# A Study in Differences Between Medium and High Levels of Factory Automation in Selected Semiconductor Device Manufacturers

**by**

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# DEDICATION

To my beloved parents for being my guiding light and instilling in me the importance of life-long learning

To my wife for always being by my side through the challenging times and my source of inspiration

To all my family members for being my pillars of support

**Thank You All!**

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# ABSTRACT

Although the migration of new investments to regions with labour-cost advantage is more prevalent amongst labour-intensive manufacturing companies, it is a matter of time before competition intensifies even for technology-based manufacturers. Rapid economic growth in certain geographies like China, India and Vietnam make it difficult to resist relocating manufacturing activities closer to those regions. This research attempts to uncover ways of improving the competitive edge of semiconductor device manufacturing companies based in Malaysia through the use of higher degree of mechanization in the form of factory automation in their day-to-day operations. This project is an exploratory study on whether there are significant differences in the context of certain major variables (Management, Technical and External) between semiconductor manufacturers with high and medium levels of factory automation. This study involved conducting a survey among thirteen senior management staff representing thirteen different companies involved in semiconductor device manufacturing, respectively. Results obtained from this sample of thirteen respondents (28% of the total population), indicate that from the seven dependent variables, only 'Government Incentives' is perceived differently by the two categories of companies. Whereby, those adopting higher levels of automation seem to have benefited more from government allocated incentives compared to those in the medium category. The significant contextual differences among the variables may also explain the automation-levels adopted by a company and the results of this study is beneficial for semiconductor manufacturers to identify key areas to focus on in efforts to enhance operational productivity through higher levels of factory automation.

# ABSTRAK

Walaupun penempatan semula pelaburan baru ke wilayah-wilayah yang mempunyai kos buruh yang lebih rendah adalah lebih ketara di kalangan syarikat-syarikat berintensifkan tenaga buruh, lambat laun, tekanan persaingan akan turut dirasai oleh pengeluar-pengeluar yang berasaskan teknologi. Pertumbuhan ekonomi rancak di sesetengah tempat seperti di China, India dan Vietnam menjadi tarikan yang sukar diabaikan oleh pekilang untuk berpindah ke sana. Penyelidikan ini berusaha mencari jalan meningkatkan dayasaing syarikat-syarikat pengeluar peranti semikonduktor yang beroperasi di Malaysia melelui peningkatan tahap penggunaan automasi kilang dalam operasi mereka. Penyelidikan ini mengkaji sama ada terdapat perbezaan signifikan dalam hubungan pembolehubah (Pengurusan, Teknikal dan Luaran) di antara pengeluar semikonduktor bertahap automasi tinggi dan sederhana. Kajian ini melibatkan soal selidik yang diedarkan di kalangan tigabelas orang pengurus kanan yang mewakili tigabelas syarikat yang terlibat dengan pengeluaran peranti semikonduktor. Keputusan daripada tigabelas responden tersebut (28% daripada populasi) menunjukkan bahawa, daripada tujuh pembolehubah dependen, hanya 'Insentif Kerajaan' didapati berbeza dari sudut pandangan kedua-dua ketegori syarikat. Yaitu, mereka yang menggunakan tahap automasi tinggi telah menerima manfaat yang lebih berbanding dengan mereka yang ditahap sederhana. Perbezaan konteksual yang signifikan di antara pembolehubah-pembolehubah dapat juga menerangkan tahap automasi yang dipergunakan oleh sesebuah syarikat dan keputusan daripada kajian ini bermanfaat kepada pengeluar-pengeluar semikonduktor untuk mengenalpasti perkara-perkara penting yang perlu diberi tumpuan dalam usaha meningkatkan produktiviti melalui peningkatan tahap automasi kilang.

# Chapter 1

# INTRODUCTION

## 1.1 Background

Malaysia is currently among the world's leaders for semiconductor assembly, testing and packaging, with industry names such as Intel, Motorola, Agilent, AMD, National Semiconductor, Fairchild, Hitachi, Toshiba, Infineon and STMicroelectronics among the MNCs based in the country. The main activities are the assembly and testing of semiconductor devices, which include microprocessors, memory chips, power ICs, linear ICs, opto-devices and other logic and discrete devices (MIDA, 2005).

Owing to increased competition, semiconductor device manufacturing companies, as defined by the U.S. Patent and Trademark Office (Appendix A), in Malaysia need to enhance productivity levels in relation to aggressive start-ups from emerging economies such as in China (Shanghai Star, 2005), India and Vietnam in order to be a competitive global player and remain as a major contributor to the national Gross Domestic Product and an employer of choice for skilled and semi-skilled jobs in the country (MIDA, 2005).

The electrical and electronics industry is Malaysia's leading industrial sector, contributing significantly to the country's manufacturing output, exports and employment. In 2004, gross output of the industry totaled RM183.1 billion (US$48.2 billion), while the industry's exports of electrical and electronics products amounted to RM241.5 billion (US$63.6 billion) or 64.1% of total manufactured exports. The industry created 369,488 job opportunities, accounting for 36.6% of total employment in the manufacturing sector (MIDA, 2005).

Factory automation is seen as a facilitating factor to help retain jobs in several developed countries such as in North America and Japan (Center for Advanced Technology Program – Annual Report 1998-2001), thus the focus of this study is to understand what are the barriers that prevent higher levels of factory automation to take place in the local semiconductor manufacturing environment.

Setting up and operating a semiconductor-based manufacturing facility involves heavy investments – primarily in capital costs, technology, R&D, fabrication and test equipment as well as keeping the manufacturing lines full (Schulz, 2005). Therefore, the pressure is on the management of these companies to formulate and implement optimal ways to utilize resources to extract the best return on investments (ROI).

By definition, automation is the process of having a machine or a group of machines accomplishing tasks hitherto performed wholly or partly by humans (Hess, 2003 and Ken Van Antwerp, 2004). Factory automation can be divided into two parts:

(1) Data or information automation, and

(2) Material-handling automation, whereby, material handling refers to the physical movement of work in progress (WIP) throughout the production floor.

The use of automation to optimize the supply chain is also a focus area by more and more companies. The common goal is to achieve better transparency, shorten response time, increase quality and flexibility, and cost savings throughout the supply chain (Müller, 2005).

Although the goal of having automation solutions is to improve overall productivity, it appears that semiconductor-based factories are reluctant to pursue higher automation levels from what they already have installed thus far (Slocum, 2002). As such, this study is proposed to identify factors that influence the decision-making process at the senior management level of a company in terms of the factory automation level they adopt and to address potential barriers or constraints faced by these companies in moving towards higher levels of factory automation and achieve better productivity.

### 1.2 Research Problem

Although there is steady growth in the semiconductor industry in Malaysia (Third Industrial Master Plan Report), it is facing escalating competition from other developing economies in terms of attracting new foreign direct investments (FDI). One of the areas considered an enabler to enhance manufacturing productivity and to realize other spillover benefits within the semiconductor environment is with the effective implementation of factory automation (Weber, 2005). However, not much has been written on the factors that inhibit the enhancement of existing levels of automation adopted in the context of the local semiconductor environment. Therefore, this research attempts to identify these influencing factors and to determine if there is any significant difference in terms of how these factors are perceived to affect companies that use moderate levels of automation compared to companies that are highly automated. Thus, the necessary recommendations can be formulated to assist companies in lower categories of factory automation to migrate to higher levels.

### 1.3 Research Questions

a) What are the contextual differences in relation to the level of factory automation in the local semiconductor device manufacturing environment?

b) Are there significant differences in the way these contextual differences influence the categories of manufacturers identified – medium or high level of factory automation?

c) What are the possible ways to overcome the potential barriers to narrow the differences to a higher level of factory automation?

### 1.4 Research Objectives

a) Identify contextual differences to different levels of automation in the manufacturing environment of selected semiconductor factories in Malaysia.

b) To categorize the companies by their existing levels of factory automation.

c) To determine if any significant difference exist between companies with medium and high level of factory automation.

d) To propose possible approaches to overcome the potential barrier(s) or inhibitors to achieve higher levels of automation in order to provide a competitive edge among the local industry players in facing global competition.

### 1.5 Significance of Study

a) The Malaysian semiconductor industry is facing increasing competition for foreign direct investment (FDI) from emerging regional players such as China, India, Vietnam, Thailand and Taiwan. To address this threat, semiconductor companies currently operating or wishing to operate in Malaysia would have to find ways to differentiate themselves from regional competition by having superior overall productivity and better service offerings and consistent quality. Factory automation is seen as one of the enablers towards achieving this goal (Slocum, 2002).

b) Semiconductor device manufacturers, and in particular, wafer fabrication plants (Fabs) with investments typically exceeding USD 1 Billion per operational facility, must continuously strive towards highest possible factory output numbers to help offset heavy depreciation of fixed assets (for example, process equipment and the facility itself) and massive operating costs, including investments in human capital such as hiring, training and retaining skilled workers.

c) Typically, in a hi-tech semiconductor device manufacturing environment, sophisticated automated systems are implemented to facilitate optimum equipment and raw material utilization while maintaining high levels of quality in all aspects of production. Enhanced productivity will in turn lower operating cost by reducing wastage of resources (including direct labour). Hence, making such a manufacturing plant or factory more competitive.

d) This study is relevant in the context of identifying factors that can hinder implementation of higher levels of automation in the semiconductor device manufacturing environment with the hope to transform these companies into manufacturing entities with higher performance, better capital asset utilization and human resource management.

### 1.6 Scope of Study

The subjects of this study consist of manufacturers involved in the production of semiconductor devices and have their manufacturing operations located in Malaysia. There are two independent variables (IV) – High Level of Factory Automation (HLFA) and Medium Level of Factory Automation (MLFA) – that relate to the level of factory automation adopted among the companies sampled. While the dependent variables (DV) are made up of Strategic Consideration (SC), Implementability (TI), Economic Justification (EJ), Market Expectations (ME), Government Incentives (GI), Sustainability (TS) and Social Implications (SI). These variables are discussed in more detail in the literature review.

## 1.7 Organization of Chapters

Chapter 1 gives a background of this research topic, the problem statement and discusses its significance. Chapter 2 is a compilation of the literature review. Chapter 3 describes in more detail the methodology of the research undertaken, covering the major variables of study as described in the theoretical framework. This is followed by the study design, data collection process and techniques for analysis. The results and findings will be covered in Chapter 4. Discussions, conclusion and recommendations on how to overcome the challenges at hand in relation to the topic of this project will be covered in Chapter 5, which also touches on what could potentially be done to raise the level of factory automation among semiconductor manufacturers and to enhance Malaysia's edge in this highly competitive industry.

# Chapter 2

# LITERATURE REVIEW

***"The fully automated factory of the future employs only one man and a dog. The dog is there to make sure the man doesn't touch anything, and the man is there to feed the dog." – an old automation wisecrack***

## 2.1 Introduction

The focus of this study is on factors that influence the level of factory automation in the semiconductor industry. Thus, this literature review will first discuss the reasons for automating a semiconductor factory and then conceptualize the different levels of automation while using characteristics of a highly automated factory as a reference. Attention will then be funneled towards defining the variables that influence the level of factory automation within the given environment. The theoretical framework and hypotheses will be covered towards the end of the chapter.

## 2.2 Reasons to automate in the semiconductor device manufacturing industry

One of the earliest examples of automation within large-scale manufacturing operations comes from the automobile industry with the introduction of the moving assembly line (Womack, 1990). A more recent and relevant example to this study is that of automation in semiconductor manufacturing. The introduction of systematic automation of semiconductor wafer fabrication plants has helped to spur the phenomenal growth that the semiconductor industry has witnessed over the last decade.

According to Deininger and Weber (2005), the key characteristics of a truly effective semiconductor factory include:

a) Agile-manufacturing methods that enable rapid process changes to respond to market conditions
b) Accurate, online factory-wide tool productivity monitoring systems
c) Timely and secure information access by people across the company (and throughout the supply chain) to enable tasks to be efficiently and effectively executed

According to TechEncyclopedia (TechWeb), automation is generally defined as the replacement of manual operations by computerized methods; and factory automation refers to computer-driven assembly lines. This implies that in a manufacturing facility, the mechanical components that handle raw materials and work in process (WIP) are managed electronically via the use of computers with little or no human intervention.

Manufacturing industries are beginning to recognize that investment in robots, flexible manufacturing systems and modern manufacturing technologies may be a strategic necessity (G.J. Michael, 1984). Since embarking on such projects incur heavy investments, companies must look at the cost-benefits from the immediate, near and long term. Companies that wish to seriously compete in the global markets on the basis of competition involving technology, innovation, quality and flexibility must also create managerial accounting systems that regularly captures transaction costs and various manufacturing performance indices (R.S. Kaplan, 1998). This ability implies that the information system (IS) that a company adopts and implements should encompass both the manufacturing and enterprise systems.

Automation, in various forms, is the backbone of most major high-tech manufacturing industries. An increase in production volume, product variety and manufacturing process complexity necessitates automation to be introduced to ensure consistency and profitable production as it frees up manual labor, streamlines the flow of material, allows for management of complex processes, reduces idling WIP, faster throughput times and improves output yields and the utilization of expensive equipment (Slocum, 2002).

Automation can also play a role in promoting customer loyalty as it can be positioned as a service-offering differentiator. An example is when – with the advent of e-Business and Customer Relationship Management (CRM) solutions – factory automation facilitates data from the production floor to reach the customers around the globe 24-hours a day in near real-time. This indirectly helps to narrow the existing gaps in managing the supply chain and provide transparency of operations to valued customers.

Automation in the semiconductor industry is imperative because of the need to reduce capital and operating costs, especially as factories utilize manufacturing processes which require ever tighter tolerances (Weiss, 1996). In practically any factory, the objective is to produce output that meets customer expectations with the use of minimal resources in order to achieve the lowest possible unit cost.

According to Davis (June 1995), factory automation can positively affect each of the following factors that contribute to production cost:

i) Facility construction and operation

ii) Capital equipment usage

iii) Work in Process (WIP) – raw materials usage and throughput

iv) Direct and in-direct labour

v) Product quality and yields

The benefits of factory automation in a semiconductor environment ranges from improved labour productivity, reduction in cycle time and floor space utilization to significant output yields, quality and reliability improvements as a result of reduction in manual handling and better consistency in processing (Chang & Gamboa, 2002). This scenario also applies to many industries that have evolved over time.

According to the Encyclopedia Britannica, advantages commonly attributed to automation include higher production rates and increased productivity, more efficient use of materials, better product quality, improved safety, shorter workweeks for labour, and reduced factory lead times. Higher output and increased productivity have been two of the biggest reasons in justifying the use of automation. Thus, the fundamental purpose of automation is to improve productivity – i.e. increase output while reducing unit cost.

## 2.3 Conceptualizing the Levels of Factory Automation

In reality, automated factories and processes are too expensive to be rebuilt for each modification and design change – so from the onset, it needs to be designed to be highly customizable and flexible. The challenge would be to strike the right balance of automated and manual-based processes in order to maintain operational cost-effectiveness.

### 2.3.1 Characteristics of a "highly automated" factory

Semiconductor manufacturing is an established yet rapidly growing industry, and would typically have highly automated factories. The task to automate a semiconductor factory is significant and challenging due to its complicated production processes, sophisticated equipment, and harsh productivity requirements (IEEE, 2001).

The term "lights out" has been used to envision a fully automated factory where human hands never touch the products or WIP during the manufacturing process (Automation World, 2003). Whereas, a "highly-automated" factory is a more likely scenario that would describe an environment that is relatively close to, or approaching "lights out".

In a "Highly" automated factory, we can perhaps visualize the following generic processes taking place when a customer enters an order through electronic means:

1) The customer goes on-line to browse through the products or services offered by the supplier.
2) The customer will specify parameters such as quantity, product features and date when the goods are required.
3) The supplier's order processing system would enter the customer-provided parameters into a planning or scheduling system to check on available capacity and determine when the orders can be fulfilled and at what price.
4) Once there is a match in expectations between customer and supplier, the order will be locked-in.
5) On the supplier's side, the order will then be translated into instructions that the machines or workstations at the manufacturing floor will respond accordingly to fabricate or assemble the product in the proper sequence of operations.
6) Once the product is completed, it is tested and verified to function according to specifications, it will be shipped to the destination(s) specified by the customer.

7) Billing of customer will be triggered automatically per agreed terms before the order is officially closed.

In order to realize the above sequence of events flawlessly, various principles of automation need to be applied and executed in a well-coordinated manner.

As we examine the definition of a highly automated manufacturing environment, we see that it covers aspects of a collaborative manufacturing environment (MESA, 2004) supported by elements of Computer Integrated Manufacturing (CIM). The discussion on collaborative manufacturing and CIM are included here to elaborate further on their respective roles for semiconductor companies to achieve the status of a highly automated manufacturing environment.

Elements of CIM are generally defined as systems providing flexibility as well as data - driven computer integration for a manufacturing organization (Gunasekaran, 2003). A framework for the implementation of CIM within manufacturing is presented in Figure2.1.

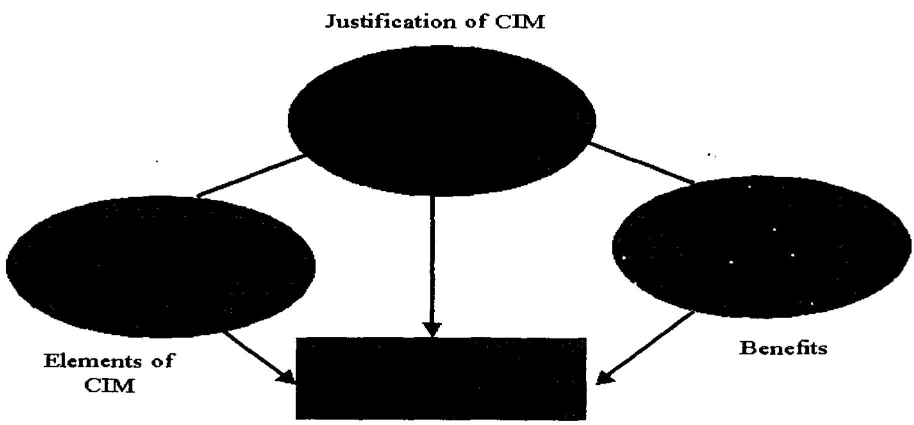


*Figure 2.1* A framework for the implementation of CIM in Manufacturing

(Source: *H B Marri, A Gunasekaran, Bulent Kobu - 2003)*

The elements of CIM are defined in the glossary. These elements, together with the implementation of the collaborative manufacturing concept (Figure 2.2) play a key role in effectively influencing the degree of automation in a factory.

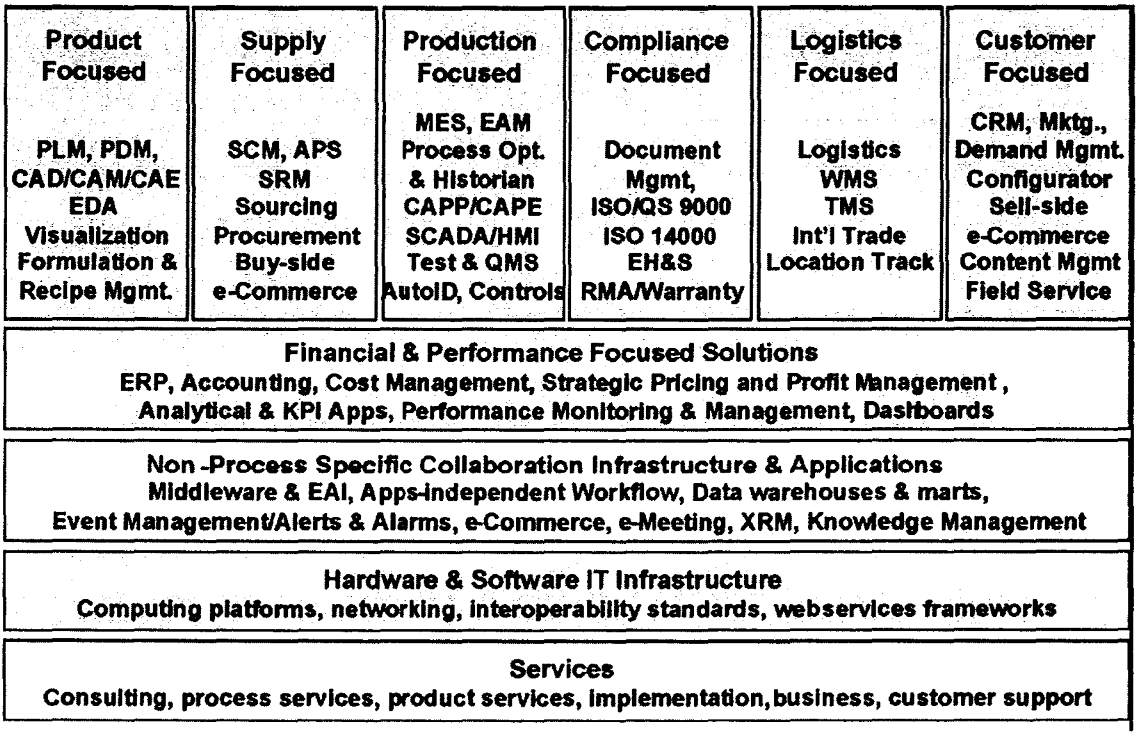


*Figure 2.2* A Collaborative Manufacturing Model encompassing Enterprise Solutions both within an enterprise and extended to partners in a supply chain [source: MESA, 2004]

## 2.4 Defining the Dependent Variables

### 2.4.1 Management Issues

The senior management of an organization is typically driven by the nature of business he/she is in and key performance indicators (KPI) imposed on them by their company's stakeholders. Industrial automation in semiconductor manufacturing is a specialty niche, complicated by several conflicting issues. Performance and cost limitations, plus technical complexities, limit spread of its use beyond narrow applications (Automation World, Oct

2003). The challenging issues that management is faced with comprise of strategic, economic and social aspects (Millen, 1984).

### 2.4.1.1 Strategic Consideration (SC)

For a semiconductor manufacturer that needs to cater to high volume and complex manufacturing processes, while maintaining lowest unit cost, creating the right balance between mass-customizability and capital expenditure on automated systems becomes a major strategic issue.

In many developed countries, automation is playing an increasing role in keeping semiconductor manufacturing operations competitive as it helps to retain their factories in these increasingly expensive labor markets (Electronic-News, Dec 2005). This can be explained by the fact that automation leverages on labor-saving properties of machines. Whereby, less people are needed to execute repetitive actions that can be duplicated through mechanical means. Automation can thus lower production costs by reducing wastage of resources, which in turn bolsters profits. Companies could then spend more of their profits on improving what they sell – through R&D. As technology advances, these improvements make products more complex and in many cases, making manual processing even less desirable.

### 2.4.1.2 Economic Justification (EJ)

Productivity improvement seems to be the prime motivator for some companies to invest heavily in industrial automation (e-News, Dec 2005). Productivity comes from automating routine decisions, while giving workers the information needed to make on-the-spot decisions, in real-time. The most successful automation implementations with corresponding productivity improvements are those that combine the understanding of all related business processes with the ability to implement information communication technology (ICT) and mechanized solutions to meet the ever-changing customer needs.

Not all financial justifications are tied to the company's bottom line. In some industries, which depend on a fast time-to-market for new products and surrounded by strong competition, the ability to switch from one product to another may be all the justification needed to prompt executive approval for automation (Spiegel, 2006). While there are some justifications that don't require proven return on investment—such as compliance, safety and security – most automation spending requires clearly justified financial gain.

Some non-financial justification for automation investment can be translated to business interests, since there are costs involved in not meeting the demands of safety, security, or compliance with various standards and/or governmental legislation.

#### 2.4.1.3 Social and Safety Implications (SI)

Automation raises several social issues which among them is the perceived impact of automation on employment. When automation was first introduced, it caused widespread fear. Some employees may feel their jobs are threathened by the introduction of automated workstations or systems. Workforce culture and adaptability to change will determine the extent of this issue. Availability of proper retraining can also help alleviate this fear (Center for Advanced Technology Program (CATP) – Annual Report 1998-2001).

On the other hand, some may argue that automation leads to higher employment by freeing up the labor force, thus, allowing more people to enter higher skilled jobs, which are typically higher paying.

There is some controversy surrounding the use of retraining to offset economic changes caused by free trade and automation. For example, most studies show that displaced factory workers in the United States on the average have lower wages after retraining to other positions when a factory is closed due to offshoring. A similar issue surrounds movement from technical jobs to liaison jobs due to offshore outsourcing (CATP – Annual Report 1998-2001). Retraining is the process of learning a new skill or trade, often in response to a change in the economic environment. Generally it reflects changes in profession choice rather than an "upward" movement in the same field.

To overcome these issues, management must motivate their employees across the board – from engineers, technicians, production workers to support staff – to be more creative, innovative and adaptable to change.

### 2.4.2 Technical Feasibility

The availability and reliability of suitable hardware and data collection methods play a critical role in determining the feasibility of an automated system. This factor can be further divided into system implementability and its sustainability.

#### 2.4.2.1 Implementability (TI)

As machines grow more autonomous, the things that can go wrong become steadily more exotic, complex, unpredictable and hard to maintain. Furthermore, because automated processes tend to run more quickly than manual ones, the cost of letting an excursion go uncorrected even for a short duration can be very high. For example, in a semiconductor manufacturing plant, millions of dollars worth of components or WIP can become plain scrap material due to that undesirable scenario such as undetected critical process parameters that drift outside their control limits.

While it is often viewed as a way to minimize human error in a system, increasing the degree and levels of automation also increases the consequences of such errors. For example, the Three Mile Island nuclear event was largely due to over-reliance on "automated safety" systems. Unfortunately, in the event, the designers had never anticipated the actual failure mode which occurred, so both the "automated safety" systems and their human overseers were inundated with vast amounts of largely irrelevant information. Ultimately, with increasing levels of automation over ever larger domains of activities, when something goes wrong the consequences rapidly approach the catastrophic (Wikipedia, 2006).

Ideally, problems arising in automated environments should be detected, diagnosed and fixed "automatically". To be really effective, automated systems must include predictive and real-time diagnostics, with error-correction capabilities that require little or no manual intervention.

In today's business environment, manufacturers are faced with the challenge of growing production demands with existing machinery and equipment, while continuing to cut costs. The most pervasive cost that drags down productivity improvements is unplanned equipment and manufacturing process downtime (Keyif, 2004). Therefore, a company which is totally dependent on automation is also vulnerable to catastrophic results if there is a major breakdown in the system.

A manufacturer may use M2M (Machine-to-Machine) communication capabilities to remotely monitor its equipment to detect or predict potential failures, to schedule optimal preventive maintenance, and to track consumption of raw materials as an alternative to manual inspection by its technicians and equipment operators (http://en.wikipedia.org/wiki/Automation). However, this effort can be too costly and sometimes technically unfeasible.

**2.4.2.2 Sustainability (TS) – through Availability of Specialized Workforce**

Skills needed for emerging technologies are demanding, requiring personnel with advanced qualifications in the respective fields. A mismatch between the requirement by industry and availability of graduates has led to a situation of graduates not being equipped with the appropriate qualifications to be readily absorbed by the industry, particularly in areas of product development and process improvements (3rd Industrial Master Plan Report, MIDA).

As the manufacturing sector continues to expand, manufacturers are more reliant on a high-performance workforce, and that qualified workers are getting harder to find (Engler, March 2006). In the real world, situations constantly arise that call for human intervention. When the so-called "automated" machine malfunctions, experts have to be summoned to troubleshoot the problem. But, this expertise is scarce and often not available when problems occur. Often resulting in production interruptions due to unscheduled or unplanned downtime.

The role of skilled and specialized personnel in a successful implementation and operations of an automation system cannot be overstated. Many companies fail to address this important issue as human resource factors such as training and education. These have tremendous influence on the outcome of any sizeable automation project. The work scope of these personnel would cover activities from system design, implementation and maintenance to minimize unscheduled interruptions over its lifespan.

In a highly mechanical and automated environment, preventive maintenance (PM) must also be regimented in order to minimize unscheduled interruptions and potential yield loss to the production line. This again requires trained technicians to be available to conduct the required work diligently.

### 2.4.3 External Factors

In a global market, there are three keys that constitute the winning edge for manufacturing and service-related industries (Pinto, 2003):

a) Proprietary products: developed quickly and inexpensively
b) High-value-added products: proprietary products and knowledge offered through effective global service providers, tailored to specific customer needs.
c) Global yet local services: the special needs and custom requirements of remote customers must be handled locally, giving them the feeling of partnership and proximity.

#### 2.4.3.1 Market Expectations (ME)

Customers have become ever more demanding. They are more interested in the level of customization that the seller can offer to meet their specific needs and less interested in 'off-the-shelf' items. Phillip Kotler described the new environment as being so different from before, that companies 'must turn from a make-and-sell philosophy to a sense-and-respond philosophy'. In other words, what matters to the seller must be whatever matters to the customer.

Expanding on the points mentioned above by Kotler and Pinto (2003), it can be said that for a manufacturer to be successful in the global market, it must be able to offer a product that meets all expectations of each individual customer, anywhere in the world, in the quickest and cheapest way possible. On top of this, customers like to feel assured that the goods will be delivered as promised without surprises. Sometimes, visibility to the product's status takes place even while the product is still undergoing the manufacturing process (i.e. WIP movement through the manufacturing line), as though the customers are virtually manufacturing their ordered products themselves.

To back Philip Kotler's description of the current market trends, The Aberdeen Group, a manufacturing analyst firm states that, at "Best-in-Class" companies, these major systems investments are being extended into integrated platforms designed to "sense, detect, analyze, and respond" in real-time. Industrial control platforms, from which real-time data emanates and through which production decisions are executed, are providing a foundation upon which forward-thinking manufacturers can proactively manage their operations.

Apart from superior customer service, compliance with standards and industry norms has to be considered as part of market expectations. There are significant lessons to be learnt from the implementation of automation in the semiconductor industry. One of which is that it exemplifies the importance of defining standards and protocols for large-scale automation to be possible (Slocum, 2002).

Standards are intrinsically difficult to implement and adopt. Standards provide interoperability and reduce overdependence on any specific supplier. Conflicting standards have negative effects on everyone. The potential users of the automation systems may postpone purchases of the system(s) to see how the market settles to the different standards. Suppliers may also limit development investments in products until there is better certainty on which way the industry is moving.

#### 2.4.3.2 Government Incentives (GI)

In the Malaysia Third Industrial Master Plan (IMP3), the government has outlined measures to be undertaken to strengthen the institutional support for the further development of the Electrical and Electronics (E&E) industry. One area is the establishment of support schemes, whereby, a comprehensive package will be formulated to assist public research institutes and encourage private sector participation in the growth initiatives, which among other things include productivity improvements through mechanization and automation.

## 2.5 Theoretical Framework

This is an exploratory research to determine whether the dependent variables represented by Management Issues (Economic Justification (EJ), Social Implications (SI) and Strategic Consideration (SC)), Technical Feasibility (Implement ability (TI) and Sustainability (TS)) and External Factors (Market Expectations (ME) and Government Incentives (GI)) differ among semiconductor manufacturers with high and medium levels of factory automation. The theoretical framework is made up of these variables and their relationship is depicted in Figure 2.3.

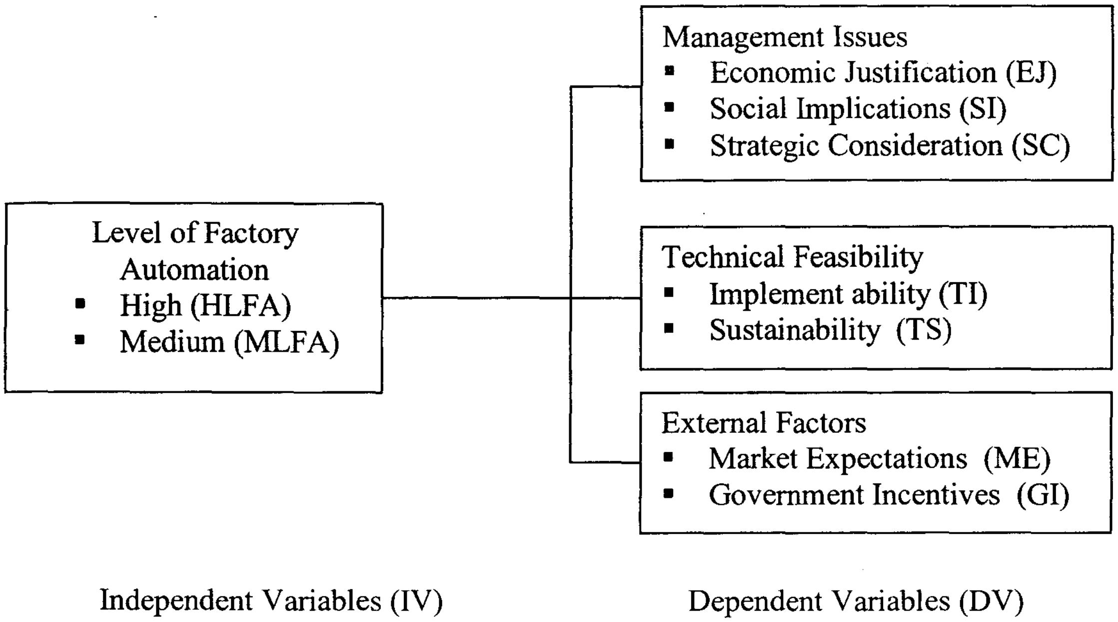


*Figure 2.3* Theoretical Framework

Summary description of variables:

(1) Economic Justification (EJ) – this includes considerations for Total Cost of Ownership (TCO), Return on Investment (ROI), Accounting standards, etc.

(2) Social Implications (SI) – willingness of workforce to adapt to changes

(3) Strategic Considerations (SC) – this includes Management's focus on long-term benefits and to building positive perception among the stakeholders

(4) Implementability (TI) – this refers to the availability of suitable technical solutions – either Commercially-off-the-shelve (COTS) or customized designs for a particular environment.

(5) Sustainability (TS) – Ability or availability of skills and infrastructure to implement and sustain the automation systems

(6) Market Expectations (ME) – in terms of meeting customer demands for better product quality and service levels

(7) Government Incentives (GI) – such as financial grants, tax relief, subsidized training, etc.

## 2.6 Research Hypotheses

From the discussions presented in the theoretical framework section, seven hypotheses are stated to test the differences in perception of various factors between companies with high and medium levels of factory automation. The hypotheses (H1-H7) are as follows:

H1: There will be significant differences in the extent of Economic Justification (EJ) between HLFA Factories and MLFA Factories

H2: There will be significant differences in the extent of Social Implications (SI) between HLFA Factories and MLFA Factories

H3: There will be significant differences in the extent of Strategic Consideration (SC) between HLFA Factories and MLFA Factories

H4: There will be significant differences in the extent of Implementability (TI) between HLFA Factories and MLFA Factories

H5: There will be significant differences in the extent of Sustainability (TS) between HLFA Factories and MLFA Factories

H6: There will be significant differences in the extent of Market Expectations (ME) between HLFA Factories and MLFA Factories

H7: There will be significant differences in the extent of Government Incentives (GI) between HLFA Factories and MLFA Factories

# Chapter 3

# METHODOLOGY

## 3.1 Introduction

The purpose of this project is to conduct an exploratory study on whether there are significant differences in the context of certain variables (Management, Technical and External) among semiconductor manufacturers with high and medium levels of factory automation. Reference is made to the theoretical framework discussed in the previous chapter. This chapter describes in more detail the research design, the variables and their measurements, data collection method, pilot test and finally the techniques and considerations for analysis.

## 3.2 Research Design

An exploratory study approach is proposed for this research since very few published studies are done specifically to address the research problem as earlier stated. Furthermore, the sample size is limited considering that the total population of this segment of the industry is small. The sampling methodology is covered in this section. The population of the study and the method used to determine the sample is discussed.

### 3.2.1 The Sample

The semiconductor industry can be defined in various ways. However, the main subject of this study is on companies directly involved in the semiconductor device-manufacturing portion of the value chain, as elaborated in Appendix B. Of the 46 companies in Malaysia