

To test this hypothesis, a relationship between the need of maintenance review (D5) and the perception on how the top management regards the maintenance function (D4) was examined using correlation and data frequency analysis.

The results show that in both countries, most of the companies rated "agree and strongly agree" on the statement of the way top management regards the maintenance function as "an important supporting function" and "an overhead". However, fewer top management views the maintenance function as "an investment".

Furthermore, the results of correlation analysis as shown in tables C.12.a and C.12.b support this hypothesis (H2), which indicate that those companies where top management do not regard the maintenance as an investment and as an important supporting function should carry out a review of the maintenance role. This is consistent with the findings reported in section 4.1.5.b, which indicate that that the majority of the respondents mentioned that the management should review the role of maintenance in their company, i.e. in the aspects of maintenance training programme, maintenance methods, procedures and maintenance organization. From the above results, it shows that top management commitment is very important in realizing the objective and the role of maintenance department.

As conclusion, the above findings support this hypothesis (H2): the maintenance function should be regarded as a sufficiently important function to the business strategy and get full commitment from the top management. Therefore, the second hypothesis (H2) is accepted.

According to Hill [79], in the majority of cases, manufacturing is simply not geared to the business's corporate objectives. The result is a manufacturing system, good in it self, but not designed to meet company needs So, it is important to stress that top management needs to pay a great deal to the task of ensuring that manufacturing's input into the strategic debate is comprehensive [79]. Maintenance though closely related to manufacturing is a business function of its own. The term maintenance strategy is generally viewed from the perspective of maintenance policies and concepts and its function is to provide dependable service to manufacturing. Maintenance being an integral part of manufacturing can influence the business and manufacturing strategies directly in a negative or positive way. Therefore, the highest levels of top management must commit the corporation to a strategic direction that is clearly defined and well communicated throughout to ensure that its direction is being followed.

4.2.4. Implementation of automation and technology used

In order to examine the level of automation and production technology employed in the manufacturing plant, which will be very much related to the implementation level of maintenance, the hypothesis (H3) was formulated and will be tested as follows:

■ Testing Hypothesis 3:

Hypothesis H3: The use of complex machineries (in terms of integration and production technology) will be higher for the company reporting high level of automation.

To test this hypothesis, a relationship between the level of automation (B2) and the others variables: integration level (B3), type of controllers (B5), AMT used

(B6) and CIM applications used (B7) were examined using correlation and regression analysis.

The results of correlation analysis as shown in tables C.3.a and C.3.b support this hypothesis (H3), which indicate that, in both countries, the higher the level of automation, the higher the level of integration of automation. This is consistent with the findings reported in section 4.1.2.b, which shows that the higher the automation level, the more sophisticated the type of controllers.

To further confirm this observation, the linear regression analysis was used to examine the relationship between these variables. From the tables C.21.a and C.21.b, the results indicate that the level of integration is significantly correlated with the level of automation employed.

As conclusion, the above findings support this hypothesis (H3): the use of complex machineries (in terms of integration and production technology) will be higher for the company reporting high level of automation. Therefore, the third hypothesis (H3) is accepted.

The detail of findings of the automation level employed and automation technology used in the manufacturing companies are discussed further in the following section:

a) Level of automation and integration

The results reveal that both countries have a similar level and integration of automation where the majority of the respondents, are semi automated, followed by mostly automated in their production. Automation is a dynamic technology that provides the opportunity to improve returns in increasing productivity, improving quality and reducing cost, as described in the literature [4][7][99]100]. This is confirmed by the results found in this study where in both countries, the major motivation factors in implementing automation in the manufacturing plants are "lower production cost" and "better quality". However, the results also show that "cost" is the major obstacle for the implementation of automation, followed by the factors of staff technical skill and time.

A company with high capital investment would not have major problem to invest in automation. The correlation analysis indicates that, a company that has higher annual turnover has a characteristic of employing higher level of automation. In general, the cost incurred consists of the purchase of equipment and installation, as well as providing technical manpower. However, these large scales investments can be justified by long term return of investment if the company could guarantee and benefit a better quality product and decrease the production cost.

b) Automation technology used

In general, the results show that Programmable Logic Controllers (PLC) and Relay are used extensively in the work cell controllers compared to the other type of controllers such as microprocessor controller, Distribution Controller System (DCS) and SCADA systems. This could be interpreted due to the pre-dominant and early establishment of these two types of controller (i.e. PLC and Relay) in the automation technology, whereas the other types of controllers such as DCS, Microprocessor and SCADA systems are very much incorporated with the 'state of the art" and new integrated computer based controller systems.

In comparing the utilisation of Advanced Manufacturing Technologies (AMT) in their automated systems, the findings indicate that the type and level of AMT used in both countries are of similar trend.

In terms of the use of Computer Integrated Manufacturing (CIM) applications, the findings indicate that the percentage of respondents use them in Ireland is slightly higher than in Malaysia. Computer Aided Design (CAD) and Planning Control (PPC) become the most popular and being used more extensively compared to the other CIM applications. These results could be interpreted as the active involvement in the product design stage and process planning activities in Ireland.

From the above findings related to the technologies used in automated manufacturing companies, it could be concluded that the higher the automation level employed in the manufacturing plant, the more diversify and higher technical complexity involved in terms of work cell controllers, AMT and CIM applications.

The above finding was found consistent with the results of a study conduced by Swanson [1] on the relationship between production technology and the use of specific maintenance practices in the United States manufacturing companies. She reported that technical complexity had the strongest relationship to maintenance practice. In other words, the higher the technical complexity employed, the more the comprehensive maintenance practice to be implemented.

4.2.5. Maintenance practice towards the improvement in equipment availability

a) Responsibilities of the plant maintenance department

The results demonstrate that in both countries, tasks D, C and E are most frequently rated as "one of the most important task", followed by the second three tasks which are tasks A, B and G which are most frequently rated as "one of the most important task" or as an "important task". The other tasks (tasks F, I and H), are most frequently rated as "somewhat important".

Hence, these tasks could be categorized into three groups:

i) First three most important tasks:

- TASK D: Maintaining equipment in operation
- TASK C: Restoring equipment to operation
- TASK E: Performing Preventive and Predictive maintenance

ii) Second three important tasks:

- TASK A: Monitoring the production equipment status
- TASK B: Analyzing equipment failure causes and effects
- TASK G: Helping improve the production process

iii) Somewhat important tasks:

- TASK F: Installing new equipment
- TASK I: Helping the purchasing department in OEM selection
- TASK H: Helping design the production process

From the above findings, it is shown that all the first three most important tasks which are considered very important and given very high emphasis are directly dealt with the equipment maintenance i.e. "maintaining equipment", "restoring equipment" and "performing maintenance". This is considered as a primary function of the maintenance department.

b) Role of machine operator

In terms of the responsibility of machine operators, it is found that in both countries, the majority of the companies do not put the maintenance responsibility on their machine operators. The companies put the responsibility on their machine operators for the material handling, machine set-up and gathering data and charts but not on at least the basic maintenance function. In other words, most of the companies put all the maintenance jobs under maintenance personnel responsibilities.

One of the advantages of implementing Total Productive Maintenance (TPM) has been described as a partnership approach to maintenance. Under TPM, small groups or teams create a cooperative relationship between maintenance and production that helps in the accomplishment of maintenance work. Additionally, production workers become involved in performing maintenance work, allowing them to play a role in equipment monitoring and upkeep. This raises the skill of production workers and allows them to be more effective in maintaining equipment in good condition.

c) Type of maintenance employed

In order to examine the type of maintenance employed, the hypothesis (H4-i) was formulated and will be tested as follows:

- Testing Hypothesis 4(i):

Hypothesis H4-(i): The use of specific type of maintenance practices and strategy will contribute to the improvement of equipment availability.

To test this hypothesis, a relationship between improvement equipment availability (D2.2) and the other variables which represent the types of maintenance used (C7), TPM (C8), RCM (C9) were examined using correlation and regression analysis.

The results of correlation analysis as shown in tables C.7.a support this hypothesis (H4-i) which indicate that, in Ireland, the higher the degree of preventive, predictive and Total Productive (TPM) maintenance utilization, the better the improvement of equipment availability which could be expected. To further confirm this observation, the linear regression analysis was used to examine the relationship between these variables. From the tables C.22 and C.23, the results indicate that the improvement of equipment availability is significantly correlated with specific type of maintenance employed.

As conclusion, the above findings support this hypothesis (H4-i): the use of specific type of maintenance practices and strategy will contribute to the improvement of equipment availability. Therefore, the hypothesis (H4-i) is accepted.

The data analyzed indicated that in both countries, each company used variety of maintenance programmes in its day to day operations. The detail of findings of the practice of different maintenance programmes and the degree of utilization in the manufacturing companies are discussed further in the following section:

- Types of maintenance: Breakdown, Corrective, Preventive and Predictive Maintenance

The results indicate that in both countries, preventive maintenance has the highest means values and being used extensively compared to other types of maintenance. Preventive Maintenance was rated a high degree of used and more preferable, because of the major benefit of this strategy is to reduce the probability of equipment breakdown and unexpected breakdown.

Although the results of the survey appear to indicate that Preventive Maintenance is extensively used, there is still a significant amount of utilization in Breakdown Maintenance which cause unpredictable and uncertain breakdown, whereas in maintenance optimization approach, by increasing the Preventive Maintenance should decrease the Breakdown Maintenance. The correlation analysis shows that there is a negative relationship between the improvement of equipment availability and use of breakdown maintenance, which is statistically significant. This correlation indicates that the lesser the degree of utilization on Breakdown Maintenance, the better the improvement of equipment availability that could be expected, of course with the improvement through proactive and aggressive maintenance approach.

- TPM and RCM

In Ireland, over the whole sample analyzed, 46.0 percent have practiced TPM and 24.6 percent RCM. As for Malaysia, 35.7 percent have practiced TPM and 23.8 percent RCM.

However, despite of the correlation analysis which indicates that the higher the degree of utilization of TPM, the better the improvement of equipment availability that could be expected, the results also show that there are still lack of practice of TPM and RCM among the respondents. In terms of comparison, more respondents have implemented TPM compared to RCM. The lack of practice of TPM and RCM could also be interpreted as a lack of a "total and comprehensive" maintenance approach. There is a need for further study on the reason why many companies have not yet stepped in to utilise the TPM and RCM programmes which have already proved to enhance the maintenance effectiveness.

- Maintenance approach used: proactive, aggressive and reactive maintenance

Based on the literature, the proactive and aggressive maintenance approach would be expected to lead to improvements in maintenance performance while a reactive approach would hurt performance [110].

Factor analysis and correlation analysis have been used to test the relationships between the maintenance approaches used which were derived from the maintenance responsibilities, and the maintenance contribution towards performance.

The results indicate that, in Ireland, the higher the degree of proactive maintenance approach used, the better the improvement of performance in terms of product quality, equipment availability and reduction of production cost could be expected. The correlation also indicates the higher the degree of aggressive maintenance approach used such as TPM, the better the improvement of performance in terms of product quality.

These results of the exploratory factor analysis are consistent with the three different types of maintenance approaches described in the literature.

Two tasks that load on factor 1, task C (restoring equipment to operation) and task F (installing new equipment), represent the traditional, reactive maintenance. Another four tasks load on factor 2, include task A (monitoring production equipment status), task B (analyzing equipment failure causes and effects), task D (maintaining equipment in operation) and task E (performing preventive/predictive maintenance work). These factors are all consistent with an approach to maintenance that seeks to prevent breakdowns, a proactive maintenance. Performing predictive and preventive maintenance (task E) are activities that will help a plant proactively avoid equipment failures. The other activities that load onto this factor are also consistent with a proactive approach. Indeed, monitoring production equipment status (task A) and analyzing equipment failure causes and effects (task B) provide support for knowing how often to perform preventive maintenance and which equipment conditions to monitor through predictive maintenance.

On the other hand, three tasks load on factor 3, include task G (helping to improve the production process), task H (helping to design the production process) and task I (helping the purchasing department in OEM selection), represent an improvement-oriented approach to maintenance. The activities that load on this factor represent aggressive maintenance involvement in improving equipment performance. The activities reflect a maintenance organization that interacts with other functional areas to identify equipment design improvements.

The three different maintenance strategies outlined above are expected to have differing impacts on performance. Proactive and aggressive maintenance strategies are expected to be associated with improved performance. A reactive maintenance strategy is expected to be associated with lower performance. The combination of factor analysis and correlation analysis bears out these expectations. Both the proactive and aggressive strategies have significant positive relationships with the measures of performance.

d) Utilization of CMMS and modules used

In general, Computerized Maintenance Management Systems (CMMS) assists in managing a wide range of information on the maintenance workforce, spare-parts inventories, repair schedules and equipment histories. In fact, in maintenance, there has been an increasing movement toward CMMS [86].

In order to examine the utilization of communication and coordination support (such as CMMS), the hypothesis (H4-ii) was formulated and will be tested as follows:

■ Testing Hypothesis 4-(ii):
Hypothesis H4-(ii): The use of communication and coordination support (such as CMMS) will contribute to the improvement of equipment availability.

To test this hypothesis, a relationship between improvement equipment availability (D2.2) and the use of CMMS (C10) was examined using correlation and regression analysis.

The results of the correlation analysis as shown in table C.7.a support this hypothesis (H4-ii), which indicates that, in Ireland, the use of computer Maintenance Management System (CMMS), the better the improvement of equipment availability could be expected. To further confirm this observation, the linear regression analysis was used to examine the relationship between these variables. From the table C.24, the result indicates that the improvement of equipment availability is significantly correlated with the use of CMMS.

As conclusion, the above findings support this hypothesis (H4-ii): the use of communication and coordination support (such as CMMS) will contribute to the improvement of equipment availability. Therefore, the hypothesis (H4-ii) is accepted.

The details of findings of the use of CMMS as well as the degree of utilization of the modules are discussed further in the following section:

In comparing between the two countries, as shown in figures 4.7.a and 4.7.b the results indicate that 71.4 percent of companies in Ireland have used CMMS, compared to 49.4 percent in Malaysia. Since almost all the companies are dealing with scheduling and coordinating tasks, which justify the need of CMMS, the result of utilization of CMMS in Malaysia is considered to be still low.

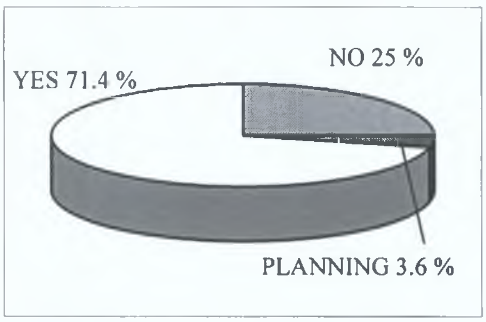


Figure 4.7.a – CMMS in Ireland

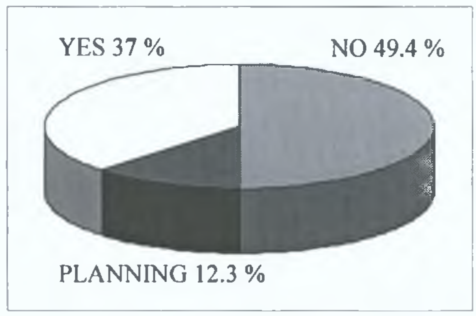


Figure 4.7.b – CMMS in Malaysia

In relation to the degree of CMMS module used, the Pareto Analysis technique has been employed in identifying the level and the most extensive CMMS module used. From the results, the CMMS modules could be classified into three categories:

i) Modules which are extensively used:
- Module B: Preventive maintenance planning and scheduling
- Module E: Equipment repair history
- Module A: Work order planning and scheduling
- Module F: Equipment part list

ii) Modules which are quite extensively used:
- Module J: Material and spare parts purchasing
- Module I: Spare part requirement budgeting
- Module H: Inventory control

iii) Modules which are quite moderately used:

- Module C: Predictive maintenance, data gathering and analysis
- Module D: Equipment failure diagnosis
- Module K: Maintenance budgeting
- Module G: Manpower planning and scheduling

This finding has some similarities to the case study results carried out by O'Dodoghue and Prendergast [87] on the benefit of CMMS implementation in the manufacturing company in Ireland. The results indicate that many benefits accrued from the CMMS implementation such as reduced cost of spares, uptime improvements, increased equipment availability, reducing lead times, increased morale, reduction in unscheduled maintenance and streamlining of work orders schedules. As such Malaysian manufacturing companies are strongly recommended to employ the CMMS system in dealing with their maintenance activities.

e) Troubleshooting methodology used

As stated in the literature, numerous techniques and troubleshooting methodologies have been developed and are currently available to the technical support function in maintaining the automated system. In order to examine the utilization of troubleshooting methodology, the hypothesis (H4-iii) was formulated and will be tested as follows:

■ Testing Hypothesis 4(iii):

Hypothesis H4-(iii): The use of appropriate maintenance troubleshooting tools will contribute to the improvement of equipment availability.

To test this hypothesis, a relationship between improvement equipment availability (D2.2) and the maintenance troubleshooting tools (C15) was examined using correlation and regression analysis.

The results of the correlation analysis as shown in tables C.8.a and C.8.b.a support this hypothesis (H4-iii). In both countries, the results indicate that the higher the degree of utilization of FMEA, SDAT, FTA and Pareto Analysis the better the improvement of equipment availability that could be expected.

To further confirm this observation, the linear regression analysis was used to examine the relationship between these variables. From the tables C.25.a and C.25.b, the results indicate that the improvement of equipment availability is significantly correlated with the maintenance troubleshooting tools used.

As conclusion, the above findings support this hypothesis (H4-iii): The use of appropriate maintenance troubleshooting tools will contribute to the improvement of equipment availability. Therefore, the hypothesis (H4-iii) is accepted.

The details of the findings of utilization of troubleshooting methodology show that in both countries, the Cause and Effect diagram was mentioned as the highest degree of troubleshooting method used, followed by Pareto Analysis, Failure Mode Effectiveness Analysis (FMEA) and Fault Tree Analysis (FTA), whereas System Analyse Design Technique (SADT) was rated the lowest degree of method used.

However, in order to optimize the benefit of using these troubleshooting methodologies, the maintenance personnel should be trained so that they could learn the required knowledge and competencies in carrying out their maintenance duties.

f) In house maintenance involvement

In order to examine the involvement of in-house maintenance in relation to the improvement of equipment availability, the hypothesis (H5) was formulated and will be tested as follows:

■ Testing Hypothesis 5:

Hypothesis H5: Higher improvement of equipment availability can be expected for the companies that use in-house maintenance in their plants.

To test this hypothesis, a relationship between improvement equipment availability (D2.2) and the involvement of in-house maintenance (C18.1) was examined using correlation and regression analysis.

The results of correlation analysis as shown in tables C.9.b support this hypothesis (H5), which indicates that, in Malaysia, the involvement of in-house maintenance, the better the improvement of equipment availability could be expected.

To further confirm this observation, the linear regression analysis was used to examine the relationship between these variables. From the tables C.26, the result indicates that the improvement of equipment availability is significantly correlated with the involvement of in-house maintenance.

As conclusion, the above findings support this hypothesis (H5): higher improvement of equipment availability can be expected for the companies that use in-house maintenance in their plants. Therefore, the hypothesis (H5) is accepted.

The details of the findings of involvement of in-house maintenance show that in both countries, almost all the respondents are involved "in-house maintenance", out of which half of them rated as "full involvement". The results also reveal that the main reason for engaging the external maintenance is due to the unavailability of internal expertise.

As been mentioned, in Malaysia, the correlation analysis indicates that there is higher improvement of equipment availability in the company which uses in-house maintenance. As for Ireland, there is no correlation found between the improvement of equipment availability and the involvement of "in-house and/or external" maintenance. Due to the geographical factor, Ireland has an advantage where its location is nearby the other European countries. As far as for Malaysia, which is geographically far away from the machine manufacturer's countries such as The United States and European countries, Malaysia needs to rely more on the availability of internal or in-house maintenance.

4.2.6. Training and human resource development

Most publications on human resource management stress the importance of training and development for individual and organizational growth and success. Human resource development is "a vital component" in human resource management [150].

"Manpower planning" is defined as "the activity of management which is aimed at coordinating the requirements for and the availability of different types of employee" [149]. A high investment in training and development can lead to the more effective utilization of high technology, higher skill levels, higher wages and lower unit labour cost, leading ultimately to competitive advantage [152].

In order to examine the issue of training and human resource development, the two hypotheses (H6-i) and (H6-ii) were formulated and will be tested as follows:

■ Testing Hypothesis 6-(i):
Hypothesis H6-(i): The maintenance employee development and training are better implemented for companies using training need analysis.

To test this hypothesis H6-(i), a relationship between the use of training need analysis (D2.2) and the implementation of training, i.e. different type of training programme conducted (E2) and the percentage of maintenance personnel who received training (E3) were examined using correlation analysis.

The results of the correlation analysis as shown in table C.13.a, support this hypothesis [H6-(i)], which indicates that, in Ireland, by conducting an appropriate training needs analysis (once a year), a better training implementation in terms of the number of staff trained and percentage of participation can be expected.

■ Testing Hypothesis 6-(ii):

Hypothesis H6-(ii): The maintenance employee development and training will contribute towards a better performance of improvement in equipment availability.

To test this hypothesis H6-(ii), a relationship between the improvement equipment availability (D2.2) and the implementation of training, i.e. different type of training programme conducted (E2) and the percentage of maintenance personnel who received training (E3) were examined using correlation analysis.

The results of the correlation analysis as shown in table C.14.a, support this hypothesis H6-(ii), which indicates that, in Ireland, by conducting an appropriate training needs analysis and good training implementation, a better of performance improvement in equipment availability can be expected.

As conclusion, the above findings support these hypotheses H6-(i): the maintenance employee development and training are better implemented for companies using training need analysis and hypothesis H6-(ii): the maintenance employee development and training will contribute towards a better performance of improvement in equipment availability. Therefore, the both hypotheses H6-(i) and H6-(ii) are accepted.

The details of findings of the training and human resource development in the manufacturing companies are discussed further in the following section:

a) Training planning and implementation

This information was sought to know about the existence of some sort of "training need analysis (TNA)" put in place, in order to identify the need of maintenance or technical training for the maintenance personnel.

The results of the survey show that in both countries, the majority of the respondents which have TNA exercise, carried out their TNA once per year. In Ireland, the correlation analysis indicates that by conducting an appropriate training need analysis, the better the training implementation in terms of the number of training and percentage of participation could be expected.

On the other hand, the results also show that more companies in Malaysia have conducted TNA compared to Ireland. In terms of the number of different training programmes which are related to maintenance, the same results were found where more different types of trainings were conducted in Malaysia compared to Ireland. The results could be due to the long establishment of Irish manufacturing industries compared to Malaysia. Malaysia as a developing industrialized country does need more training programmes in order to ensure the maintenance personnel are able to perform their job.

Based on these findings, the companies are strongly recommended to carry out their TNA analysis, so that it could help to have a better training implementation in terms of the number of training and percentage of participation. Once the companies are able to plan and implement the appropriate training to the maintenance personnel, a better equipment availability improvement could be expected. This statement is supported by the result of the correlation analysis which indicates the positive relationship between training planning and implementation, and the improvement equipment availability.

In terms of the preference of training, the survey results also indicate that in both countries, the majority of the respondents choose "in-house training" as their first option in conducting the maintenance training, where most of them are conducted by their own staff. It is understood that among the main reason why the companies prefer to conduct their in-house training is because of the possibility of using their own facilities and their own case study during the training session, which later on can be applied directly in their plant.

b) Knowledge and competency learning approach

This information was sought to understand the various means the maintenance personnel get to increase their knowledge and competencies in performing the maintenance job, either through self learning, through on-job learning, training from internal staff, training from manufacturer / vendor or training through external consultant.

It can be seen from the results that in both countries, "on the job training" and "training from internal staff " are the most appropriate and efficient approaches for the maintenance personnel to increase their knowledge and competencies in performing the maintenance job, followed by "self-learning approach" and "training from manufacturer or vendor".

On the other hand, the survey results in both countries also reveal that the majority of the respondents had never attended the maintenance conference, seminar or workshop. This result shows low participation, although the existence of such maintenance conference is supposed to be a platform for the maintenance personnel to discuss on maintenance issues and sharing information with other maintenance personnel in different organization.

In terms of the subscription of any maintenance journal and technical publication the survey reveals that 26.2 percent of the respondents in Ireland and 37.0 percent in Malaysia do not have any maintenance journal and technical publication in their maintenance department. Furthermore, even for those who subscribe it, majority of them receive the publications in small number. These findings show that there is still high percentage of companies who do not have or seldomly receive the maintenance publication. There are many reasons that probably lead to this result, among others due to: (1) the unawareness of the existence of the magazine or publication and (2) maintenance personnel do not have interest or time to read.

A study on the need for worker training in advanced manufacturing environments in United States has been conducted by Mital et al [214]. They reported that in realizing that the economic growth of the country is dependent upon developing the human resources and the productivity of people is directly proportional to the economy, it is essential to develop an industry-based generic training process that, at the very least: can enhance the skills of workers at all levels; allow the workers to dynamically cope with changing technology; give the workers options for personal and professional growth, and cut costs, increase productivity, and quality of products manufactured.

4.2.7. Resemblances between Irish and Malaysian maintenance practice

As presented in chapter two, Ireland and Malaysia have enjoyed consistently rapid growth in their Growth Domestic Product (GDP) and incoming foreign investment in technology and manufacturing industry. In this study, the comparative study will analyze the common as well as the differences between both countries in the aspect of maintenance of the automated manufacturing industry. In order to examine this aspect, the hypothesis (H7) was formulated and will be tested as follows:

■ Testing Hypothesis 7:

Hypothesis H7: As both countries, Ireland and Malaysia have similar trends of consistent rapid growth and pattern of production technology, the trend of their maintenance practices are more likely similar.

To test this hypothesis, a relationship between the level of automation (B2), production technology used (B5-B7) and maintenance practices (C7-C) were examined using the result of correlation analysis and the data distribution analysis. As reported in the previous section 4.1.2, the findings indicate that there are some similarities in terms of automation characteristics between Irish and Malaysian automated manufacturing industries, as summarized in table 4.3.

Table 4.3 – Summary of automation characteristics: comparison between Ireland and Malaysia

<table>
<tr><th></th><th>IRELAND</th><th>MALAYSIA</th></tr>
<tr><td>AUTOMATION</td><td></td><td></td></tr>
<tr><td>Automation characteristics</td><td colspan="2">• majority are in semi automated followed by mostly automated.
• majority use stand alone machines, and automated machines linked with material handling.
• the variation of automation level by unit operation is average</td></tr>
<tr><td>Work cell controller</td><td colspan="2">• PLC and Relay are used extensively
• the higher the automation level, the more sophisticated type of controllers being used</td></tr>
<tr><td>Advanced manufacturing technologies</td><td colspan="2">• majority used automation in the material load/unload, packaging / storage and inspection / testing work stations
• less than half of them use AMT in DNC, NC, CNC and robots.
• type and level of AMT used in both countries are of similar trend.</td></tr>
<tr><td>Computer Integrated Manufacturing applications</td><td colspan="2">• PPC and CAD are the most used. In terms of degree of utilization, PPC and CAD are used more extensively in Ireland compared to Malaysia.
• half of them use CAQ, CAM, CAPM or CAPP
• Percentage of respondents used CIM applications in Ireland is slightly higher than in Malaysia.</td></tr>
</table>

In consistent with the above, the findings also indicate that, in terms of maintenance practices, there are some similarities as well between two countries, with some minor exceptions on the relationship between improvement of performance and the type of maintenance and the use of CMMS. Table 4.4 shows the summary of maintenance practices in comparison between Ireland and Malaysia.

Table 4.4 – Summary of maintenance practices: comparison between Ireland and Malaysia

	IRELAND	MALAYSIA
MAINTENANCE		
Responsibilities of maintenance function	• Three maintenance tasks (task D, C and E) are most frequently rated as "one of the most important tasks" • all the maintenance tasks were classified in the same category of factors, representing different type of maintenance used	
Type of maintenance	• preventive maintenance is used extensively • TPM is used more than RCM	
Correlation between automation and type of maintenance	• the higher the level of automation, the higher the degree of utilization of preventive maintenance	• the higher the level of automation, the higher the degree of utilization of predictive maintenance
Correlation between type of maintenance and improvement of performance	• the higher the degree of proactive maintenance approach used (preventive and predictive), the better the improvement of performance in terms of product quality, equipment availability and reduction of production cost. • the higher the degree of aggressive maintenance approach used such as TPM, the better the improvement of performance in terms of product quality.	• No correlation found • No correlation found
Use of CMMS	• Three modules in CMMS (module B, E, A and F) have been used extensively	
Correlation between the use of CMMS and improvement of equipment availability	• the higher the degree of utilization of CMMS, the better the improvement of equipment availability	• No correlation found
Use of troubleshooting tools	• "Cause and Effect diagram" is the most frequently used	
Correlation between the use of troubleshooting tools and improvement of equipment availability	• the higher the degree of utilisation of FMEA, SDAT, FTA and Pareto Analysis, the better the improvement of equipment availability	
In-house versus outsourcing maintenance	• majority of them are fully involved in employing "in-house maintenance" • majority of them are moderately involved in engaging "outsourcing maintenance" (vendors and manufacturers) • main reason of engaging the external maintenance is due to the unavailability of internal expertise. in their maintenance department	

As conclusion, the above findings support this hypothesis (H7): As both countries, Ireland and Malaysia have similar trends of consistent rapid growth and pattern of production technology, the trend of their maintenance practices are more likely similar. Therefore, the hypothesis H7 is accepted.

As stated in the aim of this study in chapter one, the objective of this comparative study is to analyze the common as well as the difference between the practices in both countries – Ireland as an industrialized country and Malaysia as a developing industrialized country. Historically, Ireland in the early sixties was an underdeveloped country. However over the past forty years, it experienced sustained phenomenal growth in industrialization and its economy is still growing at the highest rate among the European countries. Malaysia is a new comer in the scene of developing industrialized country and has enjoyed rapid economic growth for about fifteen years. In order to sustain similar rate of economic growth in the future, Malaysia is prepared to emulate Ireland and other countries in order to continue to invest towards the development of technology, human resource and self reliant industrialization. With similar trends of consistent rapid growth and pattern of production technology, Malaysia could learn and emulate the good practice in the Irish manufacturing industries as Ireland has gone through the experience in terms of sustained rapid growth of economic development over a longer period of time.

4.2.8. Contributions of maintenance efforts towards performance improvement

The results show that in both countries the maintenance effort contributes the highest percentage in the improvement of equipment availability, followed by the reduction of production cost and product quality. In addition, the correlation analysis indicates that the higher the improvement of equipment availability, the better the improvement on the product quality and the reduction of production cost. In other correlation analysis results, it indicates that the higher the improvement of the performance, the higher the level of satisfaction on the maintenance achievement.

Based on the results reported in this study, the key findings related to the maintenance practice and approaches which contribute towards improvement of equipment availability in Ireland are summarized as follow:

- Higher degree of utilization of proactive maintenance approach such as preventive and predictive maintenance
- Higher degree of utilization of aggressive maintenance approach such as TPM
- Lesser degree of utilization of reactive maintenance approach such as breakdown maintenance
- Higher degree of utilization of Computerized Maintenance Management System (CMMS)
- Higher degree of utilization of maintenance troubleshooting technique such as FMEA, SDAT, FTA and Pareto Analysis

In terms of the manpower development, by conducting an appropriate training need analysis (TNA), a better training implementation in terms of number of training and percentage of participation can be expected. Consequently, by having good training planning and implementation, improvement on equipment availability can be expected. On the other hand, it can be seen from the results that in both countries, "on the job training" and "training from internal staff " are the most appropriate and efficient approaches for the maintenance personnel to increase their knowledge and competencies in performing the maintenance job.

Finally, based on the theoretical understanding found in the literature and the empirical findings in this study, in line with the stated objective of this research, the maintenance strategy will be reformulated. The decision elements in developing the maintenance strategy, as discussed in section 2.3.9, will be used as a guideline. This framework will lead to the proposed deployment strategy for the development of maintenance personnel in Malaysian automated manufacturing companies, where the author has adopted the findings from the empirical data of this study in each maintenance elements accordingly. This includes the key findings related to the maintenance practice and approaches which contribute towards improvement of equipment availability. The author strongly believes that the improvement of equipment reliability and performance could be expected due to resulting highly competent and self reliant in maintenance personnel.

4.3. Chapter Summary

This chapter has reported and analyzed the results from survey carried out in the Irish and Malaysian manufacturing companies. It presented further discussions on the information from the findings which consist of data interpretation and evaluation from the descriptive statistics, frequency distributions, cross-tabulations, analysis as well as the comparison study between both countries. As for the hypotheses testing, for each hypothesis there was a discussion of the empirical findings in order to facilitate the analysis in relation to the aims of this study.

Finally, based on the results and discussions, it summarized the key findings related to the maintenance practice and approaches which linked to the development of deployment strategy for the development of maintenance personnel in Malaysian manufacturing companies. This is presented in the next chapter.

Chapter 5

DEPLOYMENT STRATEGY FOR THE DEVELOPMENT OF MAINTENANCE PERSONNEL IN MALAYSIAN MANUFACTURING COMPANIES

5.0. Introduction

In this chapter, in line with the aims of this research stated in chapter one, a deployment strategy for the development of maintenance personnel is proposed by the author. The deployment strategy presented here will be incorporated within the maintenance strategy in Malaysian automated manufacturing companies, which based on the theoretical understanding in the literature and the empirical data findings in this study. The author believes that the development of the maintenance personnel is fundamental to the maintenance strategy, which will increase the equipment reliability and performance due to the high competent and self reliant maintenance personnel.

5.1. Linkage between Business, Manufacturing and Maintenance Strategy Planning Development

As highlighted in section 2.3, it is important to link the maintenance strategy in the frame work of manufacturing strategy in order to ensure that maintenance plays an important contribution in the manufacturing companies. As a first step, it is important to clarify the maintenance strategy within the framework of the company's business strategy, as illustrated in figure 5.1, which in turn will determine the manufacturing strategy. The key aspect of linking the maintenance strategy to the manufacturing strategy as well as the business strategy is to have maintenance team members determine the contribution that maintenance can make in each of the areas in the production line.

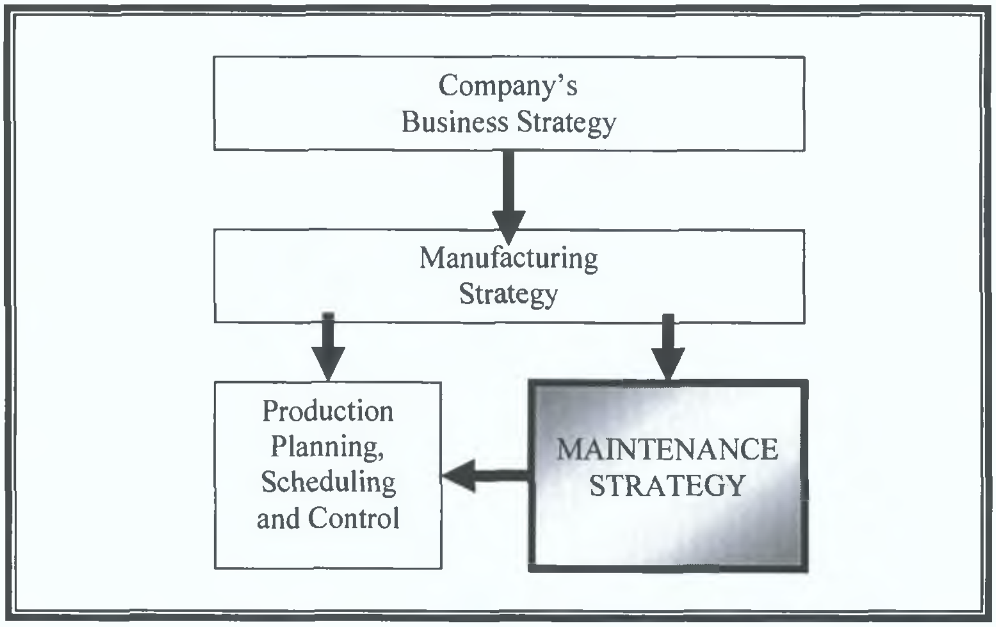


Figure 5.1 - The link between business, manufacturing and maintenance strategy

In this maintenance context, in order to ensure that the objectives and the roles of maintenance department could be implemented and realized effectively, full commitment from the top management is required. On top of that, the maintenance itself should be regarded as an important function in the organization. This is clearly demonstrated from the results of this study which suggest that the top management commitment is very important in realizing the success of maintenance implementation. The result shows that the top management must view maintenance as an investment and an important supporting function, not just an overhead to the company's expenses.

Based on the above, the author believes that the top management must involve and give full commitment to the maintenance department in developing and implementing the maintenance strategy, and identify the priority approach for the key items of plant and equipment in terms of their contribution to operating plants. Once a manufacturing organization understands its points of strategic emphasis, it has the basis for making further maintenance strategy planning development.

5.2. Maintenance Strategy and its Elements

The author believes that in order to manage a company with diversity of equipment, technology and environment as reported in this study, a comprehensive maintenance strategy must be established and implemented. It is very important to realize that the way maintenance strategy is managed has an impact on the operating dimensions of cost, quality, and reliability of the plant. An effective maintenance strategy is one that fits the needs of the business strategy and supports the manufacturing strategy by focusing on the maintenance activities which describe allocation of resources within the manufacturing function in a way that allows achievement of the maintenance objectives.

Table 5.1 - Formulated maintenance strategy

DECISION ELEMENTS (*adopted from [2][11][112]*)	MAINTENANCE DIMENSIONS / (*Reference-Empirical data*)	HYPOTHESES / (*Reference-Questionnaires No*)
a) Maintenance policy and concepts	Type of maintenance / (Ref: 4.2.5-c) In-house and outsourcing / (Ref: 4.2.5-f)	Hypothesis H4-i / (C7, C8, C9) Hypothesis H5 / (C18, C19)
b) Maintenance organizational structure	Maintenance responsibility / (Ref: 4.2.5-a)	/ (C5, C6)
c) Maintenance planning and control system	CMMS utilization / (Ref: 4.2.5-d)	Hypothesis H4-ii / (C10, C11, C12)
d) Maintenance tools and support	Maintenance troubleshooting / (Ref: 4.2.5-e)	Hypothesis H4-iii / (C15)
e) Maintenance human resources development	Training and human resource development / (Ref: 4.2.6)	Hypothesis H6-ii, H6-i / (E1-E9)
f) Maintenance performance measurement	Maintenance performance improvement / (Ref: 4.2.8)	/ (D1, D2)

Based on the theoretical understanding, as described by Pinjala and Pintelon [2], Visser [112] and Tsang [11], as discussed in section 2.3.9, the maintenance strategy is re-formulated by the author. As shown in table 5.1, the maintenance strategy formulated in this study is developed and corresponded to the tested hypotheses. The empirical data findings are then adopted to address each maintenance dimensions accordingly. Based on the above, the maintenance strategy can be described as a combination of all aspects of maintenance management which include the maintenance policy, concept, organizational structure, tools and support, planning and control system, performance measurement and the development of maintenance personnel, which give the direction for maintenance department in achieving its objective.

In following sub-sections, the author will elaborate the above maintenance strategy decision elements in adopting the findings from the empirical data in each maintenance dimension conducted in this study accordingly.

5.2.1. Maintenance policy and concepts

The strategic decisions involved in the maintenance policy and concepts include the type of maintenance used such as preventive to predictive maintenance, maintenance concept such as TPM and RCM, and maintenance outsourcing policy which involves the justification of maintenance outsourcing requirement.

Based on the findings presented in section 4.2.5.c, the Malaysian manufacturing companies should increase the use of proactive and aggressive maintenance approach and at the same time reduce the use of reactive maintenance. The companies should identify and optimize the use of appropriate type of maintenance from preventive to predictive maintenance according to the need of their plant, which includes routine servicing such as cleaning and lubricating, as well as periodic inspection and calibration. The results show that in Ireland the higher degree of utilization of proactive and aggressive maintenance, the better improvement of equipment availability can be expected.

In terms of the maintenance outsourcing policy, based on the findings presented in section 4.2.5.f, the Malaysian companies need to rely more on the availability of internal or in-house maintenance. This is due to the geographical factor, which is geographically far away from the machine manufacturer's countries. This involves development of its own maintenance personnel. Any engagement from outsourcing maintenance due to unavailability of internal expertise should be justified and well managed.

5.2.2. Maintenance organizational structure and function

The strategic decisions involved in the maintenance organizational structure include the organizational structure, number of maintenance facilities, plant specialization, workforce location, and maintenance responsibilities. These decisions are made by considering factors such as manufacturing policy and human resource policy, plant and maintenance capacity, as well as the workforce specialization (mechanics, electricians, automation specialise, etc).

In identifying the maintenance responsibility, the author suggests that the findings in this study as presented in section 4.2.5.a, can be used as a guideline to organize and prioritize the most important functions in the maintenance department.

5.2.3. Maintenance planning and control system

The strategic decisions involved in the planning and control system of maintenance include the control of maintenance activities, maintenance information and the maintenance resources including people, materials and tools. It also includes maintenance management system such as the utilization of CMMS.

The findings of this study indicate that most of the companies in Ireland have used the CMMS, where as in Malaysia, the utilization is considered to be still low. On the other hand, correlation analysis indicates that the higher the degree of utilization of CMMS, the better the improvement of equipment availability that could be expected. In order to manage and to control the maintenance activities, the Malaysian manufacturing companies are strongly recommended to employ the CMMS system. The author suggests that the findings in this study as presented in section 4.2.5.d. can be used as a guideline to decide on the most useful module in CMMS system.

5.2.4. Maintenance tools and support

The strategic decisions involved in the maintenance tools and support include the use of tools, equipment, spares, condition monitoring equipment, expert system and troubleshooting methodology employed.

Based on the findings presented in section 4.2.5.e, the Malaysian manufacturing companies should optimized the use of appropriate troubleshooting methodologies such as the Cause and Effect diagram, Pareto Analysis, Failure Mode Effectiveness Analysis (FMEA) and Fault Tree Analysis (FTA) and System Analyse Design Technique (SADT). The results show that the higher degree of utilization of maintenance troubleshooting technique, the better improvement of equipment availability can be expected.

On the other hand, the companies should also ensure the availability of manual guidelines for the maintenance personnel references to maintain the automated system. Proper and accurate documentations, which describe the description of the system (functionality and technical specification), procedure of maintenance, list of possible malfunction and guideline for rectification of any malfunction are considered very important and extremely valuable to the reliability of the equipments.

5.2.5. Maintenance human resource development

The strategic decisions involved in the human resource development of maintenance include the recruitment policy, training and development, culture and management style, performance recognition and reward systems. These aspects will be elaborated further by the author in the following section 5.3.5.

5.2.6. Maintenance performance measurement

The findings indicate that almost all the respondents measure the equipment performance which reflects the outcome of maintenance contribution to their plant. Maintenance performance measurement systems play a particularly important role in the execution of a maintenance strategy.

As reported in this study, each company has its own method and approach in measuring the maintenance performance. In general, it must provide a system of checks and balances and feedback loops that allow constant monitoring of progress against the maintenance strategic objectives. Based on the current maintenance practice cited in the literature, the author proposed three indicators of maintenance performance which are commonly used as follows:

- Measures of equipment performance, such as availability, reliability and overall equipment effectiveness.

- Measures of cost performance, such as labour and material costs of maintenance

- Measures of process performance, such as ratio of planned and unplanned work and schedule compliance.

This is similar to what has been adopted from the work of Campbell [215].

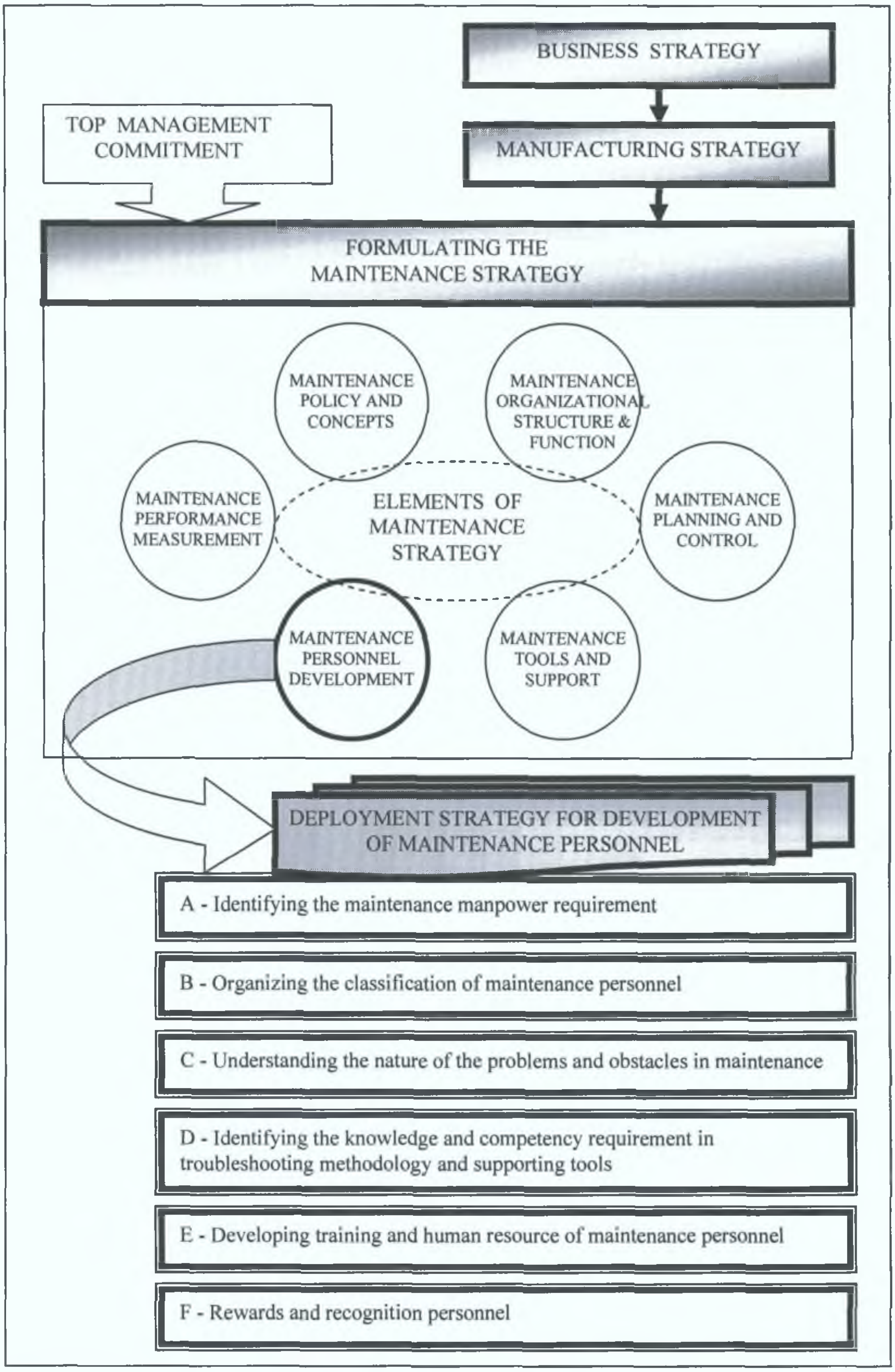


Figure 5.2 - Deployment strategies for the development of maintenance personnel incorporated within the company's maintenance strategy

5.3. Deployment Strategy for the Development of Maintenance Personnel

In any discussion of strategy, it is important to consider how the strategy will be controlled. Equally important as the strategies are the means by which they are deployed into organizational activity. In this section, the deployment of strategy refers to translating the strategy formulated into organizational activity. In line with the stated objective of this research, the process of formulating the maintenance strategy in the previous section leads to the deployment strategies for the development of maintenance personnel, as illustrated in figure 5.2.

One of the maintenance strategy elements formulated by the author is the maintenance personnel development. One of the key findings related to the maintenance practice and approaches which contribute towards improvement of equipment availability is to have good training planning and implementation. Without doubt, the skills of maintenance personnel determine the effectiveness and the efficiency of the functionality of maintenance department. This is supported by the results found in the manufacturing environment which indicate that the ability to tap into and maximize the human potential of the organization is a major determinant of the success [8].

Based on the above and the findings in this study, the deployment strategy for the development of maintenance personnel in Malaysian automated manufacturing companies is proposed by the author. The deployment strategy proposed here will be incorporated within the formulated maintenance strategy, in adopting the findings from the empirical data of this study, as follow:

a) Identifying the maintenance manpower requirement

b) Organizing the classification of maintenance personnel

c) Understanding the nature of the problems and obstacles in maintenance

d) Identifying the knowledge and competency requirement in troubleshooting methodology and supporting tools

e) Developing training and human resource of maintenance personnel

f) Rewards and recognition

This deployment strategy is proposed by the author as the outcome of this study to contribute and solve the issues that have been presented in the aim of this study. In the following sub-sections, based on the empirical findings of this study, the author describes the details of the above proposed deployment strategies.

5.3.1. Identifying the maintenance manpower requirement

The first step would be to convert a maintenance activity plan or forecast to a personnel plan or manpower requirement. This will determine the right number of maintenance personnel required to meet the maintenance objectives. The second step, once the number of manpower has been calculated, is the need to identify what are the job skills as well as the level of qualification and educational background will be required of the maintenance employees.

5.3.2 Organizing the classification of maintenance personnel

In general, the author observes that the traditional maintenance organizations structure is hierarchical and highly functionalized: engineering is responsible for the design and procurement of new plant as well as modification of existing ones, production is responsible for operating the plant, and maintenance for maintaining it. Furthermore, the maintenance personnel is organized into highly specialized trades. This type of organizational design has the problems such as low utilization of resources and does not foster a sense of ownership of assets that can result in poor operational efficiency.

The organization and the classification of maintenance personnel could be organised in a better way since the maintenance work to be performed is an important factor affecting the design of maintenance organizations. The author proposes that the classification of maintenance personnel can be done as follow:

(i) *Level 1 maintenance* is performed to keep the plant running. It covers activities such as minor repairs, process testing, production scheduling and environmental control - the immediate support required by the production plant.

(ii) *Level 2 maintenance* covers those activities that produce significant changes to the condition of the plant, such as major component replacement and detailed inspection. It is *in-situ* work executed intermittently.

(iii) *Level 3 maintenance* requires very special skills and facilities. It covers activities such as overhauls, reconditioning and plant modifications.

This approach is similar to what has been advocated in the work of Clamp [216]. From the author's observation, the categorization of maintenance personnel to different levels has a similarity to what has been practiced in the Total Productive Maintenance (TPM) concept. In fact, in the TPM concept, some of the maintenance tasks in "Level 1 maintenance" are delegated to the machine operators as one of their responsibilities. Under TPM, small groups or teams create a cooperative relationship between maintenance and production that helps in the accomplishment of maintenance work. Additionally, production workers become involved in performing maintenance work allowing them to play a role in equipment monitoring and upkeep. This raises the skill of production workers and allows them to be more effective in maintaining equipment in good condition.

5.3.3. Understanding the nature of the problems and obstacles in maintenance

The maintenance department should understand and identify the nature of the problems and obstacles in maintenance. From the findings, the author has reported that the problems encountered in maintenance can be classified according to the area and technology used, such as mechanical, electrical and electronic parts. The major problems are also found due to the aspect of maintenance personnel such as "lack of competencies and technical skill", "inadequate training" and "not enough manpower".

To overcome these obstacles, the author emphasis that the maintenance manpower team should consist of multi-skill and multi-task personnel who are able to solve the problems according to the area and technology used in the production plant, through the maintenance personnel training and development. As a temporary measure, in the case of the unavailability of internal expertise, the maintenance personnel should be able to identify and manage the appropriate external outsourcing.

5.3.4. Identifying the knowledge and competency requirement in troubleshooting methodology and supporting tools

From the empirical data findings, the author has identified three aspects of knowledge and competency which are required by the maintenance personnel, as follows:

i) Maintenance concepts and related technology.

As the company employs various types of maintenance from preventive to predictive maintenance, maintenance personnel should have the knowledge not only on the maintenance concepts but also extended to the technology related to that. For example, in predictive maintenance, the knowledge in vibration analysis, infrared thermography and non-destructive tests will be very useful.

ii) Maintenance troubleshooting methodology

The maintenance personnel should be trained in using the maintenance troubleshooting methodologies and techniques since the findings indicate that the higher the degree of utilization of FMEA, SDAT, FTA and Pareto Analysis, the better the improvement of equipment availability that could be expected.

iii) Computerized Maintenance Management System

Once the management has decided to implement the CMMS system, the maintenance personnel should be trained so that the utilisation of the system can be optimized, which can assist in managing a wide range of information in maintenance.

5.3.5. Developing training and human resource of maintenance personnel

Based on the findings in this study the author strongly believes that training and human resource development is the main ingredient in developing the maintenance personnel. Furthermore, most publications on human resource management stress on the importance of training and development of individual and organizational growth and success.

One of the most important issue towards the success of the implementation is the maintenance human resource management strategy. Human resources play an effective role in the planning and execution of maintenance strategy through the development of a human resource planning. It is a process which requires a number of labour hours, staff job requirement or job description followed by specification of staff requirements for training and development. A high investment in training and human resource development can lead to higher knowledge and competency level, and more effective utilization of high technology in maintenance leading ultimately to reliability of equipment and competitive advantage.

The maintenance personnel human resource development is outlined by the author as follows:

i) Develop and implement the training plan

Training Need Analysis (TNA) or other appropriate tool has to be in place, in order to identify the need of maintenance or technical training for the maintenance personnel. The findings indicate that by conducting an appropriate training need analysis, a better training implementation in terms of the number of training and percentage of participation, could be expected. In addition, it also indicated that by having an appropriate training need analysis and good implementation on the training in terms of the number of training and percentage of participation, some improvement of equipment availability could be expected.

Among the major factors contributing to the success of each organization is the tremendous emphasis on training and the budgeting process associated with it. The training budget is the key to how the companies are able to implement the strategic human resource plan, which is linked directly to the organizational main strategic plan. This is why the top management commitment is very important in realizing the successful of any operation management strategy.

The following questions should help in establishing the training plan:

- What is needed to implement the training plan?
- What do the employees need to learn?
- Who will train the employees?
- When and where should the training be given?

The findings also indicate that "on job training" and "training from internal staff" lead to the most appropriate and efficient approach for the maintenance personnel to increase their knowledge and competencies in performing the maintenance job. On the other hand the majority of the companies choose "in-house training" as their first option in conducting the maintenance training, where they could use their own facilities and their own case study during the training session, which later on can be applied directly in their plant.

iii) Type of maintenance training

• Specific training

The organization should ensure that the plant recruits suitably qualified and competence personnel, according to the defined job descriptions. This is the most critical aspect since the diagnostics and maintenance of intelligent and automated instruments requires expertise of skilled and specialized personnel.

In order to accomplish these defined tasks and responsibilities, special attention to the career development of automation professional is required, in terms of automation technology and the associated facilities, as well as the development of best practices in operation and maintenance. Educational resources, which can include technical consultation as well as training, must be available and accessible to employees with identified needs.

For that, a comprehensive and on-going training programme for maintenance personnel is a basic ingredient for success in maintaining the manufacturing plant. As such, it is being proposed by the author that the maintenance training programme should cover all the required related to the maintenance activities, including:

- Production and manufacturing processes
- Functionality of equipments or systems
- Maintenance policy, concept and procedure
- Maintenance tools and techniques
- Maintenance management
- Failure diagnosis, detection and rectification
- Safety rules and regulation

However, the training should not only be limited to the transfer of the technical skills and knowledge needed for maintenance task performance. It should also cover generic matters like soft behavioral skills, supervisory and teamwork skills, problem-solving techniques, team dynamics and facilitation skills as well as the knowledge on what determines the value of its product and services to customers.

- Maintenance conference and publication

In relation to the participation of the maintenance staff in any maintenance conference, seminar or workshop, the finding in this study shows low participation where more than half of the companies did not attend any conference related to maintenance. As for the maintenance publication, the findings show that there is still high percentage of companies who do not have or seldom receive or subscribe the maintenance publication.

As such, it is being proposed that the company should send their maintenance personnel to attend the maintenance conferences and subscribing the maintenance or technical publication of professional literature concerning the maintenance issues. The existence of such maintenance conference is supposed to be a platform for the maintenance personnel to discuss the maintenance issues and sharing information and experience with the maintenance personnel from other organizations.

iv) Performance measurement in training

The company should set up performance measurement to ensure completion of the training plan. The data should include the rating of actual performance against the plan at organization, department and individual levels. This information will be used to identify the level of on going training required to maintain the proficiency of the maintenance workforce.

5.3.6. Rewards and recognition

Finally, from the author's point of view, one of the elements which should be considered important as well in the deployment strategies for the development of maintenance personnel is the issue of rewards and recognition. The desire to obtain status in organizational settings is human nature. Instead of working against such human instincts, managers are advised to recognize and reward employees through status recognition in flexible ways [217]. A wide variety of remuneration programmes that take into account factors other than rank, experience and length of service could be used such as new skills and knowledge as well as multi-skilled employees.

5.4. Chapter Summary

In this chapter, the author has emphasized the importance of commitment of the top management in realizing the success of maintenance implementation and has highlighted the importance of linkage of the maintenance strategy in the frame work of manufacturing strategy. Based on the elements of the maintenance strategy, the author has formulated the maintenance strategy which is a combination of all aspects of maintenance management which include the maintenance policy, concept, organizational structure, tools and support, planning and control system, performance measurement and the involvement of maintenance personnel, which give the direction for maintenance department in achieving its objective. The empirical data findings are then adopted to address each maintenance dimensions accordingly.

Finally, in line with the stated objectives of this research and based on the theoretical understanding in the literature and the empirical data findings in this study, the author presented the deployment strategy for the development of maintenance personnel incorporated within the maintenance strategy in Malaysian automated manufacturing companies.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

The principal findings of the research and proposed recommendations are summarized in this chapter, followed by the thesis contribution and the recommendations for future work.

6.1. Conclusions

The following conclusions can be drawn from this research:

- Through this research, a comparative study between both countries regarding maintenance of the automated manufacturing industry had been carried out in Ireland and Malaysia. Malaysia as a developing industrialized country could learn and emulate the good maintenance practice in the Irish manufacturing industries as Ireland has gone through the experience in terms of sustained rapid growth of economic development over a longer period of time.

- An empirical study on the implementation of maintenance practices in the automated manufacturing companies in both countries has been presented in this thesis. In relation to the technologies used in automated manufacturing companies, it could be concluded that the higher the automation level employed in the manufacturing plant, the more diversity and higher technical complexity are being used. Consequently, in terms of the maintenance aspect, the higher the technical complexity employed, the more comprehensive the maintenance practice to be implemented. The results show in both countries that the maintenance effort contributes the highest percentage in the improvement of equipment availability.

• Based on the results reported in this study, the key findings relating to the maintenance practice and approaches which contribute towards improvement of equipment availability in Ireland are summarized as follow: Higher degree of utilization of proactive maintenance, aggressive maintenance, Computerized Maintenance Management System and maintenance troubleshooting techniques.

• Results of this study clearly suggest that the top management commitment is very important in realizing the success of maintenance implementation. Based on the literature and the findings in this research, a maintenance strategy has been formulated by the author. Finally, in line with the stated objective of this research, the process of formulating the maintenance strategy leads to the deployment strategies for the development of maintenance personnel in Malaysian manufacturing companies to be incorporated within the company's maintenance strategy in line with Irish manufacturing companies as examples.

• It is being proposed by the author that the maintenance personnel team should consist of multi-skill and multi-task personnel who are able to solve the problems according to the area and technology used in the production plant. This requirement can be achieved through maintenance personnel training and development. In terms of the manpower development, by conducting an appropriate training need analysis, training planning and implementation, an improvement of equipment availability can be expected.

• A comprehensive survey methodology for collecting data was designed, used and presented in this thesis. In accordance with the standard practice of professional survey bodies, this study has followed with utmost care all the well-established principles and guidelines, especially on the procedure of the survey design and process, as well as the data processing analysis techniques employed.

6.2. Thesis Contributions

The result of this study would contribute greatly to the understanding of deployment strategy for the development of maintenance personnel in Malaysian automated manufacturing company incorporated within the company's maintenance strategy. In general, this study has contributed in the following manner:

- A comparative study has been presented on aspects of maintenance implementation in the automated manufacturing companies between Ireland and Malaysia. There has been little or no substantial research carried out in the aspect of maintenance in the automated manufacturing environment in Ireland and Malaysia. This is therefore important as it addresses the need for this kind of research in the Irish and Malaysian context. The results indicate that in both countries, the higher the automation level, the more sophisticated technologies are associated with. As such, more comprehensive maintenance programme should be implemented, so that the improvement of performance in the equipment availability can be achieved. The results also indicate that in both countries the major problem encountered by the maintenance department is related to the issue of staff maintenance personnel which are due to the lack of knowledge, competencies and motivation. These can be overcome through the employee development approach that leads to the improvement of the plant availability and performance. These are up-to-date information to the body of knowledge and can provide new insight to current situation and guideline for the maintenance department as far as Malaysian and Irish automated manufacturing industries are concerned.

- In this study, seven hypotheses have been formulated based on the preliminary study and the review of the literature, which has been positively substantiated through appropriate designed research methodology. In accordance with the standard practice of professional survey bodies, this study has followed with utmost care all the well-established principles and guidelines, in the research methodology chosen, as well as the data processing software and analysis techniques employed.

- Based on the findings in this research, the deployment strategy for the development of maintenance personnel in Malaysian manufacturing companies has been proposed by the author incorporated within the company's maintenance strategy in comparison with Irish manufacturing companies as examples. This is seen as an original contribution and should be used by the Malaysian Manufacturing companies in improving the maintenance performance, by developing its own highly competent and self reliant internal maintenance teams through employee development, thus leading to the reduction of reliance on external maintenance agencies.

6.3. Future Work

The results of this study point to some further opportunities for research. Some suggestions for future work which relates to this thesis are listed as follows:

- This study examines the maintenance practices which currently deal with the current technology used in the manufacturing industries. Further investigation can be done on the expected maintenance trends in future and how the companies cope with the associated technological changes in order to achieve better product and service quality. It is recommended that on going researches need to be carried out in monitoring the development of maintenance trends and at the same time to establish the database on the correlation between the company maintenance practices and company performance.

- While some fairly strong relationships were found between various parameters, this study does not include the contribution of quality practices in maintenance. Further investigation can be carried out on the recommended approach for maintenance practices in automated system in industry, which will integrate the interest and the needs of quality practitioners.

REFERENCES

[1] L. Swanson, 1997, "An empirical study of the relationship between production technology and maintenance management", International Journal of Production Economics, Vol. 53, pp 191-207

[2] S. K. Pinjala and L. Pintelon, 2005, "An empirical investigation on the relationship between business and maintenance strategies", International Journal of Production Economics" Article in press - available online 5 February 2005

[3] N. I. Van Kessel, 1993, "Searching for the Optimum Through the Application of Maintenance Concepts: Maintenance Engineering in Theory and Practice", Maintenance and Asset Management Journal, UK, Vol. 8, No. 2, June 1993

[4] D. Biros and M. Sadowski, 2000, "Automation in the year 2005", Process Control News (for the Pulp and Paper Industries), Fadum Enterp Inc, Boulder, CO, USA, Vol. 20, No. 11, Nov 2000, pp 2

[5] L. Pintelon, L. Gelders and F. VanPuyvelde, 2000, "Maintenance Management" (2nd ed), Acco Belgium, Leuven

[6] Aigner, Christian, Soergel and Guenter, 1998, "Modern automation, maintenance and process support" Stahl und Eisen, Verlag Stahleisen GmbH, Duesseldorf, Germany, Vol. 118, No 11, pp 113-119

[7] D. J. Adler, Christie, V. J. Hughes, T. Mark, P. J. Owen and J. R. Krenzke, 2000, "Faster, better, cheaper", Process Control News (for the Pulp and Paper Industries), Fadum Enterp Inc, Boulder, CO, USA, Vol. 20, No. 6, pp 1.

[8] D. Power and A. Sohall, 2000, "Human resource management strategies and practices in Just-In-Time environments: Australian case study evidence" Technovation, Vol 20, Issue 7. July 2000, Pages 373-387

[9] R. McLachlin, 1997. "Management initiative and just-in-time manufacturing", Journal of Operations Management 15, pp. 271–292

[10] K. Birdi, C. Allan and P. Warr, 1997, "Correlates and Perceived Outcomes of Four Types of Employee Development Activity". Journal of Applied Psychology, Volume 82, Issue 6 , December 1997, Pages 845-857

[11] A. H. C, Tsang, 2002, "Strategic dimensions of maintenance management", Journal of Quality in Maintenance Engineering, Vol 8 No 1, 2002, pg 7-39

[12] B. Blumberg, D. R. Cooper and P. S. Schindler, 2005, "Business Research Methods". MC Graw Hill, Beckshire, UK

[13] K. F. Punch, 1998, "Introduction to Social Research – Quantitative & Qualitative approach", Sage Publication, London.

[14] S. Sarantakos, 1993, "Social research", Macmillan Press Ltd, London

[15] S. H. Zanakis and I. B. Fernandez, 2005, "Competitiveness of nations: A knowledge discovery examination" , European Journal of Operational Research, Volume 166, Iss. 1

[16] S. Sundqvist, L. Frank and K. Puumalainen, 2005, "The effects of country characteristics, cultural similarity and adoption timing on the diffusion of wireless communications", Journal of Business Research, Volume 58, Issue 1 , January 2005, Pages 107-110

[17] R. J. Calantone, D. Kim, J. B. Schmidt and S. T. Cavusgil, 2005. "The influence of internal and external firm factors on international product adaptation strategy and export performance: A three-country comparison", Journal of Business Research, Article in Press - Available online 11 July 2005.

[18] S. Wunder, 2005, "Macroeconomic Change, Competitiveness and Timber Production: A Five-Country Comparison" World Development, Volume 33, Issue 1 , January 2005, Pages 65-86

[19] R. Broek, A. Wijkb and W. Turkenburga, 2002, "Electricity from energy crops in different settings—a country comparison between Nicaragua, Ireland and the Netherlands" Biomass and Bioenergy, Volume 22, Issue 2 , February 2002, Pages 79-98

[20] M. Hobday, A. Cawsonb and S. R. Kimc, 2001, "Governance of technology in the electronics industries of East and South-East Asia", ,Volume 21, Issue 4 , April 2001, Pages 209-226

[21] J. Travers, 2000, "The Evolution of Economic Policies in the Republic of Ireland: The Underlying Reasons for the High Economic Growth Rates of the 1990s", Forfas, http://www.forfas.ie/news.asp?page_id=218

[22] http://www.mida.gov.my/ Malaysian Industrial and Development Authority

[23] http://www.idaireland.com. IDA- IDA Ireland is an Irish Government agency with responsibility for securing new investment from overseas in manufacturing and traded services sectors

[24] UNDP (United Nation Development Programme), 2001, "Human Development Report", Oxford University Press, New York

[25] C. Selltiz, M. Jahoda, M. Deutsch and S. W. Cook, 1959, "Research methods in social relations", 2ne edition, London, Methuen

[26] H. F. Wolcott, 1990, "Writing up qualitative research", Newbury Park, CA, Sage

[27] R. Preece, 1994, "Starting research: an introduction to academic research and dissertation writing", London: Printer Publishers

[28] J. W. Creswell, 1994, "Research Design: qualitative and quantitative approaches", California, Sage Publication

[29] B. B. Flynn, S. Sakakibara, R. G. Schroeder, K. A. Bates and E. J. Flynn, 1990, "Empirical research methods in operation management", Journal of Operations Management, Vol. 9, No. 2, April 1990

[30] G. R. Adams and J. D. Schvaneveldt, 1991, "Understanding research methods", (2nd Edition), New York, Longman

[31] E. III. Lawler, A. M. Mohrman Jr., S. A. Mohrman, G. E. Ledford Jr. and T. G. Cummings (Eds), 1995, "Doing research that is useful for theory and practices". San Francisco, Jossey-Bass

[32] M. J. Baker, 2000, "Writing a literature review", The marketing review, 1, pg 219-247

[33] A. D. Jankowics, 2000, "Business Research Projects", 3rd Edition, London: Thomson Learning, pg 178

[34] C. Hart, 1998, "Doing a Literature Review", London Saga Publication

[35] T. Kelly, 2000, "The human factor – Auditing human factors in maintenance management", Maintenance and Asset Management Journal, UK, Vol. 15, No. 5, Dec 2000

[36] A. Mital and A. Pennathur, 2004, "Advanced technologies and humans in manufacturing workplaces: an interdependent relationship", Volume 33, Issue 4 , April 2004, Pages 295-313

[37] B .Bidanda, P. Ariyawongrat, K. L. Needy, B, A. Norman, and W. Tharmmaphornphilas, 2005, "Human related issues in manufacturing cell design, implementation, and operation: a review and survey", Computer & Industrial Engineering. Volume 48, Issue 3, May 2005, pages 507-523

[38] B. Bidanda, R.C. Warner, P.J. Warner and R.E. Billo, 1999, "Project management and implementation of cellular manufacturing", In: I.A. Shahrukh (Ed), "Handbook of cellular manufacturing systems" (pp. 413–452).

[39] S.A. Hopkins, 1989, "An integrated model of management and employee influences on just-in-time implementation", SAM Advanced Management Journal 54, pp. 15–20

[40] V.L. Huber and K.A. Brown, 1991, "Human resource issues in cellular manufacturing: A sociotechnical analysis", Journal of Operations Management 10 1, pp. 138–159

[41] S. Wei Zeng, 1997, "Discussion on maintenance strategy, policy and corresponding maintenance systems in manufacturing", Reliability Engineering and System Safety, Elsevier Science Ltd, No 55, pp 161-162

[42] M. Vineyard, K. A. Gyampah and J. R. Meredith, 1999, "Failure rate distributions for flexible manufacturing systems: An empirical study", European Journal of Operation Research, Vol 116, Issue 1, 1 July 1999, Pages 139-155

[43] K.A.Ghani, and Jayabalan, V., 2000, "Advanced manufacturing technology and planned organisational change", The Journal of High Technology Management Research, Vol. 11, No.1, pp. 1-18

[44] E. Jengkinson, 1990, "Changing the industrial culture", in J. Monaghan & C. G. Lyons (Ed), "Advanced manufacturing technology & systems – Proceeding of the 7th Conference of the Iris manufacturing Committee", Dublin, Ireland

[45] Efstathiades, A., Tassou, S.A., Oxinos, G., and Antoniou, A., 2000, "Advanced manufacturing technology transfer and implementation in developing countries", Technovation, Vol. 20, pp. 93-102

[46] D.D. Tippett, 1989, "Technology implementation management", In: Proceedings of the Second International Conference on Engineering Management: Managing Technology in a Competitive International Environment, Toronto, Ont., Canada, September, pp. 135-139

[47] J.P. Kotter, and L.A. Schlesinger, 1979, "Choosing strategies for change", Harvard Business Review, pp. 106-114

[48] U.R. Pareek, 1981, "Designing and managing human resources systems", New Delhi: Oxford and IBH

[49] A. Gupta, I.J. Chen, and W. Rom, 1993, "Understanding the human aspects of flexible manufacturing systems through management development", Journal of Management Development, Vol. 12, No. 1, pp. 33-42

[50] T. Wilkinson, 1989, "All change at work: The human dimensions", London: Institute of Personnel Management

[51] B.D. Bamane, 1994, "Impact of technological change", Technovation, Vol. 14, No. 1, pp. 3-5

[52] H.H. Larsen, M.P. O'Driscoll, and M. Humphries, 1991, "Technological innovation and the development of managerial competencies", Technovation Vol. 11, No. 7, pp. 419-427

[53] K.A. Ghani and M. Sugumar, 1997, "Questionnaire to measure psychological barriers to technological change", Paper presented in the 3rd International Conference of the Indian Academy of Applied Psychology, Chennai, India, December, pp. 29-31

[54] P.S. Adler, 1986, "New technologies, new skills", California management review, Vol. 29, No. 1, pp. 9-28

[55] S.A. Zahra, 1994, "Technological choices within competitive strategy types: a conceptual integration", International Journal of Technology Management, Vol. 9, No. 2, pp. 172-195

[56] F.W. Swierczek, 1991, "The management of technology: human resource and organisational issues", International Journal of Technology Management, Vol. 6, No. 1/2, pp. 1-14

[57] L.D. Barton, and W.A. Kraus, 1985, "Implementing new technology", Harvard Business Review, Vol. 64, No. 6, pp 102-110

[58] K. Davids, and R. Martin, 1992, "Shop-floor rebellions", Industrial Society, pp. 26-27

[59] T.A. Kochan, 1988, "On the human side of technology", ICL Technical Journal, pp. 391-400

[60] F. Fallik, 1988, "Managing organisational change: Human factors and automation", London: Taylor and Francis

[61] P.L. Nemetz, and L.W. Fry, 1988, "Flexible manufacturing organisations: Implications for strategy formulation and organisation design", Academy of Management Review, Vol. 13, pp. 627-638

[62] G.H. Gaynor, 1996, "Handbook of technology management", New York: McGraw Hill

[63] A.S. Sohal, 1996, "Assessing advanced manufacturing technology (AMT) implementations: an empirical field study", Technovation, Vol. 16, No. 8, pp. 337-384

[64] K.G. Diem, 2002, "Choosing a data collection method for survey research", The State University of New Jersey, Desktop publishing by RCE/Resource Centre Revised: February, 2002. *

[65] V.L. Huber, and N.L. Hyer, 1985, "The human factor in cellular manufacturing", Journal of Operations Management, Vol. 5, No. 3, pp. 213-228

[66] D.Y. Golhar, and S.P. Deshpande, 1993, "An empirical investigation of HRM practices in JIT", Production and Inventory Management Journal, Vol. 34, No. 4, pp. 28-32

[67] F. Huq, 1992, "Labour issues in the implementation of group technology cellular manufacturing", Production and Inventory Management Journal, Vol. 33, No. 4, pp.15-20

[68] D. Otley, 1994, "Better performance management", Management Accounting, Jan, Vol 75, No. 1, pp 44-45

[69] M. Harrison, 1993, "Operation Management Strategy" Pitman Publishing, London.

[70] M.A, Vonderembse and G.P. White, 1991, Operation Management, West, St. Paul

[71] J. B. Dilworth, 1992, Operation Management, McGrawHill, New York

[72] D. Benneth, C. Lewis and M. Oakley, 1988, Operation Management, Philip Allan, London

[73] A. C. Hax and N.S. Majluf, 1991, "The Strategy Concept and Process - A Pragmatic Approach, Prentice-Hall International, Inc., New Jersey

[74] P. E. Moody, 1997, "Leading Manufacturing Excellence", John Wiley & sons, Inc. pp. 45

[75] P. F. Drucker, 1994, "The theory of the business", Harvard Business Review, 72, 5, 95-104

[76] R. H. Hayes and S.C. Wheelwright, 1984, "Restoring our Competitive Edge: Competing through Manufacturing, Wiley, Chichester

[77] D. A Garvin, 1992, "Operations strategy: Text and cases", Prentice Hall International, New York

[78] G.S. Dangayacha and S.G. Deshmukhb, 2004, "An exploratory study of manufacturing strategy practices of machinery manufacturing companies in India", Omega, Article in press - available online 25 December 2004

[79] T. Hill, 1995, "Manufacturing strategy: text and cases", MacMillan Press Ltd, London

[80] S. L. Beckman, W. A. Boller, S. A. Hamilton, J. W. Monroe, 1997, "Using manufacturing as a competitive weapon", in P. E. Moody (Ed), "Leading Manufacturing Excellence", John Wiley & sons, Inc. pp. 68-80

[81] J.K. Pinto and D.P. Slevin, 1987, "Critical factors in successful project implementation", IEEE Transactions on Engineering Management EM-34 1, pp. 22–27

[82] F. Olorunniwo and G. Udo, 2002, "The impact of management and employees on cellular manufacturing implementation", International Journal of Production Economics, Vol 76, Issue 1, 1 March 2002, pp 27-38

[83] D.R. Beck, 1983, "Implementing top management plans through project management", In: D.I. Cleland and W.R. King, (Ed) Project Management Handbook, Van Nostrand, New York, pp. 166-184

[84] C. Sum, J.S.K. Ang and L. Yeo, 1997, "Contextual elements of critical success factors in MRP implementation", Production and Inventory Management Journal 38 3, pp. 77–83

[85] P. Draycott, 1997, "People: Aligning strategy with people", Maintenance and Asset Management Journal, UK, Vol. 12, No 5, Dec 1997

[86] L. Swanson, 2002, "An information-processing model of maintenance management", International Journal of Production Economics, Vol. 83, Issue 1, pp 45-64

[87] C. D. O'Dodoghue and J.G. Prendergast, 2003, "Benefits of Computerized Maintenance Management Systems implementation in manufacturing plants", Advances and Materials and Processing Technology Proceeding Conference 2003, pp 653-656.

[88] K. Lewandowski, 1990, "Key factors in improving maintenance skills", Maintenance and Asset Management Journal, UK, Vol 5, No 1, March/April 1990

[89] R. Sivalingam, 1997, "Applying best practices to maintenance: a 12 steps programme for moving down the road to recovery", Plant Engineering, Vol. 51, No 6, June 1997, pp 120 (2).

[90] www.plant-maintenance.com, 2000, "Maintenance Techniques"

[91] P. Willmott, 1990, "Maintenance and profitability", Maintenance and Asset Management Journal, UK, Vol. 5, No 1, March/April 1990

[92] P. De Groote, 1994, "Trends in Maintenance Management in Europe", Maintenance and Asset Management Journal, UK, Vol. 9, No. 5, Nov/Dec 1994

[93] F.L. Cooke, 2003, "Plant maintenance strategy: Evidence from four British manufacturing firms", Journal of Quality in Maintenance Engineering Vol 9 Pg 3 pp. 239–249

[94] R. Smith, 2000, "Technical Training Division Life Cycle Engineering", Inc http://www.lce.com/technicaltrain/

[95]. V.S.Nagalingam and G. C. I. Lin, 1999. "Latest developments in CIM", Robotics and Computer Integrated Manufacturing 15, pp. 423–430

[96] J.M. Shaw, 2000, "Information-based manufacturing with the web", International Journal of Flexible Manufacturing Systems 12, pp. 115–129

[97] A.S. Sohal, 1997, "A longitudinal study of planning and implementation of advanced manufacturing technologies", International Journal of Computer Integrated Manufacturing 10 1-4, pp. 281–295.

[98] D. N. Anderson, 1992, "Innovation, Quality, Time – The partnership for Customer Satisfaction", Flexible Automation and Information Management, CRC Press, Inc, USA

[99] M. P. Groover, 1987, "Automation, Production Systems, and Computer Integrated Manufacturing", Englewood Cliffs, New Jersey: Prentice-Hall.

[100] S. B. Morriss, 1995, "Automated manufacturing Systems: Actuators, Controls, Sensors and Robotics", New York USA, McGraw-Hill

[101] W. HE and A. Kusiak, 1994, "Future Trends in Computer Integrated manufacturing", Design of Work and Development of Personnel in Advanced Manufacturing, John Wiley & Sons, Inc, pp 553-569

[102] D. I. Cho and M. Parlar, 1991, "A survey of maintenance models for multi-unit systems", European Journal of Operational Research 51, pp. 1–23

[103] P. Collins and F. Hull, 1986, "Technology and span of control: Woodward revisited", Journal of Management Studies , Vol. 23 , pp. 143–164.

[104] N. Paz and W. Leigh, 1994, "Maintenance scheduling: issues, results and research needs. ", International Journal of Operations and Production Management Vol 14, pp. 47–69.

[105] L.M.A Pintelon, F.L.B Van Puyvelde and L.F. Gelders, 1995, "An age-based replacement policy with non-zero repair times for a continuous production process", International Journal of Production Research **33** 8, pp. 2111–2123

[106] K. Dameter, 2003, "Manufacturing strategy and competitiveness", International Journal of Production Economics 81–82, pp. 205–213

[107] G. Waeyenbergh and L. Pintelon, 2004, "Maintenance concept development: A case study", International Journal of Production Economics 89, pp. 395–405

[108] B. Al-Najjar and I. Alsyouf, 2003, "Selecting the most efficient maintenance approach using fuzzy multiple criteria decision making", International Journal of Production Economics 84, pp. 85–10

[109] Gadhi, Karim, Simeu-Abazi and Zineb, 2001, "The modelling of a manufacturing system taking account of the equipment ageing and wear", IEEE Symposium on Emerging Technologies and Factory Automation, ETFA, Institute of Electrical and Electronics Engineers Inc., Vol. 1, pp 503-507

[110] L. Swanson, 2001, "Linking maintenance strategies to performance". International Journal of production Economics, Vol. 70 Issue 3, pp 237-244

[111] Kwaliteg Management Services http://www.kwaliteg.co.za/maintenance

[112] J. K. Visser. 1998, "Modelling maintenance performance: a practical approach" IMA Conference, Edinburgh, pg 1-3

[113] J. Hendry and G. Johnson (Eds), with J. Newton, 1993, "Strategic thinking – leadership and management of change", New York, John Wiley and sons

[114] R. I. Daft, 1989, "Organisation theory and design, 3rd Ed., St Paul, West Publication Company

[115] N.B. Macintosh, 1994, "Management accounting and control systems: an organizational and behavioral approach", Chichester: John Wiley and Sons.

[116] P.M. Mannix and J. C. Pelham, 1996, "Today's management methods", John Wiley and sons, pp 155-168

[117] B. Collins and E. Huge, 1993, "Management by policy", Milwaukee: ASQC Quality Press, pp 60

[118] M. Rausand, 1998, "Reliability Centered Maintenance". Reliability Engineering and System Safety, S0951-8320(97)00092-6, pp 121-132

[119] J. Moubray, 1997, "Reliability-centred Maintenance", 2nd ed., Butterworth-Heinemann, Oxford

[120] D. L. Babcock, 1996, "Managing Engineering and Technology", 2nd edition, New Jersey Prentice Hall, pp.187-215

[121] B. S. Blanchard and W. J. Fabrycky, 1990, "System Engineering and Analysis" 2nd edition Englewood Cliffs, NJ: Prentice-Hall, Inc, pp. 393-405

[122] J. Bateman, 1995, "Preventive maintenance: Stand alone manufacturing compared with cellular manufacturing", Industrial Management Vol. 37, No 1, pp 19-21

[123] D. K. Vanzile and I. Otis, 1992, "Measuring and controlling machine performance", In: G. Salvendy, Editor, Handbook of Industrial Engineering, Wiley, New York , pp. 1575–1584.

[124] C. Gits, 1992, "Design of maintenance concepts", International Journal of Production Economics, Vol. 24, No 3, pp. 217–226.

[125] F. Herbaty. 1990, "Handbook of Maintenance Management Cost Effective Practices", (2nd Edition), Noyes Publications, Park Ridge, NJ .

[126] R. Eade, 1997, "The importance of predictive maintenance", Iron Age New Steel, Vol. 13 No. 9, pp. 68-72.

[127] S. Nakajima. 1989, "Total Productive Maintenance Development Program: Implementing Total Productive Maintenance", Productivity Press, Cambridge, MA

[128] S. Macaulay, 1988, "Amazing things can happen if you...`Keep it Clean'", Production, Vol. 100, No 5, pp. 72–74

[129] B. Maggard and D. Rhyne, 1992, "Total productive maintenance: A timely integration of production and maintenance", Production and Inventory Management Journal, Vol. 33, No. 4, pp. 6–10

[130] D. Briggs, 1994, "Total Productive Maintenance and Reliability Centred Maintenance, Competing or Complementary?", Maintenance and Asset Management Journal, UK, Vol. 9, No. 4, Sept. 1994

[131] C. Trunk, 1997, "The nuts and bolts of CMMS", Material Handling Engineering, Vol. 52, No. 10, pp 47(7), Penton Publishing Inc

[132] M. Lamendola, 1998, " Repair more, repair less: where to focus", EC & M Electrical Construction of Maintenance, Vol. 98, No. 9, Intertec Publishing Corporation.

[133] T. Wireman, 2001, "Climbing the ladder to world class maintenance status", Engineering and Mining Journal, Vol. 202, No 8, pp 2-6

[134] P. G. Hawkins and D. J. Woollons, 1998, "Failure Modes and Effects analysis of complex engineering systems using functional models", Artificial Intelligence in Engineering, Vol. 12, pp 375-397

[135] F. I. Khan and S. A. Abbasi, 2000, "Analytical simulation and PROFAT II: a new methodology and a computer automated tool for fault tree analysis in chemical process industries"

[136] K. Santarek and I.M. Buseif, 1997, "Modelling and design of flexible manufacturing systems using SADT and Petri nets tools", University of Technology, Warsaw, Poland.

[137] K. Ishikawa, 1986, "Guide to Quality Control"

[138] http://erc.msh.org/quality/pstools/pspareto.cfm

[139] G. Langan, 1995, "Maintenance automation: out of the broom closet and into the boardroom", IIE Solutions, Publisher: IIE, Norcross, GA, USA p 14-17.

[140] S. Dunn, 2005, "Maintenance outsourcing - Critical issues", The Plant Maintenance Resource Center, www.plant-maintenance.com

[141] Ildhammar, 2005, "Contract maintenance or not", IDCON, Raleigh, NC, http://www.idcon.com/article-cont1.htm

[142] R.A. Bettis, S.P. Bradley and G. Hamel, 1992, "Outsourcing and industrial decline." Academy of Management Executive 6 1, pp. 7–22

[143] L. Loh and N. Venkatraman,,1992; "Determinants of information technology outsourcing: a cross-sectional analysis", Journal of Management Information Systems 9 1 , pp. 7–24.

[144] O. K. Ngwenyama and N. Bryson, 1999, "Making the information system outsourcing decision: a transaction cost approach to analyzing outsourcing decision problems." European Journal of Operational Research 115 2, pp. 351–367.

[145] J. C. Robertson, 1998, "Abandoning the adjustable wrench maintenance Mentality" http://www.swspitcrew.com/html/aug_98.htm

[146] R. A. Smith, 2000, "How to develop and implement a successful maintenance skills training program", Technical Training Corporation, www.techtraincorp.com

[147] P. De Groote, 1991, "Industrial maintenance in developing countries", Maintenance and Asset Management Journal, UK, Vol. 5, No. 4, Jan 1991

[148] D. Samson, A. S. Sohal,. and E. Ramsay, 1993. "Human resource issues in manufacturing improvement initiatives; case study experiences in Australia." The International Journal of Human Factors in Manufacturing 3 2, pp. 135–152

[149] A. Bowey, 1975, "A guide to manpower planning", Macmillan, London.

[150] E. Keep, 1989, "Corporate training stategies: the vital component?", in J. Storey (Ed.), "New perspective on human resource management", Routledge, London.

[151] D. Laird, 1985, "Approaches to training and development", 2nd Edition, Addison-Wesley Publishing Co., USA

[152] J. Storey and K. Sisson, 1993, "Managing human resources and industrial relations", Open University Press, Buckingham.

[153] M. Marchington and A. Wilkinson, 1996, "Core Personnel and Development", Institute of Personnel Development, London, England.

[154] M. Reid and H. Barrington, 1997, "Training intervention: Managing employee development, 5th edition, IPD London.

[155] R. Harrison, 1997, "Employee development". IPD London.

[156] P. Sparrow and J. Hiltrop, 1994, "European human resource management in transition", Prentice Hall, London.

[157] A. Collin, 1994, "Learning and development", in I.Beardwell, L. Holden (Eds), "Human Resource Management: A contemporary perspective", Pitman, London.

[158] S, Truelove, 1992, "Handbook of training and development", Blackwell Publishers, Oxford, UK.

[159] E. Moorby, 1996, "How to succeed in employee development", 2nd edition, McGrawHill, Maidenhead.

[160] T. Boydell and M. Leary, 1996, "Identifying training needs" IPD, London.

[161] J. Steward, 1999, "Employee development practice" Pitman Publishing, London

[162] T. H. Boydell, 1983, "A guide to the identification of training needs", British Association for Commercial and Industrial eEducation, London.

[163] A. Kearns and F, Ruane, 2001, "The tangible contribution of R&D-spending foreign-owned plants to a host region: a plant level study of the Irish manufacturing sector", Research Policy, Volume 30, Issue 2 , Feb 2001, Pages 227-244

[164] http://www.ireland.com/explore/about/industry.htm

[165] 2004, ESRI Quarterly Economic Commentary, Spring 2005 & OECD Economic Outlook No. 76, Dec 2004

[166] http://www.statistics.gov.my 2005: Department of Statistics, Malaysia

[167] Ministry of Finance, Malaysia, 2005. "Economic Report 2004/2005" published by the 2, Kuala Lumpur

[168] Central Bank of Malaysia, 2005, "Annual Report 2004", Kuala Lumpur

[169] H. Simon, 1980, "The behavioural and social sciences, Science, 209, pg 72-78

[170] O. Nodoushani, 2000, "Epistemological foundations of management theory and research methodology" Human System management, 19, Pg 71-80, IOS Press

[171] M. Easterby-Smith, R. Thrope and A. Lowe, 1991, "Management research: An introduction", Sage, London

[172] H. F. Wolcott, 1992, "Posturing in qualitative inquiry", in M.D. LeCompte, W.L. Millroy and J. Preissle (eds), "Handbook of Qualitative Research in Education", San Diego, CA, Academic Press, pp 3-52

[173] M. Hammersley, 1992, "Deconstructing the qualitative-quantitative divide", in J. Brannen (ed), "Mixing methods: Qualitative and quantitative research", Aldershot: Avebury pp 39-55

[174] J. Brewer and A. Hunter, 1989, "Multimethod research: A synthesis of styles", Newbury Park, CA, Sage

[175] J.A. Maxwell, 1996, "Qualitative research design: an interactive approach ", California, Sage Publication

[176] A. Pinsonneault and K. L. Kraemer, 1993, "Survey research methodology in management information system: An assessment", Journal of Management Information System, Vol 10, No 2, pg 75-105

[177] F. N. Kerlinger, 1986, "Foundation of behavioral research", 3rd Edition, New York: Holt, Rinehart and Winston

[178] M. J. Baker, 2001, "Selecting a research methodology", The marketing review, 1, pg 373-397

[179] S. Hart, 1987, "The use of the survey in industrial market research", Journal of marketing Management, Vol.3, No. 1, pg 25-38

[180] P. L. Alreck and R. B. Settle, 1985, "The survey research handbook", Homewood III

[181] C. Moser and G. Kalton, 1971, Survey methods in social investigation, Heinemann Educational

[182] F. J. Fowler, 1984, "Survey research methods", Beverly Hills, Sage Publication, Inc.

[183] J. R. Whitman, 2002, "Surveys for starters – an introduction to designing and conducting management surveys", Surveytools Corporation, USA

[184] http://www.businessworld.ie/cd/Top1000/index.htm, 2003

[185] http://www.enterprise-ireland.com, 2003

[186] http://www.kompass.ie/about-kompass/marketplace.html, 2003

[187] Ireland KOMPASS CD-ROM 1998/1999 database

[188] http://www.fmm.org.my, 2003

[189] D. H. T. Walker, 1997, "Choosing an appropriate research methodology", Construction Management and Economy, No 15, 1997, pg 149-159

[190] R. Czaja and J. Blair, 1996, "Designing survey", Pine forge Press

[191] S. Sudman, 1982, "Asking questions", San Fracisco, Jossey-Bass Publishers

[192] A. Fink, 1995, "How to ask survey questions, London, Sage Publications, Inc

[193] R. R. Pagano, 1994, "Understanding statistics in the behavioural sciences", Fourth Edition, USA, West Publishing Company

[194] M.Y. Ismail, 1998, "Implementation of quality management in the manufacturing industry", Phd Thesis, School of Mechanical and manufacturing Engineering in Dublin City University, Ireland

[195] E.E Adam,. P. M Swamidass, 1989, "Assessing operations management from a strategic perspective", Journal of Management, Vol. 15, No. 2, pp. 181-203

[196] Vickery, S.K., Droge, C., Markland, R.E., 1993, "Production competence and business strategy: do they affect business performance", Decision Sciences, Vol. 24, No. 2, pp. 435-455

[197] B. M. Deros, S. M. Yusof, and A. M. Salleh, 2004, A survey on benchmarking perceptions of importance and practices in Malaysian companies", ICAMT 2005 Proceedings, 11-13 may 2004, Kuala Lumpur

[198] W. L. Neuman, 1994, "Social Research Methods: Quantitative and Qualitative approaches", 2nd edition, Boston: Allyn and Bacon

[199] R.A. Zeller, 1997, “Validity” in J.P. Keeves (ed), Educational Research, Methodology and Measurement: An International Handbook, 2nd Edition, Oxford: Elsevier, pp 822-829

[200] Introduction to SPSS “Applied Technologies for Learning in the Arts & Sciences (ATLAS) (Revised September,)”, 2002, Available online: http://www.atlas.uiuc.edu/Stats/News%20and%20Resources/documents/SPSS-F102b.pdf

[201] H. N. Norman, C. H. Hull, J. G. Jenkings, K. Steinbrenner and D. H. Bent, 1975, “Statistical package for the social sciences (SPSS)”, McGraw-Hill, Inc

[202] C.C Ragin, 1994, “Constructing social research”, Thousnaf Oaks, CA: Pine Forge

[203] P. Kline, 1994, “An easy guide to factor analysis”, Routledge Publisher, London

[204] J.V Saraph, P.G Benson and R.G. Schroeder, 1989, “An Instrumant for measuring the critical factors of quality management”, Decision Science, Vol 20 No 4, pp 810-829

[205] S. Rahman, 2001, “A comparative study of TQM practice and organisational performance of SMEs with and without ISO 9000 certification”, International Journal of Quality and Reliability Management, Vol. 18 No 1, pp 35-49, MCB University Press

[206] D. George and P. Mallery, 1995, SPSS/PC+ step by step: A simple guide and reference”, Wadsworth Publishing Co.

[207] SPSS version 11 course tutorial software, 2003

[208] J. Kim and C. Mueller, 1978, “Introduction to factor analysis”, Sage Publications, Beverly Hills, CA

[209] J. Reilly, 1997, “Understanding statistics and its applications in business, science and engineering”, Ireland, Folen Publisher

[210] H.J. Motulsky, “Analysing data with GraphPad Prism”, GraphPad Software Inc., San Diego CA, 1999, pp. 135-153, www.graphpad.com

[211] J. Cohen, and P. Cohen, “Applied multiple regression/correlation analysis for the behavioural sciences”, Second Edition, Lawrence Erlbaum Associates (LEA), Publishers Hillsdale, New Jersey London, 1983, pp. 25 and 79

[212] S. M. Stahl and J. D. Hennes, 1980, “Reading and understanding applied statistics”, Missouri, USA, The C.V. Mosby Company.

[213] L. G. Spraque, 1997, "Strategic analysis for global manufacturing", in P. E. Moody (Ed), "Leading manufacturing excellence", John Wiley & sons, Inc. pp. 68-80

[214] A. Mital, A. Pennathur, R. L. Huston, D. Thompson, M. Pittman, G. Markle, D. B. Kaber, L. Crumpton, R. R. Bishu, K. P. Rajurkar, V. Rajan, J. E. Fernandez, M. McMulkin, S. Deivanayagam, P. S. Ray and D. Sule, 1999, "The need for worker training in advanced manufacturing technology (AMT) environments: A white paper", International Journal of Industrial Ergonomics, Vol 24, Issue 2, pg 173-184

[215] J. D. Campbell, 1995, "Outsourcing in maintenance management: a valid alternative to self provision", Journal of Quality in Maintenance Engineering, 1.3, 18-24

[216] Clamp, A.C., 1996, "Profit from your maintenance", Work Structuring Ltd., Surrey

[217] N. Nicholson, 1998, "How hardwired is human behaviour?" Havard Business Review, 76, 4, Pg 134-147

APPENDIX A1

SN NO: [ ][-][ ][ ][ ]

DCU
Dublin City University
Ollscoil Chathair Bhaile Átha Cliath

SURVEY QUESTIONNAIRE **OCT 2003**

DUBLIN CITY UNIVERSITY, IRELAND STUDY ON SYSTEMATIC MAINTENANCE IMPLEMENTATION STRATEGY IN AUTOMATED MANUFACTURING SYSTEM

STUDY NO: 52149676 ver2

The School of Mechanical and Manufacturing Engineering of Dublin City University is studying Systematic Maintenance Implementation Strategy in the Automated Manufacturing System.
As part of this study, would you please fill up this questionnaire. Thank you for your kind cooperation

Please circle, tick or fill in the blanks provided. Please answer ALL questions.

This questionnaire is divided into 5 sections:

- Section A: General Information
- Section B: Level of Automation
- Section C: Maintenance Programme
- Section D: Productivity Performance
- Section E: Training Program

ALL THE INFORMATIONS WILL BE TREATED STRICTLY CONFIDENTIAL

Name : ____________________
Designation : ____________________

Company Name : ____
Company Address : ____
____

Telephone No : ________________ Fax No: ________________
Email Address : ____________________

Information

Section A: General Information

A1. What type of Industrial / Manufacturing group:
(*Please circle major group – ONE only*)

- ◘ 1. Electrical and Electronic
- ◘ 2. Plastics & Rubber
- ◘ 3. Metal & Mech. Engineering
- ◘ 4. Chemical & Allied Products
- ◘ 5. Food, Tobacco & Beverages
- ◘ 6. Wood and Furniture
- ◘ 7. Stationery, Paper & printing
- ◘ 8. Industrial equipment
- ◘ 9. Automotive & Transportation
- ◘ 10. Textile, Clothing & Footwear
- ◘ 11 Clay & Building Ind. Products
- ◘ 12. Others (specify) ________________

A2. Ownership:

- ◘ 1. Local: _____ %
- ◘ 2. Foreign: _____ %

A3. Is the firm a subsidiary or part of some larger organisation (*circle one*)?

- ◘ 1. Yes
- ◘ 2. No

A4. How many years has your company been in business (*circle one*)?

- ◘ 1. Less than 5 years
- ◘ 2. 6-10 years
- ◘ 3. 11-20 years
- ◘ 4. 21-30 years
- ◘ 5. More than 30 years

A5. Number of employees on site (*circle one*)?

- ◘ 1. Less than 25
- ◘ 2. 25 to 50
- ◘ 3. 51 to 100
- ◘ 4. 101 to 250
- ◘ 5. 251 to 500
- ◘ 6. More than 500

A6. Approximate Turnover:

◘ US$ ________ million or in ◘ €/£/RM _____ million

A7. Has the firm practiced / been awarded (*circle as apply*):

- ◘ 1. ISO 9000
- ◘ 2. ISO 14000
- ◘ 3. TQM
- ◘ 4. Other (specify) ________

Automation

Section B: Level of Automation

B1. The main method of manufacture (*circle one*)?

- ◘ 1. Job Shop Production
- ◘ 2. Batch Production
- ◘ 3. Mass Production
- ◘ 4. Process Production

B2. What is the level of automation used in production in your plant (*circle one*)?

- ◘ 1. No automation
- ◘ 2. Sparsely automated
- ◘ 3. Semi automated
- ◘ 4. Mostly automated
- ◘ 5. Fully automated

B3. How would you describe the level of integration of automation used in production (*circle as apply*)?

- ◘ 1. No automation
- ◘ 2. Stand alone automated machines
- ◘ 3. Automated machines linked with material handling
- ◘ 4. Fully Automated Production line
- ◘ 5. Fully Computer Integrated Manufacturing system

B4. How does the level of automation vary by unit operation (*circle one*)?

No variation □1 □2 □3 □4 □5 Varies widely

B5. To what extent are each of the following work cell controller used (*circle as apply*):

*[Scale: **0** - Do not have; **1** – Used Minimally; **3** - Use Moderately; **5** – Use Extensively]*

5.1. Relay	0 □	1 □	2 □	3 □	4 □	5 □
5.2. PLC - Programmable Logic Controller	0 □	1 □	2 □	3 □	4 □	5 □
5.3. DSC – Distributed Control System	0 □	1 □	2 □	3 □	4 □	5 □
5.4. Microprocessor/computer-based control system	0 □	1 □	2 □	3 □	4 □	5 □
5.5. SCADA – Superv. Contr. & Data Acquis. Syst.	0 □	1 □	2 □	3 □	4 □	5 □
5.6. Other (specify)________________________	0 □	1 □	2 □	3 □	4 □	5 □

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B6. To what extent are each of the following advanced manufacturing technologies used (*circle as apply*):

*[Scale: **0** - Do not have; **1** – Used Minimally; **3** - Use Moderately; **5** – Use Extensively]*

6.1. NC - Numerical Controlled	0 □	1 □	2 □	3 □	4 □	5 □
6.2. CNC - Computer Numerical Controlled	0 □	1 □	2 □	3 □	4 □	5 □
6.3. DNC - Direct Numerical Control	0 □	1 □	2 □	3 □	4 □	5 □
6.4. Robotics	0 □	1 □	2 □	3 □	4 □	5 □
6.5. Automated material load/unload workstations	0 □	1 □	2 □	3 □	4 □	5 □
6.6. Automated packaging/storage workstations	0 □	1 □	2 □	3 □	4 □	5 □
6.7. Automated inspection and testing workstations	0 □	1 □	2 □	3 □	4 □	5 □
6.8. Other (specify)________________________	0 □	1 □	2 □	3 □	4 □	5 □

B7. To what extent are each of the following Computer Integrated Manufacturing application and activities used in your plant (*circle as apply*):

*[Scale: **0** - Do not have; **1** – Used Minimally; **3** - Use Moderately; **5** – Use Extensively]*

7.1. CAD (Computer Aided Design)	0 □	1 □	2 □	3 □	4 □	5 □
7.2. CAM (Computer Aided Manufacturing)	0 □	1 □	2 □	3 □	4 □	5 □
7.3. CAPP (Computer Aided Process Planning)	0 □	1 □	2 □	3 □	4 □	5 □
7.4. CAQ (Computer Aided Quality Control)	0 □	1 □	2 □	3 □	4 □	5 □
7.5. CAPM (Computer Aided Project Mgmt)	0 □	1 □	2 □	3 □	4 □	5 □
7.6. PP&C (Production, Planning and Control)	0 □	1 □	2 □	3 □	4 □	5 □
7.7. Other (specify)________________________	0 □	1 □	2 □	3 □	4 □	5 □

B8. How would you describe the level of integration of Communication Networking used in production (*circle one*)?

- 1. No Networking
- 2. Sparsely linked
- 3. Semi linked
- 4. Mostly linked
- 5. Fully linked

B9. What kind of Communication Networking do you employ in your plant (*circle as apply*)?

- 1. No Network
- 2. Local Area Network LAN
- 3. Wide Area Network WAN
- 4. Wireless Local Area Network WLAN
- 5. Others (pls specify) ____________________

B10. Please indicate the automated areas (*circle as apply*)

- 1. Raw material receiving and pre-processing
- 2. Main Processing
- 3. Post process and handling
- 4. Other areas (pls specify) _________________
- 4. Inspection
- 5. Wrapping & Packaging
- 6. Warehousing and storage

B11. Please rank the obstacles for implementation of Automated Manufacturing System (*circle as apply*):

*[Scale: **1** – Not an obstacle; **3** – somewhat obstacle; **5** – Major obstacle]*

11.1. Time	1 □	2 □	3 □	4 □	5 □
11.2. Cost	1 □	2 □	3 □	4 □	5 □
11.3. Technical skills of staff	1 □	2 □	3 □	4 □	5 □
11.4. Management commitment	1 □	2 □	3 □	4 □	5 □
11.5. The nature of business not suitable for automation.	1 □	2 □	3 □	4 □	5 □

If some of the obstacles are not listed above please specify and rank them below:

11.6. ______________________________	1 □	2 □	3 □	4 □	5 □
11.7. ______________________________	1 □	2 □	3 □	4 □	5 □

B12. What is the motivation to implement the Automated manufacturing technology in your production line (*circle as apply*)?

*[Scale: **0** – Not at all; **1** – minor factor; **3** – average factor; **5** – major factory]*

12.1. Access to process information	0 □	1 □	2 □	3 □	4 □	5 □
12.2. Lower production cost	0 □	1 □	2 □	3 □	4 □	5 □
12.3. Improved personnel safety	0 □	1 □	2 □	3 □	4 □	5 □
12.4. Improved product safety	0 □	1 □	2 □	3 □	4 □	5 □
12.5. Better quality	0 □	1 □	2 □	3 □	4 □	5 □
12.6. Obsolescence of older technology	0 □	1 □	2 □	3 □	4 □	5 □
12.7. Other (specify) ________________	0 □	1 □	2 □	3 □	4 □	5 □

Section C: Maintenance Programme

C1. What is the title of the person in charge of the Maintenance of Automated system (Head)

- ________________________________

C2. To whom (designation) does this person (*question C1*) normally report?

- ________________________________

C3. Number of employees in maintenance department (*circle one*)?

- 1. Less than 5
- 2. 6 to 10
- 3. 11 to 20
- 4. 21 to 50
- 5. 51 to 100
- 6. more than 100

C4. Please state numbers of maintenance personnel in the following categories:

- 1. Management ____
- 2. Specialist ____
- 3. Engineer ____
- 4. Technician ____
- 5. Fitter ____
- 6. General worker____
- 7. Others (specify) ____

C5. How much emphasis is placed on each of the following activities as responsibilities of your plant's maintenance department: (*circle as apply*)

*[Scale: **0** – Not applicable; **1** – Not Important; **3** – Somewhat important; **5** – one of the most important]*

5.1. Monitoring the production equipment status	0 □	1 □	2 □	3 □	4 □	5 □
5.2. Analyzing equipment failure causes and effects	0 □	1 □	2 □	3 □	4 □	5 □
5 3. Restoring equipment to operation	0 □	1 □	2 □	3 □	4 □	5 □
5 4. Maintaining equipment in operation	0 □	1 □	2 □	3 □	4 □	5 □
5 5. Performing preventive/predictive maint. work	0 □	1 □	2 □	3 □	4 □	5 □
5 6. Installing new equipment	0 □	1 □	2 □	3 □	4 □	5 □
5 7. Helping improve the production process	0 □	1 □	2 □	3 □	4 □	5 □
5 8. Helping design the production process	0 □	1 □	2 □	3 □	4 □	5 □
5 9. Helping the purchasing dept in OEM selection	0 □	1 □	2 □	3 □	4 □	5 □
5 10. Other (specify) ______________________	0 □	1 □	2 □	3 □	4 □	5 □

C6. A part from running their own machine, operators in your company are also responsible for: (*circle as apply*)

- 1. Machine set-ups
- 2. Material handling
- 3. Doing maintenance
- 4. Gathering Data / charts
- 5. Job scheduling
- 6. Other (specify) _________

C7. To what extent are each of the following types of maintenance used in your plant? (*circle as apply*)

[Scale: **0** *- Do not have;* **1** *– Used Minimally;* **3** *- Use Moderately;* **5** *– Use Extensively]*

7.1. Breakdown Maintenance	0 □	1 □	2 □	3 □	4 □	5 □
7.2. Corrective Maintenance	0 □	1 □	2 □	3 □	4 □	5 □
7.3. Preventive Maintenance	0 □	1 □	2 □	3 □	4 □	5 □
7.4. Predictive Maintenance	0 □	1 □	2 □	3 □	4 □	5 □
7.5. Other (specify) ____________________	0 □	1 □	2 □	3 □	4 □	5 □

C8. To what extent does your company practice Total Productive Maintenance (TPM) program? (*circle one*)

- 1. Not Applicable
- 2. Plan to implement
- 3. If YES, to what extent used: 1 □ 2 □ 3 □ 4 □ 5 □

[Scale: **1** *– Used Minimally;* **3** *- Use Moderately;* **5** *– Use Extensively]*

C9. To what extent does your company practice Reliability Centred Maintenance (RCM) program? (*circle one*)

- 1. Not Applicable
- 2. Plan to implement
- 3. If YES, to what extent used: 1 □ 2 □ 3 □ 4 □ 5 □

[Scale: **1** *– Used Minimally;* **3** *- Use Moderately;* **5** *– Use Extensively]*

C10. Does your company use any Computerized Maintenance Management System (CMMS): (*circle one*)

- 1. Not at all
- 2. Plan to implement
- 3. If YES, to what extent used: 1 □ 2 □ 3 □ 4 □ 5 □

[Scale: **1** *– Used Minimally;* **3** *- Use Moderately;* **5** *– Use Extensively]*

C11. If YES (*Question C10*), please specify the name/type of the CMMS used:

- ____

C12. To what extent are each of the CMMS modules used? (*circle as apply*)

[Scale: **0** *- Do not have;* **1** *– Used Minimally;* **3** *- Use Moderately;* **5** *– Use Extensively]*

13.1. Work-order planning and scheduling	0 □	1 □	2 □	3 □	4 □	5 □
13.2. Preventive maint. planning and scheduling	0 □	1 □	2 □	3 □	4 □	5 □
13.3. Predictive maint. Data gathering and analysis	0 □	1 □	2 □	3 □	4 □	5 □
13.4. Equipment failure diagnosis	0 □	1 □	2 □	3 □	4 □	5 □
13.5. Equipment repair history	0 □	1 □	2 □	3 □	4 □	5 □
13.6. Equipment parts list	0 □	1 □	2 □	3 □	4 □	5 □
13.7. Manpower planning and scheduling	0 □	1 □	2 □	3 □	4 □	5 □
13.8. Inventory control	0 □	1 □	2 □	3 □	4 □	5 □
13.9. Spare parts requirement planning	0 □	1 □	2 □	3 □	4 □	5 □
13.10. Material and spare parts purchasing	0 □	1 □	2 □	3 □	4 □	5 □
13.11. Maintenance Budgeting	0 □	1 □	2 □	3 □	4 □	5 □
13.12. Others (specify) ____________________	0 □	1 □	2 □	3 □	4 □	5 □

NOTE: For Question* C13 – C20, *all the questions are referred to the <u>Automated System and Machineries.</u>

C13. How would you describe, in general, the task of carrying out the maintenance of automated system in your company (*circle one*):

- 1. Very difficult
- 2. Difficult
- 3. Average
- 4. Minor difficulties
- 5. No problem at all
- 6. Others (specify) ______________

C14. Please rank the major breakdown / problems occurred according to the area and technology used, (*circle as apply*):

[Scale: **1** – minor difficulty; **3** – *average;* **5** – major difficulty*]*

14.1. Mechanical Part	1 □	2 □	3 □	4 □	5 □
14.2. Electrical Part	1 □	2 □	3 □	4 □	5 □
14.3. Electronic Part	1 □	2 □	3 □	4 □	5 □
14.4. Pneumatic / Hydraulic Part	1 □	2 □	3 □	4 □	5 □
14.5. Control System	1 □	2 □	3 □	4 □	5 □
14.6. NC / CNC machines	1 □	2 □	3 □	4 □	5 □
14.7. Robots	1 □	2 □	3 □	4 □	5 □
14.8. Communication Networking	1 □	2 □	3 □	4 □	5 □
14.9. Comp. Intgrat. Mfg (CIM) Application	1 □	2 □	3 □	4 □	5 □
14.10.Others (specify) _______________	1 □	2 □	3 □	4 □	5 □

C15. Which of the following methods are used in the troubleshooting tasks, and to what extent: (*circle as apply*)

[Scale: **0** - *Do not have;* **1** – *Used Minimally;* **3** - *Use Moderately;* **5** – *Use Extensively]*

15.1. Failure Modes Effects & (Criticality) Analysis (FMEA)	0 □	1 □	2 □	3 □	4 □	5 □
15.2. System Analysis Design Techniques (SADT)	0 □	1 □	2 □	3 □	4 □	5 □
15.3. Cause & Effect Diagram (Fish Bone/Ishikawa Diagram)	0 □	1 □	2 □	3 □	4 □	5 □
15.4. Fault Tree Analysis (FTA)	0 □	1 □	2 □	3 □	4 □	5 □
15.5. Pareto Analysis	0 □	1 □	2 □	3 □	4 □	5 □
15.6. Others (specify) ___________________________	0 □	1 □	2 □	3 □	4 □	5 □

C16. Please rank the major problems and obstacles in carrying out the maintenance of automated system in your plant: (*circle as apply*)

[Scale: **1** – *Not an obstacle;* **3** – *somewhat obstacle;* **5** – *Major obstacle]*

16.1. Maintenance Personnel / Manpower *(See C 17)*	1 □	2 □	3 □	4 □	5 □
16.2. Time consuming	1 □	2 □	3 □	4 □	5 □
16.3. Cost	1 □	2 □	3 □	4 □	5 □
16.4. Tool & Material	1 □	2 □	3 □	4 □	5 □
16.5. Technique & Procedure	1 □	2 □	3 □	4 □	5 □
16.6. Production disturbance	1 □	2 □	3 □	4 □	5 □
16.7. Inadequate guideline from manufacturers	1 □	2 □	3 □	4 □	5 □
16.8. Lack of Management commitment	1 □	2 □	3 □	4 □	5 □

If some of the obstacles are not listed above please specify and rank them below:

16.9.______________________________	1 □	2 □	3 □	4 □	5 □

C17. If the staff maintenance personnel (C16.1) is among the major problems and obstacles in carrying out the maintenance of automated system in your plant, what are the reasons? (*circle as apply*)

[Scale: **1** – *Not an obstacle;* **3** – *somewhat obstacle;* **5** – *Major obstacle]*

17.1. Lack of Competencies & technical skills	1 □	2 □	3 □	4 □	5 □
17.2. Lack of supervisory skills	1 □	2 □	3 □	4 □	5 □
17.3. Inadequate Training	1 □	2 □	3 □	4 □	5 □
17.4. Not Enough Manpower	1 □	2 □	3 □	4 □	5 □
17.5. Lack of motivation	1 □	2 □	3 □	4 □	5 □
17.6. Lack of teamwork	1 □	2 □	3 □	4 □	5 □
17.7. Attitude problem	1 □	2 □	3 □	4 □	5 □
17.8 High Turnover of staff	1 □	2 □	3 □	4 □	5 □

If some of the obstacles are not listed above please specify and rank them below:

17.9.______________________________	1 □	2 □	3 □	4 □	5 □

C18. How do you categorise the participants of "In-house Maintenance", compared to the external / other agencies engaged in maintenance duties (*circle as apply*)?

*[Scale: **0** – No involvement; **1** – Minimal Involvement; **3**- Moderate Involvement; **5** – Fully Involvement]*

18.1. In-house maintenance (own staff)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
18.2. Maintenance Consultant Company	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
18.3. Vendor & Manufacturer	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
18.4. Others (specify) ____________________	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

C19. Please specify the reason of appointing "external agencies" (Question C18) to perform some of the maintenance duties (*circle as apply*):

- 1. Not Applicable
- 2. Under Warranty
- 3. Internal Expertise not available
- 4. Others (specify) ______________

C20. To what extent are each of the following types of manual guidelines (hardcopy and soft copy) are available for the maintenance personnel references to maintain the Automated system in your plant (*circle as apply*)?

*[Scale: **0** – Not available; **1** – Minimal content; **3**- Moderate content; **5** – Complete document]*

- A-HARD COPY FORMAT (*eg: book / file*):

A1. Description of the system (Functionality & Technical Specification)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
A2. Procedure of maintenance	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
A3. List of possible malfunction	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
A4. Guideline for rectification of any malfunction	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
A5. Other (specify:________________________)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

- B-SOFT COPY FORMAT (*eg: CD, diskette software*):

B1. Description of the system (Functionality & Technical Specification)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
B2. Procedure of maintenance	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
B3. List of possible malfunction	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
B4. Guideline for rectification of any malfunction:	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
B5. Other (specify:________________________)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

Productivity

Section D: Productivity & Performance

D1. How does your company measure the equipment performance (*circle as apply*):

- 1. Overall Equipment Effectiveness (OEE)
- 2. Company's own standard (specify) __________________
- 3. Others (specify) __________________

D2. Over the past three years, how much has maintenance effort contributed to the following improvement (*circle as apply*):

*[Scale: **1** – Less than 20 % of performance improvement; **3** – About 50 % of performance improvement; **5** – More than 80 % of performance improvement*

2.1. Improvement of product quality	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.2. Improvement of equipment availability	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
2.3. Improvement of reduction of production cost	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

D3. In general, from your personal point of view, are you satisfied with the maintenance achievement so far compared to what you were expected to achieve (*circle one*)?

*[Scale: ; **1** – Not Satisfy; **3**- Moderate; **5** – Very Satisfy]*

◘ WHAT YOU WERE SUPPOSED TO ACHIEVE	1 □	2 □	3 □	4 □	5 □
◘ WHAT YOU HAVE ACHIEVED NOW	1 □	2 □	3 □	4 □	5 □

D4. In general, how do you think the top management regards the maintenance function? (*circle as apply*): *[Scale: ; **1** – Disagree; **3**- Moderate; **5** – Agree]*

4.1. Regards as an overhead	1 □	2 □	3 □	4 □	5 □
4.2. Regards as an investment	1 □	2 □	3 □	4 □	5 □
4.3. Regards as an important supporting function	1 □	2 □	3 □	4 □	5 □
4.4. Others (specify) ____________________	1 □	2 □	3 □	4 □	5 □

D5. Should management review the role of maintenance within the company? (*circle as apply*)

◘ 1. Yes ◘ 2. No

D6. If Yes (D5), please specify in which area or matters to be reviewed (*circle as apply*):

*[Scale: **0** – No Change; **1** – Minor review; **3**- Moderate review; **5** – Major review]*

6.1. Maintenance Organisation	0 □	1 □	2 □	3 □	4 □	5 □
6.2. Maintenance Methods & Procedures	0 □	1 □	2 □	3 □	4 □	5 □
6.3. Maintenance Training Programme	0 □	1 □	2 □	3 □	4 □	5 □
6.4. Others: Pls Specify ________________	0 □	1 □	2 □	3 □	4 □	5 □

Section E: Training

E1. Do you carry out some sort of "*TNA –Training Need Analysis*" in order to identify the need of maintenance or technical training for your maintenance staff? (circle one)

0 □ Do not have **2** □ Once every two years

1 □ Once per year **3** □ Every three or more years

E2. Approximately how many different training programmes (related to maintenance) does a maintenance personnel attend each year (per person)? (*circle one*)

◘ 1. Less than 2 ◘ 3. 5 to 7

◘ 2. 2 to 4 ◘ 4. more than 7

E3. What percent of maintenance personnel received training last year? (*circle one*)

◘ 1. 0 % to 20 % ◘ 4. 61 % to 80 %

◘ 2. 21 % to 40 % ◘ 5. 81 % to 100 %

◘ 3. 41 % to 60 %

E4. On average, how many hours of training (related to maintenance) do each of the following maintenance personnel receive per year? (*circle as apply*)

[Scale: **0**: 0 H **1**: 1-20 H **2**: 21 – 40 **3**: 41 – 60 H **4**: 61 – 80 H **5**: More than 81H]

4.1. Management	0 □	1 □	2 □	3 □	4 □	5 □
4.2. Specialist	0 □	1 □	2 □	3 □	4 □	5 □
4.3. Engineer	0 □	1 □	2 □	3 □	4 □	5 □
4.4. Technician	0 □	1 □	2 □	3 □	4 □	5 □
4.5. Fitter	0 □	1 □	2 □	3 □	4 □	5 □
4.6. General worker	0 □	1 □	2 □	3 □	4 □	5 □
4.7. Others (specify: __________	0 □	1 □	2 □	3 □	4 □	5 □

E5. Approximately, what percent of 'In house / external (venue)" versus "own staff / external trainer" maintenance training' conducted throughout a year? (*Total should be 100%*)

- 1. In House, conducted by own staff : _________ %
- 2. In House, conducted by external trainer : _________ %
- 3. External, conducted by own staff : _________ %
- 4. External, conducted by external trainer : _________ %

E6. To what extent by each of the following means, does the maintenance personnel get to increase their knowledge and competencies in performing their maintenance job (*circle as apply*): *[Scale:* **0** *– Not Applicable;* **1** *– Minimum ;* **3** *- Moderate ;* **5** *– Most effective]*

6.1. Self learning	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.2. Through On -Job learning	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.3. Training from internal staff	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.4. Training from manufacturer/vendor	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.5. Training from external consultant	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐
6.6. Other (Specify: _______________)	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐

E7. During the last two years, did any one of the maintenance staff attend any maintenance conference, seminar or workshop which was organized by external organization as a platform to discuss on the maintenance aspect with the maintenance personnel in the other organization? (*circle one*)

- 1. Yes
- 2. No

E8. If Yes (E7), please specify the conference title / organization:

____

E9. Does the maintenance department subscribes or receives any maintenance journal, technical publication or other form of professional literature concerning the maintenance issues? (*circle one*)

- 1. Do not have
- 2. Very seldom
- 3. One (1) or two (2) publications per month
- 4. More than three(3) publications per month

Thank you for your patience and
your kind cooperation is very much appreciated

RE-CONTACT

In case we need to get some further information on the above study, are you willing to be participated and be contacted again? ◘ YES ◘ NO

If **YES**, Please specify the preferable mode of further conversation (*circle as apply*):

- 1. Through email
- 2. Through questionnaire
- 3. Through interview (by prior appointment at your premises)

Please return (using the pre-addressed and stamped envelope) **to:**

Professor Dr. S. Hashmi
Head of School,
School of Mechanical and Manufacturing Engineering,
Dublin City University, Dublin 9,
REPUBLIC OF IRELAND

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APPENDIX A2

The SURVEY CODE used for all the analysis and computation carried out in this thesis

:

CODE	DESCRIPTION
	A - COMPANY BACKGROUND
A1	Type of industry
A2	Ownership
A3	Large organization / subsidiary
A4	Years in business
A5	Number of employee
A6	$ Annual turnover (investment)
A7-1	ISO 9000 award
A7-2	ISO 14000 award
A7-3	TQM award
	B - AUTOMATION
B1	Method of manufacturer
B2	Level of automation
B3	Level of integration of automation
B4	Variation of automation
	Work cell controller:
B5-1	Relay
B5-2	PLC
B5-3	DCS
B5-4	Microprocessor
B5-5	SCADA
	AMT used:
B6-1	NC
B6-2	CNC
B6-3	DNC
B6-4	Robotics
B6-5	Automatic Material
B6-6	Automated Packaging
B6-7	Automated Inspection
	CIM applications:
B7-1	CAD
B7-2	CAM
B7-3	CAPP

B7-4	CAQ
B7-5	CAPM
B7-6	PP&C
B8	Level of integration of Comm. Networking
B9	Type of Communication Networking
B10	Automated area
	Obstacle for implementation AMS:
B11-1	Time
B11-2	Cost
B11-3	Staff's technical skills
B11-4	Management commitment
B11-5	Unsuitability of business nature
	Motivation to implement AMS:
B12-1	Access to process information
B12-2	Lower production cost
B12-3	Improved personnel safety
B12-4	Improved product safety
B12-5	Better quality
B12-6	Obsolescence of older technology
	C - MAINTENANCE
C1	Title maintenance personnel
C2	Title answerable person
C3	Number of maintenance employee
C4	Number of maintenance personnel per category
	Maintenance responsibilities:
C5-1	Monitoring the production equipment status
C5-2	Analyzing equipment failure causes and effects
C5-3	Restoring equipment to operation
C5-4	Maintaining equipment in operation
C5-5	Performing preventive/predictive maintenance work
C5-6	Installing new equipment
C5-7	Helping improve the production process
C5-8	Helping design the production process
C5-9	Helping the purchasing dept in OEM selection
C6	Operators responsibility
	Types of maintenance:
C7-1	Breakdown Maintenance
C7-2	Corrective Maintenance
C7-3	Preventive Maintenance
C7-4	Predictive Maintenance
C8	Total Productive Maintenance
C9	Reliability Centered maintenance

C10	CMMS-Computer Maintenance Management System
	CMMS Modules:
C12-1	Preventive maintenance planning and scheduling
C12-2	Predictive maintenance data gathering and analysis
C12-3	Equipment failure diagnosis
C12-4	Equipment repair history
C12-5	Equipment parts list
C12-6	Manpower planning and scheduling
C12-7	Inventory control
C12-8	Spare parts requirement planning
C12-9	Material and spare parts purchasing
C12-10	Maintenance budgeting
C13	Maintenance task - Degree of difficulty
	Major breakdown - area & technology:
C14-1	Mechanical part
C14-2	Electrical part
C14-3	Electronic part
C14-4	Pneumatic / Hydraulic part
C14-5	Control system
C14-6	NC / CNC machines
C14-7	Robots
C14-8	Communication Networking
C14-9	Computer Integrated Manufacturing (CIM) application
	Troubleshooting methodology:
C15-1	Failure Modes Effects & (Criticality) Analysis (FMEA)
C15-2	System Analysis Design Techniques (SADT)
C15-3	Cause & Effect Diagram (Fish Bone/Ishikawa)
C15-4	Fault Tree Analysis (FTA)
C15-5	Pareto Analysis
	Major problem in maintaining AMS:
C16-1	Maintenance personnel / manpower
C16-2	Time consuming
C16-3	Cost
C16-4	Tools & materials
C16-5	Technique & procedure
C16-6	Production disturbance
C16-7	Inadequate guideline from manufacturers
C16-8	Lack of management commitment
	Major maintenance personnel problems:
C17-1	Lack of competencies & technical skills
C17-2	Lack of supervisory skills
C17-3	Inadequate training
C17-4	Not enough manpower

C17-5	Lack of motivation
C17-6	Lack of teamwork
C17-7	Attitude problem
C17-8	High turnover of staff
	In-house / external maintenance:
C18-1	In-house maintenance (own staff)
C18-2	Maintenance consultant company
C18-3	Vendor & manufacturer
C19	Reason appointment of external
	A - Hardcopy manual:
C20-A1	Description of the system
C20-A2	Procedure of maintenance
C20-A3	List of possible malfunction
C20-A4	Guideline for rectification of any malfunction
	B - Softcopy manual:
C20-B1	Description of the system
C20-B2	Procedure of maintenance
C20-B3	List of possible malfunction
C20-B4	Guideline for rectification of any malfunction
	D - PERFORMANCE
D1	Equipment performance measurement
	Maintenance effort towards improvement:
D2-1	Improvement of product quality
D2-2	Improvement of equipment availability
D2-3	Improvement of reduction of production cost
D3	Level of satisfaction
	Top management perception:
D4-1	Regards as an overhead
D4-2	Regards as an investment
D4-3	Regards as an important supporting function
D5	Should review required
	Review of maintenance role:
D6-1	Maintenance organization
D6-2	Maintenance methods & procedures
D6-3	Maintenance training programme
	E - TRAINING
E1	Training Need Analysis (TNA)
E2	Different training program attended
E3	Percent of maintenance personnel attended training
	Total Hours of training:
E4-1	Management

E4-2	Specialist
E4-3	Engineer
E4-4	Technician
E4-5	Fitter
E4-6	General worker
	Percent Location versus trainer:
E5-1	In House, conducted by own staff
E5-2	In House, conducted by external trainer
E5-3	External, conducted by own staff
E5-4	External, conducted by external trainer
	Learning Approaches:
E6-1	Self learning
E6-2	Through On -Job learning
E6-3	Training from internal staff
E6-4	Training from manufacturer/vendor
E6-5	Training from external consultant
E7	Conference
E8	Conference title
E9	Maintenance publication

APPENDIX B

Results of Survey: Ireland and Malaysia

B-1. Company background

a) Type of industry / manufacturing group

Table B.1.a - Type of industries / manufacturing group (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Electrical and Electronic	22.6	19
Plastic & Rubber	8.3	7
Metal & Mech Engineering	3.6	3
Chemical *Allied Products	6.0	5
Food, Tobacco & Beverages	17.9	15
Wood & Furniture	2.4	2
Stationery, paper & printing	9.5	8
Industrial equipment	1.2	1
Automotive & Transportation	3.6	3
Textile, clothing & footwear	3.6	3
Clay & Building Industry Products	1.2	1
Medical Devices	3.6	3
Pharmaceutical	8.3	7
Others	7.1	6
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	83
	100.0	84

Table B.1.b Type of industries / manufacturing group (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Electrical and Electronic	23.5	19
Plastic & Rubber	8.6	7
Metal & Mech Engineering	9.9	8
Chemical *Allied Products	19.8	16
Food, Tobacco & Beverages	9.9	8
Wood & Furniture	1.2	1
Stationery, paper & printing	2.5	2
Automotive & Transportation	6.2	5
Clay & Building Industry Products	3.7	3
Medical Devices	1.2	1
Others	12.3	10
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	80
	100.0	81

b) Ownership and status of the firm

Table B.2.a – Company's ownership status (IRELAND)

IE - 84 RESPONDENTS	%	Freq
100% Local	36.9	31
100% Foreign	59.5	50
Majority Local	1.2	1
Majority Foreign	1.2	1
Equal 50-50%	1.2	1
% Missing – No Answer	0.0	0
% Valid – Answered	100.0	84
	100.0	84

Table B.2.b – Company's ownership status (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
100% Local	23.5	19
Majority Local	12.3	10
Equal 50-50%	1.2	1
Majority Foreign	17.3	14
100% Foreign	44.4	36
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	80
	100.0	81

Table B.3.a – Company's subsidiary (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Yes	73.8	62
No	26.2	22
% Missing – No Answer	0.0	0
% Valid – Answered	100.0	84
	100	84

Table B.3.b – Company's subsidiary (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Yes	80.2	65
No	19.8	16
% Missing - No Answer	0.0	0
% Valid – Answered	100.0	81
	100.0	81

c) Number of years

Table B.4.a - Number of years in business (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Less 5 years	2.4	2
6 - 10 years	7.1	6
11 – 20 years	15.5	13
21 – 30 years	21.4	18
More than 30 years	52.4	44
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	83
	100.0	84

Table B.4.b - Number of years in business (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Less 5 years	3.7	3
6 - 10 years	19.8	16
11 - 20 years	37.0	30
21 - 30 years	19.8	16
More than 30 years	18.5	15
% Missing - No Answer	1.2	1
% Valid – Answered	98.7	80
	100.0	81

d) Number of employees

Table B.5.a - Number of employees (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Less than 25	1.2	1.0
25 to 50	8.3	7.0
51 to 100	19.0	16.0
101 to 250	28.6	24.0
251 to 500	28.6	24.0
More than 500	13.1	11.0
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	83
	100.0	84.0

Table B.5.b - Number of employees (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Less than 25	2.5	2
25 to 50	3.7	3
51 to 100	9.9	8
101 to 250	23.5	19
251 to 500	29.6	24
More than 500	30.9	25
% Missing - No Answer	0.0	0
% Valid – Answered	100.0	81
	100.0	81

e) Approximate annual turnover

Table B.6.a - Company's approximate annual turnover, in Euro (IRELAND)

IE - 84 RESPONDENTS	%	Freq
1 - 10M	9.5	8.0
11 - 25M	11.9	10
26 - 50M	19.0	16
51 - 100M	13.1	11
101 - 250M	8.3	7
More than 251M	3.6	3
% Missing - No Answer	34.5	29
% Valid – Answered	65.5	55
	100.0	84

Table B.6.b - Company's annual turnover, in Ringgit Malaysia (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
1 - 10M	9.9	8
11 – 25M	6.2	5
26 – 50M	9.9	8
51 - 100M	8.6	7
101 - 250M	19.8	16
More than 251M	24.7	20
% Missing - No Answer	21.0	17
% Valid - Answered	79.0	64
	100.0	81

(1.00 Euro = 5.00 Ringgit Malaysia – May 2005 exchange rate)*

f) Awards or certification received

Table B.7.a – ISO 9000 certification achievement (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Yes	67.9	57
No	32.1	27
% Missing - No Answer	0.0	0
% Valid – Answered	100.0	84
	100	84

Table B.7.b – ISO 9000 certification achievement (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Yes	86.4	70
No	13.6	11
% Missing - No Answer	0.0	0
% Valid - Answered	100.0	81
	100.0	81

Table B.8.a – ISO 14000- certification achievement (IRELAND)

IE – 84 RESPONDENTS	%	Freq
Yes	27.4	23
No	72.6	61
% Missing - No Answer	0.0	0
% Valid – Answered	100.0	84
	100	84

Table B.8.b – ISO 14000- certification achievement (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Yes	40.7	33
No	59.3	48
% Missing - No Answer	0.0	0
% Valid - Answered	100.0	81
	100.0	81

Table B.9.a – TQM certification achievement (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Yes	10.7	9
No	89.3	75
% Missing - No Answer	0.0	0
% Valid – Answered	100.0	84
	100	84

Table B.9.b – TQM certification achievement (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Yes	13.6	11
No	86.4	70
% Missing - No Answer	0.0	0
% Valid - Answered	100.0	81
	100.0	81

B2. Automation

a) Main method of manufacture

Table B.10.a - Different methods of production (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Job shop production	4.8	4.0
Batch Production	38.1	32.0
Mass Production	22.6	19.0
Process Production	33.3	28.0
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	83
	100.0	84

Table B.10.b - Different methods of production (MALAYSIA)

MY – 81 RESPONDENTS	%	Freq
Job shop production	3.7	3
Batch Production	12.3	10
Mass Production	33.3	27
Process Production	50.6	41
% Missing - No Answer	0.0	0
% Valid – Answered	100.0	81
	100.0	81

b) Level of automation

Table B.11.a – Level of automation (IRELAND)

IE - 84 RESPONDENTS	%	Freq
1. No Automation	1.2	1
2. Sparsely automated	16.7	14
3. Semi Automated	50.0	42
4. Mostly Automated	25.0	21
5. Fully Automated	7.1	6
% Missing - No Answer	0.0	0
% Valid – Answered	100	84
	100.0	84

Table B.11.b – Level of automation (MALAYSIA)

MY – 81 RESPONDENTS	%	Freq
1. No Automation	1.2	1
2. Sparsely automated	14.8	12
3. Semi Automated	43.2	35
4. Mostly Automated	28.4	23
5. Fully Automated	12.4	10
% Missing - No Answer	0.0	0
% Valid – Answered	100.0	81
	100.0	81

c) Level of integration of automation

Table B.12.a - Level of integration of automation (IRELAND)

IE - 84 RESPONDENTS	Abbrv	%	Freq
No automation	No Autm	1.2	1
Stand alone	Std Alone	44.1	37
Automated machines linked with material handling	Autm Mc w MH	31.0	26
Fully automated production line	Fully Autm	13.1	11
Fully Computer Integrated manufacturing system	Fully CIM	9.5	8
% Missing - No Answer	% Missing	1.2	1
% Valid – Answered	% Valid	98.8	83
		100	84

Table B.12.b - Level of integration of automation (MALAYSIA)

MY - 81 RESPONDENTS	Abbrv	%	Freq
No automation	No Autm	1.2	1
Stand alone	Std Alone	32.1	26
Automated machines linked with material handling	Autm Mc w MH	38.3	31
Fully automated production line	Fully Autm	17.3	14
Fully Computer Integrated manufacturing system	Fully CIM	11.1	9
% Missing - No Answer	% Missing	0.0	0
% Valid – Answered	% Valid	100.0	81
		100.0	81

d) Variation of automation level by unit operation

Table B.13.a - Variation of automation level by unit operation (IRELAND).

IE - 84 RESPONDENTS	%	Freq
No variation	8.3	7
Little variation	21.4	18
Average	28.6	24
Varies quite widely	21.4	18
Varies widely	14.3	12
% Missing - No Answer	6.0	5
% Valid - Answered	94.0	79
	100.0	84

Table B.13.b - Variation of automation level by unit operation (MALAYSIA)

MY – 81 RESPONDENTS	%	Freq
No variation	11.1	9
Little variation	19.8	16
Average	42.0	34
Quite varies widely	4.9	4
Varies widely	17.3	14
% Missing - No Answer	4.9	4
% Valid - Answered	95.1	77
	100.0	81

e) Work cell controller used

Table B.14.a - Type and to what extent of work cell controller used (IRELAND)

IE - 84 RESPONDENTS	A - Relay	B – PLC	C - DCS	D - MicroP	E – SCADA
0: Do not have	13.1	8.3	39.3	13.1	31.0
1: Used Minimally	15.5	7.1	8.3	9.5	10.7
2: Use quite moderately	6.0	4.8	8.3	10.7	11.9
3: Use Moderately	16.7	22.6	7.1	27.4	8.3
4: Use quite extensively	10.7	16.7	0.0	15.5	10.7
5: Use extensively	26.2	35.7	8.3	11.9	10.7
% Missing - No Answer	11.9	4.8	28.6	11.9	16.7
Total % In Use	75.0	86.9	32.1	75.0	52.4
% Valid - Answered	88.1	95.2	71.4	88.1	83.3
	100.0	100.0	100.0	100.0	100.0
Mean Value	2.85	3.46	2.66	1.23	1.87

Table B.14.b - Type and to what extent of work cell controller used {MALAYSIA)

MY - 81 RESPONDENTS	A - Relay	B - PLC	C – DCS	D - MicroP	E – SCADA
0: Do not have	3.7	3.7	30.9	14.8	44.4
1: Used Minimally	13.6	6.2	8.6	17.3	11.1
2: Use quite moderately	8.6	1.2	3.7	9.9	6.2
3: Use Moderately	25.9	21.0	12.3	21.0	8.6
4: Use quite extensively	16.0	28.4	12.3	13.6	7.4
5: Use extensively	27.2	37.0	16.0	14.8	2.5
% Missing - No Answer	4.9	2.5	16.1	8.6	19.8
Total % In Use	91.4	93.8	53.1	76.5	35.8
% Valid – Answered	95.1	97.5	84.0	91.4	80.2
	100.0	100.0	100.0	100.0	100.0
Mean Value	3.25	3.80	2.18	2.50	1.13

f) Advanced manufacturing technologies used

Table B.15.a - Use of Advanced Manufacturing Technologies in their automated systems (IRELAND)

IE – 84 RESPONDENTS	A – NC	B - CNC	C – DNC	D - ROBOTIC	E - M.LOAD	F - PACKAG'G	G - INSPECT'N
0: Do not have	50.0	46.4	59.5	40.5	26.2	36.9	29.8
1: Used Minimally	0.0	3.6	3.6	16.7	11.9	8.3	7.1
2: Use quite moderately	8.3	9.5	6.0	15.5	14.3	9.5	11.9
3: Use Moderately	8.3	7.1	1.2	7.1	19.0	14.3	16.7
4: Use quite extensively	4.8	6.0	3.6	7.1	11.9	11.9	9.5
5: Use extensively	8.3	9.5	3.6	0.0	7.1	6.0	13.1
% Missing - No Answer	20.2	17.9	22.6	13.1	9.5	13.1	11.9
Total % In Use	29.8	35.7	17.9	46.4	64.3	50.0	58.3
% Valid – Answered	79.8	82.1	77.4	86.9	90.5	86.9	88.1
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	1.28	1.41	0.66	1.12	2.00	1.69	2.09

Table B.15.b - Use of Advanced Manufacturing Technologies in their automated systems (MALAYSIA)

MY - 81 RESPONDENTS	A - NC	B - CNC	C - DNC	D - ROBOTIC	E - M.LOAD	F - PACKAG'G	G - INSPECT'N
0: Do not have	38.3	45.7	50.6	40.7	18.5	38.3	27.2
1: Used Minimally	14.8	9.9	4.9	12.3	9.9	6.2	6.2
2: Use quite moderately	6.2	1.2	4.9	8.6	9.9	9.9	14.8
3: Use Moderately	16.0	19.8	13.6	11.1	17.3	14.8	24.7
4: Use quite extensively	4.9	3.7	1.2	3.7	19.8	7.4	7.4
5: Use extensively	1.2	4.9	3.7	8.6	14.8	12.3	8.6
% Missing - No Answer	18.5	14.8	21.0	14.8	9.9	11.1	11.1
Total % In Use	43.2	39.5	28.4	44.4	71.6	50.6	61.7
% Valid - Answered	81.5	85.2	79.0	85.2	90.1	88.9	88.9
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	1.24	1.30	1.00	1.42	2.60	1.81	2.06

g) Computer Integrated Manufacturing (CIM) applications and activities used

Table B.16.a - Implementation of CIM applications (IRELAND)

IE - 84 RESPONDENTS	A - CAD	B - CAM	C - CAPP	D – CAQ	E - CAPM	F - PP&C
0: Do not have	21.4	45.2	40.5	33.3	39.3	21.4
1: Used Minimally	9.5	13.1	7.1	17.9	10.7	6.0
2: Use quite moderately	10.7	8.3	11.9	10.7	9.5	2.4
3: Use Moderately	19.0	7.1	11.9	13.1	13.1	15.5
4: Use quite extensively	11.9	6.0	6.0	3.6	8.3	21.4
5: Use extensively	21.4	10.7	11.9	10.7	6.0	27.4
% Missing - No Answer	6.0	9.5	10.7	10.7	13.1	6.0
Total % In Use	72.6	45.2	48.8	56.0	47.6	72.6
% Valid - Answered	94.0	90.5	89.3	89.3	86.9	94.0
	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	2.58	1.42	1.68	1.64	1.52	2.97

Table B.16.b - Implementation of CIM applications (MALAYSIA)

MY - 81 RESPONDENTS	A - CAD	B - CAM	C - CAPP	D – CAQ	E - CAPM	F - PP&C
0: Do not have	23.5	46.9	40.7	46.9	42.0	21.0
1: Used Minimally	8.6	8.6	12.3	8.6	13.6	7.4
2: Use quite moderately	12.3	2.5	7.4	4.9	6.2	9.9
3: Use Moderately	25.9	19.8	12.3	17.3	9.9	22.2
4: Use quite extensively	14.8	6.2	3.7	3.7	4.9	12.3
5: Use extensively	7.4	3.7	4.9	2.5	3.7	19.8
% Missing - No Answer	7.4	12.4	18.5	16.1	19.8	7.4
Total % In Use	69.1	40.7	40.7	37.0	38.3	71.6
% Valid – Answered	92.6	87.7	81.5	84.0	80.2	92.6
	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	2.24	1.32	1.27	1.16	1.17	2.61

h) Level of integration of communication networking used

Table B.17.a - Level of integration of communication networking used (IRELAND)

IE - 84 RESPONDENTS	%	Freq
No Networking	9.5	8
Sparsely linked	17.9	15
Semi linked	27.4	23
Mostly linked	29.8	25
Fully linked	14.3	12
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	83
	100	84

Table B.17.b - Level of integration of communication networking used (MALAYSIA)

MY – 81 RESPONDENTS	%	Freq
No Networking	13.6	11
Sparsely linked	11.1	9
Semi linked	28.4	23
Mostly linked	30.9	25
Fully linked	14.8	12
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	80
	100.0	81

i) Type of communication networking used

Table B.18.a - Type of communication networking used (IRELAND)

IE - 84 RESPONDENTS	%	Freq
No Networking	7.1	6
LAN Local Area Network	75.0	63
WAN Wide Area Network	8.3	7
WLAN Wireless LAN	2.4	2
Others	1.2	1
% Missing - No Answer	6.0	5
% Valid - Answered	94.0	79
	100	84

Table B.18.b - Type of communication networking used (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
No Networking	7.4	6
LAN Local Area Network	74.1	60
WAN Wide Area Network	6.2	5
WLAN Wireless LAN	4.9	4
Others	2.5	2
% Missing - No Answer	4.9	4
% Valid - Answered	95.1	77
	100.0	81

j) Obstacles for implementation of automated manufacturing system

Table B.19.a - Level of obstacles for implementation of automated manufacturing system (IRELAND)

IE – 84 RESPONDENTS	A - Time	B - Cost	C - Skill	D - Mgmt C	E - Nature
1: Not an obstacle	10.7	2.4	8.3	10.7	14.3
2: Minor obstacle	9.5	7.1	16.7	22.6	10.7
3: Somewhat obstacle	29.8	15.5	33.3	23.8	26.2
4: Quite major obstacle	11.9	28.6	16.7	15.5	9.5
5: Major obstacle	11.9	35.7	3.6	3.6	14.3
% Missing - No Answer	26.2	10.7	21.4	23.8	25.0
% Valid - Answered	73.8	89.3	78.6	76.2	75.0
	100.0	100.0	100.0	100.0	100.0
Mean value	3.06	3.98	2.87	2.71	2.98

Table B.19.b - Level of obstacles for implementation of automated manufacturing system (MALAYSIA)

MY – 81 RESPONDENTS	A – Time	B - Cost	C - Skill	D - Mgmt C	E - Nature
1: Not an obstacle	22.2	7.4	9.9	19.8	21.0
2: Minor obstacle	8.6	4.9	16.0	13.6	21.0
3: Somewhat obstacle	43.2	23.5	40.7	32.1	23.5
4: Quite major obstacle	12.3	17.3	16.0	19.8	7.4
5: Major obstacle	3.7	43.2	14.8	8.6	11.1
% Missing - No Answer	9.9	3.7	2.5	6.2	16.1
% Valid – Answered	90.1	96.3	97.5	93.8	84.0
	100.0	100.0	100.0	100.0	100.0
Mean value	2.63	3.87	3.10	2.83	2.60

k) Motivation factors in implementing the automated manufacturing system

Table B.20.a - Motivation factors in implementing the automated manufacturing system (IRELAND)

IE - 84 RESPONDENTS	A - Access	B - Cost	C - Safety	D - Product S	E - Quality	F - Obsolescence
0: Not at all	4.8	1.2	6.0	10.7	2.4	7.1
1: Minor factor	7.1	2.4	1.2	4.8	1.2	11.9
2: Quite average factor	8.3	2.4	6.0	4.8	3.6	9.5
3: Average factor	28.6	17.9	28.6	16.7	9.5	21.4
4: Quite major factor	7.1	13.1	20.2	21.4	28.6	21.4
5. Major factor	26.2	57.1	28.6	25.0	42.9	13.1
% Missing - No Answer	17.9	6.0	9.5	16.7	11.9	15.5
% Valid – Answered	82.1	94.0	90.5	83.3	88.1	84.5
	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.27	4.24	3.56	3.30	4.14	2.16

Table B.20.b - Motivation factors in implementing the automated manufacturing system (MALAYSIA)

MY - 81 RESPONDENTS	A - Access	B - Cost	C - Safety	D - Product S	E - Quality	F - Obsolescence
0: Not at all	1.2	2.5	1.2	2.5	1.2	6.2
1: Minor factor	4.9	4.9	4.9	2.5	0.0	6.2
2: Quite average factor	4.9	3.7	4.9	0.0	1.2	11.1
3: Average factor	28.4	24.7	40.7	30.9	13.6	33.3
4: Quite major factor	24.7	23.5	21.0	40.7	33.3	16.0
5. Major factor	25.9	35.8	18.5	14.8	44.4	19.8
% Missing – No Answer	9.9	4.9	8.6	8.6	6.2	7.4
% Valid - Answered	90.1	95.1	91.4	91.4	93.8	92.6
	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.64	3.78	3.43	3.64	4.25	3.14

B-3. Maintenance Programme

a) Number of employees in maintenance department

Table B.21.a - Number of employees in the maintenance department. (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Less than 5	22.6	19
6 to 10	31.0	26
11 to 20	14.3	12
21 to 50	21.4	18
51 to 100	6.0	5
More than 100	1.2	1
% Missing - No Answer	3.6	3
% Valid – Answered	96.4	81
	100.0	84

Table B.21.b - Number of employees in the maintenance department. (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Less than 5	17.3	14
6 to 10	13.6	11
11 to 20	24.7	20
21 to 50	33.3	27
51 to 100	8.6	7
More than 100	0.0	0
% Missing - No Answer	2.5	2
% Valid – Answered	97.5	79
	100.0	81

b) Responsibilities of plant's maintenance department

Table B.22.a - Tasks and activities as responsibilities of the plant's maintenance department (IRELAND)

IE - 84 RESPONDENTS	A - Monitor	B - Analyze	C - Restore	D - Maintain	E - Perform	F – Install	G - Improve	H - Design	I - Purchase
0: Not Applicable	2.4	2.4	1.2	1.2	1.2	3.6	3.6	4.8	6.0
1: Not important	8.3	2.4	1.2	1.2	2.4	6.0	2.4	13.1	10.7
2: Little important	7.1	17.9	2.4	1.2	7.1	17.9	10.7	13.1	20.2
3: Somewhat important	20.2	21.4	7.1	8.3	15.5	35.7	23.8	29.8	22.6
4: Important	26.2	31.0	11.9	25.0	34.5	23.8	33.3	17.9	15.5
5: One of the most important	29.8	19.0	71.4	58.3	32.1	8.3	21.4	14.3	16.7
% Missing - No Answer	6.0	6.0	4.8	4.8	7.1	4.8	4.8	7.1	8.3
% Valid - Answered	94.0	94.0	95.2	95.2	92.9	95.2	95.2	92.9	91.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.58	3.41	4.53	4.41	3.89	3.00	3.52	2.92	2.88

Table B.22.b - Tasks and activities as responsibilities of the plant's maintenance department (MALAYSIA)

MY - 81 RESPONDENTS	A - Monitor	B - Analyze	C - Restore	D - Maintain	E - Perform	F – Install	G - Improve	H - Design	I - Purchase
0: Not Applicable	2.5	2.5	2.5	1.2	1.2	2.5	3.7	6.2	12.3
1: Not important	2.5	2.5	3.7	0.0	1.2	7.4	1.2	6.2	7.4
2: Little important	3.7	4.9	3.7	2.5	1.2	12.3	4.9	11.1	9.9
3: Somewhat important	18.5	21.0	11.1	12.3	9.9	30.9	28.4	39.5	25.9
4: Important	22.2	29.6	25.9	28.4	27.2	24.7	35.8	19.8	24.7
5: One of the most important	48.1	37.0	50.6	53.1	56.8	19.8	23.5	14.8	16.0
% Missing - No Answer	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.7
% Valid – Answered	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	96.3
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	4.05	3.89	4.11	4.32	4.37	3.30	3.65	3.08	2.95

c) Operators responsible

Table B.23.a - Responsibility of machine operators, a part from running the machine (IRELAND)

IE - 84 RESPONDENTS	A -Mc setup	B - Mtrl Hndlg	C - Maintnc	D - Gtr Dta	E - Joc Scdl
YES	66.7	71.4	20.2	65.5	17.9
NO	33.3	28.6	79.8	34.5	82.1
% Missing - No Answer	0.0	0.0	0.0	0.0	0.0
% Valid - Answered	100.0	100.0	100.0	100.0	100.0
	100.0	100.0	100.0	100.0	100.0

Table B.23.b - Responsibility of machine operators, a part from running the machine (MALAYSIA)

MY - 81 RESPONDENTS	A -Mc setup	B - Mtrl Hndlg	C - Maintnc	D - Gtr Dta	E - Joc Scdl
YES	54.3	60.5	37.0	58.0	19.8
NO	42.0	35.8	59.3	38.3	76.5
% Missing - No Answer	3.7	3.7	3.7	3.7	3.7
% Valid – Answered	96.3	96.3	96.3	96.3	96.3
	100.0	100.0	100.0	100.0	100.0

d) Types of maintenance used

Table B.24.a -Types of maintenance strategies used (IRELAND)

IE - 84 RESPONDENTS	A - Breakdown	B - Corrective	C - Preventive	D - Predictive	E - TPM	F - RCM
Do not have	0.0	1.2	1.2	16.7	47.6	58.3
Plan to implement	0.0	0.0	0.0	0.0	15.5	11.9
1: Use minimally	9.5	4.8	4.8	16.7	9.5	11.9
2: Use quite moderately	7.1	4.8	8.3	21.4	7.1	4.8
3: Use moderately	25.0	27.4	23.8	19.0	14.3	2.4
4: Use quite extensively	27.4	35.7	31.0	14.3	2.4	2.4
5: Use extensively	31.0	22.6	29.8	8.3	2.4	2.4
% Missing - No Answer	0.0	3.6	1.2	3.6	1.2	6.0
Total % In Use	100.0	95.2	97.6	79.8	35.7	23.8
% Valid - Answered	100.0	96.4	98.8	96.4	98.8	94.0
	100.0	100.0	100.0	100.0	100.0	100.0
Mean Value	3.63	3.65	3.69	2.23	1.83	1.29

Table B.24.b -Types of maintenance strategies used (MALAYSIA)

MY - 81 RESPONDENTS	A - Breakdown	B - Corrective	C – Preventive	D - Predictive	E – TPM	F - RCM
Do not have	1.2	0.0	0.0	8.6	23.5	59.3
Plan to implement	0.0	0.0	0.0	0.0	25.9	11.1
1: Use minimally	8.6	6.2	0.0	3.7	3.7	2.5
2: Use quite moderately	12.3	7.4	3.7	18.5	0.0	6.2
3: Use moderately	32.1	35.8	17.3	27.2	29.6	8.6
4: Use quite extensively	16.0	30.9	24.7	17.3	9.9	8.6
5: Use extensively	25.9	18.5	53.1	21.0	6.2	1.2
% Missing - No Answer	3.7	1.2	1.2	3.7	1.2	2.5
Total % In Use	95.1	98.8	98.8	87.7	49.4	27.2
% Valid - Answered	96.3	98.8	98.8	96.3	98.8	97.5
	100.0	100.0	100.0	100.0	100.0	100.0
Mean Value	3.36	3.49	4.29	3.08	3.22	1.51

e) Use of Computerized Maintenance Management System (CMMS)

Table B.25.a - Use of CMMS (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Not Applicable	25.0	21
Plan to implement	3.6	3
Yes – Implemented	71.4	60
	100.0	84

Table B.25.b - Use of CMMS (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Not Applicable	49.4	40
Plan to implement	12.3	10
Yes – Implemented	37.0	30
% Missing – No Answer	1.2	1
	100.0	81

Table B.26.a – Degree of CMMS utilization (IRELAND)

IE - YES CMMS	Valid %	%	Freq
1: Minimal	6.7	4.8	4.0
2: Quite moderate	6.7	4.8	4.0
3: Moderate	38.3	27.4	23.0
4: Quite extensive	16.7	11.9	10.0
5: Extensive	31.7	22.6	19.0
Total Yes: 60 RESPONDENTS	100.0	71.4	60.0

Table B.26.b – Degree of CMMS utilization (MALAYSIA)

MY - YES CMMS	Valid %	%	Freq
1: Minimal	10.0	3.7	3
2: Quite moderate	13.3	4.9	4
3: Moderate	20.0	7.4	6
4: Quite extensive	16.7	6.2	5
5: Extensive	40.0	14.8	12
Total Yes: 30 RESPONDENTS	100.0	37.0	30

f) Use of CMMS modules

Table B.27.a – Degree of utilization for each of CMMS modules used (IRELAND)

IE – 60 RESPONDENTS	A - W.Order	B - Preventive	C - Predictive	D - Diagnosis	E - Rpr H'tory	F - Partlist	G - Manpower	H - Inventory	I - Spareparts	J - Purchase	K - Budget
0: Do not have	11.7	3.3	25.0	21.7	6.7	15.0	31.7	21.7	16.7	15.0	28.3
1: Used Minimally	13.3	3.3	13.3	13.3	6.7	6.7	28.3	18.3	15.0	16.7	25.0
2: Use quite moderately	3.3	3.3	10.0	23.3	10.0	5.0	6.7	6.7	10.0	8.3	5.0
3: Use Moderately	18.3	20.0	23.3	20.0	20.0	16.7	11.7	6.7	11.7	8.3	20.0
4: Use quite extensively	13.3	20.0	10.0	6.7	21.7	23.3	10.0	13.3	16.7	15.0	11.7
5: Use extensively	31.7	46.7	10.0	8.3	30.0	25.0	3.3	26.7	23.3	31.7	5.0
% Missing - No Answer	8.3	3.3	8.3	6.7	5.0	8.3	8.3	6.7	6.7	5.0	5.0
% Valid - Answered	91.7	96.7	91.7	93.3	95.0	91.7	91.7	93.3	93.3	95.0	95.0
	100	100	100	100	100	100	100	100	100	100	100
Mean value	2.78	3.80	1.85	1.81	3.18	2.76	1.25	2.31	2.46	2.71	1.61

Table B.27.b – Degree of utilization for each of CMMS modules used (MALAYSIA)

MY – 30 RESPONDENTS	A - W.Order	B - Preventive	C - Predictive	D - Diagnosis	E - Rpr H'tory	F - Partlist	G - Manpower	H - Inventory	I - Spareparts	J - Purchase	K - Budget
0: Do not have	6.7	0.0	3.3	10.0	3.3	6.7	13.3	13.3	10.0	10.0	16.7
1: Used Minimally	0.0	3.3	6.7	16.7	10.0	6.7	10.0	10.0	10.0	6.7	20.0
2: Use quite moderately	6.7	0.0	13.3	20.0	6.7	3.3	20.0	3.3	10.0	10.0	10.0
3: Use Moderately	13.3	23.3	26.7	10.0	16.7	16.7	30.0	26.7	20.0	16.7	30.0
4: Use quite extensively	33.3	30.0	20.0	20.0	30.0	30.0	3.3	13.3	30.0	26.7	3.3
5: Use extensively	36.7	40.0	23.3	16.7	30.0	30.0	13.3	26.7	13.3	23.3	13.3
% Missing - No Answer	3.3	3.3	6.7	6.7	3.3	6.7	10.0	6.7	6.7	6.7	6.7
% Valid - Answered	96.7	96.7	93.3	93.3	96.7	93.3	90.0	93.3	93.3	93.3	93.3
	100	100	100	100	100	100	100	100	100	100	100
Mean value	3.67	3.90	3.03	2.43	3.40	3.26	2.10	2.77	2.70	2.93	2.03

g) Level of maintenance difficulty

Table B.28.a - Level of maintenance difficulty (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Very Difficult	2.4	2
Difficult	20.2	17
Average	46.4	39
Minor Difficult	20.2	17
No problem at all	4.8	4
% Missing - No Answer	6.0	5
% Valid – Answered	94.0	79.0
	100.0	84

Table B.28.b - Level of maintenance difficulty (MALAYSIA)

MY – 81 RESPONDENTS	%	Freq
Very Difficult	1.2	1
Difficult	16.0	13
Average	44.4	36
Minor Difficult	23.5	19
No problem at all	8.6	7
Others	2.5	2
% Missing - No Answer	3.7	3
% Valid - Answered	96.3	78.0
	100.0	81

h) Major breakdown according to the area and technology used

Table B.29.a - Major breakdown and problems according to the area and technology used (IRELAND)

IE – 84 RESPONDENTS	A - Mech	B - Elec	C - Elcn	D - PneHyd	E - Cntrl	F – NC/CNC	G - Robots	H - C.Netw	I – CIM Apl
1: Minor difficulty	6.0	8.3	9.5	13.1	14.3	22.6	15.5	13.1	22.6
2: Quite average	10.7	16.7	21.4	25.0	20.2	8.3	10.7	16.7	9.5
3: Average	48.8	40.5	32.1	36.9	27.4	11.9	19.0	21.4	9.5
4: Quite major difficulty	22.6	22.6	25.0	15.5	16.7	3.6	6.0	10.7	2.4
5: Major difficulty	4.8	4.8	3.6	1.2	7.1	1.2	1.2	1.2	0.0
% Missing – No Answer	7.1	7.1	8.3	8.3	14.3	52.4	47.6	36.9	56.0
% Valid - Answered	92.9	92.9	91.7	91.7	85.7	47.6	52.4	63.1	44.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.10	2.99	2.90	2.63	2.79	2.00	2.36	2.52	1.81

Table B.29.b - Major breakdown and problems according to the area and technology used (MALAYSIA)

MY – 81 RESPONDENTS	A - Mech	B - Elec	C - Elcn	D - PneHyd	E - Cntrl	F - NC/CNC	G - Robots	H - C.Netw	I - CIM Apl
1: Minor difficulty	6.2	11.1	8.6	13.6	11.1	24.7	24.7	21.0	25.9
2: Quite average	16.0	17.3	19.8	19.8	18.5	9.9	7.4	16.0	4.9
3: Average	34.6	42.0	28.4	44.4	34.6	7.4	11.1	22.2	11.1
4: Quite major difficulty	22.2	16.0	18.5	8.6	12.3	7.4	4.9	7.4	6.2
5: Major difficulty	11.1	2.5	13.6	3.7	8.6	2.5	4.9	2.5	2.5
% Missing – No Answer	9.9	11.1	11.1	9.9	14.8	48.1	46.9	30.9	49.4
% Valid – Answered	90.1	88.9	88.9	90.1	85.2	51.9	53.1	69.1	50.6
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.18	2.80	3.10	2.66	2.87	2.10	2.21	2.34	2.10

i) Troubleshooting methods used

Table B.30.a – Maintenance troubleshooting methodology employed (IRELAND)

IE - 84 RESPONDENTS	A - FMEA	B - SADT	C – CED	D - FTA	E – Pareto
0: Do not have	38.1	56.0	34.5	38.1	33.3
1: Use minimally	13.1	10.7	14.3	11.9	11.9
2: Use quite moderately	4.8	4.8	11.9	9.5	3.6
3: Use moderately	11.9	3.6	17.9	15.5	11.9
4: Use quite extensively	9.5	1.2	7.1	2.4	10.7
5: Use extensively	4.8	0.0	2.4	0.0	13.1
% Missing – No Answer	17.9	23.8	11.9	22.6	15.5
Total % In Use	44.0	20.2	53.6	39.3	51.2
% Valid – Answered	82.1	76.2	88.1	77.4	84.5
	100.0	100.0	100.0	100.0	100.0

Table B.30.b – Maintenance troubleshooting methodology employed (MALAYSIA)

MY - 81 RESPONDENTS	A - FMEA	B - SADT	C - CED	D - FTA	E – Pareto
0: Do not have	17.3	42.0	7.4	25.9	16.0
1: Use minimally	11.1	11.1	3.7	8.6	7.4
2: Use quite moderately	9.9	3.7	9.9	7.4	4.9
3: Use moderately	19.8	9.9	27.2	12.3	19.8
4: Use quite extensively	12.3	1.2	19.8	9.9	22.2
5: Use extensively	7.4	2.5	17.3	11.1	12.3
% Missing – No Answer	22.2	29.6	14.8	24.7	17.3
Total % In Use	60.5	28.4	77.8	49.4	66.7
% Valid – Answered	77.8	70.4	85.2	75.3	82.7
	100.0	100.0	100.0	100.0	100.0

j) Major problems and obstacles in maintaining of automated system

Table B.31.a - Major problems and obstacles in maintaining of automated system (IRELAND)

IE – 84 RESPONDENTS	A-Personnel	B-Time	C-Cost	D-Tool	E-Technic	F-ProdDist	G-Indqte	H-MgmtCmt
1: Not an obstacle	6.0	8.3	9.5	13.1	14.3	22.6	15.5	13.1
2: Minor obstacle	10.7	16.7	21.4	25.0	20.2	8.3	10.7	16.7
3: Somewhat obstacle	48.8	40.5	32.1	36.9	27.4	11.9	19.0	21.4
4: Quite major obstacle	22.6	22.6	25.0	15.5	16.7	3.6	6.0	10.7
5: Major obstacle	4.8	4.8	3.6	1.2	7.1	1.2	1.2	1.2
% Missing – No Answer	7.1	7.1	8.3	8.3	14.3	52.4	47.6	36.9
% Valid - Answered	92.9	92.9	91.7	91.7	85.7	47.6	52.4	63.1
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.09	3.08	2.77	2.10	2.57	4.04	2.48	2.13

Table B.31.b - Major problems and obstacles in maintaining of automated system (MALAYSIA)

MY – 81 RESPONDENTS	A-Personnel	B-Time	C-Cost	D-Tool	E-Technic	F-ProdDist	G-Indqte	H-MgmtCmt
1: Not an obstacle	9.9	8.6	6.2	9.9	9.9	6.2	6.2	19.8
2: Minor obstacle	7.4	14.8	16.0	16.0	9.9	7.4	17.3	34.6
3: Somewhat obstacle	35.8	32.1	28.4	39.5	37.0	30.9	37.0	17.3
4: Quite major obstacle	23.5	23.5	19.8	14.8	22.2	22.2	16.0	7.4
5: Major obstacle	13.6	6.2	17.3	4.9	7.4	21.0	8.6	4.9
% Missing – No Answer	9.9	14.8	12.4	14.8	13.6	12.4	14.8	16.1
% Valid - Answered	90.1	85.2	87.7	85.2	86.4	87.7	85.2	84.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.26	3.04	3.29	2.87	3.09	3.51	3.04	2.32

k) Major problems of the maintenance personnel

Table B.32.a - Major problems of the maintenance personnel in maintaining of automated system (IRELAND)

IE – 84 RESPONDENTS	A-Tech Skl	B-Supv skl	C-Ind Trng	D-Manp	E-Motivn	F-TeamWk	G-Attd	H-HTurnO
1: Not an obstacle	10.7	17.9	6.0	11.9	15.5	20.2	20.2	42.9
2: Minor obstacle	9.5	11.9	15.5	9.5	17.9	10.7	13.1	3.6
3: Somewhat obstacle	17.9	14.3	21.4	11.9	7.1	15.5	7.1	3.6
4: Quite major obstacle	9.5	8.3	9.5	10.7	10.7	7.1	11.9	2.4
5: Major obstacle	10.7	0.0	2.4	11.9	3.6	1.2	2.4	0.0
% Missing – No Answer	41.7	47.6	45.2	44.0	45.2	45.2	45.2	47.6
% Valid – Answered	58.3	52.4	54.8	56.0	54.8	54.8	54.8	52.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.00	2.25	2.76	3.02	2.43	2.23	2.32	1.34

Table B.32.b - Major problems of the maintenance personnel in maintaining of automated system (MALAYSIA)

MY - 81 RESPONDENTS	A-Tech Skl	B-Supv skl	C-Ind Trng	D-Manp	E-Motivn	F-TeamWk	G-Attd	H-HTurnO
1: Not an obstacle	4.9	7.4	7.4	12.3	11.1	18.5	14.8	21.0
2: Minor obstacle	8.6	19.8	6.2	14.8	22.2	27.2	13.6	24.7
3: Somewhat obstacle	21.0	29.6	32.1	29.6	21.0	16.0	25.9	19.8
4: Quite major obstacle	27.2	12.3	25.9	9.9	12.3	7.4	12.3	3.7
5: Major obstacle	19.8	4.9	3.7	8.6	7.4	3.7	7.4	4.9
% Missing - No Answer	18.5	25.9	24.7	24.7	25.9	27.2	25.9	25.9
% Valid – Answered	81.5	74.1	75.3	75.3	74.1	72.8	74.1	74.1
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean value	3.60	2.83	3.16	2.83	2.77	2.32	2.78	2.28

l) Involvement of "External Maintenance"

Table B.33.a - Participants of "in-house and external maintenance" in maintenance duties (IRELAND)

IE - 84 RESPONDENTS	A-Inhouse	B - Consultant	C-Vendor&Mfc
0: No involvement	0.0	34.5	2.4
1: Minimal involvement	1.2	13.1	9.5
2: Quite moderate involvement	2.4	14.3	15.5
3: Moderate involvement	8.3	17.9	36.9
4: Quite fully involvement	19.0	7.1	16.7
5: Fully involvement	59.5	0.0	8.3
% Missing - No Answer	9.5	13.1	10.7
% With Involvement	90.5	52.4	86.9
% Valid – Answered	90.5	86.9	89.3
	100.0	100.0	100.0
Mean value	4.47	1.42	2.91

Table B.33.b - Participants of "in-house and external maintenance" in maintenance duties (MALAYSIA)

MY - 81 RESPONDENTS	A-Inhouse	B - Consultant	C-Vendor&Mfc
0: No involvement	0.0	22.2	2.5
1: Minimal involvement	0.0	22.2	16.0
2: Quite moderate involvement	3.7	14.8	17.3
3: Moderate involvement	13.6	21.0	40.7
4: Quite fully involvement	27.2	7.4	9.9
5: Fully involvement	48.1	2.5	1.2
% Missing - No Answer	7.4	9.9	12.4
% With Involvement	92.6	67.9	85.2
% Valid – Answered	92.6	90.1	87.7
	100.0	100.0	100.0
Mean value	4.29	1.73	2.49

m) Reason of engaging the "External Maintenance"

Table B.34.a - Reason of engaging the external maintenance (IRELAND)

IE – 84 RESPONDENTS	%	Freq
Not applicable	6.0	5
Under warranty	9.5	8
Internal expertise not available	38.1	32
Both: Under Warranty & No Internal Expertise.	28.6	24
Others	6.0	5
% Missing - No Answer	11.9	10
% Valid – Answered	88.1	74.0
	100.0	84

Table B.34.b - Reason of engaging the external maintenance (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Not applicable	11.1	9
Under warranty	6.2	5
Internal expertise not available	40.7	33
Both: Under Warranty & No Internal Expertise	29.6	24
Others	4.9	4
% Missing - No Answer	7.4	6
% Valid – Answered	92.6	75
	100.0	81

n) Availability of manual guidelines (hardcopy format)

Table B.35.a - Availability of manual guidelines in the form of hardcopy format (IRELAND)

IE - 84 RESPONDENTS	A-Description	B-Procedure	C-Malfunction	D-Rectification
0: Not available	0.0	0.0	3.6	2.4
1: Minimal content	2.4	4.8	6.0	3.6
2: Quite moderate content	1.2	8.3	17.9	23.8
3: Moderate content	28.6	26.2	33.3	27.4
4: Quite complete document	31.0	32.1	20.2	25.0
5: Complete document	28.6	19.0	9.5	6.0
% Missing - No Answer	8.3	9.5	9.5	11.9
% Valid - Answered	91.7	90.5	90.5	88.1
	100.0	100.0	100.0	100.0
Mean value	3.89	3.57	2.98	2.98

Table B.35.b - Availability of manual guidelines in the form of hardcopy format (MALAYSIA)

MY - 81 RESPONDENTS	A-Description	B-Procedure	C-Malfunction	D-Rectification
0: Not available	1.2	2.5	3.7	3.7
1: Minimal content	6.2	4.9	8.6	9.9
2: Quite moderate content	2.5	4.9	7.4	12.3
3: Moderate content	29.6	33.3	38.3	37.0
4: Quite complete document	28.4	25.9	24.7	19.8
5: Complete document	23.5	19.8	8.6	8.6
% Missing - No Answer	8.6	8.6	8.6	8.6
% Valid - Answered	91.4	91.4	91.4	91.4
	100.0	100.0	100.0	100.0
Mean value	3.62	3.47	3.07	2.93

o) Availability of manual guidelines (soft copy format)

Table B.36.a - Availability of manual guidelines in the form of softcopy format (IRELAND)

IE - 84 RESPONDENTS	A-Description	B-Procedure	C-Malfunction	D-Rectification
0: Not available	19.0	22.6	23.8	23.8
1: Minimal content	15.5	11.9	13.1	16.7
2: Quite moderate content	10.7	14.3	15.5	16.7
3: Moderate content	10.7	11.9	14.3	14.3
4: Quite complete document	10.7	13.1	7.1	4.8
5: Complete document	11.9	7.1	6.0	2.4
% Missing – No Answer	21.4	19.0	20.2	21.4
% Valid - Answered	78.6	81.0	79.8	78.6
	100.0	100.0	100.0	100.0
Mean value	2.18	2.03	1.82	1.57

Table B.36.b - Availability of manual guidelines in the form of softcopy format (MALAYSIA)

MY - 81 RESPONDENTS	A-Description	B-Procedure	C-Malfunction	D-Rectification
0: Not available	18.5	18.5	23.5	23.5
1: Minimal content	13.6	14.8	16.0	16.0
2: Quite moderate content	12.3	6.2	11.1	16.0
3: Moderate content	19.8	18.5	19.8	17.3
4: Quite complete document	8.6	14.8	11.1	7.4
5: Complete document	13.6	13.6	6.2	6.2
% Missing – No Answer	13.6	13.6	12.4	13.6
% Valid - Answered	86.4	86.4	87.7	86.4
	100.0	100.0	100.0	100.0
Mean value	2.31	2.43	1.97	1.86

B-4. Productivity performance

a) Measurement of the performance of equipment

Table B.37.a - Methods used in equipment performance measurement (IRELAND)

IE - 84 RESPONDENTS	%	Freq
1. Overall Equipment Effectiveness	34.5	29
2. Company's own standard	41.7	35
3. Other	8.3	7
% Missing - No Answer	15.5	13
% Valid - Answered	84.5	71.0
	100.0	84

Table B.37.b - Methods used in equipment performance measurement (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
1. Overall Equipment Effectiveness	46.9	38
2. Company's own standard	34.6	28
3. Other	9.9	8
% Missing - No Answer	8.6	7
% Valid – Answered	91.4	74.0
	100.0	81

b) Contribution of maintenance effort towards improvement

Table B.38.a - Maintenance effort contributed to the performance improvements (IRELAND)

IE - 84 RESPONDENTS	A-Product Quality	B-Equip Availability	C-Reduce Prod Cost
Less than 20%	20.2	10.7	15.5
About 35%	20.2	8.3	23.8
About 50%	39.3	35.7	29.8
About 65%	10.7	27.4	22.6
More than 80%	4.8	14.3	4.8
% Missing - No Answer	4.8	3.6	3.6
% Valid – Answered	95.2	96.4	96.4
	100.0	100.0	100.0
Mean value	2.57 (43.6%)	3.27 (3.27%)	2.76 (46.4%)

Table B.38.b - Maintenance effort contributed to the performance improvements (MALAYSIA)

MY - 81 RESPONDENTS	A-Product Quality	B-Equip Availability	C-Reduce Prod Cost
Less than 20%	8.6	4.9	16.0
About 35%	16.0	13.6	7.4
About 50%	38.3	32.1	35.8
About 65%	24.7	33.3	27.2
More than 80%	6.2	9.9	7.4
% Missing - No Answer	6.2	6.2	6.2
% Valid - Answered	93.8	93.8	93.8
	100.0	100.0	100.0
Mean value	3.04 (50.6%)	3.32 (54.8%)	3.07 (51.1%)

c) Level of satisfaction on the maintenance achievement

Table B.39.a - Level of satisfaction on the maintenance achievement (IRELAND)

IE - 84 RESPONDENTS	%	Freq
1: Not satisfy	3.6	3
2: Quite moderate	10.7	9
3: Moderate	38.1	32
4: Satisfy	36.9	31
5: Very satisfy	9.5	8
% Missing - No Answer	1.2	1
% Valid - Answered	98.8	83.0
	100.0	84

Table B.39.b - Level of satisfaction on the maintenance achievement (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
1: Not satisfy	3.7	3
2: Quite moderate	12.3	10
3: Moderate	49.4	40
4: Satisfy	27.2	22
5: Very satisfy	4.9	4
% Missing - No Answer	2.5	2
% Valid - Answered	100.0	81.0
	102.5	83

d) Top management view on the maintenance function

Table B.40.a - Top management view on the maintenance function (IRELAND)

IE - 84 RESPONDENTS	A-Overhead	B-Investment	C-Supporting funct
1: Strongly disagree	11.9	13.1	7.1
2: Disagree	10.7	29.8	4.8
3: Moderate	17.9	20.2	17.9
4: Agree	25.0	19.0	35.7
5: Strongly agree	23.8	6.0	31.0
% Missing - No Answer	10.7	11.9	3.6
% Valid - Answered	89.3	88.1	96.4
	100.0	100.0	100.0
Mean value	3.42	2.71	3.81

Table B.40.b - Top management view on the maintenance function (MALAYSIA)

MY – 81 RESPONDENTS	A-Overhead	B-Investment	C-Supporting funct
1: Strongly disagree	12.3	9.9	2.5
2: Disagree	3.7	9.9	6.2
3: Moderate	30.9	38.3	24.7
4: Agree	27.2	22.2	29.6
5: Strongly agree	19.8	14.8	32.1
% Missing - No Answer	6.2	4.9	4.9
% Valid - Answered	93.8	100.0	95.1
	100.0	104.9	100.0
Mean value	3.41	3.23	3.87

e) Need of review on the role of maintenance

Table B.41.a - Need of review on the maintenance's role (IRELAND)

IE - 84 RESPONDENTS	%	Freq
YES	28.6	24
NO	67.9	57
% Missing - No Answer	3.6	3
% Valid – Answered	96.4	81
	100.0	84

Table B.41.b – Need of review on the maintenance's role (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
NO	18.5	15
YES	79.0	64
% Missing - No Answer	2.5	2
% Valid - Answered	97.5	79
	100.0	84

f) Area or matters to be reviewed

Table B.42.a - Area to be reviewed in maintenance (IRELAND)

IE - 84 RESPONDENTS	A-Organisation	B-Methods	C-Training
0: No change	2.4	2.4	1.2
1: Minor review	6.0	1.2	3.6
2: Quite moderate review	3.6	4.8	1.2
3: Moderate review	23.8	23.8	26.2
4: Quite major review	9.5	20.2	15.5
5: Major review	20.2	15.5	15.5
% Missing - No Answer	34.5	32.1	36.9
% Valid - Answered	65.5	67.9	63.1
	100.0	100.0	100.0
Mean value	3.42	3.54	3.55

Table B.42.b - Area to be reviewed in maintenance (MALAYSIA)

MY - 81 RESPONDENTS	A-Organisation	B-Methods	C-Training
0: No change	2.5	3.7	2.5
1: Minor review	7.4	3.7	0.0
2: Quite moderate review	8.6	3.7	3.7
3: Moderate review	19.8	27.2	28.4
4: Quite major review	27.2	35.8	28.4
5: Major review	14.8	7.4	16.0
% Missing - No Answer	19.8	18.5	21.0
% Valid – Answered	80.2	81.5	79.0
	100.0	100.0	100.0
Mean value	3.32	3.35	3.62

B-5. Training Programme

a) Implementation of "*TNA –Training Need Analysis*" exercise

Table B.43.a - Training Need Analysis (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Do not have	35.7	30
Once per year	40.5	34
Once every two years	8.3	7
Every three or more years	7.1	6
% Missing – No Answer	8.3	7
% Valid - Answered	91.7	77
	100.0	84

Table B.43.b - Training Need Analysis (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Do not have	9.9	8
Every three or more years	1.2	1
Once every two years	3.7	3
Once per year	84.0	68
% Missing – No Answer	1.2	1
% Valid – Answered	98.8	80
	100.0	81

b) Number of different training programmes (related to maintenance)

Table B.44.a - Number of different maintenance training programmes conducted (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Less than 2	61.9	52
2 to 4	22.6	19
5 to 7	6.0	5
More than 7	6.0	5
% Missing - No Answer	3.6	3
% Valid - Answered	96.4	81
	100.0	84

Table B.44.b - Number of different maintenance training programmes conducted (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Less than 2	40.7	33
2 to 4	43.2	35
5 to 7	8.6	7
More than 7	6.2	5
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	80
	100.0	81

c) Percent of maintenance personnel received training per year

Table B.45.a - Percent of maintenance personnel received training per year (IRELAND)

IE - 84 RESPONDENTS	%	Freq
0 to 20 %	34.5	29
21 to 40 %	8.3	7
41 to 60 %	10.7	9
61 to 80 %	19.0	16
81 to 100 %	25.0	21
% Missing - No Answer	2.4	2
% Valid - Answered	97.6	82
	100.0	84

Table B.45.b - Percent of maintenance personnel received training per year (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
0 to 20 %	30.9	25
21 to 40 %	14.8	12
41 to 60 %	23.5	19
61 to 80 %	14.8	12
81 to 100 %	13.6	11
% Missing - No Answer	2.5	2
% Valid – Answered	97.5	79
	100.0	81

d) Number of hours of training (related to maintenance) do each of the following maintenance personnel receive per year

Table B.46.a - Number of hours of training - related to maintenance (IRELAND)

IE – 84 RESPONDENTS	A-Management	B-Specialist	C-Engineer	D-Technician	E-Fitter	F-Gen Worker
0 hour	17.9	11.9	14.3	13.1	14.3	22.6
1 – 20 hours	32.1	14.3	17.9	17.9	21.4	25.0
21 to 40 hours	19.0	14.3	22.6	22.6	15.5	10.7
41 to 60 hours	3.6	10.7	7.1	14.3	15.5	2.4
61 to 80 hours	4.8	2.4	4.8	4.8	3.6	2.4
More than 81 hours	0.0	3.6	2.4	3.6	3.6	1.2
% Missing - No Answer	22.6	42.9	31.0	23.8	26.2	35.7
% Valid – Answered	77.4	57.1	69.0	76.2	73.8	64.3
	100.0	100.0	100.0	100.0	100.0	100.0

Table B.46.b - Number of hours of training - related to maintenance (MALAYSIA)

MY - 81 RESPONDENTS	A-Management	B-Specialist	C-Engineer	D-Technician	E-Fitter	F-Gen Worker
0 hour	18.5	13.6	6.2	2.5	8.6	14.8
1 - 20 hours	30.9	21.0	23.5	19.8	17.3	32.1
21 to 40 hours	23.5	9.9	33.3	42.0	23.5	3.7
41 to 60 hours	16.0	18.5	23.5	23.5	11.1	3.7
61 to 80 hours	2.5	2.5	1.2	7.4	0.0	2.5
More than 81 hours	1.2	1.2	1.2	0.0	0.0	0.0
% Missing - No Answer	7.4	33.3	11.1	4.9	39.5	43.2
% Valid – Answered	92.6	66.7	88.9	95.1	60.5	56.8
	100	100	100	100	100	100

e) Type of 'In house / external (venue)" versus "own staff / external trainer" maintenance training' conducted yearly

Table B.47.a – Preference of type of in-house/external training, conducted by own staff/external trainer (IRELAND)

IE - 84 RESPONDENTS	First Option	Second Option
A-In house / Own staff	46.4	20.2
B-In house / External trainer	20.2	33.3
C-External / Own staff	2.4	1.2
D-External / External staff	14.3	20.2
% Missing - No Answer	16.7	25.0
% Valid - Answered	83.3	75.0
	100.0	100.0

Table B.47.b – Preference of type of in-house/external training, conducted by own staff/external trainer (MALAYSIA)

MY - 81 RESPONDENTS	First Option	Second Option
A-In house / Own staff	56.8	24.7
B-In house / External trainer	12.3	37.0
C-External / Own staff	1.2	6.2
D-External / External staff	24.7	23.5
% Missing – No Answer	4.9	8.6
% Valid - Answered	95.1	91.4
	100.0	100.0

f) Knowledge and competency learning approach

Table B.48.a - Learning approach in increasing knowledge and competencies (IRELAND)

IE - 84 RESPONDENTS	A-Self Lrng	B-On job	C-Internal	D-vendor	E-Consultant
0: Not applicable	2.4	2.4	4.8	6.0	23.8
1: Minimum	4.8	3.6	3.6	1.2	14.3
2: Quite moderate	13.1	6.0	9.5	17.9	22.6
3: Moderate	25.0	14.3	19.0	32.1	17.9
4: Effective	28.6	46.4	41.7	15.5	4.8
5: Most effective	13.1	21.4	10.7	20.2	2.4
% Missing - No Answer	13.1	6.0	10.7	7.1	14.3
% Valid - Answered	86.9	94.0	89.3	92.9	85.7
	100.0	100.0	100.0	100.0	100.0
Mean value	3.28	3.73	3.36	3.19	1.68

Table B.48.b - Learning approaches in increasing knowledge and competencies (MALAYSIA)

MY - 81 RESPONDENTS	A-Self Lrng	B-On job	C-Internal	D-vendor	E-Consultant
0: Not applicable	0.0	0.0	0.0	0.0	8.6
1: Minimum	13.6	1.2	4.9	6.2	12.3
2: Quite moderate	11.1	2.5	3.7	16.0	21.0
3: Moderate	42.0	22.2	38.3	27.2	32.1
4: Effective	25.9	39.5	32.1	35.8	18.5
5: Most effective	4.9	33.3	18.5	13.6	4.9
% Missing - No Answer	2.5	1.2	2.5	1.2	2.5
% Valid – Answered	97.5	98.8	97.5	98.8	97.5
	100.0	100.0	100.0	100.0	100.0
Mean value	2.97	4.02	3.57	3.35	2.58

g) Maintenance conference, seminar or workshop

Table B.49.a - Participation in any maintenance conference / seminar (IRELAND)

IE - 84 RESPONDENTS	%	Freq
YES	38.1	32
NO	60.7	51
% Missing - No Answer	1.2	1
% Valid – Answered	98.8	83
	100.0	84

Table B.49.b - Participation in any maintenance conference / seminar (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
YES	45.7	37
NO	53.1	43
% Missing - No Answer	1.2	1
% Valid - Answered	98.8	80
	100.0	81

h) Subscription of any maintenance journal and technical publication

Table B.50.a - Subscription of maintenance journal / technical publication (IRELAND)

IE - 84 RESPONDENTS	%	Freq
Do not have	26.2	22
Very seldom	31.0	26
1 or 2	31.0	26
More than 3	8.3	7
% Missing - No Answer	3.6	3
% Valid - Answered	96.4	81
	100.0	84

Table B.50.b - Subscription of maintenance journal / technical publication (MALAYSIA)

MY - 81 RESPONDENTS	%	Freq
Do not have	37.0	30
Very seldom	34.6	28
1 or 2	18.5	15
More than 3	7.4	6
% Missing - No Answer	2.5	2
% Valid – Answered	97.5	79
	100.0	81

APPENDIX C

Results of Statistical Analysis: Ireland and Malaysia

C-1. Factor of company characteristics and background

Table C.1.a – Multi correlation among the company characteristics and background (IRELAND)

Correlations

			Company Ownership	Subsidiary of larger organisation	No. of years in business	No. of employee	Approximate Turnover
Spearman's rh	Company Ownership	Correlation Coeffici	1.000	.567**	.176	.443**	.310*
		Sig. (2-tailed)	.	.000	.112	.000	.021
		N	84	84	83	83	55
	Subsidiary of larger organisation	Correlation Coeffici	.567**	1.000	.187	.395**	.351**
		Sig. (2-tailed)	.000	.	.091	.000	.009
		N	84	84	83	83	55
	No. of years in busine	Correlation Coeffici	.176	.187	1.000	.156	.081
		Sig. (2-tailed)	.112	.091	.	.161	.559
		N	83	83	83	82	54
	No. of employee	Correlation Coeffici	.443**	.395**	.156	1.000	.737**
		Sig. (2-tailed)	.000	.000	.161	.	.000
		N	83	83	82	83	55
	Approximate Turnove	Correlation Coeffici	.310*	.351**	.081	.737**	1.000
		Sig. (2-tailed)	.021	.009	.559	.000	.
		N	55	55	54	55	55

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Ireland: Table C.1.a shows that there is a positive relationship between the approximate annual turnover and the company foreign ownership (0.310), as well as the company being a subsidiary of larger organization (0.351). The P values (0.021 and 0.009 respectively) of these relationships indicate that the relationships are statistically significant.

The results also indicate that there are positive relationships between the number of employees and the company ownership (0.443), the company being a subsidiary of larger organization (0.395), as well as the annual turnover (0.737). The P values (0.000) of these relationships indicate that the relationships are statistically significant.

Table C.1.b – Multi correlation among the company characteristics and background (MALAYSIA)

Correlations

			Company Ownership	Subsidiary of larger organisation	No. of years in business	No. of employee	Approximate Turnover
Spearman's rh	Company Ownershir	Correlation Coeffic	1.000	.300**	-.045	.029	.001
		Sig. (2-tailed)	.	.007	.693	.800	.994
		N	81	81	80	81	64
	Subsidiary of larger organisation	Correlation Coeffic	.300**	1.000	-.090	.162	.261*
		Sig. (2-tailed)	.007	.	.427	.148	.038
		N	81	81	80	81	64
	No. of years in busin	Correlation Coeffic	-.045	-.090	1.000	.274*	.273*
		Sig. (2-tailed)	.693	.427	.	.014	.030
		N	80	80	80	80	63
	No. of employee	Correlation Coeffic	.029	.162	.274*	1.000	.330**
		Sig. (2-tailed)	.800	.148	.014	.	.008
		N	81	81	80	81	64
	Approximate Turnov	Correlation Coeffic	.001	.261*	.273*	.330**	1.000
		Sig. (2-tailed)	.994	.038	.030	.008	.
		N	64	64	63	64	64

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Malaysia: Table C.1.b shows that there is a positive relationship between the approximate annual turnover and the company being a subsidiary of larger organization (0.261), as well as the number of years in operation (0.273). The P values (0.038 and 0.030 respectively) of these relationships indicate that the relationships are statistically significant.

The results also indicate that there is a positive relationship between the number of employees and the annual turnover (0.330), as well as the number of years in operation (0.274). The P values (0.008 and 0.014 respectively) of these relationships indicate that the relationships are statistically significant.

C-2. Factor of automation level

Table C.2.a – Multi correlation between the automation level and the company characteristics (IRELAND)

Correlations

			Level of automation used	Company Ownership	Subsidiary of larger organization	No. of years in business	No. of employee	Approximate Turnover
Spearman's rho	Level of automation used	Correlation Coefficient	1.000	.039	.109	.150	.137	.294*
		Sig. (2-tailed)	.	.724	.325	.175	.216	.029
		N	84	84	84	83	83	55

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.2.a shows that there is a positive relationship between the automation level and the approximate annual turnover (0.294). The P value (0.029) indicates that the relationship is statistically significant.

Table C.2.b – Multi correlation between the automation level and company characteristics (MALAYSIA)

Correlations

			Level of automation used	Company Ownership	Subsidiary of larger organisation	No. of years in business	No. of employee	Approximate Turnover
Spearman's rho	Level of automation used	Correlation Coefficient	1.000	.183	.089	-.101	.198	.278*
		Sig. (2-tailed)	.	.101	.428	.374	.077	.026
		N	81	81	81	80	81	64

* *Correlation is significant at the .05 level (2-tailed).*

Malaysia: Table C.2.b shows that there is a positive relationship between the automation level and the approximate annual turnover (0.278). The P value (0.026) indicates that the relationship is statistically significant.

Table C.3.a – Correlation between the level of automation and the level of integration of automation (IRELAND)

Correlations

			Level of automation used	Level of integration
Spearman's rho	Level of automation used	Correlation Coefficient	1.000	.756**
		Sig. (2-tailed)	.	.000
		N	84	83
	Level of integration	Correlation Coefficient	.756**	1.000
		Sig. (2-tailed)	.000	.
		N	83	83

**. Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.3.a shows that there is a positive relationship between the level of automation and the level of integration of automation (0.756). The P value (0.00) indicates that the relationship is statistically significant.

Table C.3.b – Correlation between the level of automation and the level of integration of automation (MALAYSIA)

Correlations

			Level of automation used	Level of integration
Spearman's rho	Level of automation used	Correlation Coefficient	1.000	.501**
		Sig. (2-tailed)	.	.000
		N	81	81
	Level of integration	Correlation Coefficient	.501**	1.000
		Sig. (2-tailed)	.000	.
		N	81	81

**. Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.3.b shows that there is a positive relationship between the level of automation and the level of integration of automation (0.501). The P value (0.00) indicates that the relationship is statistically significant.

Table C.4.a – Correlation between the level of automation and maintenance practice (IRELAND)

Correlations

			Level of automation used	Breakdown Maintenance	Corrective Maintenance	Preventive Maintenance	Predictive Maintenance
Spearman's rhc	Level of automation us	Correlation Coefficie	1.000	-.121	.190	.343**	.184
		Sig. (2-tailed)	.	.274	.089	.002	.100
		N	84	84	81	83	81
	Breakdown Maintenanc	Correlation Coefficie	-.121	1.000	.059	-.376**	-.291**
		Sig. (2-tailed)	.274	.	.604	.000	.009
		N	84	84	81	83	81
	Corrective Maintenanc	Correlation Coefficie	.190	.059	1.000	.379**	.170
		Sig. (2-tailed)	.089	.604	.	.001	.134
		N	81	81	81	80	79
	Preventive Maintenanc	Correlation Coefficie	.343**	-.376**	.379**	1.000	.482**
		Sig. (2-tailed)	.002	.000	.001	.	.000
		N	83	83	80	83	80
	Predictive Maintenance	Correlation Coefficie	.184	-.291**	.170	.482**	1.000
		Sig. (2-tailed)	.100	.009	.134	.000	.
		N	81	81	79	80	81

**. Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.4.a shows that there is a positive relationship between the level of automation and use of preventive maintenance (0.343). The P value (0.002) indicates that the relationship is statistically significant

Table C.4.b – Correlation between the level of automation and maintenance practice (MALAYSIA)

Correlations

			Level of automation used	Breakdown Maintenance	Corrective Maintenance	Preventive Maintenance	Predictive Maintenance
Spearman's rh	Level of automation u	Correlation Coeffic	1.000	-.149	.061	.170	.324**
		Sig. (2-tailed)	.	.194	.592	.131	.004
		N	81	78	80	80	78
	Breakdown Maintena	Correlation Coeffic	-.149	1.000	.405**	-.167	-.225*
		Sig. (2-tailed)	.194	.	.000	.145	.049
		N	78	78	78	78	77
	Corrective Maintenan	Correlation Coeffic	.061	.405**	1.000	.111	.150
		Sig. (2-tailed)	.592	.000	.	.326	.190
		N	80	78	80	80	78
	Preventive Maintenar	Correlation Coeffic	.170	-.167	.111	1.000	.418**
		Sig. (2-tailed)	.131	.145	.326	.	.000
		N	80	78	80	80	78
	Predictive Maintenan	Correlation Coeffic	.324**	-.225*	.150	.418**	1.000
		Sig. (2-tailed)	.004	.049	.190	.000	.
		N	78	77	78	78	78

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Malaysia: Table C.4.b shows that there is a positive relationship between the level of automation and use of predictive maintenance (0.343). The P value (0.002) indicates that the relationship is statistically significant.

C-3. Factor of maintenance practices towards the improvement in equipment availability

Table C.5.a – Correlation between the number of employees in maintenance and the total number of employees (IRELAND)

Correlations

			No. of employee	Number of employees in maintainence
Spearman's rho	No. of employee	Correlation Coefficient	1.000	.649**
		Sig. (2-tailed)	.	.000
		N	83	80
	Number of employees in maintainence	Correlation Coefficient	.649**	1.000
		Sig. (2-tailed)	.000	.
		N	80	81

**. Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.5.a shows that there is a positive relationship between the number of employees in maintenance and the total number of employees (0.649). The P value (0.000) indicates that the relationship is statistically significant.

Table C.5.b – Correlation between the number of employees in maintenance and the total number of employees (MALAYSIA)

Correlations

			No. of employee	Number of employees in maintainence
Spearman's rho	No. of employee	Correlation Coefficien	1.000	.515**
		Sig. (2-tailed)	.	.000
		N	81	79
	Number of employees in maintainence	Correlation Coefficien	.515**	1.000
		Sig. (2-tailed)	.000	.
		N	79	79

**. Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.5.b shows that there is a positive relationship between the number of employees in maintenance and the total number of employees (0.515). The P values (0.000) indicate that the relationship is statistically significant.

Table C.6.a – Correlation between the improvement of equipment availability and the type of maintenance used (IRELAND)

Correlations

			Improvement of equipment availability	Breakdown Maintenance	Corrective Maintenance	Preventive Maintenance	Predictive Maintenance
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	-0.332**	0.062	0.394**	0.332**
		Sig. (2-tailed)	.	0.002	0.590	0.000	0.003
		N	81	81	78	80	78

** Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.6.a shows that there is a positive relationship between the improvement of equipment availability and the use of preventive maintenance (0.394) and predictive maintenance (0.332). The P values (0.000 and 0.003 respectively) indicate that the relationships are statistically significant. However, there is a negative relationship between the improvement of equipment availability and the use of breakdown maintenance (-0.332). The P values (0.002) indicate that the relationship is statistically significant. As for the corrective maintenance, there is no significant relationship between the improvement of equipment availability and the corrective maintenance.

Table C.6.b – Correlation between the improvement of equipment availability and the type of maintenance used (MALAYSIA)

Correlations

			Improvement of equipment availability	Breakdown Maintenance	Corrective Maintenance	Preventive Maintenance	Predictive Maintenance
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	.015	.111	.184	.170
		Sig. (2-tailed)	.	.900	.342	.112	.148
		N	76	75	76	76	74

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Malaysia: Table C.6.b shows there is no relationship between the improvement of equipment availability and the type of maintenance used. The same findings were also found as shown in table C.7.b, that there is no relationship between the improvement of equipment availability and use of TPM, RCM and the use of CMMS.

Table C.6.c– Correlation between maintenance approach used (derived from maintenance responsibilities) and maintenance contribution towards performance (IRELAND)

Correlations

			Improvement of product quality	Improvement of equipment availability	Improvement of reduction of production cost
Spearman's rho	TASK A.B.D.E (Proactive)	Correlation Coefficient	0.251*	0.423**	0.364**
		Sig. (2-tailed)	0.032	0.000	.0001
		N	73	74	74
	TASK G,H,I (Aggressive)	Correlation Coefficient	0.405**	0.179	0.183
		Sig. (2-tailed)	0.000	0.127	0.118
		N	73	74	74
	TASK C,F (Reactive)	Correlation Coefficient	0.003	-0.007	-0.095
		Sig. (2-tailed)	0.983	0.464	0.484
		N	73	74	74

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Ireland: Table C.6.c shows that there is a positive relationship between the proactive approach (task A,B,D,E) and the improvement of product quality (0.251), the improvement of equipment availability (0.423) and the improvement of reduction of production cost. The P values (0.032, 0.000 and 0.001 respectively) indicate that the relationships are statistically significant. On the other hand, a similar positive relationship found between the aggressive approach (task G,H,I) and the improvement of product quality (0.405). The P values (0.000) indicates that the relationships are statistically significant.

Malaysia:
There is no relationship between the maintenance approach used and and the improvement of performance in all aspects

Table C.7.a – Correlation between the improvement of equipment availability and the maintenance types used (IRELAND)

Correlations

			Improvement of equipment availability	TPM – Total Productive Maintenance	RCM - Reliability Centred Maintenance	CMMS - Computerized Maintenance Management System
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	0.333**	0.141	0.286**
		Sig. (2-tailed)	.	0.003	0.223	0.010
		N	81	80	76	81

** Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.7a shows that there is a positive relationship between the improvement of equipment availability and use of *TPM - Total Productive Maintenance (0.333) and* the use of CMMS - Computerized Maintenance Management System (0.286). The P values (0.003 and 0.010 respectively) indicate that the relationships are statistically significant. As for the RCM - Reliability Centered Maintenance, there is no significant relationship between the improvement of equipment availability and the use of RCM.

Table C.7.b – Correlation between the improvement of equipment availability and the maintenance types used (MALAYSIA)

Correlations

			Improvement of equipment availability	TPM - Total Productive Maintenance	RCM - Reliability Centred Maintenance	CMMS Computerized Maintenance Management System
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	-.134	-.222	-.176
		Sig. (2-tailed)	.	.423	.346	.371
		N	76	38	20	28

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Table C.8.a – Correlation between the improvement of equipment availability and the maintenance troubleshooting methodology used (IRELAND)

Correlations

			Improvement of equipment availability	FMEA - Failure Modes Effects & Analysis	SADT - System Analysis Design Techniques	Cause & Effect Diagram	FTA - Fault Tree Analysis	Pareto Analysis
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	0.430**	0.288*	0.181	0.264*	0.173
		Sig. (2-tailed)	.	0.000	0.023	0.128	0.037	0.156
		N	81	67	62	72	63	69

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Ireland: Table C.8.a shows that there is a positive relationship between the improvement of equipment availability and use of FMEA (0.430), the use of SADT (0.288) and the use of FTA (0.264). The P values (0.000, 0.023 and 0.037 respectively) indicate that the relationships are statistically significant. As for the Cause and Effect diagram and Pareto Analysis, there is no significant relationship were found.

Table C.8.b – Correlation between the improvement of equipment availability and the maintenance troubleshooting methodology used (MALAYSIA)

Correlations

			Improvement of equipment availability	FMEA - Failure Modes Effects & Analysis	SADT - System Analysis Design Techniques	Cause & Effect Diagram	FTA - Fault Tree Analysis	Pareto Analysis
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	.439**	.355**	.160	.331**	.265*
		Sig. (2-tailed)	.	.000	.007	.192	.010	.032
		N	76	62	56	68	60	66

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

Malaysia: Table C.8.b shows that there is a positive relationship between the improvement of equipment availability and use of FMEA (0.439), the use of SADT (0.355), the use of FTA (0.331) and the use of Pareto Analysis (0.265). The P values (0.000, 0.007, 0.010 and 0.032 respectively) indicate that the relationships are statistically significant. As for the Cause and Effect diagram, there is no significant relationship was found.

Table C.9.a – Multi correlation between the improvement of equipment availability and involvement of "in-house and external" maintenance (IRELAND)

Correlations

			Improvement of equipment availability	In-house maintenance (own staff)	Maintenance Consultant Company	Vendor & Manufacturer
Spearman's rho	Improvement of equipment availability	Correlation Coefficier	1.000	-.001	.049	.009
		Sig. (2-tailed)	.	.993	.689	.939
		N	81	73	70	72
	In-house maintenance (own staff)	Correlation Coefficier	-.001	1.000	-.102	-.186
		Sig. (2-tailed)	.993	.	.392	.115
		N	73	76	72	73
	Maintenance Consultant Company	Correlation Coefficier	.049	-.102	1.000	.196
		Sig. (2-tailed)	.689	.392	.	.102
		N	70	72	73	71
	Vendor & Manufactur	Correlation Coefficier	.009	-.186	.196	1.000
		Sig. (2-tailed)	.939	.115	.102	.
		N	72	73	71	75

Ireland: Table C.9.a shows that there is no significant relationship between the improvement of equipment availability and the involvement of "in-house and external" maintenance.

Table C.9.b – Multi correlation between the improvement of equipment availability and involvement of "in-house and external" maintenance (MALAYSIA)

Correlations

			mprovemen of equipmen availability	In-house maintenance (own staff)	Maintenance Consultant Company	Vendor & Manufacture
Spearman's r	Improvement of equipment availab	Correlation Coeff	1.000	.305**	.143	-.006
		Sig. (2-tailed)	.	.008	.231	.959
		N	76	74	72	70
	In-house mainten (own staff)	Correlation Coeff	.305**	1.000	-.449**	-.084
		Sig. (2-tailed)	.008	.	.000	.487
		N	74	75	73	71
	Maintenance Consultant Comp	Correlation Coeff	.143	-.449**	1.000	.256*
		Sig. (2-tailed)	.231	.000	.	.031
		N	72	73	73	71
	Vendor & Manufa	Correlation Coeff	-.006	-.084	.256*	1.000
		Sig. (2-tailed)	.959	.487	.031	.
		N	70	71	71	71

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Malaysia: Table C.9.b shows that there is positive relationship between the improvement of equipment availability and the involvement of "in-house maintenance" (0.305). The P values (0.008) indicate that the relationships are statistically significant.

However, there is no significant relationship between the improvement of equipment availability and the involvement of maintenance consultant as well as with the vendor and manufacturer.

C-4. Factor of performance improvement and management

Table C.10.a – Multi correlation between the performance outcomes contributed from the maintenance effort (IRELAND)

Correlations

			Improvement of equipment availability	Improvement of product quality	Improvement of reduction of production cost
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	.642**	.663**
		Sig. (2-tailed)	.	.000	.000
		N	78	78	78
	Improvement of product quality	Correlation Coefficient	.642**	1.000	.652**
		Sig. (2-tailed)	.000	.	.000
		N	78	78	78
	Improvement of reduction of production cost	Correlation Coefficient	.663**	.652**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	78	78	78

**. Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.10.a shows that there is a positive relationship between the improvement of equipment availability and the improvement of product quality (0.642), as well as the improvement of reduction of production cost (0.663). The P values (both are 0.000) indicate that the relationships are statistically significant. In addition, there is a positive relationship between the improvement of product quality and the improvement of reduction of production cost (0.652). The P value (0.000) indicates that the relationship is statistically significant.

Table C.10.b – Multi correlation between the performance outcomes contributed from the maintenance effort (MALAYSIA)

Correlations

			Improvement of product quality	Improvement of equipment availability	Improvement of reduction of production cost
Spearman's rhc	Improvement of product quality	Correlation Coefficie	1.000	.483**	.530**
		Sig. (2-tailed)	.	.000	.000
		N	76	76	76
	Improvement of equipment availability	Correlation Coefficie	.483**	1.000	.602**
		Sig. (2-tailed)	.000	.	.000
		N	76	76	76
	Improvement of reductic of production cost	Correlation Coefficie	.530**	.602**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	76	76	76

**. Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.10.b shows that there is a positive relationship between the improvement of equipment availability and the improvement of product quality (0.483), as well as the improvement of reduction of production cost (0.602). The P values (both are 0.000) indicate that the relationships are statistically significant. In addition, there is a positive relationship between the improvement of product quality and the improvement of reduction of production cost (0.530). The P value (0.000) indicates that the relationship is statistically significant

Table C.11.a – Correlation between satisfaction level on the maintenance achievement and the maintenance contribution towards improvement (IRELAND)

Correlations

			Maintenance achievement	Improvement of product quality	Improvement of equipment availability	Improvement of reduction of production cost
Spearman's rho	Maintenance achievement	Correlation Coefficient	1.000	0.260*	0.381**	0.484**
		Sig. (2-tailed)	.	0.021	0.000	0.000
		N	83	79	80	80

* Correlation is significant at the .05 level (2-tailed).
** Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.11.a shows that there are positive relationships between the satisfaction level on the maintenance achievement and the maintenance contribution towards improvement: the improvement of product quality (0.260), the improvement of equipment availability (0.381) and the improvement of reduction of production cost (0.484). The P values (0.021, 0.000 and 0.000) indicate that the relationships are statistically significant.

Table C.11.b – Correlation between satisfaction level on the maintenance achievement and the maintenance contribution towards improvement (MALAYSIA)

Correlations

			Maintenance achievement	Improvement of product quality	Improvement of equipment availability	Improvement of reduction of production cost
Spearman's rho	Maintenance achievedment	Correlation Coefficient	1.000	.332**	.250*	.224
		Sig. (2-tailed)	.	.003	.029	.051
		N	79	76	76	76

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Malaysia: Table C.11.b shows that there are positive relationships between the satisfaction level on the maintenance achievement and the maintenance contribution towards improvement: the improvement of product quality (0.332) as well as the improvement of equipment availability (0.250). The P values (0.003 and 0.029 respectively) indicate that the relationships are statistically significant.

Table C.12.a – Correlation between top management regards on the maintenance and need of review on the maintenance role (IRELAND)

Correlations

			Review the role of maintenance	Top mgmt - Regards as an overhead	Top mgmt - Regards as an investment	Top mgmt - Regards as an important supporting function
Spearman's rho	Review the role of maintenance	Correlation Coefficient	1.000	.182	-.294*	-.246*
		Sig. (2-tailed)	.	.126	.013	.030
		N	81	72	71	78
	Top mgmt - Regards as an overhead	Correlation Coefficient	.182	1.000	-.307**	-.335**
		Sig. (2-tailed)	.126	.	.009	.004
		N	72	75	72	73
	Top mgmt - Regards as an investment	Correlation Coefficient	-.294*	-.307**	1.000	.467**
		Sig. (2-tailed)	.013	.009	.	.000
		N	71	72	74	73
	Top mgmt - Regards as an important supporting function	Correlation Coefficient	-.246*	-.335**	.467**	1.000
		Sig. (2-tailed)	.030	.004	.000	.
		N	78	73	73	81

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.12.a shows that there are negative relationships between the need of management review of the maintenance role and the way top management regards maintenance as an investment (-0.307) as well as the way top management regards the maintenance as an important supporting function (-0.335). The P values (0.009 and 0.004 respectively) indicate that the relationships are statistically significant. However there is no significant relationship between the need of management review of the maintenance role and the way top management regards the maintenance as "an overhead".

Table C.12.b – Correlation between top management regards on the maintenance and need of review on the maintenance role (MALAYSIA)

Correlations

			Review the role of maintenance	Top mgmt - Regards as an overhead	Top mgmt - Regards as an investment	Top mgmt - Regards as an important supporting function
Spearman's rho	Review the role of maintenance	Correlation Coefficient	1.000	-.009	-.137	-.292*
		Sig. (2-tailed)	.	.940	.239	.011
		N	79	76	76	76
	Top mgmt - Regards as an overhead	Correlation Coefficient	-.009	1.000	-.173	-.202
		Sig. (2-tailed)	.940	.	.139	.084
		N	76	76	74	74
	Top mgmt - Regards as an investment	Correlation Coefficient	-.137	-.173	1.000	.507**
		Sig. (2-tailed)	.239	.139	.	.000
		N	76	74	77	76
	Top mgmt - Regards as an important supporting function	Correlation Coefficient	-.292*	-.202	.507**	1.000
		Sig. (2-tailed)	.011	.084	.000	.
		N	76	74	76	77

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.12.b shows that there are negative relationships between the need of management review of the maintenance role and the way top management regards the maintenance as an important supporting function (-0.292). The P values (0.011) indicate that the relationships are statistically significant. However there is no significant relationship between the need of management review of the maintenance role and the way top management regards the maintenance as "an overhead" as well as "an investment".

C-5. Factor of training development and supporting documentation

Table C.13.a – Cross correlation table of the training planning and training implementation (IRELAND)

Correlations

			TNA -Training Need Analysis	Different type training programmes	Percent of maintenance personnel received training
Spearman's rho	TNA -Training Need Analysis	Correlation Coefficient	1.000	.401**	.491**
		Sig. (2-tailed)	.	.000	.000
		N	77	75	76
	Different type training programmes	Correlation Coefficient	.401**	1.000	.551**
		Sig. (2-tailed)	.000	.	.000
		N	75	81	81
	Percent of maintenance personnel received training	Correlation Coefficient	.491**	.551**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	76	81	82

**. Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.13.a shows that there are positive relationships between training needs analysis (TNA) conducted and the different type training programmes attended (0.401) as well as the percent of maintenance personnel receiving training (0.491). The P values (both are 0.000) indicate that the relationships are statistically significant.

Table C.13.b - Cross correlation table of the training planning and training implementation (MALAYSIA)

Correlations

			TNA -Training Need Analysis	Different type training programmes	Percent of maintenance personnel received training
Spearman's rho	TNA -Training Need Analysis	Correlation Coefficient	1.000	.105	.162
		Sig. (2-tailed)	.	.352	.153
		N	80	80	79
	Different type training programmes	Correlation Coefficient	.105	1.000	.598**
		Sig. (2-tailed)	.352	.	.000
		N	80	80	79
	Percent of maintenance personnel received training	Correlation Coefficient	.162	.598**	1.000
		Sig. (2-tailed)	.153	.000	.
		N	79	79	79

**. Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.13.b shows that there are positive relationships between different type training programmes attended and the percent of maintenance personnel received training (0.598). The P values (0.000) indicate that the relationships are statistically significant.

Table C.14.a – Correlation between improvement of equipment availability and the training planning and implementation (IRELAND)

Correlations

			Improvement of equipment availability	TNA -Training Need Analysis	Different type training programmes	Percent of maintenance personnel received training
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	0.276*	0.196	0.264*
		Sig. (2-tailed)	.	0.017	0.083	0.018
		N	81	74	79	80

* Correlation is significant at the .05 level (2-tailed).

Ireland: Table C.14.a shows that there are positive relationships between improvement of equipment availability and training need analysis conducted (0.276), as well as the percent of maintenance personnel received training (0.264). The P values (0.017 and 0.018 respectively) indicate that the relationships are statistically significant.

Table C.14.b – Correlation between improvement of equipment availability and the training planning and implementation (MALAYSIA)

Correlations

			Improvement of equipment availability	TNA -Training Need Analysis	Different type training programmes	Percent of maintenance personnel received training
Spearman's rho	Improvement of equipment availability	Correlation Coefficient	1.000	.132	.001	-.003
		Sig. (2-tailed)	.	.257	.995	.982
		N	76	76	76	75

** Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.14.b shows there is no relationship between improvement of equipment availability and training need analysis conducted, as well as the training implementation.

Table C.15.a – Cross correlation between different approaches of learning (IRELAND)

Correlations

			NA -Training leed Analysis	Self learning	Through On Job learning	Training from internal	Training from manufacturer vendor	Training from external consultant
Spearman's r	TNA -Training Need Analysis	Correlation Coeff	1.000	-.153	.152	.309**	.190	.388**
		Sig. (2-tailed)	.	.215	.199	.009	.107	.001
		N	77	67	73	70	73	70
	Self learning	Correlation Coeff	-.153	1.000	.382**	.089	.100	-.099
		Sig. (2-tailed)	.215	.	.001	.472	.411	.430
		N	67	73	72	68	70	66
	Through On -Job le	Correlation Coeff	.152	.382**	1.000	.379**	.248*	.165
		Sig. (2-tailed)	.199	.001	.	.001	.031	.167
		N	73	72	79	75	76	72
	Training from intern	Correlation Coeff	.309**	.089	.379**	1.000	.243*	.320**
		Sig. (2-tailed)	.009	.472	.001	.	.038	.007
		N	70	68	75	75	73	69
	Training from manufacturer/vendc	Correlation Coeff	.190	.100	.248*	.243*	1.000	.221
		Sig. (2-tailed)	.107	.411	.031	.038	.	.064
		N	73	70	76	73	78	71
	Training from exterr consultant	Correlation Coeff	.388**	-.099	.165	.320**	.221	1.000
		Sig. (2-tailed)	.001	.430	.167	.007	.064	.
		N	70	66	72	69	71	72

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

Ireland: Table C.15.a shows that there are positive relationships between various means of learning approach. It shows that there is positive correlation between "on job learning" and self learning (0.382), "training from internal" (0.379) as well as "training from manufacturer" (0.243). The P values (0.001, 0.001 and 0.031 respectively) indicate that the relationships are statistically significant.

Table C.15.b – Cross correlation between different approaches of learning (MALAYSIA)

Correlations

			TNA -Training leed Analysis	Self learning	Through On -Job learning	Training from internal	Training from manufacturer/ vendor	Training from external consultant
Spearman's rt	TNA -Training Need Analysis	Correlation Coeffic	1.000	.015	.020	-.115	.010	-.006
		Sig. (2-tailed)	.	.893	.862	.313	.929	.958
		N	80	79	80	79	80	79
	Self learning	Correlation Coeffic	.015	1.000	.116	-.013	-.043	-.111
		Sig. (2-tailed)	.893	.	.307	.908	.707	.333
		N	79	79	79	78	79	78
	Through On -Job lear	Correlation Coeffic	.020	.116	1.000	.532**	.337**	.140
		Sig. (2-tailed)	.862	.307	.	.000	.002	.218
		N	80	79	80	79	80	79
	Training from internal	Correlation Coeffic	-.115	-.013	.532**	1.000	.324**	.137
		Sig. (2-tailed)	.313	.908	.000	.	.004	.232
		N	79	78	79	79	79	78
	Training from manufacturer/vendor	Correlation Coeffic	.010	-.043	.337**	.324**	1.000	.555**
		Sig. (2-tailed)	.929	.707	.002	.004	.	.000
		N	80	79	80	79	80	79
	Training from externa consultant	Correlation Coeffic	-.006	-.111	.140	.137	.555**	1.000
		Sig. (2-tailed)	.958	.333	.218	.232	.000	.
		N	79	78	79	78	79	79

**. Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.15.b shows that there are positive relationships between various means in learning approach. It show that there are positive correlation between "on job learning" and "training from internal" (0.532), as well as "training from manufacturer" (0.337). The P values (0.000 and 0.002 respectively) indicate that the relationships are statistically significant.

Table C.16.a – Correlation between technical specification's manual and maintenance guideline's manual in hardcopy format (IRELAND)

Correlations

			Description of system (Functionality)	Procedure of Maintenance	List of possible malfunction	Guideline for rectification of any malfunction
Spearman's rho	Description of system (Functionality)	Correlation Coefficient	1.000	0.580**	0.385**	0.286**
		Sig. (2-tailed)	.	0.000	0.001	0.014
		N	77	75	74	73

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Ireland: Table C.16.a shows that there are positive relationships between the hardcopy technical specification's manual (system's functionality) and the maintenance guideline manual: procedure of maintenance (0.580), list of possible malfunctions (0.385), and guidelines for rectification of any malfunction (0.286). The P values (0.000, 0.001 and 0.014 respectively) indicate that the relationships are statistically significant.

Table C.16.b – Correlation between technical specification's manual and maintenance guideline's manual in hardcopy format (MALAYSIA)

Correlations

			Description of system (Functionality)	Procedure of Maintenance	List of possible malfunction	Guideline for rectification of any malfunction
Spearman's rho	Description of system (Functionality)	Correlation Coefficient	1.000	0.644**	0.489**	0.429**
		Sig. (2-tailed)	.	0.000	0.001	0.014
		N	74	74	74	74

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.16.b shows that there are positive relationships between the hardcopy technical specification's manual (system's functionality) and the maintenance guideline manual: procedure of maintenance (0.644), list of possible malfunction (0.489), and guideline for rectification of any malfunction (0.429). The P values (0.000) indicate that the relationships are statistically significant.

Table C.17.a – Correlation between technical specification's manual and maintenance guideline's manual in softcopy format (IRELAND)

Correlations

			Description of system (Functionality)	Procedure of Maintenance	List of possible malfunction	Guideline for rectification of any malfunction
Spearman's rho	Description of system (Functionality)	Correlation Coefficient	1.000	0.893**	0.768**	0.768**
		Sig. (2-tailed)	.	0.000	0.000	0.000
		N	66	66	65	65

* Correlation is significant at the .05 level (2-tailed).

** *Correlation is significant at the* .01 level (2-tailed).

Ireland: Table C.17.a shows there are positive relationships between the softcopy technical specification's manual (system's functionality) and the maintenance guideline manual: procedure of maintenance (0.893), list of possible malfunctions (0.768), and guidelines for rectification of any malfunction (0.768). The P values (0.000) indicate that the relationships are statistically significant.

Table C.17.b – Correlation between technical specification's manual and maintenance guideline's manual in softcopy format (MALAYSIA)

Correlations

			Description of system (Functionality)	Procedure of Maintenance	List of possible malfunction	Guideline for rectification of any malfunction
Spearman's rho	Description of system (Functionality)	Correlation Coefficient	1.000	0.838**	0.840**	0.842**
		Sig. (2-tailed)	.	0.000	0.000	0.000
		N	70	70	70	70

* Correlation is significant at the .05 level (2-tailed).

** Correlation is significant at the .01 level (2-tailed).

Malaysia: Table C.17.b shows that there are positive relationships between the softcopy technical specification's manual (system's functionality) and the maintenance guideline manual: procedure of maintenance (0.838), list of possible malfunction (0.840), and guideline for rectification of any malfunction (0.842). The P values (0.000) indicate that the relationships are statistically significant.

C-6. Summary of correlation analysis

Table C.18.a – Summary of correlation analysis (IRELAND)

IRELAND
CORRELATION ANALYSIS

	A. COMPANY BACKGROUND	A1	A2	A3	A4	A5	C3
A1	Ownership		0.567**	NC	0.443**	0.310*	
A2	Large Organisation	0.567**		NC	0.395**	0.351**	
A3	Years in business	NC	NC		NC	NC	
A4	Number of employee	0.443**	0.395**	NC		0.737**	0.649**
A5	$ Turnover	0.310*	0.351**	NC	0.737**		

	B. AUTOMATION	A1-A4	A5	B2	B3	C4-3
B2	Level of Automation	NC	0.294*		0.756**	0.343**
B3	Level of integration of automation			0.756**		

	C. MAINTENANCE	B2	C4-1	C4-2	C4-3	C4-4	D2-2
C4	Types of maintenance						
C4-1	Breakdown Maintenance	NC		NC	.-0.376**	.-0.291**	.-0.332**
C4-2	Corrective Maintenance	NC	NC		0.379**	NC	NC
C4-3	Preventive Maintenance	0.343**	.-0.376**	0.379**		0.482**	0.394**
C4-4	Predictive Maintenance	NC	.-0.291**	NC	0.482**		0.332**
C5	Total Productive Maintenance						0.333**
C6	Reliability Centered maintenance						NC
C7	CMMS Computer Maint. Mgmt System						0.286**
C9	Troubleshooting methodology						
C9-1	Failure Modes Effects & Analysis						0.430**
C9-2	System Analysis Design Techniques						0.288*
C9-3	Cause & Effect Diagram						NC
C9-4	Fault Tree Analysis (FTA)						0.264*
C9-5	Pareto Analysis						NC
C12	In house & external agencies						
C12-1	In-house maintenance (own staff)						NC
C12-2	Maintenance Consultant Company						NC
C12-3	Vendor & Manufacturer						NC

	Hard copy manual	C20-A1	C20-A2	C20-A3	C20-A4
C20-A1	Description of system		0.580**	0.385**	0.286**

	Soft copy manual	C20-B1	C20-B2	C20-B3	C20-B4
C20-B1	Description of system		0.893**	0.768**	0.768**

	D. PERFORMANCE	D2-1	D2-2	D2-3
D2	Maintenance effort towards improve			
D2-1	Improvement of product quality		0.642**	0.652**
D2-2	Improvement of equipment availability	0.642**		0.663**
D2-3	Improvement of reduction of production cost	0.652**	0.663*	
D3	Maintenance achievement	0.260*	0.381**	0.484**

		D4-1	D4-2	D4-3	D5
D4	Top management perception				
D4-1	Regards as an overhead		.-0.307**	.-0.335**	NC
D4-2	Regards as an investment	.-0.307**		0.467**	.-0.294*
D4-3	Regards as an important supporting fctn	.-0.335**	0.467**		.-0.246*
D5	Review of maintenance role	NC	.-0.294*	.-0.246*	

	E. TRAINING	D2-2	E1	E2	E3
E1	Training Need analysis	0.276*		0.401**	0.491**
E2	Different type of traing progr. attended	NC	0.401**		0.551**
E3	Percent of Maint. Persnl attended traing	0.264*	0.491**	0.551**	

		E1	E6-1	E6-2	E6-3	E6-4	E6-5
E6	Learning approaches						
E6-1	Self Learning	NC		0.382**	NC	NC	NC
E6-2	Through on-job training	NC	0.382**		0.379**	0.248*	NC
E6-3	Training from internal staff	0.309**	NC	0.379**		0.243*	0.320**
E6-4	Training from manufacturer/vendor	NC	NC	0.248*	0.243*		NC
E6-5	Training from external consultant	0.388**	NC	NC	0.320**	NC	

** Correlation is significant at the level of 0.05 (2-tailes)*

*** Correlation is significant at the level of 0.01 (2-tailes)*

Survey Code – Refer to Appendix 1B

Table C.18b – Summary of correlation analysis (MALAYSIA)

MALAYSIA
CORRELATION ANALYSIS

	A. COMPANY BACKGROUND	A1	A2	A3	A4	A5	C3
A1	Ownership		0.300**	NC	NC	NC	NC
A2	Large Organisation	0.300**		NC	NC	0.261*	NC
A3	Years in business	NC	NC		0.274*	0.273*	NC
A4	Number of employee	NC	NC	0.274*		0.330**	0.515**
A5	$ Turnover	NC	0.261*	0.273*	0.330**		NC

	B. AUTOMATION	A1-A4	A5	B2	B3	C4-4
B2	Level of Automation	NC	0.278*		0.501**	0.324**
B3	Level of integration of automation			0.501**		

	C. MAINTENANCE	B2	C4-1	C4-2	C4-3	C4-4	D2-2
C4	Types of maintenance						
C4-1	Breakdown Maintenance	NC		0.405**	NC	.-0.225*	NC
C4-2	Corrective Maintenance	NC	0.405**		NC	NC	NC
C4-3	Preventive Maintenance	NC	NC	NC		0.418**	NC
C4-4	Predictive Maintenance	0.324**	.-0.225*	NC	0.418**		NC
C5	Total Productive Maintenance						NC
C6	Reliability Centered maintenance						NC
C7	CMMS Computer Maint. Mgmt System						NC
C9	Troubleshooting methodology						
C9-1	Failure Modes Effects & Analysis						0.439**
C9-2	System Analysis Design Techniques						0.355**
C9-3	Cause & Effect Diagram						NC
C9-4	Fault Tree Analysis (FTA)						0.331**
C9-5	Pareto Analysis						0.265**
C12	In house & external agencies						
C12-1	In-house maintenance (own staff)						0.305**
C12-2	Maintenance Consultant Company						NC
C12-3	Vendor & Manufacturer						NC

	Hard copy manual	C20-A1	C20-A2	C20-A3	C20-A4
C20-A1	Description of system		0.644**	0.489**	0.429**

	Soft copy manual	C20-B1	C20-B2	C20-B3	C20-B4
C20-B1	Description of system		0.838**	0.840**	0.842**

	D. PERFORMANCE	D2-1	D2-2	D2-3
D2	Maintenance effort towards improvement			
D2-1	Improvement of product quality		0.483**	0.530**
D2-2	Improvement of equipment availability	0.483**		0.602**
D2-3	Improvement of reduction of production cost	0.530**	0.602**	
D3	Maintenance achievement	0.332**	0.250**	NC

		D4-1	D4-2	D4-3	D5
D4	Top management perception				
D4-1	Regards as an overhead		NC	NC	NC
D4-2	Regards as an investment	NC		0.507*	NC
D4-3	Regards as an important supporting fctn	NC	0.507*		.-0.292*
D5	Review of maintenance role	NC	NC	.-0.292*	

	E. TRAINING	D2-2	E1	E2	E3
E1	Training Need analysis	NC		NC	NC
E2	Different type of traing progr. attended	NC	NC		0.598**
E3	Percent of Maint. Persnl attended traing	NC	NC	0.598**	

		E1	E6-1	E6-2	E6-3	E6-4	E6-5
E6	Learning approaches						
E6-1	Self Learning	NC		NC	NC	NC	NC
E6-2	Through on-job training	NC	NC		0.532**	0.337**	NC
E6-3	Training from internal staff	NC	NC	0.532**		0.324**	NC
E6-4	Training from manufacturer/vendor	NC	NC	0.337**	0.324**		0.555**
E6-5	Training from external consultant	NC	NC	NC	NC	0.555**	

** Correlation is significant at the level of 0.05 (2-tailes)*
*** Correlation is significant at the level of 0.01 (2-tailes)*
Survey Code – Refer to Appendix 1B

C-7. Results of Reliability Test

Table C.19– Result of Reliability Test

Code	Questionnaire	No. of items	Alpha (α) value	
			Ireland	Malaysia
B5	Work cell controller used	5	0.705	0.752
B6	Adv. Mfg Tech, (AMT) used	7	0.703	0.742
B7	CIM applications used	6	0.821	0.845
B12	Motivation to implement automation	6	0.723	0.702
C5	Responsibilities of maintenance:	9	0.796	0.853
C12	CMMS modules used	11	0.890	0.919
C14	Breakdown occurred per area	9	0.704	0.768
C15	Methods of troubleshooting used	5	0.793	0.776
C16	Problems in maintenance	8	0.775	0.808
C17	Maintenance personnel's problems	8	0.780	0.786
C20	Availability of manual guidelines	8	0.842	0.895
D2	Maintenance contribution	3	0.851	0.785
D6	Matters to be reviewed	3	0.762	0.705
E4	Hours of training	6	0.917	0.774
E6	Learning approach	5	0.705	0.704

C-8. Results of Validity Test

Table C.20– Result of Construct Validity Test

Code	Questionnaire	No. of items	Kaiser-Mayer-Olkin (KMO value)	
			Ireland	Malaysia
B5	Work cell controller used	5	0.469	0.669
B6	Adv. Mfg Tech, (AMT) used	7	0.594	0.685
B7	CIM applications used	6	0.765	0.803
B11	Obstacle for implement automation	5	0.640	0.654
B12	Motivation to implement automation	6	0.659	0.737
C5	Responsibilities of maintenance:	9	0.753	0.845
C7	Type of maintenance	4	0.604	0.458
C12	CMMS modules used	11	0.816	0.669
C14	Breakdown occurred per area	9	0.590	0.630
C15	Methods of troubleshooting used	5	0.779	0.746
C16	Problems in maintenance	8	0.657	0.711
C17	Maintenance personnel's problems	8	0.661	0.730
C18	In-house / external maintenance	3	0.584	0.516
C20	Availability of manual guidelines	8	0.713	0.692
D2	Maintenance contribution	3	0.724	0.697
D4	Top management view on maintnce	3	0.621	0.557
D6	Matters to be reviewed	3	0.649	0.574
E4	Hours of training	6	0.851	0.669
E6	Learning approach	5	0.683	0.597

C-9. Results of Regression analysis

Table C.21.a Model Summaries, ANOVA and Coefficients (IRELAND)

(Automation Level VS Complexity of production used)

Model Summary		ANOVA		Coefficients		
R	*R*-Square	*F*	*p*-value	Model	t	*p*-value
0.728	0.530	91.329	0.001	(Constant)	7.674	0.000
				Level of Integration	9.557	0.000**

(*) Significant at 5% level and (**) significant at 1% level

Ireland: Table C.21.a shows that larger value of R (0.728) indicates stronger relationships and R-Square model indicates 0.530 percent of the variance, which indicates that the model does fit the data well. The significance p value of the F statistic is small (0.001) demonstrates the independent variables do a good job explaining the variation in the dependent variable. The level of integration was found to have a significant impact at p-value = 0.000**. Therefore, the results indicate that the level of integration is significantly correlated with the level of automation employed.

Table C.21.b Model Summaries, ANOVA and Coefficients (MALAYSIA)

(Automation Level VS Complexity of production used)

Model Summary		ANOVA		Coefficients		
R	*R*-Square	*F*	*p*-value	Model	t	*p*-value
0.521	0.272	29.464	0.000	(Constant)	6.599	0.000
				Level of Integration	5.428	0.000**

(*) Significant at 5% level and (**) significant at 1% level

Malaysia: Table C.21.b shows that larger value of R (0.521) indicates stronger relationships and R-Square model indicates 0.272 percent of the variance, which indicates that the model does fit the data well. The significance p value of the F statistic is small (0.000) demonstrates the independent variables do a good job explaining the variation in the dependent variable. The level of integration was found to have a significant impact at p-value = 0.000**. Therefore, the results indicate that the level of integration is significantly correlated with the level of automation employed.

Table C.22.a Model Summaries, ANOVA and Coefficients (IRELAND)

(Improvement of equipment availability VS Preventive maintenance)

Model Summary		ANOVA		Coefficients		
R	*R*-Square	*F*	*p*-value	Model	T	*p*-value
0.472	0.223	5.014	0.001	(Constant)	3.659	0.000
				Preventive maintenance	2.134	0.036*

(*) Significant at 5% level and (**) significant at 1% level

Ireland:

Table C.22.a shows that larger value of R (0.472) indicates stronger relationships and R-Square model indicates 0.223 percent of the variance, which indicates that the model does fit the data well. The significance p value of the F statistic is small (0.001) demonstrates the independent variables do a good job explaining the variation in the dependent variable. The preventive maintenance was found to have a significant impact at p-value = 0.036*. Therefore, the results indicate that the practice of preventive maintenance is significantly correlated with the improvement of equipment availability.

Table C 23 a - Model Summaries, ANOVA and Coefficients (IRELAND)

(Improvement of equipment availability VS Total Productive maintenance)

Model Summary		ANOVA		Coefficients		
R	*R*-Square	*F*	*p*-value	Model	T	*p*-value
0 316	0 130	11 657	0 001	(Constant)	20 683	0 000
				Total Productive Maint	3 414	0 001**

(*) Significant at 5% level and (**) significant at 1% level

Ireland

Table C 23 a shows that larger value of R (0 316) indicates stronger relationships and R-Square model indicates 0 130 percent of the variance, which indicates that the model does fit the data well The significance p value of the F statistic is small (0 001) demonstrates the independent variables do a good job explaining the variation in the dependent variable The Total Productive maintenance was found to have a significant impact at p-value = 0 001** Therefore, the results indicate that the practice of Total Productive maintenance is significantly correlated with the improvement of equipment availability

Table C 24 a - Model Summaries, ANOVA and Coefficients (IRELAND)

(Improvement of equipment availability VS Use of CMMS)

Model Summary		ANOVA		Coefficients		
R	*R*-Square	*F*	*p*-value	Model	T	*p*-value
0 241	0 058	4 875	0 030	(Constant)	13 702	0 000
				Total Productive Maint	2 208	0 030*

(*) Significant at 5% level and (**) significant at 1% level

Ireland

Table C 24 a shows that larger value of R (0 241) and R-Square model indicates 0 058 percent of the variance The significance p value of the F statistic is small (0 030) demonstrates the independent variables do a good job explaining the variation in the dependent variable The use of CMMS was found to have a significant impact at p-value = 0 030* Therefore, the results indicate that the use of CMMS is significantly correlated with the improvement of equipment availability

APPENDIX D1

DCU
Dublin City University
Ollscoil Chathair Bhaile Átha Cliath

TO:

MAINTENANCE MANAGER
ENGINEERING MANAGER

1 October 2003

Dear Sir,

Survey Questionnaire on the Automated Manufacturing System

One of my post-graduate research student is studying the systematic maintenance implementation strategy in the automated manufacturing system

To this end, we have designed a survey questionnaire, a copy of which is enclosed herewith.

On behalf of the student, I am seeking your kind co-operation in sparing a few minutes to complete the questionnaire and return it using the pre-addressed and stamped envelope enclosed herewith.

Thanking you in anticipation of your kind co-operation. You support would be highly appreciated.

Yours sincerely,

Professor Saleem Hashmi
Head of School

APPENDIX D2

MALAYSIA FRANCE INSTITUTE
UNIVERSITY OF KUALA LUMPUR

TO:

MAINTENANCE MANAGER
ENGINEERING MANAGER

1 October 2003

Dear Industrial Colleague,

Survey Questionnaire on the Automated Manufacturing System

This is to acknowledge that Jamel Othman is a staff of Malaysia France Institute – UniKL, currently pursuing his post-graduate study in Dublin City University, Ireland. In his research, he is studying the systematic maintenance implementation strategy in the automated manufacturing system.

It is intended that the outcome of this research among others will serve as a guideline to the manufacturing industry. It examines the growing requirements for maintenance support, the issues that must addressed and resolved, and the technical and management challenges of implementing the level of professional maintenance in the manufacturing industry in order to achieve the desired levels of capability and competency. To this end, he has designed a survey questionnaire, a copy of which is enclosed herewith.

On behalf of him, I am seeking your kind co-operation in sparing a few minutes to complete the questionnaire and return it using the pre-addressed and stamped envelope enclosed herewith.

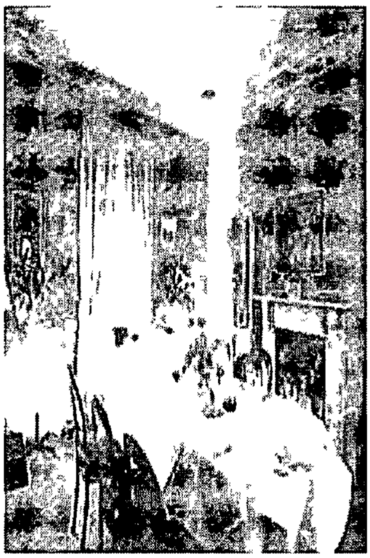
Thanking you in anticipation of your kind co-operation. You support would be highly appreciated.

Yours sincerely,

Rosly Ahmad
Managing Director
Malaysia France Institute - UniKL

APPENDIX D3

Dear Colleague, (IRELAND)



As a token of appreciation, we are going to have a **LUCKY DRAW** - for our industrial colleagues, who are assisting us by completing and returning the survey questionnaire to us

" LUNCH or DINNER

for TWO
in a restaurant of your choice "

Dear Colleague, (MALAYSIA)

As a token of appreciation, we are going to have a **LUCKY DRAW** - for our industrial colleagues, who are assisting us by completing and returning the survey questionnaire to us

" LUNCH or DINNER

for TWO at KL Tower
Revolving Restaurant! "

Seri Angkasa, KL Tower *This revolving restaurant is located at KL Tower Head about 250m above ground Speed of revolution is about 1 cycle per hour Serve buffet (local and western food)*
Note *For those outside KL, could be exchanged in a restaurant of your choice*

APPENDIX D4

DCU
Dublin City University
Ollscoil Chathair Bhaile Átha Cliath

3rd Nov 2003

TO:
MAINTENANCE MANAGER
ENGINEERING MANAGER

Dear Colleague,

REMINDER: Survey Questionnaire on the Automated Manufacturing System

This is just a polite reminder that a survey questionnaire on the above matter had been sent to you on the 1st of October 2003. We believe that the success outcome of this research **would be much depends on your cooperation** through the data provided from all the companies participated.

If you have already completed the questionnaire and returned it to us, we would like to thank you and please ignore this letter. In case if you have not done so yet, owing to any reasons, we would like to request you to kindly complete the questionnaire and return it to **us as soon as possible**.

LUCKY DRAW

Dinner for two in a restaurant of your choice
As a token of appreciation for our industrial colleagues,
who are assisting us by completing and returning
the survey questionnaire to us

Thanking you in anticipation of your kind co-operation. You support would be highly appreciated.

Yours sincerely,

Professor Saleem Hashmi
Head of School

APPENDIX E

LIST OF PUBLICATION WORKS

Jamel Othman and MSJ Hashmi, 2003, "*Maintenance Practices in Automated Manufacturing System: Overview of Current Trends*", Proceeding of The 20th International Manufacturing Conference (IMC20), Cork Ireland, 3-5 September 2003, page 445 - 453

Jamel Othman and MSJ Hashmi, 2004, "*Maintenance Responsibilities and Practicing Strategies: A survey of Automated Manufacturing Companies in Malaysia*", Proceeding of the International Conference in Advanced Manufacturing Technology (ICAMT2004), Kuala Lumpur Malaysia, 13-15 September 2004.

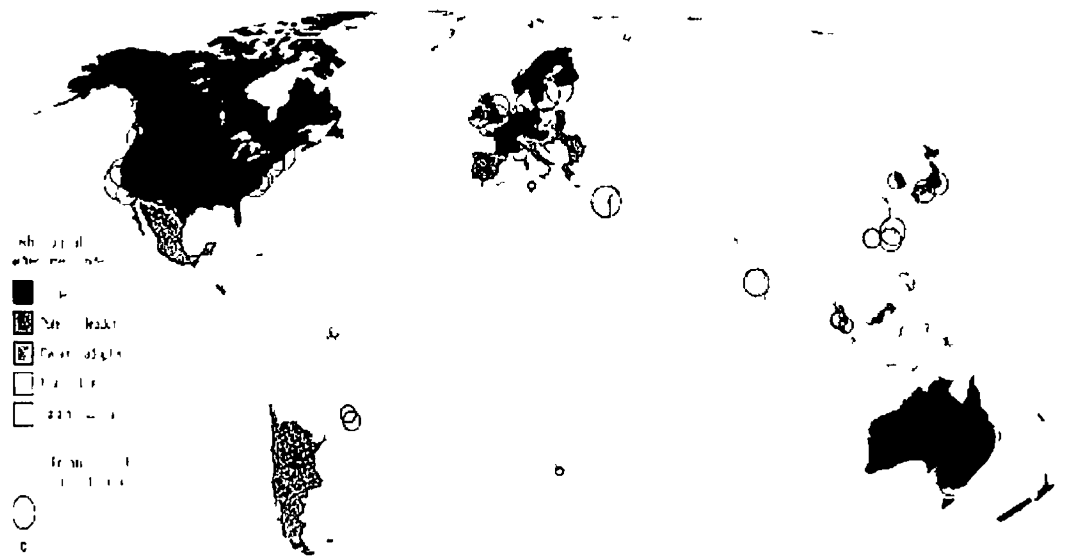
Jamel Othman and MSJ Hashmi, 2004, "*The Level of Automation and CIM Used in Manufacturing Industries: A Survey of Automated Manufacturing Companies in Ireland*", Proceeding of The Second International Conference on Manufacturing Research (ICMR2004), Sheffield United Kingdom, 7-9 September 2004, Paper No. 25, page 54-60.

Jamel Othman and MSJ Hashmi, 2005, "*The Use of Computerized Maintenance Management System and Maintenance Practicing Strategies: A survey of Automated Manufacturing Companies in Ireland*", Proceeding of The 22nd International Manufacturing Conference (IMC22), Dublin Ireland, 31 August - 2 September 2005. Paper No 23.

APPENDIX F

The Geography of Technological Innovation and Achievement

THE GEOGRAPHY OF TECHNOLOGICAL INNOVATION AND ACHIEVEMENT



Global hubs of technological innovation [illegible]

Score				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Four categories of the technology achievement index

[redacted]	POTENTIAL LEADERS	DYNAMIC ADOPTERS		MARGINALIZED
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SOURCE UNDP (United Nation Development Programme) 2001 Human Development Report Oxford University Press New York [203]