

UNIVERSITY OF KWAZULU-NATAL

***The impact of the convergence of
Information Technology and Industrial
Automation on operational excellence in the
Manufacturing Environment***

By

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A dissertation submitted in partial fulfilment of the requirements for the degree of
MASTER OF BUSINESS ADMINISTRATION

In the Graduate School of Business

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2007



DECLARATION

I hereby do solemnly declare that this dissertation is my own work and in cases where other people's work has been used it has been accordingly acknowledged. This dissertation has not been previously submitted for any other qualification in any other university.

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ACKNOWLEDGEMENTS

I would like to give my special thanks to my supervisor Professor Sam Lubbe for his guidance, constant encouragement and reassurance during the duration of writing this dissertation.

To all the industrial automation and information technology professionals whose participation was indispensable for the success of this research.

To SAB Prospecton Brewery General Manager Andrew Ferrett whose support during a busy year was unwavering.

Finally, I would like to thank my wife whose has unstintingly supported me throughout my studies, family, relatives and friends: whose continued support was absolutely necessary.

ABSTRACT

The need to increase productivity, improve quality and increase flexibility whilst continuously reducing costs is driving manufacturers to search for alternative means of converting the product idea into a manufactured product. Plant automation systems which are the nervous system and increasingly the intelligence of the plant have an integral role to play in this regard.

This study investigates the convergence between traditional IT and Industrial Automation with a view to understanding how this phenomenon will affect operational excellence within the manufacturing environment. The study further investigates the key determinants of success for automation systems within the broader business context and how this can lead to an advantage over competitors. The study is limited to manufacturing operations within the greater Durban area.

The results revealed that there is a clear relationship between industrial automation and information technology in manufacturing organisations. However, of interest is the fact that in the majority of the organisations surveyed the two functions operate as separate entities within the organisation resulting in overlaps of responsibility and accountability for key equipment and processes. Factory efficiency was found to be the key determinant of success in the majority of the organisations surveyed whilst the provisioning of production data when used strategically was found to have a positive effect in allowing the organisation to gain an advantage over its competitors. Due to the limitation of the short time frame allocated to this research, the study could not go in detail into the drivers of these findings consequently recommendations for further research is made.

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GLOSSARY OF TERMS

Application Protocol A protocol that performs a specific user purpose on top of a transport and network protocol (e.g. Ethernet\IP, SNMP, SMTP) (Panko, 2003)

Collision-based Ethernet is collision based when used with hubs as all clients share the same wire and a collision may occur when two or more clients attempt to speak at the same time (Panko, 2003).

Deterministic The ability to accurately define timing such as delays, jitter, etc. Ethernet is not a deterministic protocol because collisions cannot be predicted or avoided (Panko, 2003).

Ethernet The IEEE standard for communication over twisted pair, there are 10MBps, 100MBps and even 1GBps definitions. This is a “Link Layer” protocol (Panko, 2003).

Ethernet\IP and Ethernet\ Industrial Protocol The new open industrial application layer protocol developed by Rockwell\AB which uses TCP\IP for its network and transport. The protocol is not, as its name suggests, bound to Ethernet (Panko, 2003).

Factory Floor Firewalls The corporate firewall is not enough to protect the production network. Factory edge firewalls will be critical to maintaining the absolute security and protection of converged networks. The commonality of TCP\IP networking brings advantages but also vulnerability to hackers, viruses, and worms that could be deadly to TCP\IP factory networks. Opponents of Ethernet on the factory floor raise these justifiable concerns, but the technology exists to protect from such dangers. Cooperation between IT and factory personal is essential to manage this risk (Panko, 2003).

Industrial Control Protocols Ethernet and TCP\IP themselves do not perform any application function. They represent the link and network layers that enable common equipment, transport, and routing capabilities. Application protocols defined for specific tasks are needed to do useful things. While converged networks can take advantage of the many application protocols in use today such as HTTP (Hypertext Transfer Protocol), FTP (File Transfer Protocol), SNMP (Simple Network Management Protocol) and NTP (Network Transfer Protocol), these are not designed for control or real-time applications.

Ethernet/IP and Profinet are two examples of new TCP/IP application protocols specifically designed to address control networks found in SCADA (Supervisory Control and Data Acquisition) applications. A truly converged network will take advantage of all of these protocols to accomplish different tasks (Panko, 2003).

Information Technology (IT) is a broad subject concerned with the use of technology in managing and processing information, especially in large organisations. In particular, IT deals with the use of electronic computers and computer software to convert, store, protect process, transmit, and retrieve information (Panko, 2003).

Industrial Automation (IA) is the use of control systems such as programmable logic controllers (PLC's) and computers to control industrial machinery and processes, replacing human operators. In the scope of industrialisation, it is a step beyond mechanisation. Whereas mechanisation provided human operators with machinery to assist them with the physical requirements of work, automation greatly reduces the need for human sensory and mental requirements as well (Panko, 2003).

Networking Equipment 100 Megabit (MB), switched-Ethernet forms the keystone of the factory network. The speed far exceeds almost that of any prior control network technology. If 100 MB is not fast enough, low-cost 1G is already available. Mounting, industrialised specifications, and power input comprise most of the primary differences in switching gear for the factory and traditional IT gear (Panko, 2003).

Protocol A common language used between two systems (could be a link layer protocol such as Ethernet or a software protocol such as IP, TCP, or http of the web) (Panko, 2003).

Router-based Network A network that separates traffic using routers to form "subnets" Traffic across routers gets queued; therefore it is not as deterministic as in the case of switches (Panko, 2003).

Switch-based Network A network that utilizes Ethernet switches as opposed to routers. Switches can eliminate collisions by isolating each Ethernet client (Panko, 2003).

TCP/IP and Transport Control Protocol\ Internet Protocol The "network" and "transport" layer protocols used on the Internet and almost every LAN in the world today (Panko, 2003).

LIST OF ABBREVIATIONS

CAD – Computer Aided Design	NTP – Network Transfer Protocol
CAE – Computer Aided Engineering	OEE - Overall equipment effectiveness
CAM – Computer Aided Manufacturing	OPC – Ole for Process Control
CBM – Condition Based Maintenance	OSI – Open Systems Interconnect
CIM – Computer Integrated Manufacturing	PLC – Programmable Logic Controller
DCS – Distribute Control System	QoS - Quality of Service
DMZ - Demilitarized Zones	RAS - Remote access servers
EBITA - Earnings before Income Tax and Amortisation	RFID – Radio Frequency Identification
EDP - Electronic Data Processing	SCADA – Supervisory Control and Data Acquisition
EPM – Enterprise Performance Management	SMS – Short Message Service
ERP – Enterprise Resource Planning	SNMP – Simple Network Management Protocol
FMCG – Fast Moving Consumer Goods	STP - Spanning Tree Protocol
FTP – File Transfer Protocol	TCP/IP - Transmission Control Protocol/Internet Protocol
HMI – Human Machine Interface	TFTP - Trivial File Transfer Protocol
HTTP- Hypertext Transfer Protocol	TOP – Technical and Office Protocols
IA – Industrial Automation	UPS – Uninterruptible Power Supply
ICT - Information and Communications Technology	VLAN – Virtual Local Area Network
IT – Information Technology	WAN – Wide Area Network
KPI – Key Performance Indicator	
MAC Address – Media Access Control Address	
MAP – Manufacturing Automation Protocol	
LAN – Local Area Network	
MES – Manufacturing Execution System	
NAT - Network address translation	
NMS – Network Management System	

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

The manufacturing sector has been a strong and consistent contributor to the economic vitality of South Africa (SA). With the onslaught of imports from foreign manufacturers who have a cost advantage in either labour or natural resources, it is increasingly difficult for SA based manufacturers to maintain market share and retain current levels of employment. It is apparent that the advantages of the overseas suppliers will only be overcome through a concerted effort that improves the efficiency of South African operations while providing high-quality products at a comparable price (Sean, 2006).

The need to increase productivity, improve quality and increase flexibility all of this while reducing costs is driving manufacturers to search for alternative means of converting the product idea into a manufactured product. Plant automation systems which are the nervous system and increasingly the intelligence of the plant have an integral role to play in this regard (Zurawaski, 2005).

The past five years has seen the convergence of a number of previously independent areas of specialisation within the broad realm of Information Technology (IT). The online dictionary defines convergence as the coming together of two or more disparate disciplines or technologies (Goslak, n.d.). An example of this would be the fax revolution which was produced by a convergence of telecommunications technology, optical scanning technology, and printing technology.

The professional discipline of Electrical Engineering historically could be separated into two main areas of specialisation that of high current or power engineering and that of Light Current or Electronic Engineering. The latter was further broken down into the following fields of specialisation electronics, telecommunications, control systems, instrumentation and computer engineering (Smith & Reinertsen, 1992).

By the early 1980's it was agreed that the information and communications technology were closely linked and hence the term Information and Communications Technology or ICT first started to appear. During this convergence, however, control systems and

industrial control systems in particular were kept separate from the business network via the use of completely disparate networks that were designed, installed, maintained and managed separately and by separate teams in the same organisation (Zurawski, 2005).

In today's competitive and dynamic manufacturing environment, however, there is a critical need to complete the manufacturing supply chain by linking the manufacturing system to business applications, by integrating multi manufacturing sites operating disparate control systems and by offering transactional integration between manufacturing and other supply chain applications (Goslak, n.d.).

In this study the convergence between traditional IT and Industrial Automation is investigated with a view to understanding how this phenomenon will affect operational excellence within a manufacturing environment and in so doing provide a competitive advantage to the organisation. The study is limited to manufacturing operations within the greater Durban area.

This introductory chapter consists of eight subsequent sections that serve to introduce the research topic as well as to detail how the research is intended to be conducted. The following section details the background to the research, identifying the organisation on whose behalf this research is conducted and pertinent information about that organisation related to the research topic is provided. The motivation for the research is specified followed by the statement of problems, the value of the study and the research methodology. The final sections in this chapter include the limitations of the study, the structure of this document and a concluding chapter.

1.2 Background of the research

1.2.1 The South African Breweries Ltd – Prospecton Brewery

The principal activity of the South African Breweries Ltd (SAB) is the production, marketing and distribution of beer throughout South Africa, representing approximately 98 per cent of all beer sold in South Africa. SAB is part of the London based and listed holding company SABMiller plc and forms approximately 39% of the groups Earnings before Income Tax and Amortisation (EBITA) (SABMiller Annual Report, 2006).

Prospecton Brewery is one of the 7 (seven) SAB breweries in South Africa which in total produce over 30 million hectolitres of beer per annum. It is situated along the south coast of Kwa-zulu Natal at Jeffels Road in the Isipingo industrial area of Durban. Prospecton brewery employs 307 permanent employees and operates continuously twenty-four hours a day throughout the year producing approximately 5.3 million hectolitres of beer per annum. It is the main source of beer supply to all of Kwa-zulu Natal as well as to the northern parts of Eastern Cape. The brewery has two brew houses with the third under construction, and five packaging lines (SAB Annual Report, 2006).

SAB during the 1970's experienced huge growth across the country and as a result invested heavily in new breweries. Prospecton was built during this era in September 1974 and brew Castle Lager, Castle Draught, Castle Milk Stout, Hansa Pilsener, Amstel Lager and Redds Premium Dry and Cold. Products are packaged in returnable bottles (750ml and 660ml Quarts), non-returnable bottles (340ml and 360ml), cans (340ml) and kegs (50L and 30L) on five bottling lines (SAB Annual Report, 2006).

1.2.2 Company Culture

1.2.2.1 Vision and Mission

SAB Ltd's vision is to be the most admired company in South Africa. Their mission is to own and nurture local and international brands which are the first choice of the customer (.

It is important to understand the values of the company to be able to understand the culture of the organisation.

1.2.2.2 Values

The values were arrived at after a highly participative process with senior management, which resulted in focus on five key values. They are as follows:

- Our people are our *enduring* advantage
 - The calibre, passion and commitment of our people set us apart
 - We value and encourage diversity
 - We select and develop people for the long term
 - Performance is what counts
- Accountability is clear and personal

- We favour decentralised management and a practical maximum of local autonomy
- Goals and objectives are aligned and clearly articulated
- We prize both intellectual rigour and emotional engagement
- We are honest about performance
- We require and enable self-management
- We work and win in teams
 - We actively develop and share knowledge within the group
 - We consciously balance local and group interests
 - We foster trust and integrity in internal relationships
 - We encourage camaraderie and a sense of fun
- We understand and respect our customers and consumers
 - We are endlessly concerned with our customers' needs and perceptions
 - We build lasting relationships, based on trust
 - We aspire to offer the preferred choices of product and service
 - We innovate and lead in a changing world
- Our reputation is indivisible
 - Our reputation relies on the actions and statements of every employee
 - We build our reputation for the long term
 - We are fair and ethical in all our dealings
 - We benefit the local communities in which we operate

1.2.2.3 *Corporate Brand Essence*

- Leadership by example

1.3 Motivation for the research

The seven breweries that make up the manufacturing arm of SAB Ltd compete amongst each other for production volume on the basis of rands per hectolitre of beer produced and delivered to the customer as the ultimate measure. If Alrode brewery in Alberton, Southern Johannesburg can produce beer and deliver it to Northern Kwa-Zulu Natal cheaper than Prospecton Brewery can, central planning will allocate Alrode the volume to produce at a loss to Prospecton.

The additional volume to Alrode has the effect of increasing their operational efficiencies due to economies of scale and hence profitability whilst the opposite effect is felt at Prospecton where the operating costs remain the same and the production volume decreasing thereby increasing the cost per hectolitre and having a negative effect on profitability.

At present the company is undertaking a major IT re-organisation project called the National Information Technology Operating Model (NITOM). The results of this study will inform the decisions taken around the nature of IT in the regions and the structures thereof as part of the NITOM project whilst considering the pressures on continuously reducing operating costs.

1.4 Statement of problems

Leveraging plant automation data at the enterprise level is now vitally strategic (Smith, 2006a). A convergence of business pressures is creating a unique set of circumstances that stands to alter the role and function of control engineering in the plant. Control engineering's historic charter, to ensure the safe and efficient operation of the plant, has kept it an island unto itself for years. Automation equipment and systems and the data they generated were primarily for use by automation experts. Management interested in those data had to pick up the phone or wait to glean it from a report (Smith, 2005).

Rogge (2006) states that organisations will be able to differentiate themselves from their competitors by providing real time production information about operational processes which is increasingly key to competitiveness as product differentiation is marginalised by competition. Due to increasing regulatory mandates and escalating global competition eroding margins and shrinking cycle times, enterprise-level management wants real-time access to automation data to drive real-time strategic decisions. Key motivators are the need to preserve margins, speed the order-to-cash cycle, and maximise demand opportunities and return on assets (Smith, 2006a, Smith, 2006b, Rogge, 2006 & Greenfield, 2006).

A recent AberdeenGroup (2006) study, found better performing manufacturers were leveraging real-time plant data in boardroom decisions. The reality of the gap also was

highlighted. O'Hearn (2006) notes that sixty percent of the respondents to the study cited the gap between ERP and the shop floor as a major barrier to achieving their performance objectives.

Automation vendors also are designing and engineering comprehensive overarching architectures and integration platforms. Tock (2004) reports that when Wonderware first launched their open data connections software platform ArchestrA the focus was more around control system integration and since then during the last two years the focus has clearly shifted to an IT focus.

There may be many reasons for this change of direction, however, Greenfield (2006) notes that two issues loom largest: regulations and competition. From Sarbanes-Oxley (2002) to the TREAD Act (2000), the continued existence of a manufacturing operation is directly tied to its ability to verify that its production operations are in step with government regulations. Data proving compliance often must be transferred out of the plant environment and logged in a system accessible and understandable to the corporate personnel who deal directly with regulators (Le Plasterier, 2005c).

Competitively, manufacturers everywhere are in a fight for existence. Margins are razor thin for many products and most of the larger operations have already reaped the bulk of benefits to be gained from Lean and Six Sigma initiatives (Gunasekaran, 1999). What remains is greater productivity increases enabled through data extraction-enabled innovation. In other words, manufacturers must improve what previously could not be improved further without the benefit of proper manufacturing data, selected and presented in the most useful manner (Greenfield, 2006).

In the new and different business environment of the 21st century, the companies that can adapt, innovate and utilise global resources will generate significant growth and success. It is clear that automation within the manufacturing environment is set for a change of its role and function within the business in order to afford the organisation greater flexibility. The challenge however lies in the ability of automation to drive innovation through greater access to information and in so doing increasing productivity and delivering greater returns (Zurawski, 2005, Smith, 2006b & Greenfield, 2006).

1.5 Value of the Study

Historically the traditional IT systems and infrastructure have remained independent of and separate from the automation systems and infrastructure in the manufacturing environment (Ismat, n.d.). The negative implications of this for the business as noted by the different references have been consolidated below as follows.

- i) Increased costs in the maintenance of separate and disparate networking and communications infrastructure (Leidigh, 2005).
- ii) Difficulty in managing and maintaining a production environment controlled by disparate automation systems thereby adding increasing complexity (Nagalingam, 1999).
- iii) Inability to integrate business and automation systems resulting in difficulty in reconciling financials throughout the value chain and real time costing of the production process (Scheepers, 2006).
- iv) Inability to integrate multiple manufacturing sites with differing and proprietary systems – no scalability (Tweedie, 2005a).
- v) Inability to integrate manufacturing into the entire business value chain (Smith, 2005).
- vi) Difficulty in attracting and retaining skilled specialist resources in support of the separate systems (Johnston & Wray, 2003).

The integration of Automation systems and infrastructure with traditional IT will have some drawbacks that must be considered in the investigation. Some of the implications of this will be as follows:

- i) Greater security risk to production as traditional IT systems are at greater security risk from hackers and viruses (Tindill, 2005, Le Plasterier, 2005b).
- ii) The need to create cross-functional teams that include IT personnel as well as experts in plant systems (Le Plasterier, 2005a).

In the new and different business environment of the 21st century, the companies that can adapt, innovate and utilise global resources will generate significant growth and success (Pinto, 2004). This investigation aims to provide some answers in terms of how traditional

IT and Industrial Automation should be managed in order to afford the organisation greater flexibility, the ability to provide innovation and in so doing increase productivity and deliver greater returns.

1.6 Research Methodology

This research will be qualitative in nature and will make use of survey strategies, sample analysis instruments as well as the examination of secondary data to achieve its outcomes. It is both explanatory and analytical in nature because it seeks first to find out the nature of the relationship between traditional IT and plant automation and secondly to determine how the two should interact so as to improve the performance of manufacturing organisations and in enhancing the organisation's advantage over its competitors.

The survey strategy is used in this research project as the primary data collection method and as such the development of the research instrument is detailed in chapter three. Two types of questionnaires are used in this research project; self administered that is sent to potential candidates via email for them to complete and return to the researcher. The second option, interviewer administered was offered to particularly busy individuals to have the survey performed telephonically using the same questionnaire filled out by the researcher based on participant responses.

Excel was chosen as the application in which to develop the questionnaire as its interface is familiar to professionals in the IT or IA fields. Excel also easily facilitates multiple selection questions and validation of responses which increases the correctness of the responses. These technologies were utilised in the questionnaire design.

The responses were captured and collated in a consolidated format that is to be used in SPSS for analysis purposes.

1.7 Structure of the Study

The research comprises of six chapters. The chapters are laid out to give a clear view of understanding the research topic and related theoretical material, analysis of the collected

data and conclusion provides recommendations on how IT and plant automation structures within a manufacturing organisation will need to operate in order to improve the overall performance of the organisation.

1.7.1 Chapter One: Introduction

This chapter presented the research problem, background to the research, statement of the problem and the value of the study, details the research methodology to be followed as well as the limitations of the project.

1.7.2 Chapter Two: Literature Review

Chapter two gives the detailed theoretical background of the key concepts that required in-depth knowledge in completing the study as revealed by different authors. Previous research conducted in this field is also reviewed. The literature review is essential because it helps to demonstrate awareness of the current state of knowledge on the subject as well as to reveal opportunities for further research on the subject.

1.7.3 Chapter Three: Research Methodology

The research methodology presents an account of how the research was carried out. It describes sampling, data collection, analysis and processing. Data was collected using questionnaires, observation as well as secondary data. It also includes: the validity, reliability, and ethical considerations of the study.

1.7.4 Chapter Four: Research Results and Discussion

This chapter comprises of the presentation of research results, analysis and discussion of the data collected using the data collection instruments. The results were generated after processing data using a statistical package SPSS as mentioned in the research methodology. In addition, the results obtained form the basis for the recommendations made after the data analysis and discussion in this section.

1.7.5 Chapter Five: Recommendations and Conclusion

Chapter five comprises of the limitations of the study, recommendations for further research as well as drawing the conclusion from the research findings with emphasis on the implementation of IT and plant automation systems in manufacturing organisations.

1.8 Conclusion

This chapter has introduced the research topic by presenting the current environment in which manufacturing organisations in South Africa are operating and in so doing identifying the constraints and hence opportunities for improvement. The background to the study is presented to position the research in terms of the organisation that will be the recipient of the findings and the reasons or motivation for the research within that organisation. The details of the research problem are espoused in the section on the statement of the problem and the value of the study; details of the research methodology to be used as well as the limitations of the project have been outlined.

The following chapter on the review of the current literature will present the theoretical aspects of the study detailing key concepts and providing a critical review and comparative analysis of the major references on the topics under discussion that are related to the research problem.

CHAPTER TWO: REVIEW OF CURRENT LITERATURE

2.1 Introduction

The purpose of this chapter is to present the theoretical aspects of the study detailing key concepts and providing a critical review and comparative analysis of the major references on the topics under discussion that are related to the research problem. This is performed in a structured fashion using relevant and contemporary scholarly references organised within a concept matrix (Klopper & Lubbe, 2005). This section aids in definition of the research problem by identifying what has been resolved by prior research and funnelling the research process to the root problem to be investigated.

According to Smith, (2006b) leveraging plant automation data at the enterprise level has become a strategic competitive advantage for manufacturing operations. However, control engineering and automation has kept itself an island upon itself to ensure the safe and efficient operation of the plant and preventing outside interference that could compromise this. Furthermore, due to increasing regulatory mandates and escalating global competition enterprise-level management requires real-time access to automation data to drive real-time strategic decisions. Key motivators are the need to preserve margins, speed the order-to-cash cycle, maximise demand opportunities and return on assets (Smith, 2006b, Rogge, 2006 & Greenfield, 2006).

A number of independent sources were used in compilation of this section of the study including electronic databases; OPAC, online search engines; Google Scholar and online electronic journals. The following search terms were used in searching for references related to the problem statement; Present day role of automation in manufacturing, convergence IT and automation, real-time production information, enterprise integration, shop floor to ERP gap, control system integration and computer integrated manufacturing.

This literature survey is organised in a structured fashion beginning with the key concept of computer integrated manufacturing which serves to provide a history of how computers and automation have found their way into manufacturing and as such sets the background for the study. Industrial automation is then discussed at a high level indicating the benefits to the user as well as the manufacturer of networked intelligent devices. Networks which

are the fundamental medium that interconnects devices and that which makes industrial automation possible is discussed followed by field instruments and the role they play in being the senses to the plant automation system. Enterprise integration, organisational impact, security, key performance indicators and a review of how information can provide an organisation with strategic competitive advantage complete this section.

2.2 Computer Integrated Manufacturing (CIM)

2.2.1 Background: Drivers towards CIM

The computerisation of manufacturing results from the convergence of two trends. The first and most obvious is the technological progress in microelectronics and nano-electronics resulting in improvements in sensing, data processing and controls. The second trend that has driven the case or demand for CIM has been the need for greater flexibility in the manufacturing process (Ayres, 1991).

The inflexibility of mass production technology is well known, however, as manufacturing has become more efficient and more capital intensive over the years the cost of product change has progressively risen and the rate of technological innovation in the mass production sectors by contrast has slowed down. Since computers are by nature programmable it is generally assumed that the computerisation of manufacturing functions is tantamount to introducing greater programmability of production operations. Programmability in this sense is a prerequisite of flexibility. However, in greater reflection the linkages between computerisation and flexibility are less solid than they appear to be. Certainly the importance of operational flexibility cannot be over emphasised, however the proposition that computers increase flexibility *ipso facto* is not a given (Ayres, 1991).

2.2.2 Complexity versus Variety

The demand for ever higher performance has forced products themselves to become increasingly complex and precise. Technological progress in the direction of superior performance has generally been accompanied by increased complexity of both products and processes. Increased complexity of products increases the relative importance of assembly in manufacturing. It was the difficulty in assembly that first created the need for

inter-changeability of parts in the early nineteenth century. This in turn led to the powerful drive towards the standardisation of design and manufacturing processes. This trend also resulted in significant economies of scale that enabled manufacturers to cut their costs very sharply towards the end of the nineteenth century and in the first decades of this century (Porat, 2002).

The problems of large-scale production of standardised products led to an organisational structure and philosophy of extreme specialisation and division of labour that was relatively unsuited to small-scale production of non-standardised or customised products. It was also inflexible in the sense of being very capital intensive and thus poorly adapted to respond to unexpected changes in market conditions or technology (Nevins & Whitney, 1998).

As personal disposable incomes have increased with general economic growth and markets have globalised, demand for product variety and “customisation” have increased much faster than the demands for standardised products. In effect customers are prepared to pay a significant premium for greater choice. Manufacturers in most countries facing much stronger competition have no real choice but to satisfy that demand by offering greater choice. However variety does not come at zero cost since variety can only be achieved by sacrificing economies of scale to some extent (Ayres, 1991).

The major manufacturers have to a large extent become “systems integrators” providing only some of the more specialised parts and final assembly of subsystems from a network of suppliers. Their major economic role is design, marketing, and service not production per se (Gihl, 2005).

It has become clear that the product life cycle is getting shorter with the main evidence being the recent experience in the semiconductor industry where major new products are now introduced roughly every three years as compared with cycles of five to seven years or more in past decades (Smith & Reinertsen, 1992).

The combined effect of increasing product complexity together with increased variety on manufacturers has been to create a massive problem of information management and coordination. The response of most firms has been to computerise many individual

functions *ad hoc* without serious planning for their interaction with each other. As a direct consequence of this trend toward increasing complexity-plus-variety, information-based activities now constitute a growing fraction of all activities, both within individual manufacturing forms and in the economy as a whole (Ayres, 1991).

The result of the haphazard and *ad hoc* computerisation of many specific tasks without adequate provision for upstream and downstream consequences is information overload as the information output of the computerised functions can easily overload humans resulting in an increasing amount of “garbage information” or simply noise in the system which is costly to detect and correct (Hiltz & Turroff, 1985).

Another impact of increasing complexity and variety on manufacturers, whose extent has not widely been recognised yet has been to create an acute problem of quality control. Inspection, rework and after sales service account for an increasing fraction of total costs which could be eliminated in principle if there were no errors or defects in the manufacturing process. However, it is well known to the industrial engineering fraternity that most product defects result from human errors either in design and engineering or fabrication as errors resulting from mechanical failures are comparatively infrequent and comparatively easier to identify (Ayres, 1991).

The human propensity to make errors is inherent but can be reduced by sophisticated ergonomics: training, motivation and sophisticated work place design. But “to err is human” (Pope, 1774) so the probability of error cannot be eliminated. However, human design/engineering errors can be sharply reduced by the use of computers for assistance in those processes (CAD/CAE). Errors in machine operations and assembly can also be reduced sharply by using computers for controlling the manufacturing process (CAM) and can be cut virtually to zero as human workers over time are moved out of on-line functions.

The implication of the above is that the real motivation for introducing CIM is to simultaneously achieve flexibility (to respond quickly to market demands) and to improve quality control. Consumers in the wealthier countries are increasingly insisting on combinations of variety and quality that are more and more out of reach to traditional (i.e. manual or mechanised, but not computerised) manufacturing technology. This trend means

that it is becoming increasingly difficult for a manufacturer based in a third world country to exploit low labour costs as a basis for competitive advantage in developed markets at least for complex products such as automobiles, aircraft and capital goods. Hence manufacturers without CIM and all it implies will not be able to achieve the levels of product quality that will be demanded (Ayres, 1991).

A further implication of the reasoning is that export-based economic development strategies adopted successfully by Japan amongst others is not likely to be usable in the future by developing countries. Even though they may already have manufacturing abilities using labour-intensive means this may not automatically translate into an ability to make automobiles, aircraft and sophisticated computer and telecommunications systems. Rather small and medium-sized firms in these countries may be effectively limited to producing the less complex consumer products or sub assemblies (such as printers and keyboards) or both as sub contractors to big firms in Japan, Europe or North America. To be fully competitive across the whole range of sophisticated manufactured products will necessitate a commitment to capital-intensive, computer-controlled, virtually unmanned production facilities that will be very difficult to justify politically in countries with large pools of unskilled labour (Ayres, 1991).

2.2.3 CIM and the Systems View of Manufacturing

CIM has been deemed revolutionary in the words of Merchant (1989) one of the pioneers of the CIM concept “it is a wholly new approach to the operation of manufacturing in its entirety...that...offers enormous potential to improve manufacturing capability and cost effectiveness.” While there are many different definitions of CIM a formal definition from the Digital Equipment Corporation is as follows:

CIM is the application of computer science technology to the enterprise of manufacturing in order to provide the right information to the right place at the right time, which enables the achievement of its product, process and business goals.

The key to CIM therefore is the integration of manufacturing and office functions both off-line and on-line. This concept dates back to the 1960's (Merchant, 1989) and was a natural consequence of the emerging realisation that manufacturing is in fact a system rather than a collection of unrelated activities linked by a common end product or a common corporate

owner. What differentiates a “system” (in the technical sense of the word) from such a collection is the interdependence of the components. Figure 1 displays the systems view of CIM in a diagrammatic form (Merchant, 1989). The importance of the interdependence is clear from the diagram, although the relationships are oversimplified.

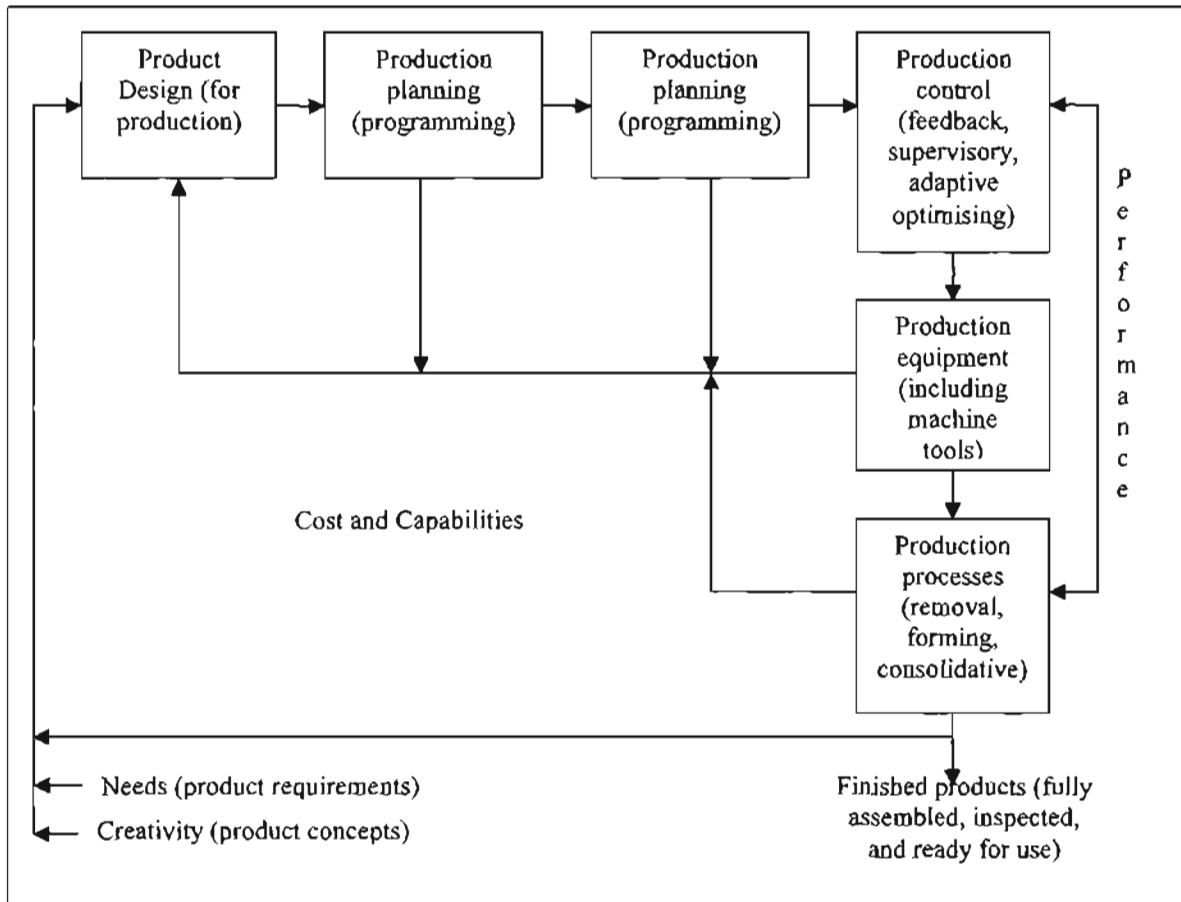


Figure 1: Concept of the computer integrated manufacturing system.
Source: Merchant, 1989.

It is said of the natural environment that there is an interdependence and casual relationship between the different systems. This may not be literally true for a manufacturing system but it a far more apposite than the converse. Yet it is the converse proposition that every activity in manufacturing is independent of every other activity that underlies the guiding philosophy of most industrial management during most the century – Taylorism. Thus in a very fundamental sense CIM is antithetical to and incompatible with Taylorism, specialisation and division of labour which is in fact counterproductive (Merchant, 1989).

CIM also has a critical technological component, namely the increasingly explicit (an increasingly digitised and computerised) knowledge base underlying many of the processes

and substitution of explicit decision algorithms implemented on electronic computers for many judgemental (an error prone) micro-scale decision processes formally made exclusively by humans. So the implementation of CIM involves the substitution of computers for humans in those non-repetitive functions such as on-line activities, while retaining humans in those non repetitive functions (such as conceptual design, planning, problem diagnosis, and trouble shooting) where human capabilities are still irreplaceable and will continue to be so for the foreseeable future (Merchant, 1989).

2.3 Industrial Automation

The concepts of CIM and the implementation thereof in the 1960's have today evolved into the field of industrial Automation that is dominated by proprietary technology and is subsequently governed by proprietary standards that prevents integration of differing and independent systems operating in the manufacturing environment.

In the past, factory automation and process control related to plant and machinery that was big, bulky, static and which represented several years, if not decades, of investment. Industrial automation hardware ranged from programmable controllers (PLCs) to large distributed control systems (DCS) with a sprinkling of PCs for the interfaces. Today, the tools of discrete automation and distributed controls are merging, with PLCs becoming front-end I/O controllers and networked PCs taking over the DCS environment (Pinto, 2005a).

Over the past few decades, some innovations have indeed given industrial automation new surges of growth: The PLC developed by Dick Morley and others of Bedford Associates of Boston, Massachusetts was designed to replace relay-logic in response to the needs of the American automotive industry which require changes to its systems on a regular basis due to model changes (Wikipedia, 2006); it generated growth in applications where custom logic was difficult to implement and change. The PLC was a lot more reliable than relay-contacts, and much easier to program and reprogram. The PLC has had a long and productive life spanning three decades and understandably has now become a commodity (Pinto, 2005b).

At about the same time that the PLC was developed, another surge of innovation came through the use of computers for control systems. Mini-computers replaced large central

mainframes in central control rooms, and gave rise to "distributed" control systems (DCS), pioneered by Honeywell with its TDC 2000 in 1975 (Honeywell, 2006). However, these were not really "distributed" because they were still relatively large clumps of computer hardware and cabinets filled with I/O connections (Gordon, n.d.).

The arrival of the PC brought low-cost PC-based hardware and software, which provided DCS functionality with significantly reduced cost and complexity. There was no fundamental technology innovation here rather, these were innovative extensions of technology developed for other mass markets, modified and adapted for industrial automation requirements (Wooldridge, 2005).

Automated factories and processes are too expensive to be rebuilt for every modification and design change so they have to be highly configurable and flexible. To successfully reconfigure an entire production line or process requires direct access to most of its control elements such as switches, valves, motors and drives down to a fine level of detail.

2.3.1 The fully automated factory

A number of different references quote the vision of fully automated factories: customers order online, with electronic transactions that negotiate batch size (in some cases as low as one), price, size and colour; intelligent robots and sophisticated machines smoothly and rapidly fabricate a variety of customised products on demand (Pinto, 2004, Wooldridge, 2005 & Gordon, n.d.).

The promise of remote-controlled automation is finally making headway in manufacturing settings and maintenance applications. The decades-old machine-based vision of automation being powerful super-robots without people to tend them underestimated the importance of communications (Cutler, n.d.). But today, this is purely a matter of networked intelligence which is now well developed and widely available.

Communications support of a very high order is now available for automated processes: many different types of sensors, very fast networks, quality diagnostic software and flexible interfaces all with high levels of reliability and pervasive access to hierarchical diagnosis and error-correction advisories through centralised operations (Messe, 2006).

The large, centralised production plant is a thing of the past. The factory of the future will be small, movable (to where the resources are, and where the customers are). For example, there is really no need to transport raw materials long distances to a plant, for processing, and then transport the resulting product long distances to the consumer. In the old days, this was done because of the localised know-how and investments in equipment, technology and personnel. Today, those things are available globally (Pinto, 2003b).

2.3.2 Benefits of Industrial Automation

The benefits of industrial automation which results in networked, intelligent devices are many; however, it is important to keep in mind that there will be two separate groups of beneficiaries. Firstly, the users of the intelligent devices, and secondly their manufacturer and the benefits they derive will not always overlap. Obviously in some cases they will coincide, for example when intelligence allows the manufacturer to provide better customer service or improved maintenance. In other cases, such as extracting usage information in order to make a better product that the user might never purchase, these benefits will accrue primarily to the manufacturer (Miller, n.d.).

	Function	Benefit
User	More access to data using a Data Historian	Improved analytical powers, system optimisation for high productivity, world class performance
	Preventive maintenance	Less downtime, higher productivity
	Predictive metrics	Less waste during setup, greater flexibility in using multiple sources of supply
	Time stamped data	Necessary for optimising large and complex systems
	Knowledge integration	Real time information makes it possible to manage to business strategies on a

		day-by-day basis
Manufacturer	Remote diagnostics	Improved customer satisfaction, reduced service requirements
	Ability to collect data about customer use	Improved market research and design procedure, reduced warranty and liability exposure
	Product differentiation	Intelligence augments the core function of the device; has significant public relations value; will eventually become a necessity to stay in the market

Table 1: Function versus benefit of Industrial Automation to Users and Manufacturers
Source: Miller, n.d.

2.3.2.1 Data Historians

Providing historical information for simple machines is relatively easy. In the case of a water softener, to calculate the average water usage is a simple calculation that can be represented in a single text phrase. The same process for a citywide power grid monitoring system requires analysis of thousands of points simultaneously. As machines get more complex so do tools required for analyzing their data. For this purpose a software tool called an Historian can be used to retain the process details of all the points in their original fidelity. Historians have been deployed by progressive manufactures all over the globe to achieve world-class operational performance. (Miller, n.d. & Pinto, 2003a)

As systems are deployed to provide key process insights and allow users to better understand their processes and improve them, data gets refined. This refinement generates a need for even greater access to similar data from other machines that support the process. Although much of this data may not be gathered at the highest level, the ability to “drill down” when additional information is needed will provide an almost limitless resource for making process improvements (Miller, n.d.).

In certain cases the fact that so much data can be stored in the backend of the device may provide legal protection to the manufacturer. It will now be more possible than ever to prove when a malfunction took place and in many cases why. This will simplify processing warranty claims and even settling issues of legal liability. What insurer's call the 'moral hazard' will be reduced (Pinto, 2002).

2.3.2.2 Continuous Improvement Cycles

All this data is an endless source of identifying potential improvements in a process. In nearly all cases, the act of getting the information is the most time consuming and costly part of the continuous improvement cycle. Having all the data readily available from the beginning compresses the cycles in the improvement process enabling agility and responsiveness to market pressures and better implementations (Pinto, 2002)

2.3.2.3 Highly distributed networks

Born from PC technology and proliferated by the latest software development tools, the ability to connect intelligent devices has become a necessity. This poses a dilemma for most equipment manufacturers. Providing an "open platform" system exposes them to support problems, increased support costs and maybe even unhappy customers (Hugo, 2006).

On the other hand providing a secure method of analyzing machine metrics can lead to higher user satisfaction (and more sales). Microsoft® has done much to standardise the way systems communicate by providing layers of network infrastructures that let systems share data in a secured fashion. This will foster the ability of systems to share information with each other while limiting the access via standard security measures (Hugo, 2006).

2.3.2.4 Predictive metrics & methods

A major benefit of local historical data is that it enables a user to optimise and tune the local process for better results and reduced waste through better understanding of process fundamentals. This information can help understand the effect of process variables such as differences in materials, environment, personnel and machine wear. Once such differences are analyzed they can create predictive metrics to help prevent the problem recurring (Miller, n.d.).

Take the example of a laminating machine. The user gets materials from multiple suppliers based on availability, price, quality and terms. Slight adjustments for each vendor's material must be made in the "press" operation of the machine to laminate the materials correctly. A Historian on the machine after a few runs with materials from Vendor A would show that the pressure used in these batches had been within certain ranges. After a few more runs the user may be able to provide a statistical prediction of the pressure for the upcoming run based on the material mix of the product, eliminating defective product in the batch during setup (Miller, n.d.).

2.3.2.5 Knowledge integration

Collecting this knowledge is the first step. Sharing it with other systems such as MRP and ERP is another. The smooth flow of information in real time from the plant floor up to the business management systems used in the IT department will make the CFO's job that much simpler; it may be that quarterly reports will be replaced by daily reports (Pinto, 2001).

2.3.2.6 Historical Data in "real-time"

For many applications the information is only relevant for a specific time. Like the price of a stock, without knowing when the stock price was at a particular value it would be of little use. Historians provide a key role in the storage of time series data. Time stamped data makes it possible to determine exactly what happened when, an invaluable tool when examining the operation of a large and complex system (Miller, n.d.).

2.3.2.7 The ability to collect information about customer use

A sensitive area is collecting information about customers' use patterns. However, pervasive networking may provide manufacturers and their sales and support chain with useful marketing and product information via a live connection into the factory floor. Data received from sensors within the equipment both large machinery and smaller, embedded devices will lessen the need to conduct customer surveys during future product planning and design. Devices could be used for collecting and reporting usage information (Hugo, 2006).

The prudent supplier will ensure that they have buy-in and procedures for protecting the user's proprietary information before going ahead. It must be borne in mind that visionary adopters are the least likely to want to exchange information on their usage for certain

privileges with the supplier since they will be seeking a competitive advantage in adopting a proprietary improvement in their manufacturing or processing methods (Hugo, 2006).

2.3.2.8 Remote diagnostics

A major opportunity arises in improving the supplier's service quality. The ability to service an intelligent device remotely and head off technical problems is a clear practical advantage. A networked device can enable diagnostic data to be sent automatically to a technical support centre and components can be detected before they fail. Both warranty management and maintenance firms can be fed machine status information and the manufacturer gains far more detailed information about a machine's internal operations in the field than a customer survey would ever yield (Pinto, 2005a).

Combining the data from all the devices in the field in this way will allow analysis of operational parameter patterns that correlate to failures – such as calls to the technical support centre. Once determined, these patterns could then be used for preventative maintenance service offerings. Together, these factors make an individual machine a much more attractive proposition for the buyer whilst augmenting the supplier's revenues and operating efficiencies (Pinto, 2003b).

2.3.2.9 Product differentiation

Perhaps more important than anything else is the boost that the network dimension gives to the device in terms of brand differentiation. Initially, like most new technologies, intelligent devices are moving from visionary purchasers out to all categories of users. Economic benefits will need to be promoted as products spread to the mainstream market. In the near future though, the public relations value brought by the manufacturer's association with cutting-edge technology concepts is likely to be a significant value. As regards product differentiation, the integration with enterprise-wide SCADA/IT systems sets a product apart, providing the user with services beyond its primary function and more importantly, augmenting the core functions of the product (Miller, n.d.).

2.4 Networking

In the industrial automation world, networks are a problem in that they cost too much time and money to design, install, and commission. This represents time and resources that could be better spent in using the information that they deliver in improving and optimising

production processes. It is not that any one network is unduly complex or time consuming to set up, but more that there are too many different networks (Brooks, 2005).

If one looks at any given machine within a manufacturing plant, one would notice that there is a network to provide information to the user (normally Ethernet), a network to communicate with I/O and variable frequency drives (usually Profibus or ControlNet), a network to communicate with simpler devices, such as sensors and control gear (usually ASi or DeviceNet), a network to communicate with servos (usually SERCOS), a safety network (often SafetyBus P) and proprietary networks to synchronise controllers when motion must be distributed (Knoblock, n.d.).

Each network requires training, requires different software configurations and different tools, different instruments and different installers. Software differences will be discussed in greater detail later but it is clear that significant cost is already being incurred with the design and integration of these disparate networks (Brooks, 2005).

Fortunately, industrial automation is not the only industry to experience this type of problem. In the commercial world there are networks for the planning system, networks for the telephone system, networks for e-mail, networks for security cameras, networks for HVAC, networks everywhere. But now we have 'convergence'—the migration of all of these services onto a single network, Ethernet. This single network not only reduces installation and maintenance cost but dramatically increases flexibility and adaptability of facilities (Brooks, 2005).

2.4.1 Manufacturing Automation Protocol

The development of the Manufacturing Automation Protocol (MAP) was initiated by General Motors in the 1980's when they recognised the significant need for computer communication standards. This started a worldwide effort lead by GM to develop MAP via the MAP Users group. The first successful demonstration of MAP occurred at the 1984 National Computer Conference shortly after which many companies began to implement MAP products and implement MAP solutions in factory floor production environments (Jones, 1987). MAP provides common standards for interconnecting computers and programmable machine tools used in factory automation. At the lowest physical level, it uses the IEEE 802.4 token bus protocol.

GM had a vision that a single MAP broadband cable would be used for all the factory's communications traffic. Everything, every programmable controller, robot controller, machine tool controller and factory floor terminal would plug into it and communicate on demand with everything else on the cable. The cable would connect any of these systems to the factory wide mainframe manufacturing control systems. This would make the shop floor supervision and factory control much easier. Order entry systems could link directly into inventory control and scheduling systems. Schedules could be downloaded straight into shop-floor terminals and could trigger the changing of control programs on individual machines. There was no limit to what could be achieved given enough imagination (Dwyer & Ioannou, 1988).

2.4.2 Technical and Office Protocols

The Boeing Company began the development of architecture for internal networks in the late 1970's. The result of their work was the Boeing Network Architecture (BNA), a subset of IBM's Systems Network Architecture (SNA) suitable for connecting the multi-vendor data centres the country had distributed around the United States. While GM was struggling with islands of automation on the factory floor, Boeing was faced with similar problems automating office and engineering functions as the typical jetliner has 3.5 million parts, each of which needs a drawing and the associated process data which explains how to make the part. By 1980 Boeing had 45 mainframes, 400 minicomputers, and nearly 20 000 workstations and terminals from more than 85 different vendors (Jones, 1987).

Boeing seized on GM's MAP initiative and adapted MAP to its own needs. The Technical and Office Protocols (TOP) is the result. The architecture was expanded in 1982 to integrate some of the office computers with the data centres. Then in 1984 it was expanded again to connect the manufacturing operation with the office computers and data processing centres. However, like GM, Boeing needed generally supported open networking. As long as the networks were one-of-a-kind specials there could never be the range of services and common availability that is required to make the computer-integrated office a reality (Jones, 1987).

2.4.2 Industrial Ethernet

The promise of Ethernet on the factory floor is that different networks will converge into one network, which can be installed once, using one set of training, one set of tools. An Ethernet that also participates in the same converged architecture as the rest of the enterprise, allowing free flow of information and one that handles all information whether it is automation or commercial data, electronic, voice, or video (Control Engineering Staff, 2006, Zabel, 2006).

To deliver this vision of truly free flow of information there are some simple requirements:

- Automation data must be able to go through a commercial switch;
- A telephone (or PC or printer) can be connected to any spare port in the network without affecting automation performance;
- The telephone's performance should not be affected by automation traffic; and
- Additional switches can be installed anywhere in the subnet.

But also there are requirements from the automation side: put simply, if Ethernet does not deliver a significant step forward on today's motion solutions then something else will have to, even if it is based on Ethernet (Madren, 2003, Zabel, 2006).

In 2000 Rockwell Automation introduced a new open standard automation protocol, Ethernet/IP (Ethernet Industrial Protocol). Despite its confusing name (it does not define a new Ethernet nor require it) as Ethernet/IP was the first mainstream, open, Ethernet and TCP/IP-based industrial protocol. The introduction of Ethernet/IP is one of the inflection points in the industry because one of the main automation players has adopted a solidly IT physical and networking layer set of protocols (Leidigh, 2005).

Rockwell Automation developed the Ethernet/IP application protocol to address the requirements of automation and industrial networks. Profinet, which was introduced by Siemens, and MODBUS/TCP reflect the same approach. All three protocols layer an industrial focused application protocol on the ubiquitous Ethernet link and TCP/IP networks. Leidigh defines the term "Industrial Ethernet" as typically being used to describe any of the Ethernet based protocol solutions for industrial use. Even this term is a misnomer because the more fundamental protocol of importance is TCP/IP as the network and transport protocols. It is TCP/IP that enables the so called "Industrial Ethernet"

protocols to take advantage of enterprise equipment (Ethernet based and others) as well as be routed into the enterprise. Prior industrial uses of Ethernet without using the TCP/IP protocols did not enable such connectivity (Leidigh, 2005).

Industrial Ethernet does not match IT-like systems identically. Besides the new industrial-focused application protocols, industrial nets are almost exclusively flat, switched networks. The switch-based network has been key to overcoming concerns about determinism in a collision-based network such as Ethernet. Enterprise networks use protocols such as SNMP (Simple Network Management Protocol) and are typically organised in subnets separated by routers; industrial nets cannot typically accept the non-deterministic delays introduced with routers, and they are only used at the edges of the network (Zabel, 2006).

2.4.3.1 The Plant Control Room

The control or automation room is where the manufacturing and process camps converge. The control room oversees systems with attributes of both camps. The control room is where the factory and enterprise networks join, and from this space the factory and enterprise networks feed data to higher-level systems. Additionally, control room systems monitor and control the factory floor network (Leidigh, 2005).

With Ethernet and TCP/IP now widely available in very low cost microcontrollers, manufacturing and process control equipment are also shifting over to the ubiquitous and standard network technology. This development very much affects convergence of manufacturing technologies. Intelligent, automated manufacturing plants can make use of wiring and infrastructure already in place for existing corporate networks, making Ethernet and TCP/IP likely to extend and lead to a greater integration of manufacturing systems with process systems and corporate IT (Leidigh, 2005).

2.4.3.2 Convergence Factors

While each vertical or application segment may have its own primary driver, automation always comes down to three major factors: cost, visibility and scalability, each having its own subset of issues (Brooks, 2005).

Ethernet and TCP/IP networks are very cost effective (Introduction to Ethernet, 1999). The widespread use and multitude of vendors for all aspects of these networks (hardware, software and tools) continues to drive down costs. The availability of personnel throughout organisations to maintain and manage these networks helps keep maintenance costs low (Leidigh, 2005).

Visibility to process data all the way to the executive level in any industrial segment is critical to meeting organisational challenges such as increasing efficiency and reducing line downtime. Regulations such as Sarbanes Oxley (SOX) and THREAD drive the need for even greater amounts of data to support compliance (Brooks, 2005). For example, FMCG (Fast Moving Consumer Goods) and pharmaceutical companies must not only make the data visible but also ensure that data such as source material and batch runs are fully traceable. Similarly, automated manufacturing operations require more data exchange with service providers such as utility companies in order to optimise and manage energy use (Leidigh, 2005).

The adoption of traditional LAN networking methodologies enables scalability of today's enterprise TCP/IP networks. Once Ethernet/IP is in place, data and control networks can take advantage of the entire range of technologies capable of carrying TCP/IP traffic. Ethernet is really the lowest common denominator of these protocols. Newer faster link layer protocols such as ATM, SONET, and extended 1GB Ethernet can be deployed where large data backbones are needed (Hogan, 2006).

These link layer protocols enable data communication over much greater distances as well. Converged TCP/IP networks can seamlessly move data from the factory floor in remote areas to a corporate headquarters. Virtual teams from geographically separated factories can work on and share material across common networks (Hogan, 2006).

2.4.3.3 The Future

Monitoring of switches and APC UPS units backing up networking and PLC equipment with the traditional enterprise SNMP protocol made great sense in the past as the applications are not real time or plant control related. The facility already had the tools and methodologies in place for equipment located elsewhere in the operation so creating separate monitoring pages within the SCADA/HMI context could be avoided, thereby

saving time and money (Hechtman, n.d.). Of course, monitoring network infrastructure such as the switches and UPS equipment is also a core competency of the IT group to begin with. Lacking such cooperation would have required duplication of tools, manpower, and time (Leidigh, 2005).

Since the health of the factory network obviously affects the health of the process, it is sometimes desirable to enable the main SCADA HMI systems to collect and display network information as opposed to requiring fully separate network management systems (NMS). Information from the industrial Ethernet network equipment can be collected through the traditional SNMP means and brought into SCADA systems via methods such as SNMP-OPC drivers. These software tools map any SNMP MIB OIDs (the individual data point in SNMP) to OPC tags that can be accessed by any standard OPC client. Using such a schema leverages protocols and technology that have wide support and can be used now with both SCADA and NMS systems in parallel if necessary. Indeed one of the most compelling reasons to use Ethernet and TCP/IP is the incredible amount of equipment, tools, and software available. Even if some things require tweaks and additions for use in the industrial world, the basis and solidity is there (Hogan, 2006).

2.5 Field Integration & Management

In their quest to lower lifecycle costs while improving productivity, companies have integrated intelligent field devices via Fieldbus technologies into their process automation solutions (Scheepers, 2006).

Device manufacturers put more intelligence into the devices. These new features could not be used by standard tools, but extra handheld tools were needed. Not all advanced device functions can be used via the Fieldbus, because the tools are not able to communicate with the device. Hence, it is not possible to identify maintenance issues before a device failure occurs, resulting in high maintenance cost and high maintenance downtimes. Many system designs still require significant integration effort to access a device's advanced features and functions. Multiple tools are needed to perform the different task such as field device configuration, commissioning, diagnostics, and maintenance. This approach causes high personnel expenditures. With these constraints, requirements to reduce cost in the production facility could not be accomplished (Scheepers, 2006).

2.5.1 Fieldbus technologies

Currently Profibus and Foundation Fieldbus are predominantly used in the process industries. The advantages in using one of those Fieldbuses is that sensors and actuators are traditionally connected to a controller via an analogue 4 - 20 mA signal. For each sensor and actuator, a 2-wire cable and an input/output unit (I/O) are needed, processing one process value. The new approach, using digital, intelligent field devices, enhances the requirements concerning communication with the device (Miller, n.d.)

Highway addressable remote transducer (Hart) technology takes a step forward. A frequency signal is modulated above the conventional 4 - 20 mA signal, which does not influence or interfere with the analogue signal transmission. Via this frequency shifted signal, intelligent field devices can be accessed bi-directionally for configuration, status requests and diagnostics (Miller, n.d.).

Today's fieldbus technologies such as Profibus and Foundation Fieldbus have extended the control system architecture to the device level (Hannover Messe, 2006). The advanced features of field devices can be used to reduce cost in engineering, commissioning, diagnostics, and maintenance.

Device integration packages for Hart, Foundation Fieldbus and Profibus provide the necessary components required to manage a field device. Furthermore, value to the Foundation Fieldbus, Profibus and Hart libraries is added by including asset management components as a standard feature. This allows the end user to identify maintenance issues before failure occurs, diagnose problem root causes, and offer corrective recommendations (Scheepers, 2006).

Compared to many other field device malfunctions, a plugged impulse line has no impact on the device hardware. If the line is plugged, the process value will remain in a valid condition. As a result, the control system continues to use that pressure value, without realising that it is "frozen". It is very difficult for operators to identify that. Normally high maintenance effort is needed to detect plugged impulse lines. Here intelligent field devices come into play. Modern differential pressure transmitters, such as the 2600T differential pressure transmitter's interface, provide a plugged impulse line detection. Those field

devices are able to detect that one or both impulse lines are plugged. It is displayed locally on the device's display (Scheepers, 2006).

Without integration, maintenance personnel would have to inspect the device directly in the field. By integrating the device into the control system, the device signals can be monitored centrally. Furthermore, the system will also perform further steps: the plugged line impulse will be reported automatically to the "maintenance workplace", which will notify the maintenance personnel for example via SMS. The asset monitor cyclically supervises the field equipment and is able to transmit detailed information about the problem, including help to solve it. This helps to reduce maintenance costs significantly (Scheepers, 2006).

2.5.2 Condition Based Maintenance

As industrial automation is no longer dominated by proprietary networks the rising availability and declining costs of Internet Protocol (IP)-based Ethernet, Transmission Control Protocol/Internet Protocol (TCP/IP) and related technologies have paved the way for open standard Internet protocols to make their way to the factory floor. The technological convergence between traditionally separate domains such as plant automation and enterprise information systems is enabling breakthrough applications that optimise the entire enterprise (Johnston & Wray, 2003).

Internet technologies create an environment particularly amenable to condition-based maintenance (CBM) by enabling the practical integration of condition monitoring and analysis tools with enterprise asset management and other enterprise business applications as part of a network-centric solution. This integration of plant floor asset management information throughout the enterprise is a key step for organisations seeking operations and maintenance (O&M) improvements to remain competitive (Hogan, 2006).

The value proposition behind Internet-based CBM is clear. Systems and processes that predict the failure of machinery on the plant floor and provide months rather than seconds of advance warning of potential failure, and then make that information available throughout the manufacturing enterprise, can spell the difference between minutes of planned maintenance and hours of unexpected, costly downtime (Hogan, 2006).

With Internet-based CBM available, the financial benefits of outsourced service management are magnified. Rather than having highly specialised and costly maintenance personnel dedicated to individual plants, the outsourced model places them in a centralised location, where their talents can be leveraged across multiple sites, or multiple customers. Many service management firms are entering this arena with packages to serve this growing trend (Johnston & Wray, 2003).

Much development work remains for this model to truly become viable. Just because the communication infrastructure is becoming much more universally available doesn't mean that all the pieces are yet in place for network-centric CBM. Information standards are critical to allowing interoperability between multi-vendor equipment suppliers, plants with global locations, and even operations and maintenance organisations within a company who must cost-effectively interoperate in a systematic fashion (Johnston & Wray, 2003).

Information standards are consolidating. A consensus for an open operations and maintenance information standard is developing around the OpenO&M initiative led by two non-profit organisations—the OPC Foundation (for OLE for Process Control) and the Machinery Information Management Open Systems Alliance (MIMOSA) (Hogan, 2006).

The OpenO&M initiative leverages the broad support of OPC and the information depth of MIMOSA to enable open, Extensible Markup Language (xml)-based integration for O&M applications including those associated with CBM. Collectively, OPC and MIMOSA bring together leading companies with extensive experience in CBM and enterprise applications integration (Hogan, 2006).

The OpenO&M information standards combine the platform, vendor- and product-neutral power of XML, OPC Foundation's XML for data access (XML-DA) standards and MIMOSA's Open System Architecture for Enterprise Application Integration (OSA-EAI) standards. These standards enable a bi-directional flow of information between operations, maintenance and emerging industrial decision support systems (Hogan, 2006).

In the future, CBM may be implemented as a Web-services model, truly leveraging the full power and convenience of the Internet. For today, an increased amount of CBM is migrating online through secure and robust virtual private networks (Johnston & Wray, 2003).

The combination of CBM, communication and information standards and outsourced service management culminates in a model that allows the health of assets to be managed with Internet-based information flow. This allows early warning of asset problems and cost-effective corrective actions to be put in place ultimately giving users the higher uptime and lower costs needed to compete effectively (Johnston & Wray, 2003).

2.6 Enterprise Integration

With the growing popularity of Ethernet Networks and the abundance of hardware and software solutions available, it is possible to integrate all components of a typical Production Facility into a tightly knit system. Office database & information systems that handle such tasks as production scheduling, data collection, invoicing, bill of ladings, certificates of analysis, order tracking, etc. can all be seamlessly integrated with the production line control system to share real-time data over common Ethernet networks. The benefits of such system integration include: automation of tasks to minimise human error, data integrity, paperless accounting, and greater accessibility through web based reporting (Goslak, n.d.).

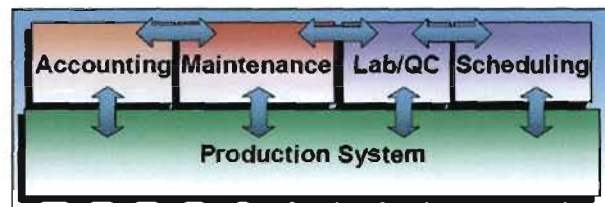
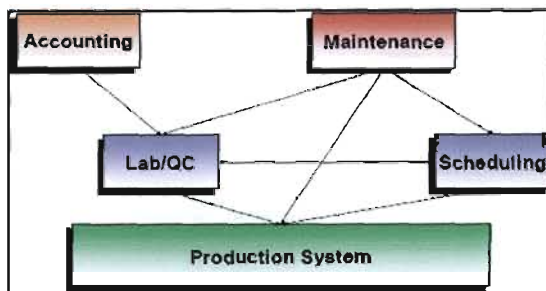


Figure 2: Typical Plant before (a) and after (b) integration
Source: Goslak, n.d.

2.6.1 What is an Integrated System?

An integrated system is one in which the Production Automation System is linked to the Business & Information Systems over one common communications network. Typically the common network is an Ethernet network since Ethernet is the most widely used and most available computer network today. With an integrated system in place, the following information systems can share information and data with the actual manufacturing process:

- Accounting/Invoicing
- Lab/QC (LIMS)
- Production Scheduling
- Maintenance (CIMMS)

Figure 2a shows a typical manufacturing environment prior to integration. Data is shared manually through loads of paper trails. In Figure 2b, an Ethernet network has been utilized to fully integrate the production automation system with all other business information systems at the plant. Now all data is shared electronically, quickly and automatically (Goslak, n.d.).

2.6.1.1 Benefits of an Integrated System

Once the production automation system is integrated with the business information systems over a common network, the following benefits can be obtained:

- Labour Cost Reduction
- Paper Reduction
- Higher Quality Control / Standardisation
- Better Record Keeping
- Decrease Maintenance Costs (simplify troubleshooting of production line problems)

2.6.2 Change of role and function of Control Engineering

A convergence of business pressures is creating a set of circumstances set to alter the role and function of control engineering in the plant. Control engineering's historic charter, to ensure the safe and efficient operation of the plant, has kept it an island unto itself for years. Automation equipment and systems and the data they generated were primarily for use by automation experts. Management interested in those data had to pick up the phone or wait to glean it from a report (Smith, 2006a).

Information is the key to differentiating an organisation and particularly information about operational processes is increasingly critical to competitiveness as product differentiation is marginalised by competition. Due to increasing regulatory mandates and escalating global competition eroding margins and shrinking cycle times, enterprise-level management wants real-time access to automation data to drive real-time strategic decisions. Key motivators are the need to preserve margins, speed the order-to-cash cycle, and maximise demand opportunities and return on assets (Smith, 2006b).

In the late nineteenth century, the manufacturing system integration arena largely focused on order management, financial accounting, customer management, and shipping and receiving. To the front office, manufacturing was basically a black box. It must be noted that some planning and scheduling handled by enterprise systems was built on manufacturing data, however, much of that data was collected on a weekly or monthly basis, then fed into the business systems. This is far too infrequent to achieve the agility and flexibility the enterprise system vendors promised (Greenfield, 2006).

Getting manufacturing data into these systems on an automated basis was another issue. Plant floor systems operate on a dynamic, at or near-real-time basis which is different from the transaction-based flat file construct of enterprise systems. This is the second reason why most automation-to-enterprise integration did not quite make it off the ground nearly a decade ago as expected the technology, in many cases, was not ready (Greenfield, 2006).

Today, vendors and analysts are largely in agreement that the software and hardware industries involved in this integration arena have learned the hard lessons from failed integrations of years past. New solutions being offered are said to be built on inside knowledge of the factory floor and to demonstrate that, instead of being designed to integrate in a top-down fashion, today's integration is bottom-up driven by the data and processes "owned" and managed by engineers and operators (Greenfield, 2006).

The inability of enterprise resource planning systems (ERP) to deliver anticipated production insights created intense interest in solutions to bridge the automation-to-enterprise gap. This drove the long-malingered manufacturing execution system (MES) market which represents just one approach to the issue that is now past a billion dollars in sales in 2005. Other integrated solutions also are penetrating the plant domain, bringing new tensions, challenges, and opportunities (Smith, 2006a).

According to a recent Control Engineering survey on enterprise integration (Greenfield, 2006), the largest portion of automation-to-enterprise integration (52%) is occurring through PLCs linked to higher-level systems. Respondents also report using MES (18.4%) and portals for manufacturing data visibility (20.4%), as well as a "mixed bag" of systems (9%) to achieve integration.

Solution vendors and analysts are eager to talk about bridging the automation-to-enterprise data transfer chasm. Interestingly, however, manufacturers seem reluctant to discuss it. Of eight vendors contacted during Smith's research, only one provided a customer willing to talk. It seems that people do not want to share best practices. The bottom line therefore is that leveraging plant automation data at the enterprise level is now vitally strategic and while it's a long way from being easy, bridges are being engineered (Smith, 2006b).

A recent AberdeenGroup study (Smith, 2006a) found better performing manufacturers were leveraging real-time plant data in boardroom decisions. The reality of the gap also was highlighted as 60% of respondents cited the gap between ERP and the shop floor as a major barrier to achieving their performance objectives. According to the Control Engineering survey, respondents' most-recent automation-to-enterprise integration projects were driven by corporate objectives including competitive issues (44.6%), supply chain integration/partner requirements (36.6%), and compliance with regulations (11.6%) (Smith, 2006a).

Generalisations about automation-to-enterprise integration are difficult to make because of the scale of critical touch points. The scope of variables is also huge, including discrete vs. process considerations, unique industry dynamics and, significantly, unique company dynamics. At the plant level, factors include:

- Diversity of type and generation of automation;
- Breadth of desired integration;
- Criticality of specific performance issues; and
- Budgets—always budgets.

Volume of process industry automation data, for example, is higher than in discrete or batch process, with much of its collection more integral to equipment safety and efficiency. Discrete manufacturing relies more on adjunct data collection from bar codes and, to some extent, RFID (Radio Frequency Identification) (Greenfield, 2006).

Process industry enterprise managers increasingly are interested in data reflecting:

- Yields;
- Capacity; and

- Equipment performance, especially relevant to maintenance.

Honeywell product manager notes that managers are interested in overall efficiencies, particularly achieving better yields and lower inventory. They are also interested in understanding plant capacity, as in commodity markets like chemicals, where it is important to whether you can take an order and where you assign it. As scheduled downtimes are expensive, coordinating equipment run times and maintenance is also important (Smith, 2006b).

Discrete and batch process enterprise managers are increasingly interested in:

- Quality;
- Material track-and-trace to document "as built" for warranty and regulatory purposes; and
- Capacity utilisation for scheduling, especially in high volume/high mix environments.

In discrete and batch process, track-and-trace and quality are more separate systems notes Julie Fraser, principal research analyst at Industry Directions. All industries are interested in equipment run-time performance measured in overall equipment effectiveness (OEE) and better plant visibility to improve responsiveness to demand-driven opportunities (Greenfield, 2006).

Universally the classic driver is: wanting to commit to customers, set realistic expectations and promises, and then meeting them which is impossible without visibility into manufacturing notes Colin Masson, AMR Research director of supply chain networks research (Greenfield, 2006).

2.6.3 Data Management

Primary data management issues revolve around access, cleansing and aggregating, context, communication, security, storage, and archiving. Standards are central to data management for easing vertical and horizontal data sharing. Always evolving, sometimes official, sometimes defacto, they range widely: from emerging standards like ISA-95 in conjunction with the World Batch Forum's (WBF) B2MML (business-to-manufacturing

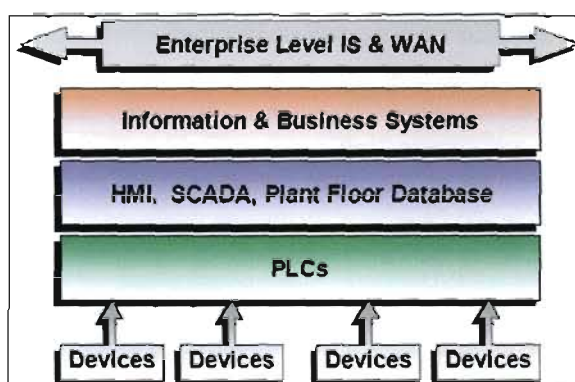
markup language for text message formatting), adapted more to process, to fairly well-established "standards" such as XML as a common text message medium and OPC for providing non-proprietary drivers for vertical and horizontal interoperability (Tweedie, 2005a).

Increasingly, MES figures prominently in many manufacturers' schemas. Classically configured to reside between the plant-floor automation layer and ERP, MES gathers and aggregates automation data, and contextualises them based on a detailed manufacturing model for exporting to higher level business systems. The hot demand for MES has spawned keen interest from automation vendors, many of whom acquired MES solutions. These include ABB (Base Ten/Consilium), Honeywell (POMS), Rockwell Automation (ProPack), and Brooks (FASTech). ERP vendors are interested as well, engineering middleware to facilitate integration with MES (Tweedie, 2005a).

Interfaces between Siemens's PCS7 (DCS solution) and its ORSI acquisition were developed soon after the acquisition, and as product development goes forward, coordinated development between the two will merge the world of process automation with higher level automation so the integration is more transparent notes Todd Stauffer, market manager for PCS7 (Tweedie, 2005b).

Top down, SAP's embrace in 2004 of ISA95 for its schema to connect ERP with MES was followed by Microsoft, Oracle, and others, giving the standard tremendous momentum. SAP subsequently partnered closely with Siemens to provide a comprehensive automation-to-enterprise solution, with ISA-95 as the linchpin (Tweedie, 2005a).

2.6.4 Integration Architectures – Typical Implementation



Most plants that have a production automation system fully integrated with business information systems follow the model shown in Figure 3. At the bottom of the model is the heart of the system – the production automation system. This consists of electrical equipment (i.e. motors,

Figure 3: Typical Architecture/Model
 Source: Goslak, n.d.

solenoids, valves, level transmitters, temperature transmitters, etc.) wired to Programmable Logic Controllers (PLC's) located throughout the plant floor. This is the heart of the system and responsible for controlling the production equipment, process interlocks, safety interlocks, sequential control, closed-loop control of process parameters and basic alarming. It is important to understand that the automation must be in place before it will be possible to achieve a fully integrated plant (Hardwick *et al.*, 1996).

In the case of a plant that already has some automation it is possible to retrofit the existing PLC's with Ethernet based controllers, however, the Ethernet backbone must be in place before all the different systems can be integrated as one.

2.6.5 Automation Vendors Response to Integration

Automation vendors also are designing and engineering comprehensive overarching architectures and integration platforms. These broad footprints ease the use of one-off application programming interface (API) linkages that typically require extensive services. Vendors and their platforms include Invensys with its ArchestrA platform and Wonderware Enterprise Integration Application, GE Fanuc using Proficy, and Rockwell Automation with its Integrated Architecture and reconfigured FactoryTalk Integrator Editions (Tweedie, 2005b).

Kevin Tock, Wonderware vice president notes that in the initial launch of ArchestrA, the focus was more around control system integration, however, in the last two years; it has shifted to being more IT-like. This change has allowed Wonderware to deliver on the objectives of enterprise application integration between Manufacturing and Business Systems which enables the integration of real-time manufacturing data with business applications, such as those from SAP, Oracle Applications and J.D. Edwards, and to other enterprise-level applications in the supply chain, such as Enterprise Asset Management applications (Korfhage, n.d.).

Multi-Site integration enables coordination and integration between different manufacturing systems on different sites; Transactional Integration Between Manufacturing and Other Supply Chain Applications which enables coordination and integration between different manufacturing and business applications, ranging from production scheduling and reporting to inventory management systems to financial

analysis packages and integration with existing messaging and middleware investments which provides the ability to utilise a customer's existing messaging and middleware systems and architectures, such as WebSphere, TIBCO and MQSeries, enabling seamless integration to Wonderware software applications within the existing IT infrastructure.

The Wonderware Enterprise Integration Application can operate automatically, transparently sending and receiving messages and forwarding and transforming message content, while concurrently controlling the sequence of operations required to keep applications interconnected and up to date in real time.

While platforms provide breadth, they tend to support large-scale projects with complex implementations. Platforms embrace a mix of protocols, standards, and third-party technology such as Microsoft's BizTalk, SAP's NetWeaver and IBM's WebSphere middleware components to orchestrate the flow of data and messages from lower- to higher-level systems using common services. Some vendors more closely align with particular middleware components to simplify deployments, such as Wonderware's reliance on BizTalk and Rockwell Automation's use of WebSphere. Virtually all equipment and systems suppliers also provide tool kits and preconfigured API adapters to link the homogenous world of plant systems (Tweedie, 2005a).

Future integration will be eased by services oriented architecture (SOA), where specific software functions are component services configured and bundled, exploiting Web services for communication and access. Presently, SOA is more vision than reality, but a consortium of vendors is working collaboratively to ease development and adoption by defining higher level services component architecture (SCA) standard (Tweedie, 2005a).

2.7 Organisational Structure

With customers and vendors alike struggling towards integrated enterprises, it is natural that that there would come a time when there was confusion as to previously well-segregated roles within the Automation and control engineering field. The further impact of the exposure of plant automation to traditional IT functions and associated processes has also contributed to the turmoil (Smith, 2006b).

While IT managers paid relatively no attention to the real-time complexities of the shop floor CEOs are realising that they should not be running a number of disconnected departments but unified companies with clear business goals. This simple fact is causing quite a stir because information is at the centre of it all and many people are not quite sure what information is useful, who should be responsible for it and if it has the remotest chance of improving their lives (Mittal, 2006).

In the 1960s and 70s, Data Processing Managers were running Data Processing Departments. Data processing personnel were not only required to look after the hardware but were also responsible for developing software that would allow the company to run its business processes more effectively. Today, however, understanding of computers has increased substantially and there is a wide proliferation of commercial software solutions. As a result the contemporary profession of Information Technology was born (Le Plasterier, 2005a).

The instrumentation engineer's job changed when he realised that optimising P&ID loops had no meaning if they didn't help the company achieve its business objectives. In order to contribute to this, he saw that he needed to change his role from instrumentation engineer to information provider. For the sake of efficiency, profitability and competitiveness, it became necessary to take a more formal approach towards the gathering and compilation of real-time information and to reconcile it with that of traditional business systems. Only in this way could Manufacturing Execution Systems (MES) become a reality (Le Plasterier, 2005b).

At present the situation exists where real-time data repositories can eclipse those of business IT systems in sheer magnitude, scope and criticality. The shop floor now has solutions like MDT's AutoSave to automatically back up and diagnose releases of HMI, PLC and robotic software. By definition, the instrumentation engineer is now involved in data processing which is in conflict with the role of traditional IT within an organisation. However, traditional IT is not entirely comfortable with working in the real-time environment in manufacturing where large quantities of data are needed on a millisecond time scale (Le Plasterier, 2005c).

The result is that at present there are companies with two IT departments, one in charge of making the money (production) and the other in charge of managing it (traditional IT). The information pipeline that connects the two can be as thick or as thin as needed and the filters at either end of this pipeline are defined by international standards like ISA S95. This solution works very well because it's the result of natural evolution and a great deal of trial and error. However this has had an impact of four stakeholders in particular:

The instrumentation engineer: Being an information supplier in charge of more than half of the company's total information assets, did not form part of his/her job description a few years ago where diagnosing processes and improving them was the norm. Therefore the Instrument Engineer needs to be able to exercise process skills while traditional IT department can assist with the management of information and its infrastructure.

The IT manager: The role of the IT manager should remain in the management of information and infrastructure.

SCADA solution vendors: SCADA solution suppliers have been caught with their alarms blaring because many still think that SCADA somehow operates outside the ambit of business information provision. Pipelines to SCADA data are next to useless. Pipelines to SCADA information are far more useful. But data is transformed into information by applications and, since there's more than one application vendor on the planet, we have a problem.

CEOs: The bottom line depends on profitable production that can only exist within a structured cloud of relevant information and is not necessarily a function of the number of IT departments in the organisation. Information is a tool that will help you achieve your business objectives. Why have preconceived ideas as to where it comes from or how it is structured? You only have to worry about that when the information you need isn't available or useful.

The answer to all the above isn't simple nor is it obvious. It took years to discover that the manufacturing sector did not need more applications but rather a structure that would allow these applications to work in concert and collaboratively.

Furthermore, the evolving converged factory networks do not look like the proprietary networks of the past. The new converged networks do not look like the typical, haphazard networks found in most enterprises either. Converged networks will require converged expertise. While controls engineers may need training on Ethernet, TCP\IP, and related technologies, almost any IT staff will have to develop skill in real-time switched networks and design for end-to-end reliability. While factory control engineers have had to create and run networks with absolute maximal uptime and resilience, it was not until the emergence of e-commerce that IT is really placed in a critical, revenue-producing role (Pinto, 2005b).

Factory networks will continue to have unique requirements, protection schemes, and specialised equipment, even if many of the underlying technologies are common. Organisations that work on cross-education and joint department programs will benefit from convergence. Organisations that fail to work together and remain independent will waste a great deal of money (Brooks, 2005 & Miller, n.d.).

2.8 Security

The trend toward using Ethernet as the sole communications network for business and industry has raised concerns about security. While proprietary networks for factory automation have major drawbacks in terms of limiting information flow and higher cost, their separation from other systems provides a measure of protection against unauthorized access (Wooldridge, 2004).

A comprehensive security plan must protect against unauthorised access from both internal and external sources. Methods of security can range from technologies based within the infrastructure itself such as physical connection paths and Virtual Local Area Networks (VLANs) to hardware and software-based devices such as firewalls and security management servers (Wooldridge, 2004).

2.8.1 Logical and Physical Security

The most secure network is one that has no connections to other systems. But that defeats the major advantage of Ethernet being easy connectivity to other Ethernet networks or the Internet for information sharing (Pendergast, 2005).

One of the most often-overlooked security measures is physically securing switches and wiring closets. Something as simple as enclosing devices in a lockable cabinet or closet and limiting access to authorised persons can prevent tampering or accidental de-coupling of a device link. In addition to physically preventing unauthorised access, it also makes sense to secure a backup copy of switch configurations using TFTP (Trivial File Transfer Protocol), a feature found in many switches, each time a change is made. This is not only a security measure but also a recovery method if a device should fail and require replacement (Pendergast, 2005).

Another method of easily securing infrastructure devices such as switches is password protection. Out of the box, most switches can be accessed using a serial DB9 console connection. This management interface is used to assign an IP address for remote TCP/IP-based telnet management (Pinto, 2005a).

Default passwords for switches may be standardised across a manufacturer's entire product line and are published in product documentation and on the web. Many users, including IT organisations, fail to change the default passwords and permissions. If an unauthorized user reaches an unsecured switch, he or she would be in complete command of the switch with the ability to change configurations or disable ports. It is therefore essential, even without an Ethernet connection to the corporate LAN or Internet, that physical security and password protection is part of any security program (Pinto, 2005a).

2.8.2 Virtual LANs

Virtual LANs are a grouping of Ethernet ports on an IEEE 802.1Q compliant switch or a grouping of switches. A VLAN may be used to help isolate packet and broadcast traffic on a factory automation network, for example, from the IT network. Measures like this are generally reserved for isolating extraneous traffic such as broadcasts that may interfere

with control communications, but can also be implemented as security tools (Seifert, 2000).

Switches can be divided into VLANs that could render devices on separate VLANs unreachable. The downside to switch port-based VLANs as a security strategy is management, since a port can belong to multiple VLANs extending across multiple switches (Seifert, 2000).

Multi-layered VLANs can be challenging to administer. For multiple VLANs to span multiple switches, the Spanning Tree Protocol, STP, may have to be disabled as well. For example, if two VLANs exist on each of two switches, each VLAN needs a connection to the corresponding VLAN on the other switch, requiring two links between each switch. STP will disallow multiple links between devices to prevent loops (Seifert, 2000).

VLANs can also be used to segment broadcast domains within a network. Since VLANs are logically segmented local area networks, physical areas do not restrict them. Utilizing VLANs reclaims network bandwidth by breaking down broadcast domains and segments one network of devices from another within the same switch (Seifert, 2000).

VLAN segmentation is accomplished by assigning the ports of a device into separate VLAN memberships. For example, ports 1 and 2 may be assigned to VLAN1. Ports 3 and 4 may be assigned to VLAN2. Ports 1 and 2 will not see broadcasts or traffic from ports 3 and 4, and vice versa. This separation is accomplished at OSI layer 2. If a third VLAN were created using ports 1, 2, 3, 4 and 5, then a device on port 5 would see all broadcast traffic from ports 1, 2, 3 and 4 (Seifert, 2000).

An example of this type of implementation is if the network administrator wants to separate traffic from office computers from PLC or SCADA devices. As these devices may not normally communicate with each other, separating them with a VLAN would allow the two networks to co-exist on the same switch (Seifert, 2000).

Other configurations can be implemented in order to conserve bandwidth for automation or other control devices. These settings include whether or not to pass or block multicasts and rate limit broadcasts. Other technologies such as Quality of Service (QoS) (Introduction to

Switch Technology, 2000), IEEE 802.3p, can prioritise packets on seven levels by setting three bits in the packet header. This allows traffic types or port assignments to have a higher priority should a bottleneck occur and can be very useful to prioritise automation traffic. Though not specifically a security measure, it does preserve the integrity of an automation network (Seifert, 2000).

2.8.3 Firewall Technologies

A firewall is a device that is implemented on a network to provide security from potential intruders. A firewall has more granular control over what can and cannot be accessed from outside the secure network than an access list can provide. A firewall can be a network appliance or a piece of software on a stand-alone server or router equipped with multiple network adapters or interfaces. A firewall provides this granular control by using its own protocol stack and, depending on the firewall, it checks each level of the stack for erroneous information (Thomas, 2006).

A firewall works by examining each packet that passes between the two adapters and comparing access rules at several different levels before allowing that packet to pass. Once a packet has been validated by all of the requirements to pass through, the firewall applies network address translation (NAT). NAT is used to hide the internal network IP addresses by substituting the actual source address with the outside address of the firewall. This acts to hide the original internal address of the sender inside the firewall (Thomas, 2006, Whitney, 2005).

Firewalls allow filtering on MAC addresses, IP addresses, port numbers or even certain commands and services. Each firewall offers a different level of security depending on the vendor, features and costs. Selecting and implementing a firewall into any infrastructure requires research, planning and feature/cost comparison (Pinto, 2005b).

Every vendor offers a different set of features, such as authentication support, logging, and additional memory and performance classes. The more security checks performed, for example, the slower transactions will take place. Some firewall management suites also allow rules to be downloaded and applied to other network devices such as routers that may be internal or external (Thomas, 2006).

2.8.4 Authentication Technologies

Password management for devices can also be an issue. Server platforms are available to centrally administer passwords. These services include RADIUS (remote authentication dial-in user service) and TACACS/TACACS+ (terminal access controller/access controller system). These services allow the secure centralised maintenance of logins and passwords. Access to a device, network or resource such as a server can be centrally administered on such a server. When users request access to a device, the user's credentials are checked against a database on the server for permission (Thomas, 2006, Whitney, 2005).

Authentication is the process where a network user establishes an identity. Verifying the identity of a user requires at least one of three authentication factors: a password, a smart card or token with hardware or software and biometrics. Each of these approaches has different advantages and drawbacks (Pinto, 2005a).

Passwords can be forgotten or shared, compromising the original goal of security. In addition, passwords can be stolen by monitoring keyboard keystrokes or network traffic, by tricking individuals into revealing their password or with brute force methods such as dictionary attack utilities (Pinto, 2003a).

Smart cards or tokens work in conjunction with hardware or software on the host, so each generated response is unique for every login. While providing strong security measures, smart cards and tokens can be lost or stolen or forgotten, and must be issued and tracked, so they are more expensive than passwords to implement and manage (Pinto, 2005a).

The strongest single approach is biometric authorization, such as fingerprint or retinal or iris scans or voice or facial recognition. Although it achieves a higher level of security, users also face more inconvenience as a consequence (Pinto, 2005b).

2.8.5 Secure Remote Access

As more and more employees find themselves on assignment outside the office, the need for remote access continues to increase. Remote access servers (RAS) and virtual private network (VPN) are two technologies that offer remote access service. Remote access is vital to organisations for sales, support, branch offices and off-site partners (Ismat, n.d.).

With RAS, a remote access client uses the telecommunications infrastructure to create a temporary physical circuit with a port on a remote access server. With VPN, a VPN client uses the Internet to create a virtual point-to-point connection with a remote VPN server (Ismat, n.d.). Although RAS has proven popular, many businesses are looking at low-cost VPN to perform the same functions and reduce telecommunications costs. A VPN can be defined as a means for using the public network infrastructure, such as the Internet, to provide private, secure access to applications and corporate network resources for remote employees, business partners and customers. With a VPN deployed across the Internet, virtual private connections can be established from almost anywhere in the world, providing secure access to a central network without having to dial directly into the corporate network (Ismat, n.d.).

VPNs reduce telecommunications costs since the remote user need only connect to a local Internet access point rather than dial long distance. A VPN uses a secure tunneled connection, allowing only authenticated users access to the corporate Intranet. With tunneling, each message packet is encapsulated or "wrapped" within an IP packet for transmission across the public network via an encrypted "tunnel." Encapsulation is presented at the security server or firewall. Upon authentication, the packet is then decoded and unwrapped for forwarding to the destination host (Seifert, 2000).

Virtual private networking solutions may be a combination of many different technologies such as encryption, user and data authentication and access control techniques working together to deliver a VPN solution that protects data privacy and ensures appropriate access control. The technologies that comprise the security component of a VPN are authentication, data encryption, user access control and event logging (Seifert, 2000).

The most important differences between VPN and RAS are the client/server software and the communications access. VPN is a much less costly approach in terms of telecommunications, equipment and personnel costs and administration can easily be handled by mid-level IT personnel. It is also a more secure approach since user and data authentication and encryption capabilities are inherent in the software (Seifert, 2000).

2.8.6 Demilitarized Zones (DMZ)

Demilitarized Zones (DMZ) are a buffer between a trusted network (SCADA network) and the corporate network or Internet, separated through additional firewalls and routers, which provide an extra layer of security against cyber attacks. Utilizing DMZ buffers is becoming an increasingly common method to segregate business applications from the SCADA network and is a highly recommended additional security measure (Seifert, 2000).

2.9 Key Performance Indicators (KPI's)

While production processes are effectively controlled through the rigorous measurement of their performance, the same cannot be said of an organisation's other processes. Accounting has its place in reporting on the status of a company's finances, but it does so too infrequently to allow for corrective action to be taken and that knowledge is not always shared with those individuals who are in a position to do something about non performance. By extending the performance measurement techniques of production to business processes, companies are realising an unprecedented level of bottom line improvement through timely and relevant information as well as personnel motivation and contribution (Martin, 2005).

2.9.1 Enterprise Performance Management (EPM)

EPM is a multi-disciplinary, cross-functional process that enables improved enterprise performance through alignment, visibility, and collaboration among business units and functional areas (Pinto, 2004). More than just connecting goals to measurements, it becomes necessary to understand which metrics are important, how they should be measured, and what adaptations are needed for local differences. The pay-off is that the right information gets to the right people, at the right time, to make an impact.

EPM aims to provide the ability to manage organisational performance from the plant floor to executive suite. Here are some of the results that EPM can achieve:

- Monitor performance of sales, marketing, operations, finance, supply chain, customer and product management.
- Provide measurements to align and optimise technologies and business processes, tactics and strategies, resources and objectives, business unit and corporate goals.
- Focus and execute on bottom-line business drivers across operational divisions to enhance enterprise-wide performance.
- Collaborate and communicate with a scalable web-based business intelligence framework for faster, smarter decision-making.
- Analyze and anticipate revenue cycles, supply chain and product performance, customer behaviour with a uniform interface.
- Leverage existing resources through flexible and adaptive business intelligence

Extending business performance measurement beyond finance into the real-time world of MES and production will mean that IT of the top floor and IT of the shop floor will have to work in concert if they are to deliver the information goods at all levels of the organisation in time frames that will allow for corrective action to be taken (Tweedie, 2005a).

With increased usage of web services, enterprise-wide performance management can become practical. Some advanced systems are already being used to automate operator forms, work-flow and data management across the enterprise. Systems are even available to enable customer-interaction for activities such as product customisation, choice of special delivery and pricing (Pinto, 2005a).

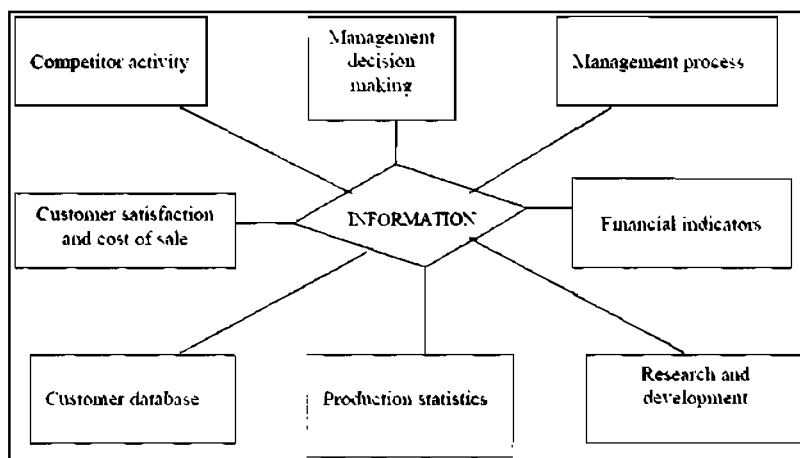
2.9.2 Enterprise Key Performance Indicators (KPI)

With the broad availability of enterprise-wide integration tools, it becomes important to develop agreed, quantifiable measurements that reflect critical success factors. These are the KPIs which reflect corporate goals that are set and measured in all parts of the enterprise. The definition of what they are and how they are measured should not change often, to ensure that different departments and locations remain in step, all synchronised to the same measurements. With a head's up view of KPIs, everyone should have the ability to manage to exceptions, monitor trends, and make smart decisions (Fitchett, n.d.).

Indeed, perhaps the key job for the future CEO, or executive board, is simply to define, monitor and control the KPIs, letting local decision-making achieve results for the integrated enterprise (Tweedie, 2005b).

2.10 How information gives Competitive Advantage

It is hard to underestimate the strategic significance of the new information technology. This technology is transforming the nature of products, processes, companies, industries, and even competition itself. Until recently, most managers treated information technology as a support service and delegated it to Electronic Data Processing (EDP) departments.



Now, however, every company must understand the broad effects and implications of the new technology and how it can create substantial and sustainable competitive advantages (Harizanova, 2003).

Figure 4: Information – the life-blood of the organisation
Source: Harizanova, 2003

The information revolution is sweeping through our economy. No company can escape its effects. Dramatic reductions in the cost of obtaining, processing, and transmitting information are changing the way we do business. The power of technology has transformed the role of information in such manner that information has become recognised as the lifeblood of the organisation (Figure 4). Without information, the modern company is dead (Papows, 1998).

Most general managers know that the revolution is under way, and few dispute its importance. As more and more of their time and investment capital are absorbed in information technology and their effect, executives today have a growing awareness that the technology can no longer be the exclusive territory of EDP or IS departments. As they see their rivals use information for competitive advantage, these executives' recognise the

need to become directly involved in the management of the new technology. In the face of rapid change, however, they don't know how (Porter & Millar, 1985).

To answer these questions, managers must first understand that information technology is more than just computers. Today, information technology must be conceived of broadly to encompass the information that businesses create and use as well as a wide spectrum of increasingly convergent and linked technologies that process the information. In addition to computers, then, data recognition equipment, communications technologies, factory automation, and other hardware and services are involved (Porter & Millar, 1985).

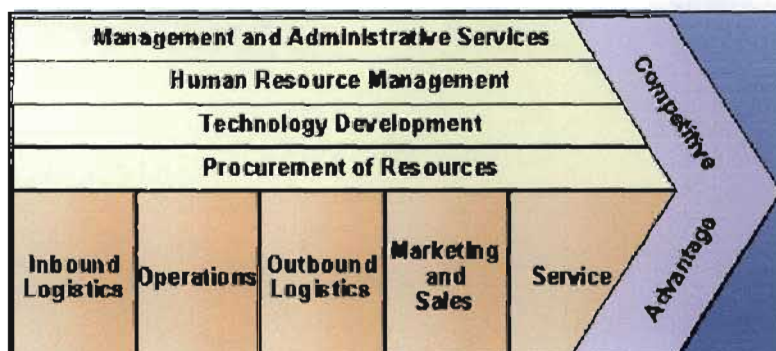
2.10.1 Technology impact on competition

The information revolution according to Porter and Miller (1985) is affecting competition in three vital ways:

- Changes industry structure and, in so doing, alters the rules of competition
- Creates competitive advantage by giving companies new ways to outperform their rivals
- Spawns whole new businesses, often from within a company's existing operations

2.10.2 Technology and the Value Chain

An important concept that highlights the role of information technology in competition is the "value chain." This concept divides a company's activities into the technologically and economically distinct activities it performs to do business. These are called value activities.



The value a company creates is measured by the amount that buyers that are willing to pay for a product or service. A business is profitable if the value it creates exceeds the cost of

Figure 5: The Value Chain
Source: Porter & Millar, 1985

performing the value activities. To gain competitive advantage over its rivals, a company must either perform these activities at a lower cost or perform them in a way that leads to differentiation and a premium price (more value).

A company's value activities fall into nine generic categories (see Figure 5). Primary activities are those involved in the physical creation of the product, its marketing and delivery to buyers, and its support and servicing after sale. Inbound logistics includes receiving materials, storing, and distribution to manufacturing premises. Operations include transformation of inputs into finished products. Outbound logistics includes storing and distributing products. Marketing and sales involves promotions and sales force. Service serves to maintain or enhance product value (Porter & Millar, 1985).

Support activities provide the inputs and infrastructure that allow the primary activities to take place. Every activity employs purchased inputs, human resources, and a combination of technologies. Firm infrastructure, including such functions as general management, legal work, and, counting, supports the entire chain. Within each of these generic categories, a company will perform a number of discrete activities, depending on the particular business. Service, for example, frequently includes activities such as installation, repair, adjustment, upgrading, and parts inventory management (Porter & Millar, 1985).

Information technology is permeating the value chain at every point, transforming the way value activities are performed and consequently the nature of the linkages among them as well. It also is affecting competitive scope and reshaping the way products meet buyer needs. These basic effects explain why information technology has acquired strategic significance and are different from the many of the other technologies businesses use.

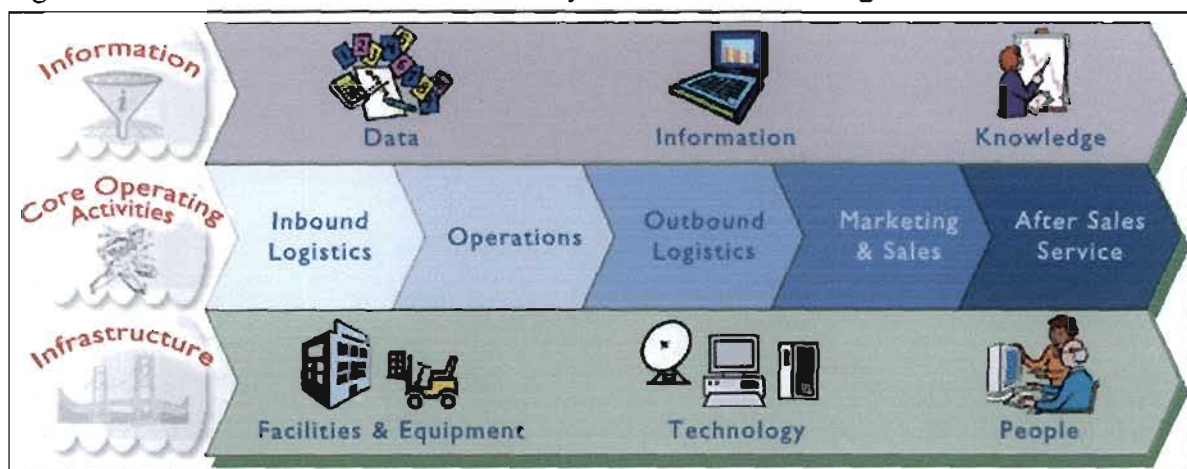


Figure 6: The Value Chain Defines Industry Structure and Relationships.
Source: Applegate et al. Corporate Information Strategy and Management, McGraw-Hill, 2002

Every value activity has both a physical and an information-processing component as depicted in Figure 6. The physical component includes all the physical tasks required to perform the activity. The information-processing component encompasses the steps required to capture, manipulate, and channel the data necessary to perform the activity

This technological transformation is expanding the limits of what companies can do faster than managers can explore the opportunities. The information revolution affects all nine categories of value activity, from improving inbound logistics by automating warehousing, improving operations via the use of flexible manufacturing, streamlining outbound logistics by implementing automated order processing, improving marketing and sales by using telemarketing and remote terminals for sales staff and improving after sales service by developing remote servicing of equipment, computer scheduling and routing of repair trucks (Porter & Millar, 1985).

IT is generating more data about activities and products, information that was not available before. Customers being used to this expect higher information content in products. IT enhances the ability to exploit linkages between activities both inside and outside the company and allows companies to coordinate activities in widely dispersed geographic locations. Often there is too much information, but IT can store and help analyze the flood of information (Porter & Millar, 1985).

2.10.3 Changing Industry Structure

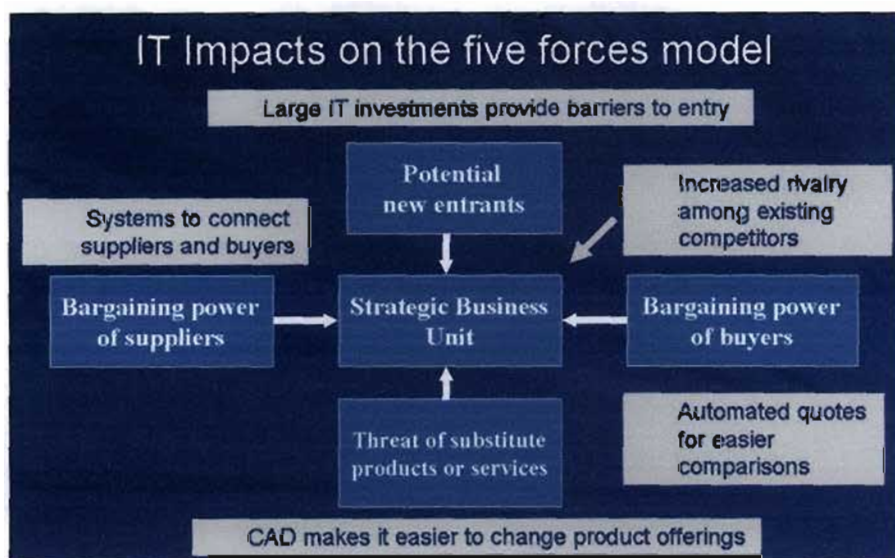


Figure 7: IT impact on the five forces model
 Source: Fisher, 2006

The structure of an industry is embodied in five competitive forces that collectively determine industry profitability: the bargaining power of buyers, the bargaining power of suppliers, the threat of new entrants, the threat of substitute products, and the

rivalry among existing competitors (see Figure 7). The collective strength of the five forces varies from industry to industry and consequently average profitability. The strength of each of the five forces can also change, either improving or eroding the attractiveness of an industry (Porter & Millar, 1985).

Information Technology can alter each of the five competitive forces and, hence, industry attractiveness as well. The technology is unfreezing the structure of many industries, creating the need and opportunity for change. For example:

- Information Technology increases the power of buyers in industries assembling purchased components. Automated bills for materials and vendor quotation files make it easier for buyers to evaluate sources of materials and make-or-buy decisions.
- Information technologies requiring large investments in complex software have raised the barriers to entry. For example, banks competing in cash management services for corporate clients now need advanced software to give customers on-line account information. These banks may also need to invest in improved computer hardware and other facilities.
- Flexible computer-aided design and manufacturing systems have influenced the threat of substitution in many industries by making it quicker, easier, and cheaper to incorporate enhanced features into products.
- The automation of order processing and customer billing has increased rivalry in many distribution industries. The new technology raises fixed costs at the same time as it displaces people. As a result, distributors must often fight harder for incremental volume.

2.10.4 Creating Competitive Advantage

In any company, information technology has a powerful effect on competitive advantage in either cost or differentiation. The technology affects value activities themselves or allows companies to gain competitive advantage by exploiting changes in competitive scope (Porter & Millar, 1985).

2.10.4.1 Lowering cost

Information technology can alter a company's costs in any part of the value chain.' The technology historical impact on cost was confined to activities in which repetitive information processing played a large part. These limits no longer exist, however. Even activities like assembly that mainly involve physical processing now have a large information processing component.

2.10.4.2 Enhancing differentiation

The impact of information technology on differentiation strategies is equally dramatic. As noted earlier, the role of a company and its product in the buyer's value chain is the key determinant of differentiation. The new information technology makes it possible to customise products. Using automation, for instance, Sulzer Brothers has increased from five to eight the number of cylinder bore sizes of new low-speed marine diesel engines. Ship owners now choose an engine that is more precisely suited to their needs and thereby recoup significant fuel savings (Porter & Millar, 1985).

2.10.4.3 Changing competitive scope

Information technology can alter the relationship between competitive scope and competitive advantage. The technology increases a company's ability to coordinate its activities regionally, nationally, and globally. It can unlock the power of broader geographic scope to create competitive advantage. Consider the newspaper industry. Dow Jones, publisher of the Wall Street Journal, pioneered the page transmission technology that links its 17 U.S. printing plants to produce a truly national newspaper. Such advances in communication plants have also made it possible to move toward a global strategy. Dow Jones has started the Asian Wall Street Journal and the Wall Street Journal-European Edition and shares much of the editorial content while printing the papers in plants all over the world (Porter & Millar, 1985).

The information revolution is creating interrelationships among industries that were previously separate. The merging of computer and telecommunications technologies is an important example. This convergence has profound effects on the structure of both industries. For example, AT&T is using its position in telecommunications as a staging point for entry into the computer industry. IBM, which acquired Rolm, the

telecommunications equipment manufacturer, is now joining the competition from the other direction. Information technology is also at the core of growing interrelationships in financial services, where the banking, insurance, and brokerage industries are merging; and in office equipment, where once distinct functions such as typing, photocopying, and data and voice communications can now be combined (Porter & Millar, 1985).

2.10.5 Spawning New Businesses

The information revolution is giving birth to completely new industries in three distinct ways.

- First, it makes new businesses technologically feasible. For example, modem imaging and telecommunications technology blend to support new facsimile services such as Federal Express's Zapmail in the early 1980's (The Printer Works, 2006). Similarly, advances in microelectronics made personal computing possible. Services such as Merrill Lynch's Cash Management Account required new Information technology to combine several financial products into one (Porter & Millar, 1985).
- Second, Information technology can also spawn new businesses by creating derived demand for new products. One example is Western Union's EasyLink service, a sophisticated, high-speed, data -communications network that allows personal computers, word processors, and other electronic devices to send messages to each other and to telex machines throughout the world (Wikipedia, 2006). This service was not needed before the spread of Information technology created a demand for it.
- Third, Information technology creates new businesses within old ones. A company with information processing embedded in its value chain may have excess capacity or skills that can be sold outside. Sears in 1988 took advantage of its skills in processing credit card accounts and of its massive scale to provide similar services to others (Wikipedia, 2006). It sells credit-authorisation and transaction-processing services to Phillips Petroleum and retail remittance-processing services to Mellon Bank. Where the information technology used in a company's value chain is sensitive to scale, a company may improve its overall competitive advantage by increasing the scale of information processing and lowering costs. By selling extra capacity outside, it is at the same time generating new revenue.

Companies also are increasingly able to create and sell to others information that is a by-product of their operations. National Benefit Life reportedly merged with American Can in part to gain access to data on the nine million customers of American Can's direct-mail retailing subsidiary. The use of bar-code scanners in supermarket retailing has turned grocery stores into market research labs. Retailers can run an advertisement in the morning newspaper and find out its effect by early afternoon. They can also sell this data to market research companies and to processors generating new revenue (Porter & Millar, 1985).

2.11 Research Questions

Having defined the research problem in chapter 1 and performed a literature survey on the topics related to the problem the key research questions pertinent to the resolution of the problem are as follows:

1. What is the relationship between Industrial Automation and Information Technology in the manufacturing organisation?
2. What are the key determinants of success (KPI's) of industrial automation systems in a manufacturing organisation?
3. Does the availability of information about manufacturing operations provide competitive advantage to the organisation?

2.12 Conclusion

This literature survey discussed the key concept of computer integrated manufacturing and how it has transformed the manner in which manufacturing takes place through the years and what the implications of this has been on manufacturing operations in particular and the quality and complexity of products in general. Industrial automation was discussed, indicating the benefits to the user as well as to the manufacturer of networked intelligent devices. Networks are covered in detail as they are critical to the success of industrial automation. Field instruments and the role they play in acting as the senses to the plant automation system are covered. Furthermore their transformation to intelligent devices that not only report on plant operations but also on their own operations is detailed. Enterprise integration, organisational impact, security and key performance indicators completed the literature survey.

Manufacturing operations have undergone a major transformation as a result of the introduction of computers. CIM, the philosophy of management predicated on the systems view of manufacturing emphasises integration of functions. The implications are that of flexible multi-skilled labour, maximum feasible use of computers and formal decision algorithms to replace error-prone humans in repetitive online tasks. This is true particularly for information capture and reproduction. As more information about manufacturing operations is becoming available to top management the way in which the factory is run and will be run in the future has changed fundamentally which has had an effect to their business models. By taking advantage of falling communication hardware costs, networked sensors and always-on Internet connectivity, new services can be created and product differentiation can be achieved.

The Internet is evolving to interconnect all network-attached devices, effectively becoming the largest data acquisition and control network. Some key enabling factors driving this are the move toward always-on broadband connections, the availability of inexpensive wireless networking (Arabe, 2002), both Wide Area Network (WAN) and Local Area Network (LAN) and falling cost of network connection hardware (Miller, n.d.). The effect however has been a change in the role of industrial automation from typically an operations focused (keeping the plant running) to a strategic business partner driving innovation and operational excellence.

The value of the study lies in the coverage of a broad range of automation and information technology related concepts highlighting where the overlap between the two lie in terms of technology drivers, people impact and business requirements. In some instances, such as networks, concepts have been investigated in greater detail as they are critical to the resolution of the research problem as highlighted by the references.

Using the research questions developed and refined via the literature survey the following chapter will focus on the research methodology that will be adopted in answering these key questions and in so doing resolving the research problem.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The literature review chapter has assisted in establishing the present situation with respect to the research problem by providing a critical review of the major references. Further it has served to uncover unsolved aspects or problems with the current situation that are encapsulated within the three key research questions. This chapter details the research methodology that is necessary to answer these questions.

The research questions that were developed in Chapter Two are firstly to identify what the relationship between Industrial Automation and Information Technology is in the manufacturing organisation (i.e. do the two operate as independent units or is there one unit that performs both functions within the organisation. The second question is on the key determinants of success (KPI's) of industrial automation systems in a manufacturing organisation. Finally does the availability of information about manufacturing operations provide competitive advantage to the organisation?

In defining the appropriate methodology to be used in answering these questions a number of business research and information technology research textbooks were used to gain an understanding of the different approaches available. Furthermore, refereed internet websites and articles were used to gather information on appropriate approach to be used.

In the sections, which follow, there will be a discussion on research design as a blueprint for achieving the goals of the research. Different research methods and instruments for data collections are covered. The method of data collection chosen is explained followed by the development of the survey instrument, steps taken to validate the questionnaire, the survey population and sample size determination and data handling ethical considerations are discussed. Finally a chapter conclusion is presented.

3.2 Research Design

According to Cooper and Schindler (2001), research design is the blueprint for achieving the goal of the research that of fulfilling objectives and answering questions. However, research design definitions differ in details, but together they give the essentials of research design:

- The design is an activity-and time based plan
- The design is always based on the research question
- The design guides the selection of resources and types of information.
- The design is a framework for specifying the relationships among the study's variables.
- The design outlines procedures for every research activity.

Thus, the design provides answers to questions such as: what techniques are used to gather data; what kind of sampling is used; and how time and cost constraints are dealt with.

	Technical	Social	Philosophical
Literature Surveys	●	●	●
Models	●	○	○
Languages	●	▪	○
Arguments	○	×	●
Mathematical proofs	●	▪	▪
Prototypes	○	▪	▪
Algorithms	●	×	▪
Surveys	▪	●	○
Case Studies	○	●	○
Experiments	○	●	▪

●	Often used
○	Sometimes used
▪	Hardly ever used
×	Not recommended for scientific research

Table 2: Research Methods for goal categories
Source: Oliver, 2003

Oliver (2003) categorises research goals in three main categories (shown in Table 2) as follows; technical, social and philosophical goals. Technical goals are those that deal with implementation of systems and related issues. Social goals are those that deal with the people side of computing, including management of IT facilities. Philosophical goals are those that deal with responsibility, accountability, legal aspects, implications and similar aspects of using computing systems. The primary methods that are frequently used for each goal are indicated, as well as those that are used less frequently. Those methods that are almost frowned upon for the various categories are also indicated.

The methods listed above are empirical, creative or tautological. Empirical methods are those that depend on observation and include surveys, case studies and experiments. Quality of empirical research depends upon the accuracy of observations and the degree to which observed results can be generalised to other cases. Creative methods are those intended to devise new abstractions or mechanisms to be used in computing; models, prototypes, algorithms and languages fall into this category. Quality of creative methods is determined by attributes such as the power, utility and simplicity of the creation (Oliver, 2003).

3.3 Methods and instruments of data collection

The main types of data include secondary and primary data. Secondary data is data that have already been collected for another purpose. They include raw data and published summaries. Primary data is the new data that has been collected specifically for a purpose that includes firsthand testimony or direct evidence concerning the research topic. Whereas secondary data can be collected by examining and reviewing raw data and published summaries, primary data is collected through observation (participant or structured), interviews (semi-structured or in-depth), and questionnaires (Saunders *et al.*, 2003). In conducting the study both primary and secondary sources of data are used to achieve the study objectives.

3.3.1 Questionnaires

Questionnaires are an inexpensive way to gather data from a potentially large number of respondents. Often they are the only feasible way to reach a number of reviewers large enough to allow statistical analysis of the results. More elaborate questionnaire design or administration may provide better objective data, and are suited to gathering reliable subjective measures, such as user satisfaction, of the system or interface in question (O' Brian, 1997).

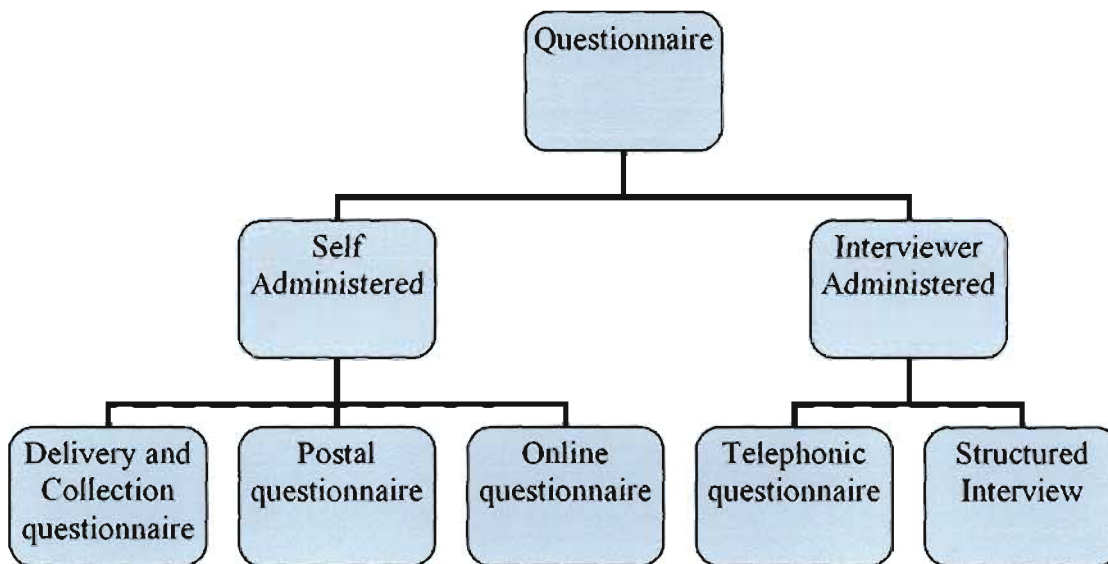


Figure 8: Types of Questionnaire
Source: Saunders *et al.*, 2003

As depicted in Figure 8 questionnaires can be either of the self-administered type which involve minimal to no contact between the researchers and respondents, or interviewer administered type (Saunders *et al.*, 2003) which involves contact. Self-administered questionnaires can be administered through delivery to and collection from respondents, through the post or via online methods such as email or web based applications, while interviewer administered questionnaires can take the form of either telephonic questionnaires or structured interviews (Saunders *et al.*, 2003).

Ultimately the selection amongst these different types of questionnaires will depend on a variety of factors related to the research question(s) and objective(s) (Saunders *et al.*, 2003). These factors, according to Saunders *et al.* (2003) include: (1) characteristics of the respondents from whom one wishes to collect data; (2) importance of reaching a particular

person as respondent; (3) importance of the respondents' answers not being contaminated or distorted; (4) size of sample one requires for the analysis, taking into account the likely response rate; and (5) types of questions one needs to ask to collect the data.

In terms of practical requirements the choice of questionnaire will also be affected by the resources the researcher has available, and in particular (1) time available to complete the data collection; (2) financial implications of the data collection and entry; (3) availability of interviewers and field workers to assist; and (4) ease of automating data entry.

Saunders *et al.*, (2003) states that careful design of the questionnaire is important to ensure high rate of response, validity and reliability of data collected. The key aspect in terms of success of the questionnaire is as put by Foddy (1994) and cited in Saunders *et al.*, (2003) in that the question must be understood by the respondent in the way intended by the researcher and the answer given by the respondent must be understood by the researcher in the way intended by the respondent. The implications are that there are a minimum four possible points of failure per question that need to be circumvented by proper design and thorough testing of the questionnaire.

3.3.2 Choice of Primary Data Collection Method

This research study aims answer the research questions in chapter two by investigating the experience of and gauging the attitudes of professionals in the field of Industrial Automation and Information Technology in a manufacturing organisation as well as to discover the cause-effect relationships amongst variables. The research therefore is both descriptive and explanatory in nature and as a result the self administered questionnaire will be utilised as the primary data-gathering tool for this instance. The option of a interviewer administered telephonic interview will also be offered to participants who wish to participate in the study but are either mobile and hence have no access to a PC or busy executives who do not have time to respond electronically. This will facilitate the collection of quantifiable data and allow for the qualitative analysis of this data to determine patterns and relationships.

3.3.3 The Likert Scale

Likert scale is a type of psychometric response scale often used in questionnaires, and is the most widely used scale in survey research (Kidder and Judd, 1986). When responding to a Likert questionnaire item, respondents specify their level of agreement to a statement. The scale is named after Rensis Likert, who published a report describing its use (Likert, 1932).

A typical test item in a Likert scale is a statement. The respondent is asked to indicate his or her degree of agreement with the statement or any kind of subjective or objective evaluation of the statement. Traditionally a five-point scale is used, however many psychometricians advocate using a seven or nine point scale. S. S. Stevens formulated an alternative technology for replacing numeric scales with cross modal matching, such as using the brightness of a light to scale the loudness of a tone. This implicitly uses a continuum or infinite response set for the scale.

Likert scaling is a bipolar scaling method, measuring either positive or negative response to a statement and subjects have to indicate the degree to which they agree or disagree with each statement on, for example, a five-point scale such as 'strongly disagree', 'disagree', 'Neither Agree nor disagree', 'Agree' and 'Strongly agree'. Sometimes Likert scales are used in a forced choice method where the middle option of "Neither agree nor disagree" is not available. Likert scales may be subject to distortion from several causes. Respondents may avoid using extreme response categories (central tendency bias); agree with statements as presented (acquiescence response bias - where research participants tend to consistently answer 'yes' to yes/no items or 'true' to true/false items, irrespective of the content of the question); or try to portray themselves or their organisation in a more favorable light (social desirability bias).

After the questionnaire is completed, each item may be analyzed separately or item responses may be summed to create a score for a group of items. Hence, Likert scales are often called summative scales.

Responses to a single Likert item are normally treated as ordinal data (that is, they have an inherent sequence), because, especially when using only five levels, one cannot assume that respondents perceive the difference between adjacent levels as equidistant. When

treated as ordinal data, Likert responses can be analyzed using non-parametric tests, such as the Mann-Whitney test, the Wilcoxon signed-rank test, and the Kruskal-Wallis test.

When responses to several Likert items are summed, they may be treated as interval data measuring a latent variable. If the summed responses are normally distributed, parametric statistical tests such as the analysis of variance can be applied. Data from Likert scales are sometimes reduced to the nominal level by combining all agree and disagree responses into two categories of "accept" and "reject". The Cochran Q, or McNemar-Test is common statistical procedures used after this transformation.

Other rating scales include 'numeric rating scales' and 'semantic differential rating scales' (Saunders *et al.*, 2003). In a numeric rating scale, a respondent is asked to rate their feelings on a scale between two extremes (e.g. poor value for money and good value for money), where there are no descriptions given for the points in between, but rather the respondent uses the number to express his feelings in response to the question, where for example the scale goes from one to ten (Saunders *et al.*, 2003).

The semantic differential rating scale is often used in consumer research to determine underlying attitudes (Saunders *et al.*, 2003). Here, the respondent is asked to rate a single object or idea on a series of bipolar rating scales, where each bipolar scale is a pair of opposite adjectives (e.g. fast-slow, unfriendly-friendly, value for money-overpriced) (Saunders *et al.*, 2003). Kervin (1999) *cited* by Saunders *et al.* (2003) states that when using the semantic differential rating scale, the position of positive and negative adjectives must be varied from left to right to reduce the tendency of respondents to read only the adjectives on the left.

Saunders *et al.* (2003) state that rating scales have been combined to measure a wide variety of concepts such as customer loyalty, service quality and job satisfaction, and for each concept, the resultant measure or scale is represented by a scale score created by combining the scores for each of the rating questions.

3.3.4 Development of the questionnaire as the primary source of data

At the end of the previous chapter, the following research questions remained to be answered: (1) what is the relationship between Industrial Automation and Information Technology in the manufacturing organisation; (2) what are the key determinants of

success (KPI's) of industrial automation systems in a manufacturing organisation, and (3) Does the availability of information about manufacturing operations provide a competitive advantage to the organisation?

The following data requirements Table 3 is prepared to match actual investigative survey questions to these research questions, to determine survey variables and categorise question types in each case (Saunders *et al.*, 2003). Use is made of the literature review in determining the type of questions required and level of detail at which they are measured. Questions are designed to gather qualitative data as accurately as possible as such they are carefully crafted and particular questions that assess a qualitative measure are well phrased to avoid ambiguity.

Research Question	Survey Questions	Variable(s) and/or Relationships measured	Question Type
<p>1. What is the relationship between Industrial Automation and Information Technology in the manufacturing organisation?</p>	<p>1.1 In comparing the fields of Industrial Automation and Information technology in a manufacturing organisation</p> <p>1.1.1 There is no relationship between the two functions in my organisation.</p> <p>1.1.2 There is some overlap between the two functions and grey areas exist in terms of responsibility.</p> <p>1.1.3 The two functions operate in conjunction with and are hence complimentary to each other.</p> <p>1.2 In terms of structures within your organisation the following are true for the Industrial Automation function and the Information Technology function.</p> <p>1.2.1 They operate independently of each other within separate structures/departments.</p>	<p>1.1 Relationship between Industrial Automation and Information technology</p> <p>1.2 Relationship between Industrial Automation and Information technology</p>	<p>1.1 Likert Scale from Strongly Agree to Strongly Disagree</p> <p>1.2 Likert Scale from Strongly Agree to Strongly Disagree</p>

<p>1.2.2 These functions are shared across one or many structures/departments.</p> <p>1.2.3 The two functions operate within one structure in my organisation.</p> <p>1.3 In terms of the network infrastructure in your organisation, comment on the following:</p> <p>1.3.1 There is a separate (Physical) Industrial Automation and IT/office network</p> <p>1.3.2 VLAN's are utilised in segregation of Industrial Automation and Office networks</p> <p>1.3.3 Industrial Automation and office networks are combined</p> <p>1.4 What communications Protocols are in use in your Industrial Automation Network?</p> <p>1.5 Industrial Automation and Manufacturing Engineering is becoming more IT focussed.</p>	<p>1.3 Relationship between Industrial Automation and Information Technology</p> <p>1.4 Relationship between Industrial Automation and Information Technology</p> <p>1.5 Relationship between</p>	<p>1.3 Likert Scale as shown (1.3.1 – 1.3.3)</p> <p>1.4 Open question to confirm use of Automation or IT protocols.</p> <p>1.5 Likert Scale from Strongly Agree to</p>
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	<p>1.6 There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?</p> <p>1.7 If agree what are these?</p> <p>1.8 My job function within the field of Industrial Automation has changed significantly in the past 2 years?</p>	<p>Industrial Automation and Information Technology</p> <p>1.6 Relationship between Industrial Automation and Information Technology</p> <p>1.7 Relationship between Industrial Automation and Information Technology</p> <p>1.8 Relationship between Industrial Automation and Information Technology</p>	<p>Strongly Disagree</p> <p>1.6 Likert Scale from Strongly Agree to Strongly Disagree</p> <p>1.7 Open question requiring details from Q1.6</p> <p>1.8 Likert Scale from Strongly Agree to Strongly Disagree</p>
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	<p>1.9 If yes in what manner do you believe this has been the case?</p>	<p>1.9 Relationship between Industrial Automation and Information Technology</p>	<p>1.9 Open question requiring details from Q1.8</p>
<p>2. What are the key determinants of success (KPI's) and effects thereon of industrial automation systems in a manufacturing organisation?</p>	<p>2.1 The key determinants/measures of success (KPI's) of Industrial Automation systems in my organisation are as follows:</p> <p>2.1.1 EVA</p> <p>2.1.2 Factory Efficiency</p> <p>2.1.3 Machine Operating Efficiency</p> <p>2.1.4 Production plan variance</p> <p>2.1.5 Sales Volumes</p> <p>2.1.6 Fixed cost Variance</p> <p>2.1.7 Utilities Variance</p> <p>2.1.8 Systems Uptime</p> <p>2.1.9 Product Quality Rating</p>	<p>2.1 Key determinants of success of Industrial Automation Systems</p>	<p>2.1 Select from options (2.1.1 to 2.1.9) in order of importance with option to add own choices.</p>

	<p>2.1.10 Other</p> <p>2.2 Do you as an Industrial Automation/IT professional feel that you have the ability to influence the KPI's listed above?</p> <p>2.2.1 I have no influence</p> <p>2.2.2 I have some influence</p> <p>2.2.3 I have much influence</p> <p>2.2.4 I have major influence</p>	<p>2.2 Effect of Industrial Automation/IT on KPI's</p>	<p>2.2 Likert Scale as shown (2.2.1 to 2.2.4)</p>
<p>3. Does the availability of information about manufacturing operations provide competitive advantage to the organisation?</p>	<p>3.1 The ability to view production information has an effect on competitive advantage of my organisation as follows:</p> <p>3.1.1 No effect what so ever</p> <p>3.1.2 Negative effect</p> <p>3.1.3 Negligible positive effect</p> <p>3.1.4 Major positive effect</p>	<p>3.1 Relationship between availability of production information and competitive advantage</p>	<p>3.1 Likert Scale as shown (3.1.1 – 3.1.4)</p>

Table 3: Research questionnaire development

3.3.5 Secondary Data Sources

Secondary data sources were evaluated for point-of-view and accuracy to ensure the interpretation is valid for the study. Secondary sources can include: Journal articles, books, encyclopaedias, critical essays, newspaper articles, internet and others (Saunders *et al.* 2003).

According to Kakooza (1992) documentation review/library research is a data collection process, which is based on reading books and other documents. Different books, Journals, internet and others were used to help in data collection so as to acquire information needed for achievement of the study objectives. This method has the following advantages as compared to other methods:

- It gives the researcher necessary background and guidelines to the research.
- It can be used to test results from other methods.

This method was used in the study to review literature on the present day role of industrial automation in manufacturing, the convergence between IT and automation, the gathering of real-time production information, enterprise integration, control system integration and computer integrated manufacturing.

3.4 Sampling Design

The basic idea of sampling is that by selecting some of the elements in a population we may draw conclusions about the entire population. There are several compelling reasons for sampling including: lower cost, greater accuracy of results, and greater speed of data collection and availability of population element (Cooper & Schindler, 2001).

The ultimate test of a sample design is how well it represents the characteristics of the population it purports to represent. In measurement terms, the sample must be valid accurate and precise. An accurate sample is one in which the underestimates and overestimates are balanced among the members of the sample. This case happens when there are enough elements in the sample (Cooper & Schindler, 2001).

Sampling can be a probability or non probability. Probability sampling which is most commonly associated with survey-based research is based on the concepts of random selection which is a controlled procedure that assures that each population element is given a known nonzero chance of selection. In contrast, non probability sampling is arbitrary (non-random) and subjective. Each member does not have a known nonzero chance of being included (Saunders *et al.*, 2003).

3.4.1 Sampling Frame

The sampling frame for any probability sample is a complete list of all the cases in the population from which the sample will be drawn. In the case of this research project the sampling frame would be all automation or IT professionals working in manufacturing organisations. However, due to the size of the sample being largely dictated by the fact that time and accessibility cannot allow the researcher to reach all participants in the sample frame the following restrictions are applied. The geographic area under investigation will be limited to that of the greater Durban area.

As such a representative population size of fifty (50) participants is chosen on a probability basis to represent the sample frame.

3.4.2 Actual Sample Size

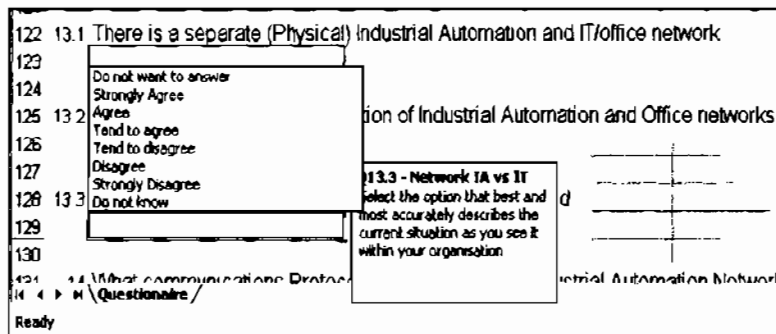
In order to ensure that the probability sample represents the population a high response rate to the survey is required. In reality however, it is likely that there will be a number of non-responses. In order to reach the required sample it is required that the researcher estimates the likely response rate and increase the sample size accordingly. The formula to be used in calculating the actual sample size is as follows:

$$n^a = \frac{n \times 100}{re\%}$$

Where n^a is the actual sample size required, n is the minimum (or adjusted minimum sample size) and $re\%$ is the estimated response rate expressed as a percentage (Saunders *et al.*, 2003).

For this research project applying the formula above reveals that the actual sample size is forty-eight (48) based on a 5% margin of error and a minimum of 44 valid responses for a 50 population sample.

3.5 Data Handling and Analysis



Questions developed in Table 3 will be implemented in a software application to facilitate the ease of response to the questions in the most

Figure 9: Excel drop down and tool tip text functionality

accurate manner possible by the participants. Microsoft Excel is chosen as the application of choice as it provides the following benefits; familiar environment to target population including management alike, ability to easily formulate multiple selection questions using drop down functionality without having to develop code to perform this function, the availability of validation to responses in terms of allowable ranges for the number of characters typed for free text responses as well as for numeric responses. Functionality also exists to provide tool tip text type input messages to guide respondents as well as error notification to enhance the user friendliness of the process as shown in Figure 9. The questionnaire used in the study is provided in Appendix III at the end of this document.

According to Witmer *et al.* (1999) cited by Saunders *et al.* (2003), email offers greater control as to who answers the questionnaire because most users read and respond to their own mail at their personal computer. Taking into account that the target population of this survey are in the fields of Information Technology and Industrial Automation the researcher decided that email will be the optimum method of transport of the survey instrument to the respondents.

The responses will be saved and analysed in a secure environment preventing unauthorised access and usage of the data.

3.6 Validity

Validity is concerned with whether the findings are really about what they appear to be about. This can be internal or external validity. External validity is the extent to which research results are generalisable (Saunders *et al.*, 2003). In this case, although the focus of this study was on manufacturing organisations in the greater Durban area, the results can be generalised for other organisations throughout the rest of the country. Whereas internal validity looks at the accuracy of information from respondents and it is hoped to check the reality of the data collected (Saunders *et al.*, 2003). Internal validity was assured through making sure that appropriate questionnaires were designed for relevant respondents.

The survey instrument used in this research investigation was validated in the following manner. Pilot testing amongst fellow students was performed to refine the questionnaire so that respondents would have no problems in decoding the questions to enable them to answer the question correctly. Furthermore the questionnaire was validated by fellow colleagues working in the field of industrial automation and information technology.

3.7 Reliability

Reliability is the degree to which data collection method or methods yielded consistent findings, similar observations would be made or conclusions reached by other researchers or there is transparency in how sense was made from the raw data (Saunders *et al.*, 2003).

3.8 Ethical Considerations

The general ethical issue in this project is that the research design should not subject the research population to embarrassment or any other material disadvantage. Consent from individual participants was ensured. Ethical issues further looks at the implications for the negotiations of access to the organisation, employees and the collection of data (Saunders *et al.*, 2003). An authorisation letter for data collection was acquired from the Graduate

School of Business is presented to participating organisations to grant permission to do the research.

3.9 Conclusion

The research design of the study has been clearly stated in this chapter where various ways of data collection and analysis have been identified.

In this Chapter a discussion on research design as a blueprint for achieving the goals of the research was detailed. The research design of the study has been clearly stated and different research methods and instruments for data collections are covered. The method of data collection chosen was explained followed by the development of the survey instrument, steps taken to validate the questionnaire, the survey population and sample size determination, data handling ethical considerations and study limitations were discussed.

An explanation of how the research is analysed is specified in the following chapter. It also presents the research results and discussion thereof.

CHAPTER 4: RESEARCH RESULTS AND DISCUSSION

4.1 Introduction

The previous chapter set out the research methodology that guided the empirical part of this study. This chapter summarises the empirical findings of the survey conducted, based on analysis of data gathered from the respondents through questionnaires. The data gathered is tabulated, expressed graphically, and statistically analyzed in this chapter.

The purpose of the data analysis is to ascertain the overall perceptions of respondents towards the subject matter. The statistical analysis will help the researcher make conclusions about the relationship between Industrial Automation and Information Technology in a manufacturing organisation (i.e. do the two operate as independent units or is there one unit within the organisation). The second question is on the key determinants of success (KPI's) of industrial automation systems in a manufacturing organisation. Finally does the availability of information about manufacturing operations provide competitive advantage to the organisation?

This chapter presents the descriptive statistical and inferential statistical, analyses of the data which is conducted using SPSS. The researcher will use the research analyses of this chapter to make recommendations and conclusions in the next chapter (Chapter 5).

4.2 Demographic Description of the Sample – Part Two

The demographic statistics for the respondents who participated in the study undertaken in the greater Durban area is detailed in this section. This is done in order to define and contextualise the environment in which the research took place as well as to provide common variables against which to compare the key variables pertaining to the research questions.

4.2.1 Age of respondents

The graph below reflects the age-group dispersion of respondents. This analysis is important to understand what proportion of the respondents is spread across the different age groups and is useful later in the research in correlation analysis to establish how this variable affects or is affected by the other variables pertaining to the research questions. The majority (77%) of respondents were in the age groups 26-35 years (44%) and 36-45 (33%). Many of the respondents (13%) were between 0–25 years with only 8% from the 46-55 years age group.

Q1 - Age Group Distribution of Respondents

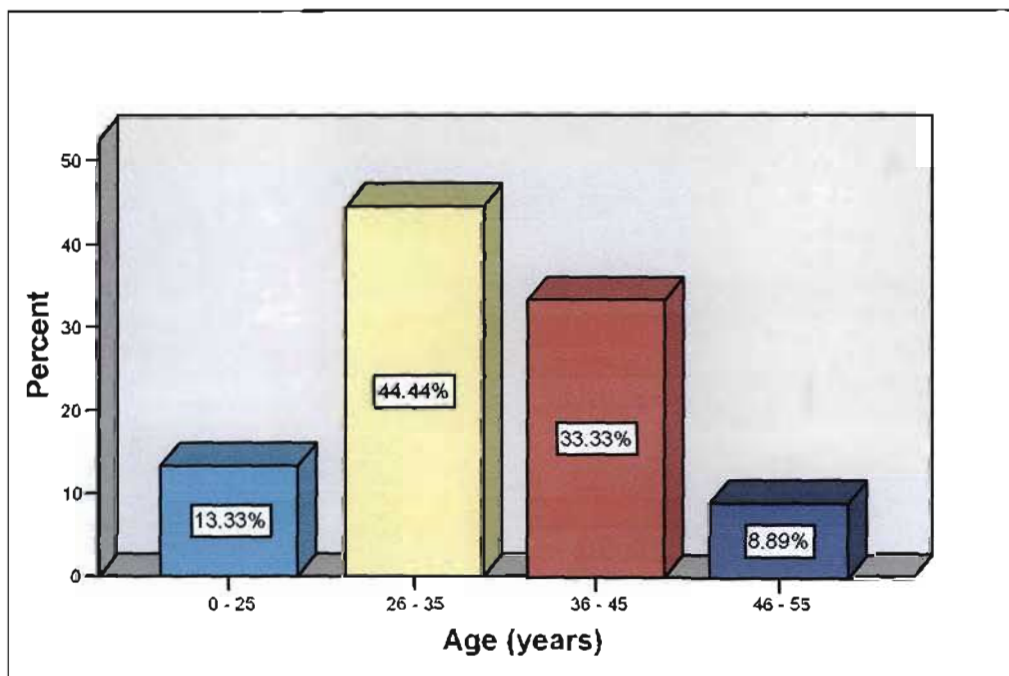


Figure 10: Age Group Distribution of Respondents

The histogram for the age distribution of the respondents reflects a mean of 3.38 with a standard deviation of 0.834 as depicted in figure 4.2 below. This implies that the mid point of the respondents fall within the 26-35 age group.

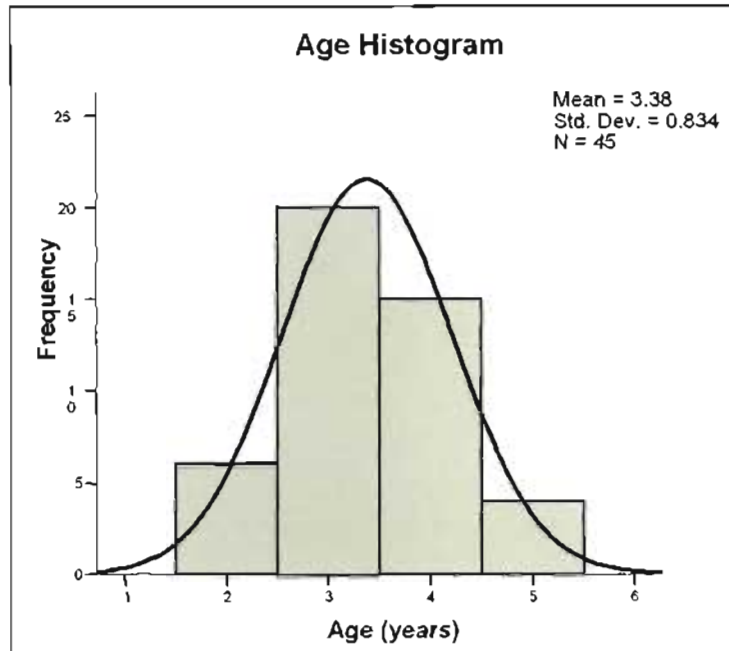


Figure 11: Respondent Age Histogram

4.2.2 Gender Contribution

Figure 12 reflects the gender distribution of respondents. This analysis is important to understand spread of the respondents in terms of gender and is useful later in the research in correlation analysis to establish how this variable affects or is affected by the other variables pertaining to the research questions.

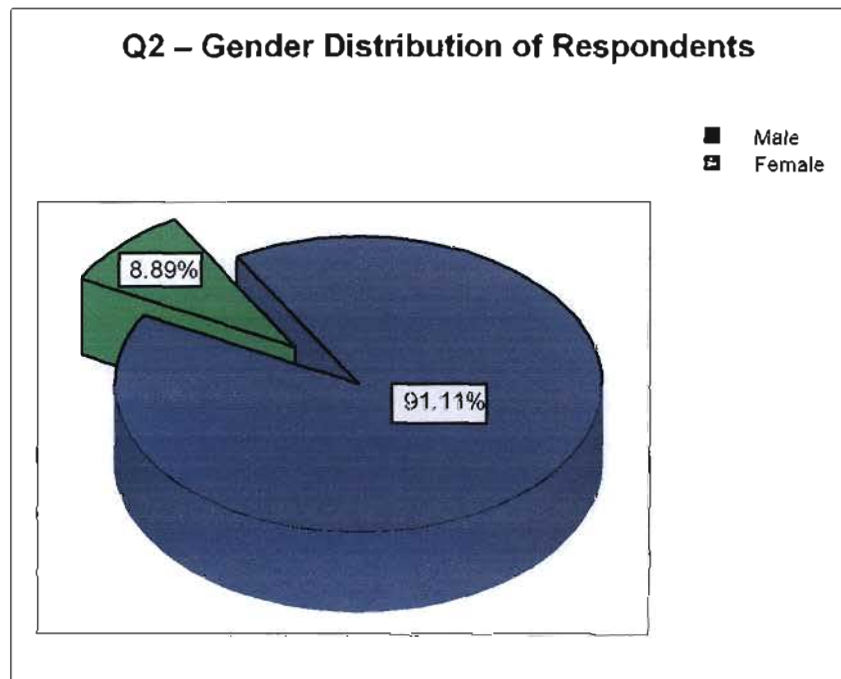


Figure 12: Gender Distribution of Respondents

Females were in the minority constituting 8%, males constituted 91%. The reasons for this result are related to two main contributory factors; firstly the field of IT and Industrial Automation are male dominated professions. The second reason would be that the researcher targeting senior members of staff to complete the questionnaire found that these senior company positions were held predominantly by males.

4.2.3 Ethnic Distribution

This analysis is important to understand what proportion of the respondents is spread across the different age groups and is useful later in the research in correlation analysis to establish how this variable affects or is affected by the other variables pertaining to the research questions. The figure below reflects that the majority of respondents who participated in this study were Asian (57%) and White (31%) with a minority contribution by African (6%) and Coloured (4%).

Q3 - Ethnic Distribution of Respondents

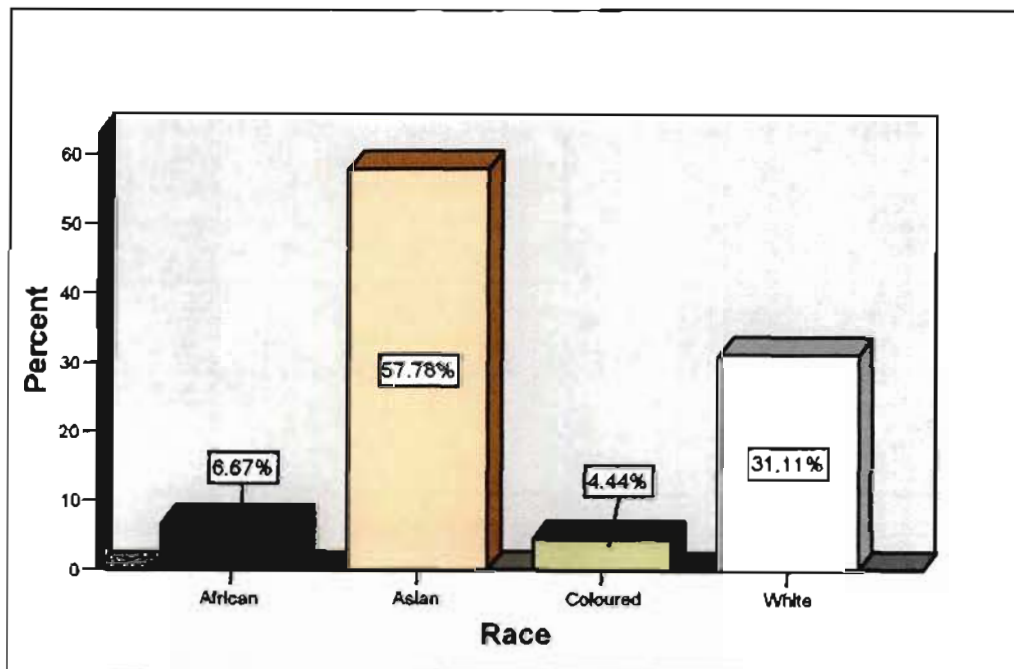


Figure 13: Ethnic Distribution of Respondents

4.2.4 Company Size Distribution

Figure 14 below reflects the distribution of the size of the companies at which the respondents work. The highest number (42%) of respondents works in small to medium size companies ranging from 10-100 employees. The greater than a thousand employee's category comprises 31% of the total distribution, with 17% coming from the 100 – 1000 category and the 8% from companies with less than 10 employees.

Q4 - Company Size Distribution

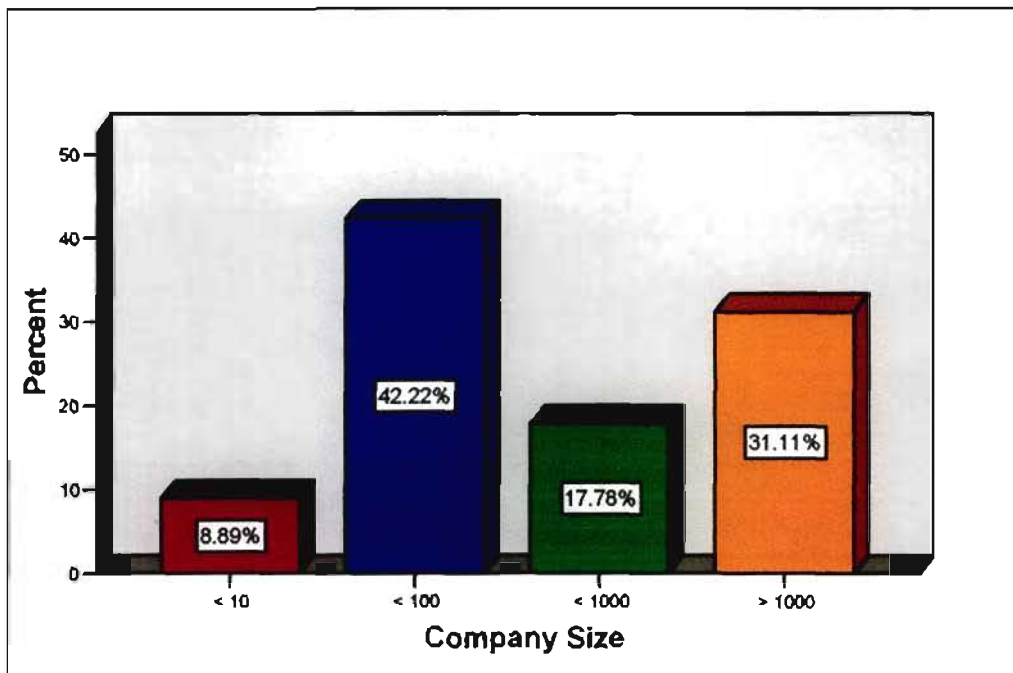


Figure 14: Company Size Distribution of Respondents

4.2.5 Industry Classification Distribution

Q5 - Industry Classification

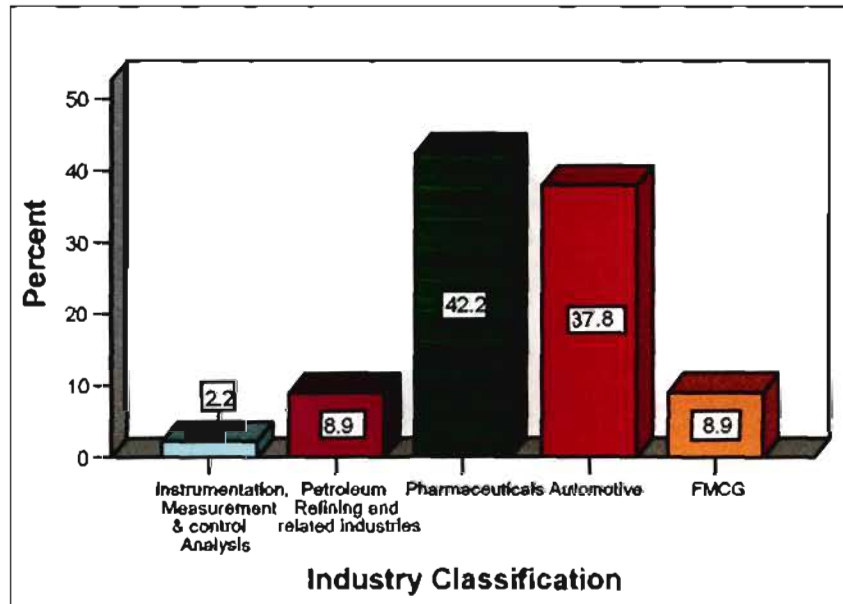


Figure 15: Industry Classification Distribution of Respondents

The distribution of the sample amongst the different industry classification categories is reflected in Figure 15. The pharmaceuticals industry at 42% represents the largest category of the total sample followed by Automotive at 37%, FMCG and Petroleum at 8.9% respectively and the smallest category being the Instrumentation Measurement and Control Analysis at 2.2%.

4.2.6 Years of Work Experience Distribution

Figure 16 below displays the distribution amongst the respondents in terms of years of work experience. Approximately half the respondents (49%) have less than 5 years work experience, 26% have between 10-19 years work experience, 17% have more than 20 years work experience and the remaining 6% have between 5 to 9 years work experience.

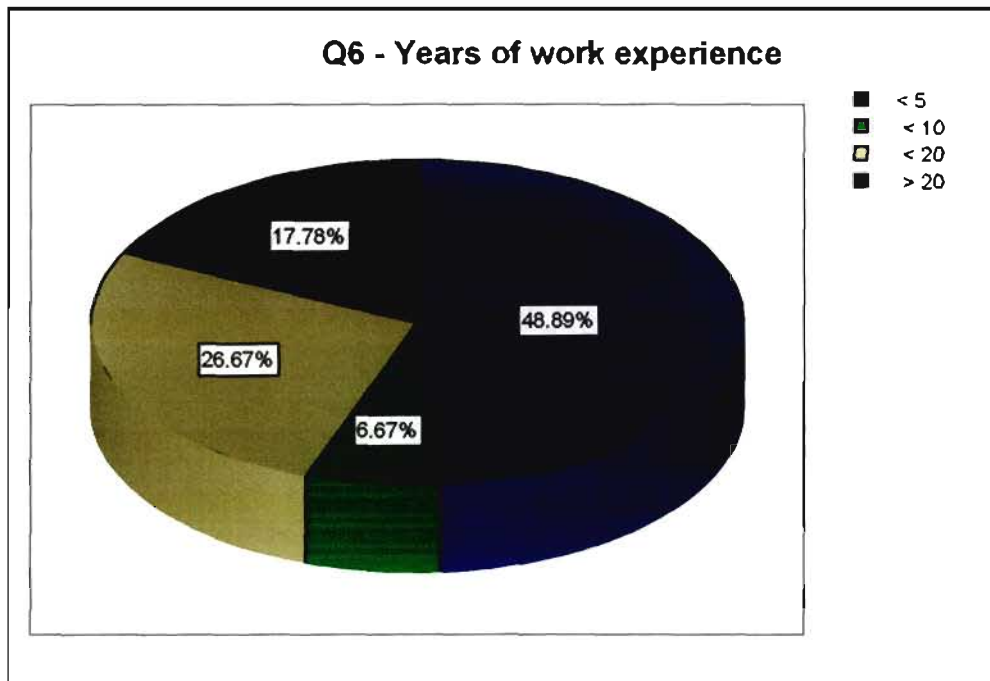


Figure 16: Years of work experience distribution of Respondents

4.2.7 Level in the organisation Distribution

The distribution of the sample in terms of the level within the organisation is reflected in Figure 17. Just over half the respondents (51%) operate at the manager level with their organisation. Engineers represent 22% of the total sample and the remainder is distributed equally (8.89%) amongst the remaining three categories of Artisan, Technician and Supervisor respectively.

Q7 - Level in the Organisation Distribution

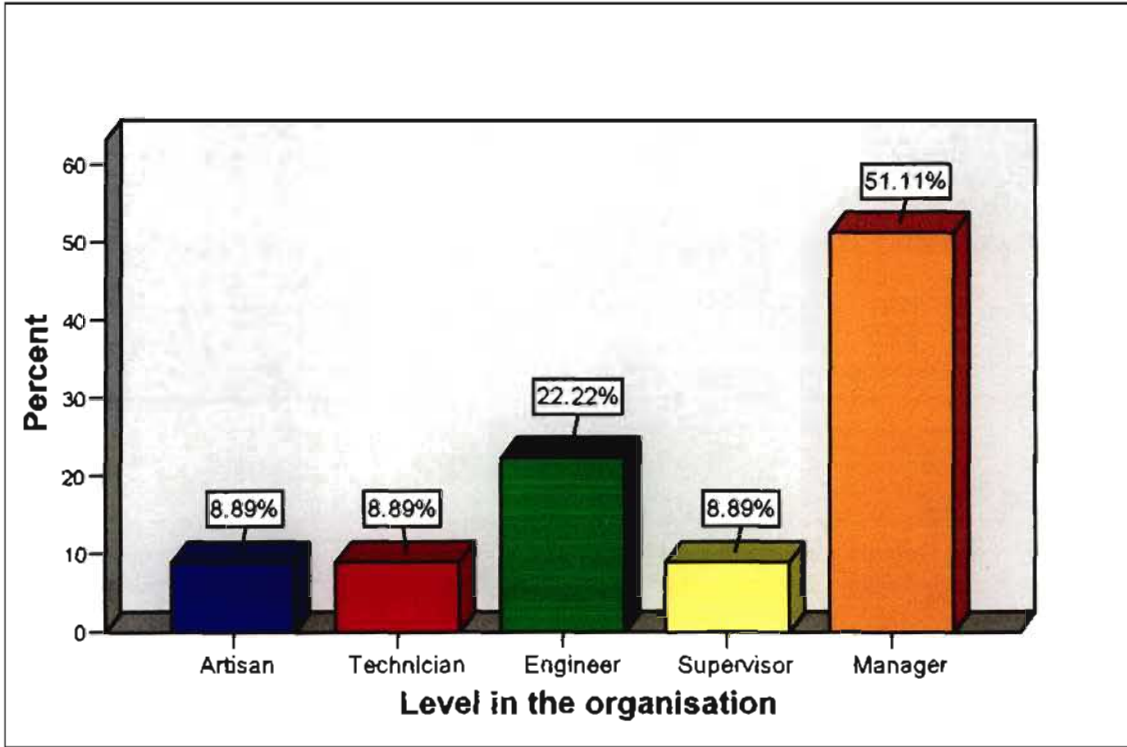


Figure 17: Level in the organisation distribution of respondents

4.2.8 Primary Focus Area

The distribution of the sample in terms of the primary focus within their organisation is reflected in Figure 18. Over half the respondents (57%) operate within and have categorised themselves as focusing on the Automation function within their organisation. Less than a quarter (24%) of the respondents considers themselves to operate in the IT function within their organisation. The remainder is distributed equally amongst the remaining two categories (8.89%) and were either unable to differentiate between the two options or did not want to answer the question.

Q8 - Primary Focus Area Distribution

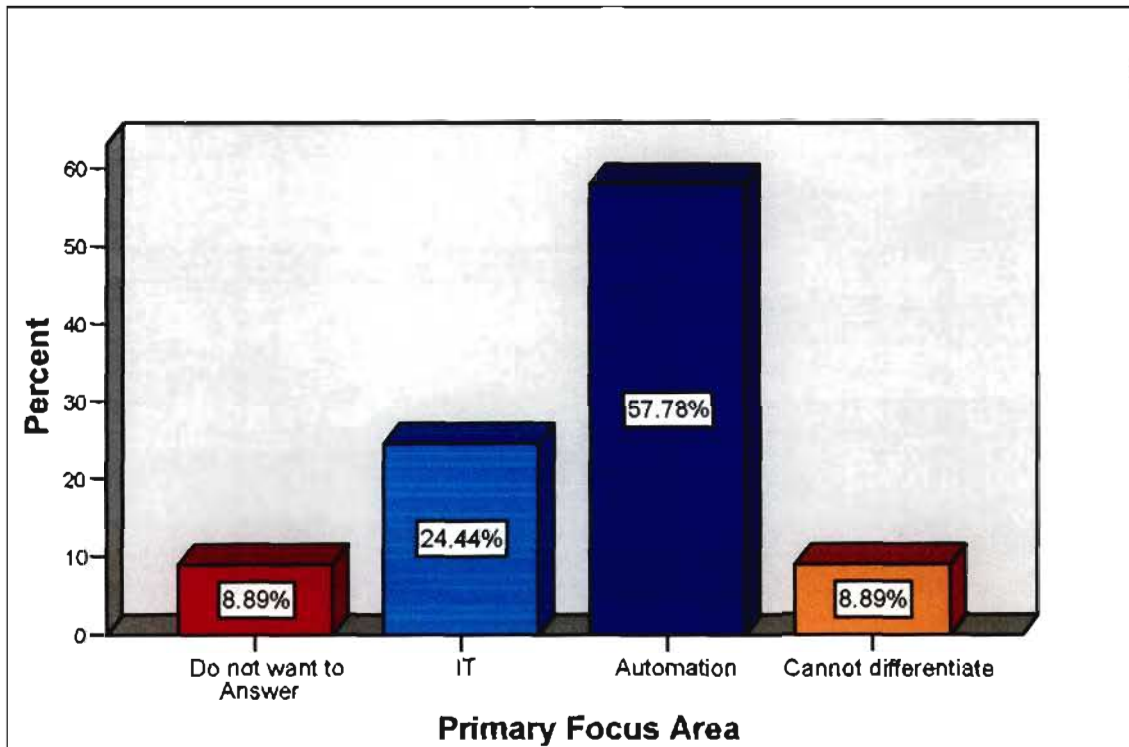


Figure 18: Primary Focus Area distribution of respondents

4.3 The Relationship between traditional IT and Automation – Part 3

This section details the results obtained from part 3 of the questionnaire investigating the relationship between traditional IT and Automation within the manufacturing organisation.

4.3.1 Comparing the fields of IA and IT in a manufacturing organisation

Figures 19 – 21 reflect the responses received in response to questions pertaining to the relationship between the Industrial Automation and the Information technology functions within the manufacturing organisation. The response to Q11.1 shown in Figure 19 reveals that the participants feel that there is a relationship between the two functions; however as per Q11.2 shown in Figure 20 clearly some overlaps and grey areas exist in terms of responsibilities.

In terms of Q11.3 responses shown in Figure 21 there seems to be a mixed reaction with equivalent percentages (26.67%) of responses either strongly agreeing or agreeing that the functions in their organisations operate in conjunction with and compliment each other, however, a marginally greater percentage (28.89%) of the responses disagree or either tend to disagree or strongly disagree (8.89%) with this sentiment. A bimodal distribution is observed in the responses to this question resulting in an inconclusive view in terms of the question asked.

Q11.1 - There is no relationship between the two functions in my organisation.

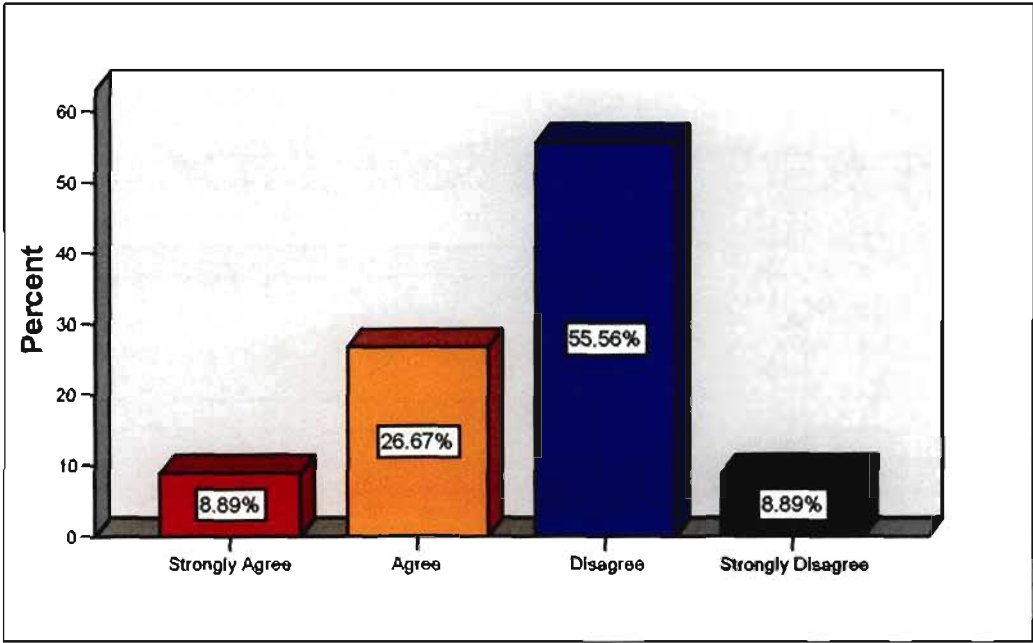


Figure 19: No relationship between functions distribution of respondents

Q11.2 - There is some overlap between the two functions and grey areas exist in terms of responsibility.

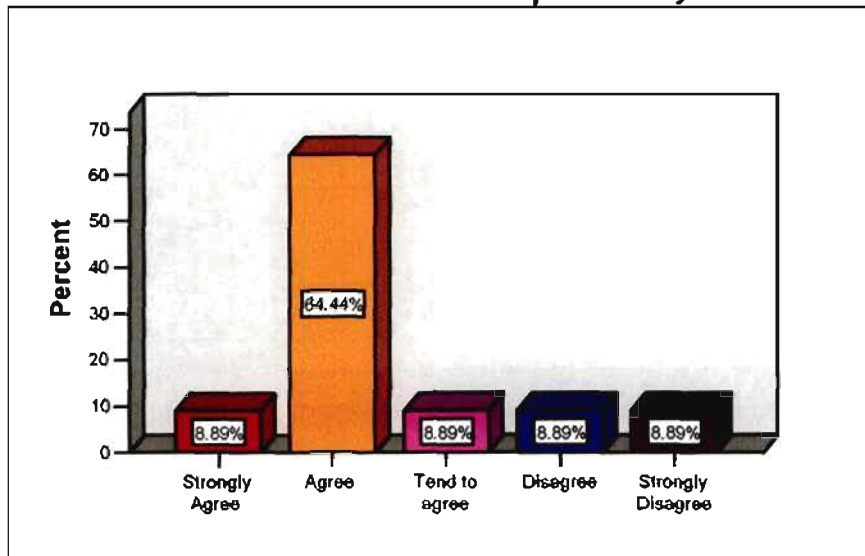


Figure 20: Overlap between functions distribution of respondents

Q11.3 - The two functions operate in conjunction with and are hence complimentary to each other

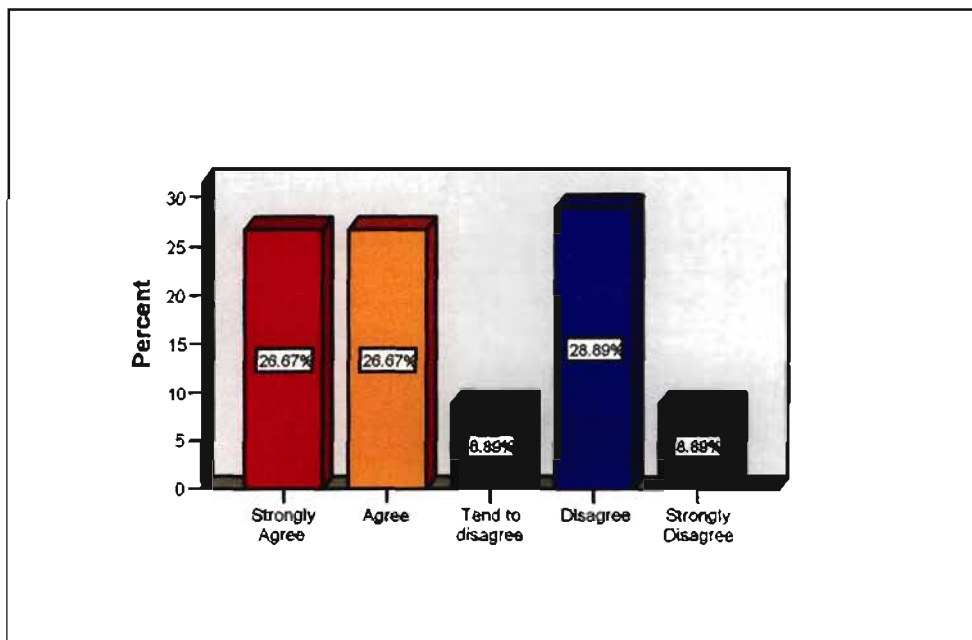


Figure 21: Functions operating in conjunction distribution of respondents

4.3.2 Organisational Structures within the manufacturing organisation

Figures 22 – 24 reflect the responses received in response to questions pertaining to the arrangement of the organisational structures for the Industrial Automation and the Information technology functions within the manufacturing organisation. The response to Q12.1 shown in Figure 22 reveals that the majority (82.22%) of participants agree that in their organisations the two functions operate independently of each other with the remained (17.78%) strongly agreeing that this is the case as well.

Q12.1 - They operate independently of each other within separate structures/departments.

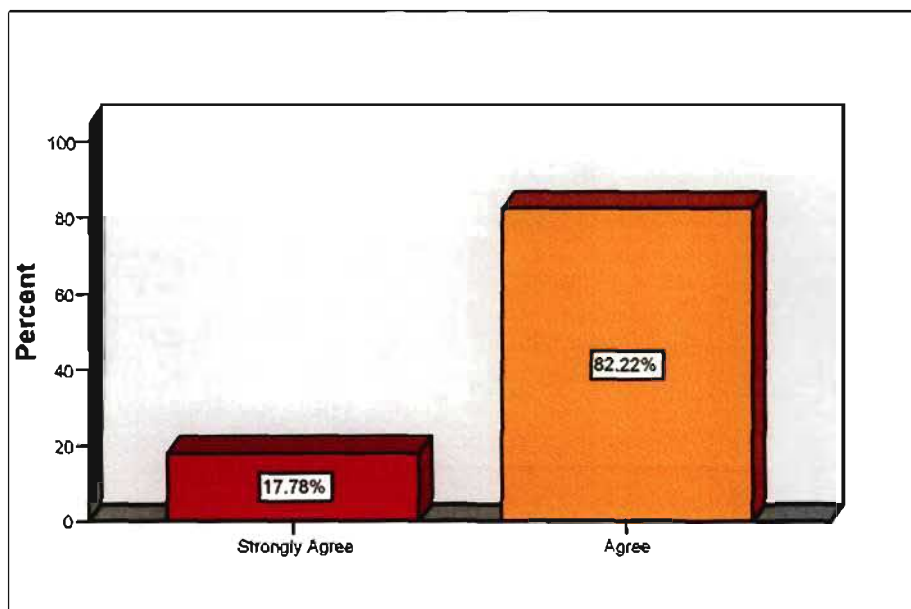


Figure 22: Functions operating in independent structures distribution of respondents

The respondents in 23 have responded positively (Cumulatively 73.33%) to the suggestion that the functions are shared across one/or many structures/departments in their organisation. However notably a significant comparative proportion of the responses disagree with this sentiment (26.76%).

The response to Q12.3 is conclusive with the majority (cumulatively 89%) of the participants either disagreeing (71.11%) or strongly disagreeing (17.78%) that in their organisation the two functions operate within one structure/department.

Q12.2 - These functions are shared across one or many structures/departments.

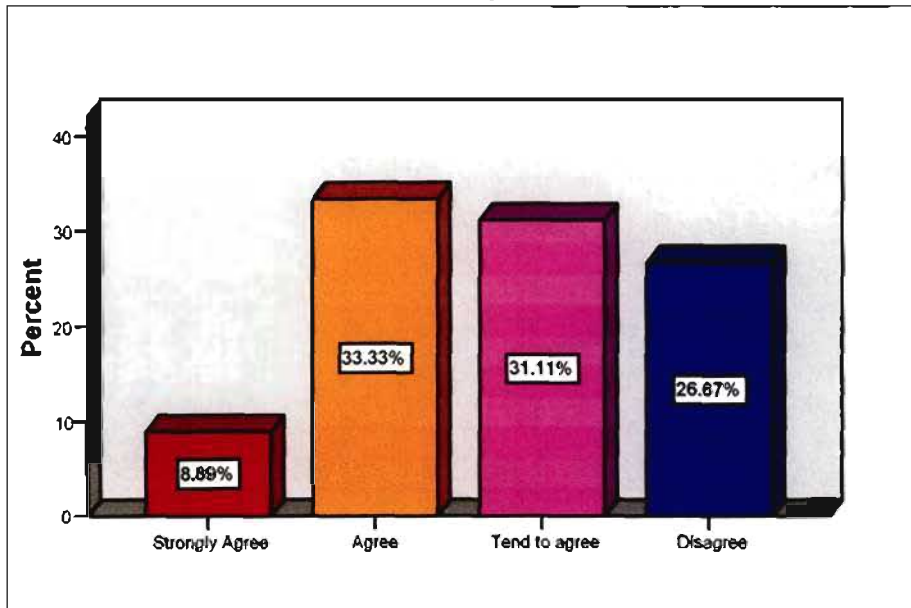


Figure 23: Functions shared across one or many structures distribution of respondents

Q12.3 - The two functions operate within one structure in my organisation

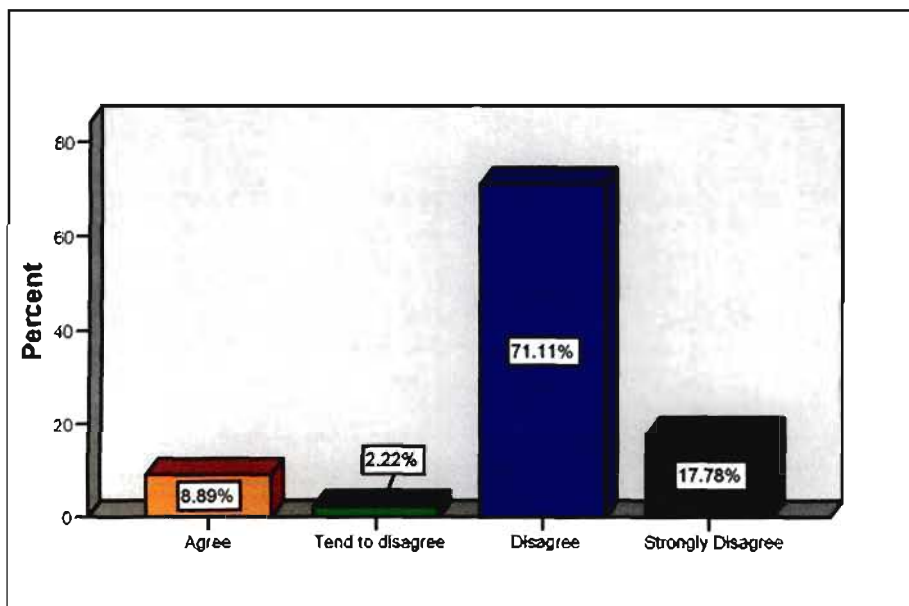


Figure 24: Functions operating within one structure distribution of respondents

4.3.3 Network Infrastructure within the manufacturing organisation

Figures 25 – 27 reflect the responses received in response to questions pertaining to the arrangement of the network infrastructure within the manufacturing organisation. The distribution of responses to Q13.1 as shown in Figure 25 reveals that a one third majority (33.33%) of participants agree that in their organisations the industrial automation network is separate (physically) from the IT/Office network.

Interestingly the split between positive responses (51.11%) to the question versus negative responses (46.67%) is marginal with the remainder (2.22%) unsure of what the situation is in their organisation.

Q13.1 - There is a separate (Physical) Industrial Automation and IT/office network

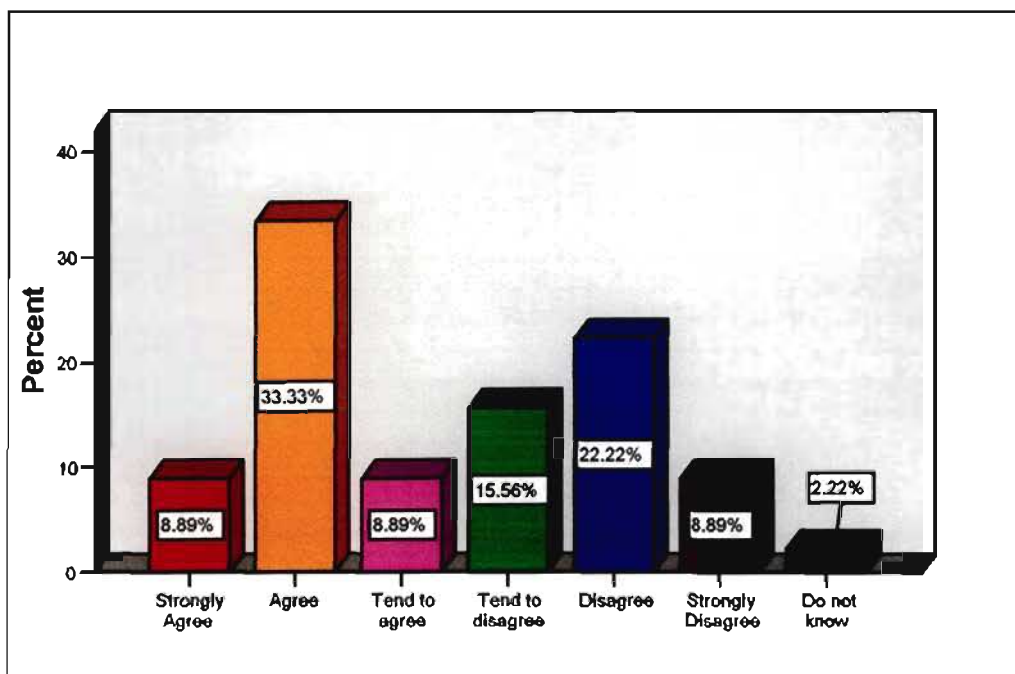


Figure 25: Separate (Physical) IA and IT network distribution of respondents

The response to Q13.2 shown in Figure 26 reflects a positive response (cumulatively 64.45%) to the use of VLAN's within their organisation. 20% of the participants responded negatively and the remainder either were unsure of what the situation is in their organisation (13.33%) or did not want to reveal the situation in their organisation (2.22%).

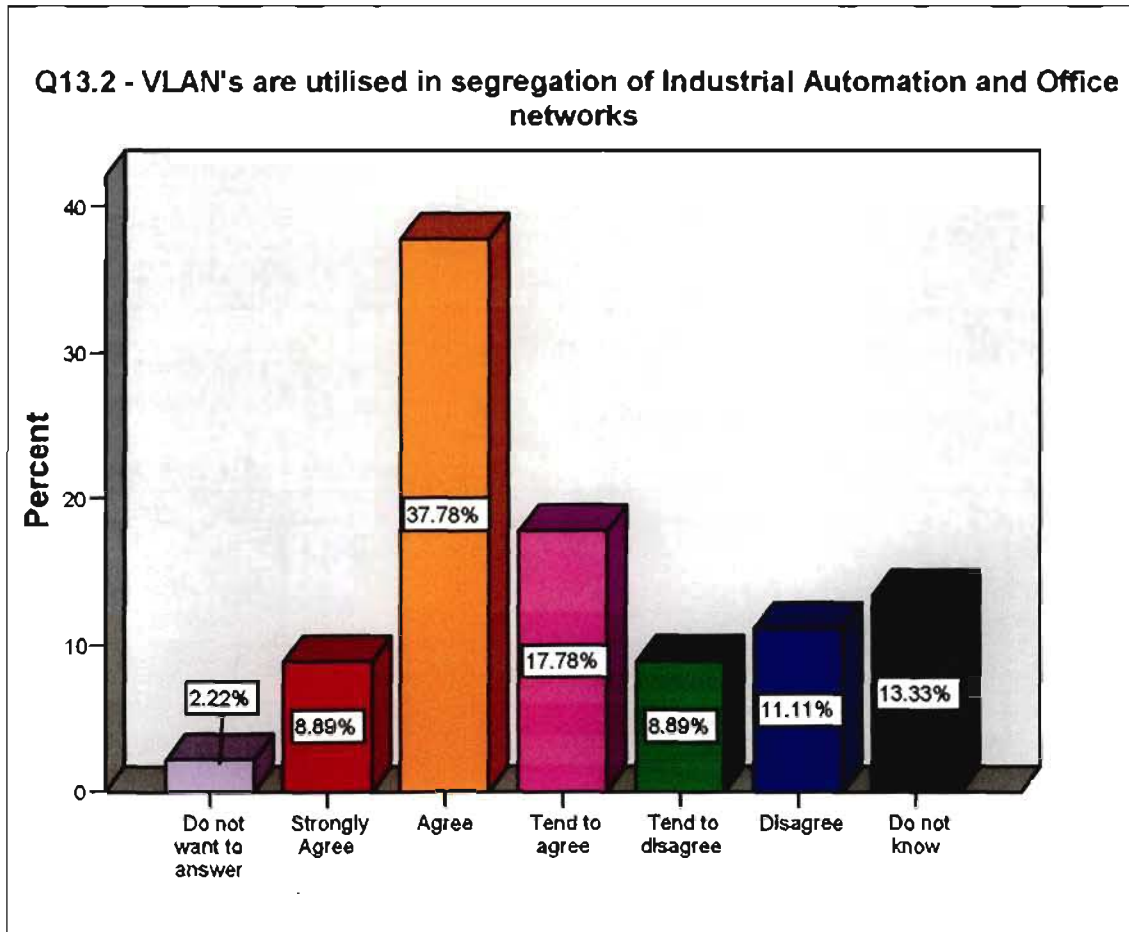


Figure 26: Use of VLAN's distribution of respondents

The response to Q13.3 shown in Figure 27 indicate that whilst the majority (31.11%) of the participants indicated that within their organisations the industrial automation and office networks are not combined which ties up with the response to Q13.1. However the overall the positive response (cumulative 51.11%) is marginally greater than the negative responses comprising of the remainder (cumulative 48.89%).

Q13.3 - Industrial Automation and office networks are combined

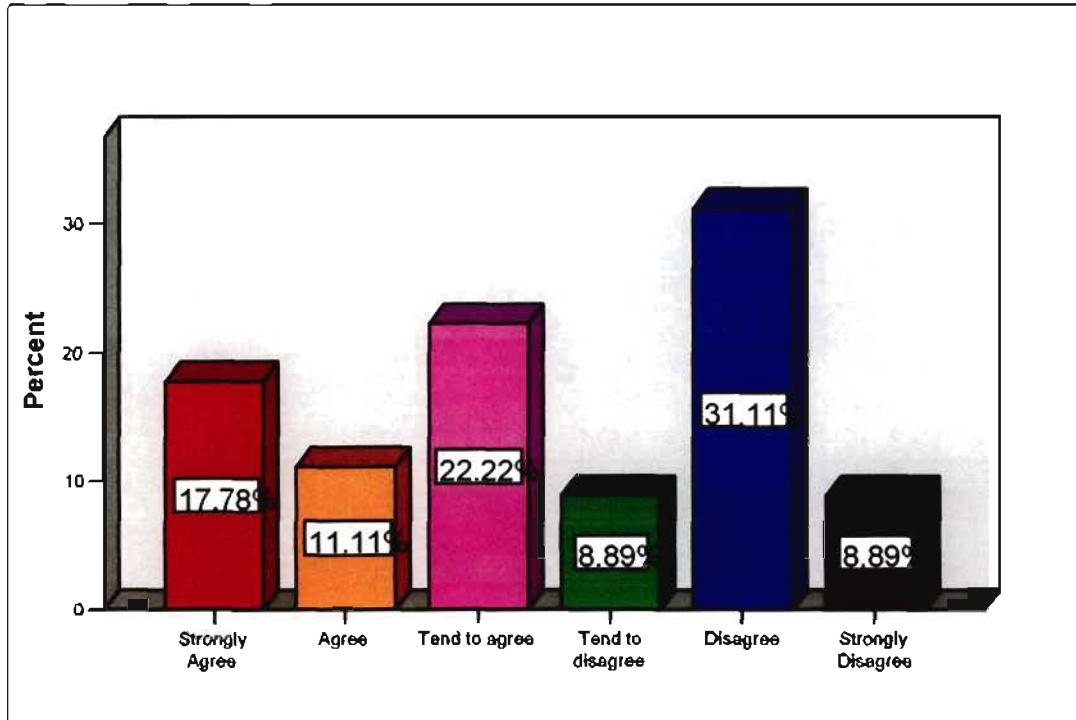


Figure 27: Combined IA and IT networks distribution of respondents

4.3.4 Focus of Industrial Automation towards IT

The responses to Q15 as shown in Figure 28 below reflects conclusively that the majority (80%) of the participants in the survey feel that Industrial Automation/Manufacturing is becoming more IT focused with the remaining (20%) feeling otherwise.

Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focused.

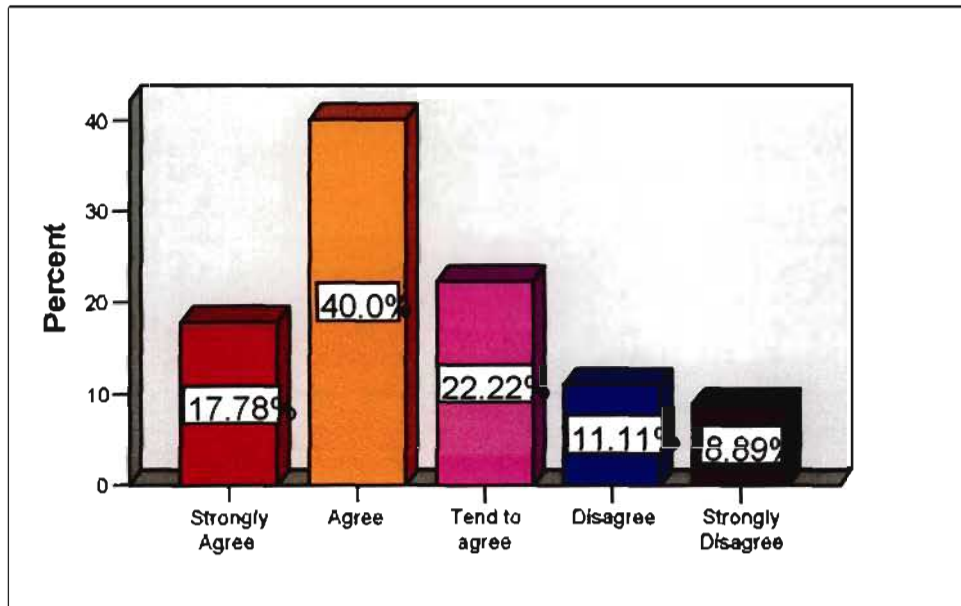


Figure 28: Focus of IA changing towards IT distribution of respondents

4.3.5 Overlap in terms of responsibility and accountability

The responses to Q16 as shown in Figure 29 below reflects conclusively that the a three quarter majority (66.67%) of the participants in the survey feel there is an overlap in terms of responsibility and accountability between Industrial Automation/Manufacturing and IT in their organisation. The remaining quarter of the respondents either disagree with this sentiment (15.56%) or tend to disagree and strongly disagree at 8.89% respectively.

Q16 - There are overlaps in terms of areas of responsibility or accountability between Industrial Automation and IT within my organisation?

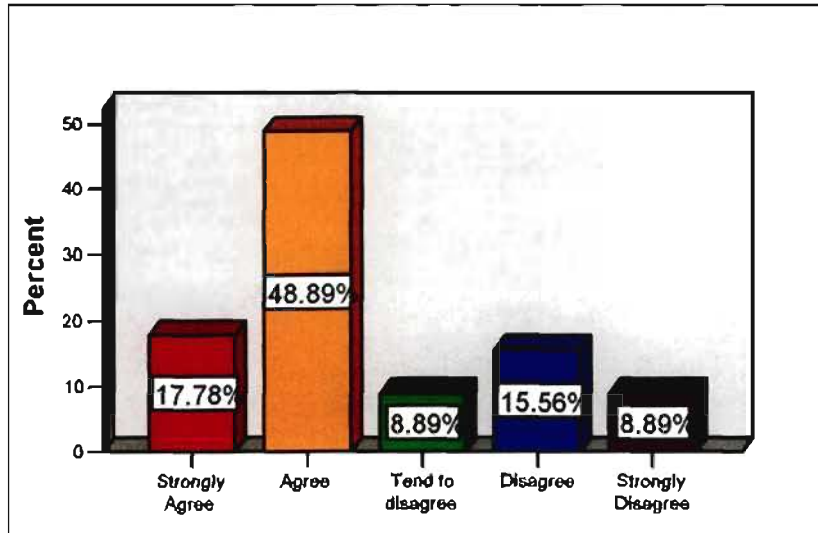


Figure 29: Accountability and responsibility overlaps distribution of respondents

4.3.6 Change in job function

The responses to Q18 as shown in Figure 30 below reflects that just over half the respondents (57.78%) of the participants in the survey disagree that there has been significant change in their job function within the last two years. Contradictorily to this 17.78% of the respondents feel that there has been significant change in their job function in the past two years.

Significantly 15.56% of respondents either did not want to answer the question or 8.89% were not in a position to answer. A reason for this could be that those participants primarily work within the IT function of their organisations.

Figure 31 that shows a cross tabulation between the focus area selected and the option selected in this question reflects that this is the case with a high count of IT focused participants responding that they do not want to answer this question.

Q18 - My job function within the field of Industrial Automation has changed significantly in the past two years?

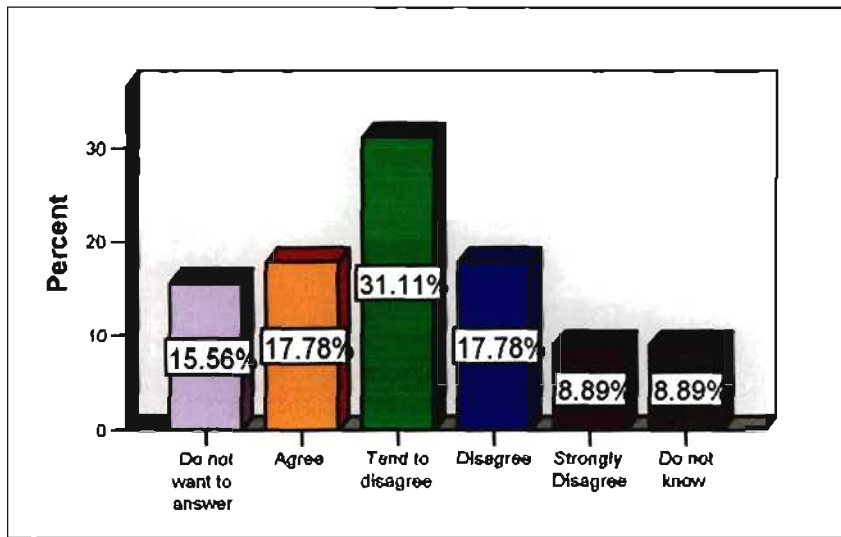


Figure 30: Job function change distribution of respondents

Q10 versus Q18

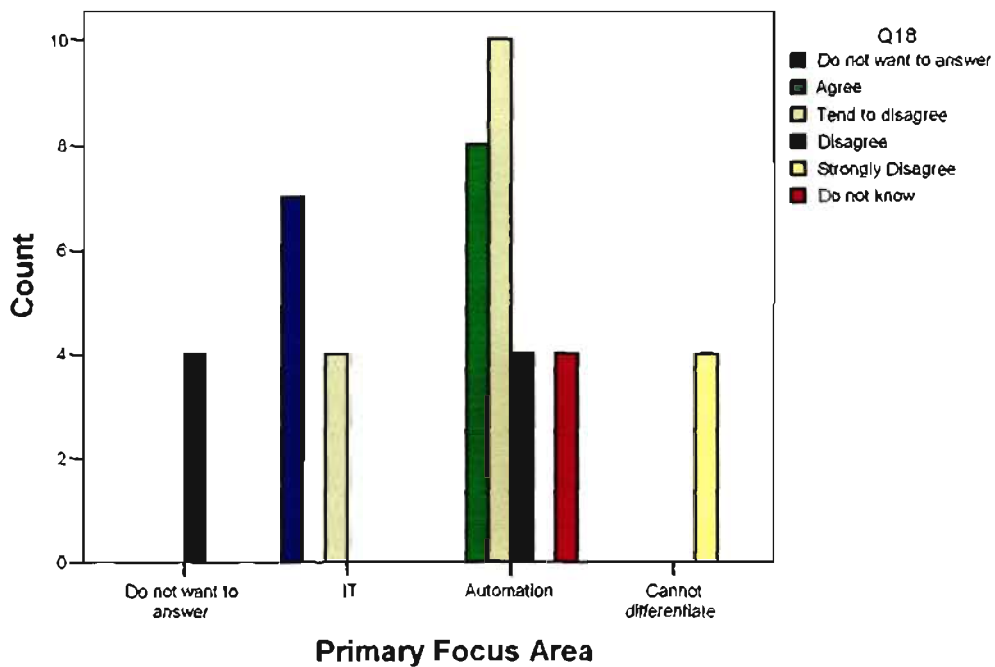


Figure 31: Cross tabulation of focus areas versus change in job function

4.4: Key determinants of Success and Strategic Competitive Advantage - Part 4

This section details the results obtained from part four of the questionnaire investigating the key determinants of success and strategic competitive advantage within the manufacturing organisation and the influence of the IT/Automation function on these..

4.4.1 Key determinants of success

The responses to Q20 as shown in Figure 32 below reflects that the option selected the most often (39.02%) by the participants in the survey as a key determinant of success was factory efficiency. This was followed by systems uptime (26.83%), product quality (14.63%) and equivalently machine operating efficiency and production plan variance (9.76%) respectively.

Q20 - What is/are the key determinant/s of success (KPI/s) in your organisation that you have direct influence upon?

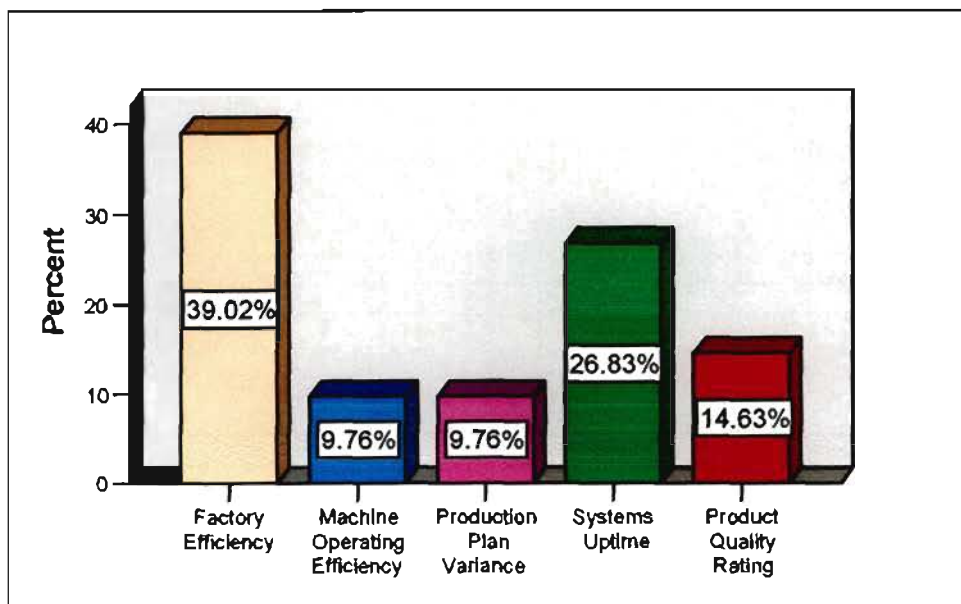


Figure 32: Job function change distribution of respondents

4.4.2 Ability to influence KPI's

The responses to Q22 as shown in Figure 33 below reflects that just over half the respondents feel that they have influence upon the KPI's in a manufacturing organisation. The remainder responded that they have much influence and major influence (19.51%) and a small proportion did not want to answer this question (9.76%).

Q22 - I as an IT/Industrial Automation professional feel that I have The ability to influence the KPI's listed above.

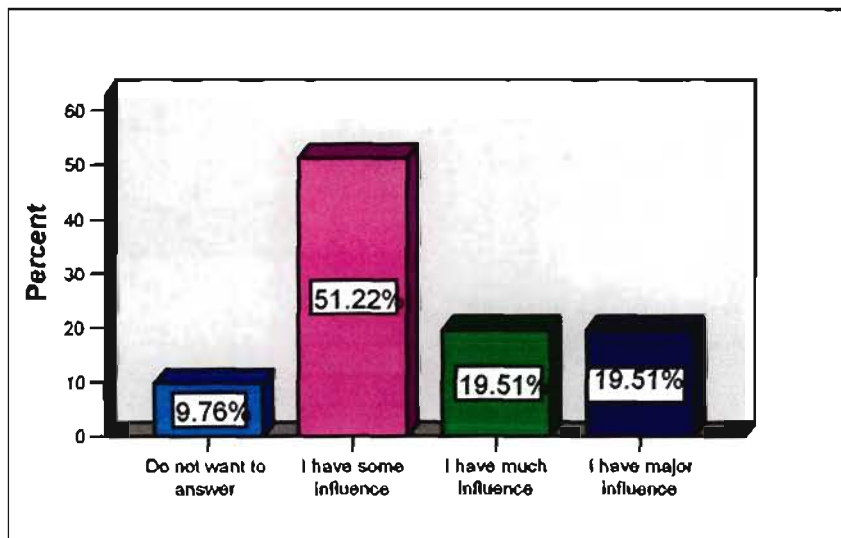


Figure 33: Ability to influence KPI's distribution of respondents

4.4.2 Key factors that contribute to strategic competitive advantage

The responses to Q23 as shown in Figure 34 below reflects a broad spread selections on the factors that provide competitive advantage to the manufacturing organisation over its competitors. The option that was selected the most was factory efficiency (24.44%) followed closely by sales volumes (22.22%), machine operating efficiency (17.78%) and systems uptime and product quality at 8.89% respectively.

A number of respondents (8) selected the other option in this question with the details provided indicating that cost per unit, man-hours per ton, flexibility and continuous improvement indices as the other factors that they consider to provide their organisation with competitive advantage over its competitors.

Q23 - What are the key factors that provide your organisation with competitive advantage over its competitors?

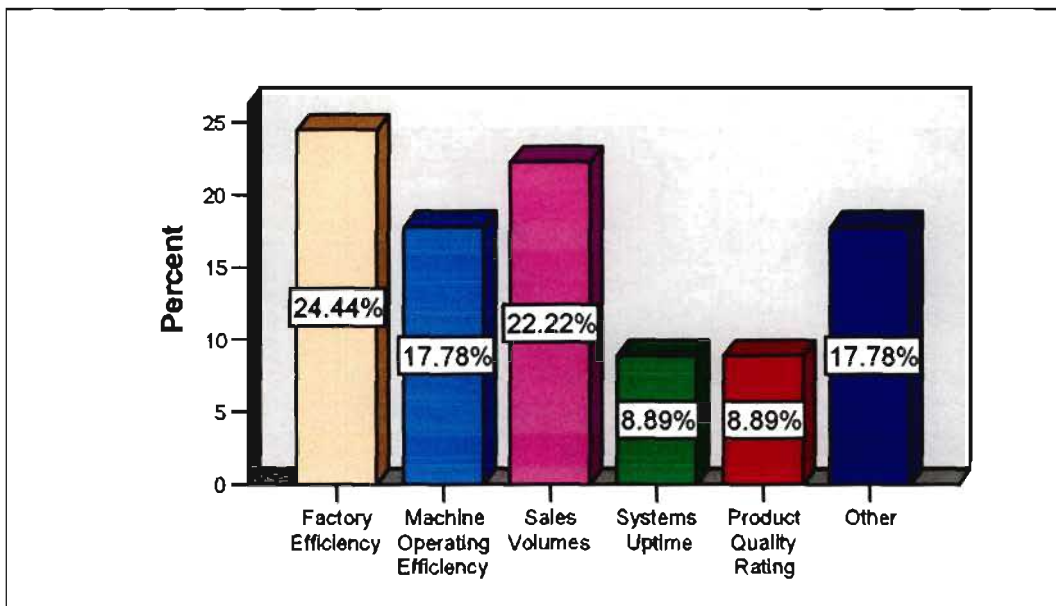


Figure 3-4: Ability to influence KPI's distribution of respondents

4.4.3 The effect of the availability of KPI's

The distribution of responses to Q25 are as shown in Figure 35 below showing that cumulatively three quarters of the participants feel that the availability of production information related to KPI's has a positive effect on the competitive advantage of their organisation. A group of participants (24.44%) feels that this has a some or minor negative effects with the remainder (8.89%) unable to comment.

Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

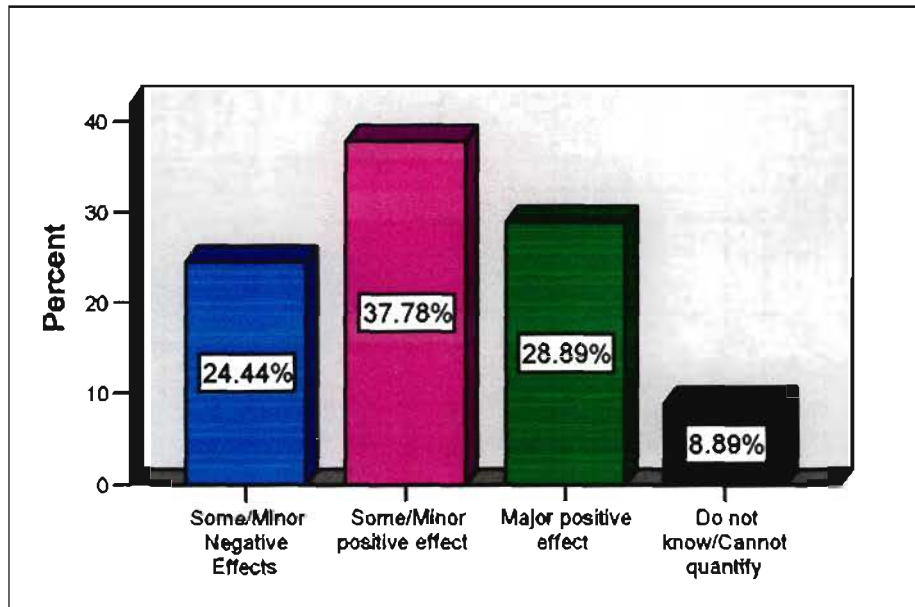


Figure 35: The effect of the availability of KPI's distribution of respondents

4.5 Correlations

Correlations are used to determine whether a relationship exists between variables and to test whether the relationship is significant (Cooper & Schindler, 2003). This study uses the Chi-Square test which is a test of statistical significance that helps to determine whether a systematic relationship exists between two variables.

This is done by computing the cell frequencies which would be expected if *no* relationship is present between the variables given the existing row and column totals (marginals).

Observed Frequency (o_i) – actual values found in
Cross-tabulation table.

Expected Frequency (e_i) – $\frac{(\text{row total} \times \text{column total})}{\text{Grand Total}}$

The decision to accept or reject H_0 (the null Hypothesis) is based on how a good a fit one has between the observed frequencies and the frequencies one would expect for each cell under the assumption that H_0 (the null hypothesis) is true.

Degrees of freedom $df = (r - 1)(c - 1)$

The expected cell frequencies are then compared to the actual values found in the table according to the following formula:

$$\chi^2 = \text{the sum of } (o_i - e_i)^2 / e_i \quad \text{across all cells}$$

To test the null hypothesis for independence we use the following Decision Criterion:

If $\chi^2 > \chi^2_{\alpha, df}$ with $(r-1)(c-1)$ degrees of freedom Reject the null Hypothesis of independence at the level of significance otherwise accept the null hypothesis.

$$\chi^2_{\text{(CORRECTED)}} = \text{The sum of all cell } - (10 - e - 0.5)^2 / e$$

If e is large the corrected and uncorrected results are almost the same.

The greater the discrepancy between the expected and actual frequencies, the larger chi-square becomes.

By itself, chi-square helps us only to decide whether variables are independent or related. It does not tell how strongly they are related. Part of the reason is that sample size and table size have such an influence on chi-square. When chi-square is thus adjusted it becomes the basis for assessing the strength of the relationship.

The following section details the Chi-Square Test procedure used to test the hypothesis of independence of 2 variables of Classification.



4.5.1 Summary of the Chi-Square Test

Step1: State Hypotheses

H₀: the classifications are independent (NOT RELATED)

H₁: the classifications are dependent (RELATED OR ASSOCIATED IN SOME WAY)

Step2: degrees of freedom

df = (r-1)(c-1).....degrees of freedom

level of significance = most common 5% =0.05

Step 3

$\chi^2_{\alpha,df}$ with (r-1)(c-1) degrees of freedom

Step 4

Calc: $\chi^2 = \text{the sum of } (O_i - E_i)^2 / E_i \text{ across all cells}$

Step 5

If $\chi^2 > \chi^2_{\alpha,df}$ with (r-1)(c-1) degrees of freedom Reject the null Hypothesis of independence at the level of significance otherwise accept the null hypothesis.

4.5.2 The Phi (ϕ) Coefficient

For a 2 X 2 table, the phi statistic is a suitable measure of association, i.e., a measure of strength of relationship.

Phi (ϕ) makes a correction for the fact that the value of chi-square is directly proportional to the number of cases N by adjusting the χ^2 value. Its formula is:

$$\phi = \left[\frac{\chi^2}{N} \right]^{1/2}$$

When $\Phi = 0$ then no relationship exists and the value of +1 when the variables are perfectly related. Φ is between -1 and 1. Values close to -1 or +1 indicate strong association whereas values close to zero indicates a weak association.

4.5.3 Summary of the Cramer's V Test

In qualitative data analysis one cannot rely on the results of one test to conclude relationships between variables but require confirmation via other methods. Cramer's V is a slightly modified version of ϕ used in the chi-square test which is suitable for larger tables. Cramer's V is used to adjust ϕ for either the number of rows or the number of columns in the table, depending on which of the two is smaller. Its formula is:

$$V = \left[\frac{\phi^2}{\min(r - 1, c - 1)} \right]^2$$

V ranges from 0 to +1 when several nominal categories are involved. Thus a large value of V merely signifies that a high degree of association exists, without revealing the manner in which the variables are associated. A value of 1 suggests that a perfect association exists, whereas a value of 0 suggests that no association between the variables exist.

Summary: Is suitable for larger tables. Ranges from 0 to +1. Values close to 1 indicate strong association.

4.5.4 Summary of Contingency coefficient (C)

This is a measure of association based on chi-square which can be used with a table of any size. It should be used to compare tables having the same dimensions, i.e., the same number of rows and columns.

The value ranges between 0 and 1, with 0 indicating no association between the row and column variables and values close to 1 indicating a high degree of association between the variables. The maximum value possible depends on the number of rows and columns in a table. A value of 1 suggests that a perfect association exists, whereas a value of 0 suggests that no association between the variables exist.

$$C = \left(\frac{X^2}{X^2 + N} \right)^{1/2}$$

4.5.5 Correlation tests results

The Table 4 below summarises the results obtained in performing the above tests on the results obtained via the survey. As indicated in section 4.2 the demographic variables both gives an indication of the environment in which the research was conducted but also provides common variables against which to compare the key variables pertaining to the research questions in order to better understand their behaviour which leads to the development of conclusions based on these results. The full calculations showing how these results were derived are provided in Appendix VIII.

Variables	Tests			
	Chi-Square	P-Value	Cramer's V	Contingency Coefficient
Q1 vs. Q15	$\chi^2 = 45.056 >$ $\chi^2_{0.05,12} = 21.0261$ Significant Relationship	P-Value = 0.000 < 0.05 Significant Relationship	Cramer's V = 0.578 Moderate degree of association	C = 0.707 Moderate degree of association
Q1 vs. Q16	$\chi^2 = 28.543 >$ $\chi^2_{0.05,12} = 21.0261$ Significant Relationship	P-Value = 0.005 < 0.05 Significant Relationship	Cramer's V = 0.46 Low degree of association	C = 0.623 Low degree of association
Q1 vs. Q18	$\chi^2 = 62.638 >$ $\chi^2_{0.05,15} = 24.9958$ Significant Relationship	P-Value = 0.000 < 0.05 Significant Relationship	Cramer's V = 0.681 Moderate degree of association	C = 0.763 Moderate degree of association
Q1 vs. Q22	$\chi^2 = 22.192 >$ $\chi^2_{0.05,9} = 16.9190$ Significant Relationship	P-Value = 0.008 < 0.05 Significant Relationship	Cramer's V = 0.425 Low degree of association	C = 0.593 Low degree of association
Q1 vs. Q25	$\chi^2 = 21.189 >$ $\chi^2_{0.05,9} = 16.9190$ Significant Relationship	P-Value = 0.012 < 0.05 Significant Relationship	Cramer's V = 0.396 Low degree of association	C = 0.566 Low degree of association
Q2 vs. Q15	$\chi^2 = 15.366 >$ $\chi^2_{0.05,4} = 9.48773$	P-Value = 0.004 < 0.05	Cramer's V = 0.585	C = 0.505 Moderate

	Significant Relationship	Significant Relationship	Moderate degree of association	degree of association
Q2 vs. Q16	$\chi^2 = 4.590 <$ $\chi^2_{0.05,4} = 9.48773$ No relationship	P-Value = 0.332 > 0.05 No relationship	Cramer's V = 0.319 Very Low degree of association	C = 0.304 Low degree of association
Q2 vs. Q18	$\chi^2 = 9.721 <$ $\chi^2_{0.05,5} = 11.0705$ No relationship	P-Value = 0.084 > 0.05 No relationship	Cramer's V = 0.465 Very low degree of association	C = 0.421 Low degree of association
Q2 vs. Q22	$\chi^2 = 4.221 <$ $\chi^2_{0.05,3} = 7.81473$ No relationship	P-Value = 0.084 > 0.05 No relationship	Cramer's V = 0.321 Very low degree of association	C = 0.306 Very low degree of association
Q2 vs. Q25	$\chi^2 = 3.097 <$ $\chi^2_{0.05,3} = 7.81473$ No relationship	P-Value = 0.377 > 0.05 No relationship	Cramer's V = 0.262 Very low degree of association	C = 0.254 Very low degree of association
Q5 vs. Q15	$\chi^2 = 75.071 >$ $\chi^2_{0.05,1} = 21.0261$ Significant Relationship	P-Value = 0.000 0.05 Significant Relationship	Cramer's V = 0.746 Moderate - high degree of association	C = 0.791 High degree of association
Q5 vs. Q16	$\chi^2 = 79.680 >$ $\chi^2_{0.05,1} = 21.0261$ Significant Relationship	P-Value = 0.000 0.05 Significant Relationship	Cramer's V = 0.768 Moderate - high degree of association	C = 0.799 High degree of association
Q5 vs. Q18	$\chi^2 = 77.687 >$ $\chi^2_{0.05,1} = 24.0958$ Significant Relationship	P-Value = 0.000 0.05 Significant Relationship	Cramer's V = 0.759 Moderate - high degree of association	C = 0.796 High degree of association
Q5 vs. Q22	$\chi^2 = 46.980 >$ $\chi^2_{0.05,1} = 16.9190$ Significant Relationship	P-Value = 0.000 0.05 Significant Relationship	Cramer's V = 0.618 Moderate degree of association	C = 0.731 High degree of association
Q5 vs. Q25	$\chi^2 = 58.983 >$ $\chi^2_{0.05,1} = 16.9190$ Significant Relationship	P-Value = 0.000 0.05 Significant Relationship	Cramer's V = 0.661 Moderate degree of association	C = 0.753 High degree of association
Q7 vs. Q15	$\chi^2 = 55.117 >$ $\chi^2_{0.05,1} = 21.0261$ Significant Relationship	P-Value = 0.000 0.05 Significant Relationship	Cramer's V = 0.639 Moderate degree of association	C = 0.742 Moderate degree of association
Q7 vs. Q16	$\chi^2 = 39.760 >$ $\chi^2_{0.05,1} = 21.0261$ Significant Relationship	P-Value = 0.000 0.05 Significant Relationship	Cramer's V = 0.543 Moderate degree of association	C = 0.685 Moderate degree of association

Q7 vs. Q18	Significant Relationship $\chi^2 = 80.753$ $\chi^2_{0.05,15} = 24$ Significant Relationship	Relationship P-Value = 0.000 < 0.05 Significant Relationship	of association Cramer's V = 0.773 Moderate - High degree of association	association C = 0.801 High degree of association
Q7 vs. Q22	$\chi^2 = 51.128$ $\chi^2_{0.05,15} = 16.0190$ Significant Relationship	P-Value = 0.000 < 0.05 Significant Relationship	Cramer's V = 0.645 Moderate degree of association	C = 0.745 Moderate degree of association
Q7 vs. Q25	$\chi^2 = 37.689$ $\chi^2_{0.05,9} = 16.9190$ Significant Relationship	P-Value = 0.000 < 0.05 Significant Relationship	Cramer's V = 0.528 Moderate degree of association	C = 0.675 Moderate degree of association
Q8 vs. Q15	$\chi^2 = 37.662 >$ $\chi^2_{0.05,10} = 26.2962$ Significant Relationship	P-Value = 0.000 < 0.05 Significant Relationship	Cramer's V = 0.457 Low degree of association	C = 0.675 Moderate degree of association
Q8 vs. Q16	$\chi^2 = 75.010 >$ $\chi^2_{0.05,10} = 26.2962$ Significant Relationship	P-Value = 0.000 > 0.05 Significant Relationship	Cramer's V = 0.646 Moderate degree of association	C = 0.791 Moderate - High degree of association
Q8 vs. Q18	$\chi^2 = 75.522 >$ $\chi^2_{0.05,20} = 31.4104$ Significant Relationship	P-Value = 0.000 > 0.05 Significant Relationship	Cramer's V = 0.648 Moderate degree of association	C = 0.792 Moderate degree of association
Q8 vs. Q22	$\chi^2 = 89.327 >$ $\chi^2_{0.05,12} = 21.0261$ Significant Relationship	P-Value = 0.000 > 0.05 Significant Relationship	Cramer's V = 0.852 High degree of association	C = 0.828 High degree of association
Q8 vs. Q25	$\chi^2 = 62.354 >$ $\chi^2_{0.05,12} = 21.0261$ Significant Relationship	P-Value = 0.000 > 0.05 Significant Relationship	Cramer's V = 0.680 Moderate degree of association	C = 0.762 Moderate degree of association
Q10 vs. Q15	$\chi^2 = 78.173 >$ $\chi^2_{0.05,12} = 21.0261$ Significant Relationship	P-Value = 0.000 < 0.05 Significant Relationship	Cramer's V = 0.761 Moderate - high degree of association	C = 0.797 Moderate - high degree of association
Q10 vs. Q16	$\chi^2 = 69.138$ $\chi^2_{0.05,12} = 21.0261$ Significant Relationship	P-Value = 0.000 < 0.05 Significant Relationship	Cramer's V = 0.716 Moderate - High degree of association	C = 0.778 Moderate degree of association
Q10 vs. Q18	$\chi^2 = 92.405 >$ $\chi^2_{0.05,15} = 24.9958$	P-Value = 0.000 < 0.05	Cramer's V = 0.827	C = 0.820 High degree of

Q10 vs. Q22	Significant Relationship $\chi^2 = 68.955$ $\chi^2_{(df=1)} = 16.9190$ Significant Relationship	Significant Relationship P-Value = 0.000 0.05	High degree of association Cramer's V = 0.749 Moderate - high degree of association	association C = 0.792 Moderate - high degree of association
Q10 vs. Q25	Significant Relationship $\chi^2 = 44.529$ $\chi^2_{(df=1)} = 16.9190$ Significant Relationship	Significant Relationship P-Value = 0.000 0.05	Moderate degree of association Cramer's V = 0.574	Moderate degree of association C = 0.705
Q15 vs. Q16	Significant Relationship $\chi^2 = 113.399$ $\chi^2_{(df=1)} = 26.2962$ Significant Relationship	Significant Relationship P-Value = 0.000 0.05	Moderate - High degree of association Cramer's V = 0.794	High degree of association C = 0.846
Q15 vs. Q18	Significant Relationship $\chi^2 = 113.188$ $\chi^2_{(df=1)} = 31.4104$ Significant Relationship	Significant Relationship P-Value = 0.000 0.05	Moderate - High degree of association Cramer's V = 0.793	
Q20 vs. Q23	Significant Relationship $\chi^2 = 120.035$ $\chi^2_{(df=1)} = 31.4104$ Significant Relationship	Significant Relationship P-Value = 0.000 0.05	High degree of association Cramer's V = 0.856	High degree of association C = 0.863
Q22 vs. Q25	Significant Relationship $\chi^2 = 26.802$ $\chi^2_{(df=1)} = 16.9190$ Significant Relationship	Significant Relationship P-Value = 0.000 0.05	Moderate degree of association Cramer's V = 0.574	Moderate degree of association C = 0.688

Table 4: Summary of correlation test results

4.6 Conclusion

This chapter presented the survey results, and gave an interpretation and statistical analyses of the data collected from manufacturing companies in the greater Duran Area. Descriptive frequency statistics reflected respondents' answers to specific questions.

The researcher defined various study variables. Central tendency statistics were applied to determine average perceptions to these variables, and correlation statistics were applied to ascertain whether there were relationships between these variables and the strength of these relationships.

The demographic description of the respondents who participated in the study was described. The impact of the demographic dispersion on the study results was ascertained through the chi-square, p-value, Cramer's V and Contingency coefficient test results.

These research results and the analyses of the data will be used to make conclusions and recommendations which will be discussed in the next chapter.

CHAPTER 5: RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

This chapter presents the recommendations and conclusions which are based on the findings from the study. The research questions raised in chapter two of this study will be answered, recommendations for future research will be made, the limitations of the study will be discussed and the final conclusion to the study will be presented.

5.2 What is the relationship between IT and IA?

The survey results indicate that there is a strong relationship between the industrial automation and the information technology functions within the manufacturing organisation and as such there are a number of grey areas that exist in terms of responsibility. There was a mixed response in terms of whether the two functions operate in conjunction with each other and are hence complimentary to each other as the results to this question is inconclusive.

In terms of the results on the arrangement of organisational structures the results indicate strongly that the work is not shared amongst different teams/departments but that these functions operate as separate teams/departments within the manufacturing organisation.

The results on the networking architecture present in manufacturing organisations indicate that the majority have office networks that are kept separate from the industrial automation networks. However a large proportion of respondents indicated the use of VLAN technology at their organisations.

The respondents when asked if they have noticed a change in their job function in the last two years responded in the negative.

The findings and conclusions in this section when applied to the research question indicate that there is a strong relationship between the two functions within the manufacturing

organisation. However, of concern is the fact that the majority of the organisations surveyed still maintain separate organisational structures as well as network architectures. This is not an ideal situation and will be addressed further in the recommendations section of this study.

5.3 What are the key determinants of success and competitive advantage?

The key determinants of success encapsulated in KPI's for a manufacturing organisation is factory efficiency and systems uptime with product quality ratings being third on the list.

In terms of the ability to influence these KPI's IT and Automation professionals feel that they have the ability to influence these key measures of success.

Interesting the spread of responses to the competitive advantage question was spread out to a greater extent with a more equal spread than when compared to the KPI question. Factory efficiency tops the list with sales volumes and machine operating efficiency in descending order of selection.

5.4 Does the availability of production information increase competitive advantage?

The conclusion drawn from the study on the effect of production information on the competitive advantage of the organisation is that based on the results obtained there is a positive effect observed.

5.5 Recommendations to senior management

The following recommendations to senior management stems from the results collected via the study and the conclusions drawn from them.

- i) The study has shown that there is a close relationship between the IT and the Industrial Automation function within the manufacturing environment. As a result

the study has shown that there are overlaps in terms of accountability for the different IT and plant automation processes between the separate functions within the organisation. Based on the above the recommendation is for senior management to combine the separate functions into one combined team/department that is constituted of both IT and Industrial Automation specialists that work together in a galvanised fashion to provide information on production performance to senior management so that appropriate decisions on corrective action can be taken.

- ii) The study has demonstrated that at present manufacturing organisations install and maintain separate office and automation networks. It is recommended that these be combined via the use of VLAN technology. This would allow for a single physical network that is separated logically into office and automation networks. Coupled to this recommendation would be a recommendation to migrate all manufacturing automation equipment to a single interconnected plant-wide network running on a single protocol such as an industrial Ethernet. The benefit of this would be the ability to automate the provision of production information ensuring better production and process management.
- iii) Assess information intensity. A company's first task is to evaluate the existing and potential information intensity of the products and processes of its business units. To help managers accomplish this the following measures of the potential importance of information has been developed:

It is very likely that information technology will play a strategic role in an industry that is characterised by one or more of the following, features:

- Potentially high information intensity in the value chain - a large number of suppliers or customers with whom the company deals directly, a product requiring a large quantity of information in selling, a product line with many distinct product varieties, a product composed of many parts, a large number of steps in a company's manufacturing process, a long cycle time from the initial order to the delivered product.
- Potentially high information intensity in the product - a product that mainly provides information, a product whose operation involves substantial information processing, a product whose use requires the buyer to process a lot of information, a product requiring especially high costs for buyer training, a

product that has many alternative uses or is sold to a buyer with high information intensity in his or her own business.

- iv) Determine the role of information technology in industry structure. Managers should predict the likely impact of information technology on industry's structure. They must examine how information technology might affect each of the five competitive forces. Not only is each force likely to change but industry boundaries may change as well. Chances are that a new definition of the industry may be necessary.
- v) Identify and rank the ways in which information technology might create competitive advantage. The starting assumption must be that the technology is likely to affect every activity in the value chain. Equally important is the possibility that new linkages among activities are being made possible. By taking a careful look, managers can identify the value activities that are likely to be most affected in terms of cost and differentiation. Obviously, activities that represent a large proportion of cost or that are critical to differentiation bear closest scrutiny, particularly if they have a significant information-processing component. Activities with important links to other activities inside and outside the company are also critical. Executives must examine such activities for ways in which information technology can create sustainable competitive advantage.

In addition to taking a hard look at its value chain, a company should consider how information technology might allow a change in competitive scope. Can information technology help the company serve new segments? Will the flexibility of information technology allow broad-line competitors to invade areas that were once the province of niche competitors? Will information technology provide the leverage to expand the business globally? Can managers harness information technology to exploit interrelationships with other industries? Or, can the technology help a company create competitive advantage by narrowing its scope?

- A fresh look at the company's product may also be in order:
- Can the company bundle more information with the product?
- Can the company embed information technology in it?

- vi) Investigate how information technology might spawn new business. Managers should consider opportunities to create new businesses from existing ones.

Information technology is an increasingly important avenue for corporate diversification. Identifying opportunities to spawn new businesses requires answering questions such as:

- What information generated (or potentially generated) in the business could the company sell?
 - What information-processing capacity exists internally to start a new business?
 - Does information technology make it feasible to produce new items related to the company's product?
- vii) Develop a plan for taking advantage of information technology. This action plan should rank the strategic investments necessary in hardware and software, and in new product development activities that reflect the increasing information content in products. Organisational changes that reflect the role that the technology plays in linking activities inside and outside the company are likely to be necessary.

5.6 Recommendations for future research

The field of Information Technology and Industrial Automation is a dynamic one as such further research can be conducted on the following:

- Given the changes occurring in the industry what would be the strategic role of the Information Systems Department within a manufacturing concern. What skills would be required to support this role?
- What constitutes fully automated performance management within the manufacturing environment?
- Plant floor to enterprise level integration – what is the business case for this? How do automation systems and business systems talk to each other to ensure a consistent view of what is happening in the organisation.

5.7 Limitations of the study

Among different limitations to the study, the following were identified: when a questionnaire is administered, the researchers control over the environment is somewhat

limited. This is why questionnaires are inexpensive to administer. This loss of control means the validity of the results is more reliant on the honesty of the respondent. Consequently, it is more difficult to claim complete objectivity with data obtained through questionnaires.

The sample size of this survey was limited to fifty participant situated in the greater Durban area due to limitations on time and accessibility of each eligible participant. The implications of this would be inaccuracy due to the actual sample not representing the full sampling frame and a small number of responses having a large impact on the results.

These limitations must be considered in application of the results of the research findings to other areas or organisations.

5.8 Conclusion

The objective of this study was to investigate the relationship between information technology and industrial automation in the manufacturing environment. This study has demonstrated that there is a close relationship between these two functions with the organisation even resulting in overlap and inconsistencies with respect to accountabilities within the plant. The results have shown, however, that in the majority of the organisations that participated in the study these two functions are managed independently in two separate groupings or departments within the same organisation.

A further objective of the study was to identify what are the key drivers within the manufacturing environment that the IT/IA function would have influence over and that are measured and managed in order to ensure the organisations success. The study has shown that factory efficiency is the key driver of success and was also selected as the key factor for competitive advantage.

Finally the question was raised on the effect of production information relating to the KPI's on the organisations performance and in particular advantage against its competitors. The study has shown that the provision of information of this nature in a timely fashion increases the performance and competitive advantage of the organisation.

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APPENDIX

Appendix I – Search Terms

Present day role of Automation in manufacturing

Convergence – IT and Automation

Real-time production information

Enterprise Integration - Shop floor to ERP Gap

Control System Integration

Sarbanes-Oxley

TREAD Act

Data extraction-enabled innovation

Computer Integrated Manufacturing

Appendix II – Concept Matrix

References	a. IT and Engineering Convergence	b. Enterprise System Integration	c. Data Integration	d. MES Software	e. Networking	f. Security	g. Computer Integrated Manufacturing	h. Field Integration & Management	i. Industrial Automation	j. Legacy Systems	k. Evolving Roles and responsibilities within IT and Automation	l. Key Performance Indicators - Metrics	m. Competitive Advantage of Information
1. Aberdeen Group. Manufacturing Operations. 2006			✓						✓				
2. Arabe K. Wireless Factories May Be Here Sooner Than You Think. 2002					✓								
3. Brooks P. Ethernet Convergence. 2005	✓	✓			✓								
4. Cutler R. Plant Floor Automation Requirements for Food ERP Systems			✓										
5. Fitchett D. What is true downtime cost (TDC)													
6. Gordon L. Cybercentricism: the new virtual management													

Concepts	a. IT and Engineering Convergence	b. Enterprise System Integration	c. Data Integration	d. MES Software	e. Networking	f. Security	g. Computer Integrated Manufacturing	h. Field Integration & Management	i. Industrial Automation	j. Legacy Systems	k. Evolving Roles and responsibilities within IT and Automation	l. Key Performance Indicators - Metrics	m. Competitive Advantage of Information
References 7. Goslak M. Integrating Production Line Automations Systems with Office Information Systems. n.d. 8. Greenfield. D. Business Technologies Boost Engineering. 2006 9. Gunasekaran A. Agile manufacturing: A framework for research and development. 1999 10. Harizanova A. Management Information Systems in tailoring industry. 2003 11. Hardwick. Spooner. Rando & Morris. Sharing Manufacturing Information in virtual enterprises. 1996 12. Hechtman S. Enterprise HMI Systems: Is the cost too high?. 2006	✓	✓	✓				✓		✓		✓		

Concepts	a. IT and Engineering Convergence	b. Enterprise System Integration	c. Data Integration	d. MES Software	e. Networking	f. Security	g. Computer Integrated Manufacturing	h. Field Integration & Management	i. Industrial Automation	j. Legacy Systems	k. Evolving Roles and responsibilities within IT and Automation	l. Key Performance Indicators - Metrics	m. Competitive Advantage of Information
References 13. Hogan H. Coalescing Networks. 2006 14. Control Engineering Staff. Industrial Ethernet moves into mainstream. mission-critical applications. 2006 15. Introduction to Ethernet. 1999 16. Ismat N. A Growing Ethernet challenge on the Plant Floor 17. Johnston A & Wray I. Asset Maintenance Goes Online. 2003 18. Knoblock K. Ethernet Hardware for Industrial Environments. 2006 19. Korflage D. Data Transport Utility (DTU): An Introduction and Overview. 2006	✓			✓	✓			✓	✓	✓			

References	a. IT and Engineering Convergence	b. Enterprise System Integration	c. Data Integration	d. MES Software	e. Networking	f. Security	g. Computer Integrated Manufacturing	h. Field Integration & Management	i. Industrial Automation	j. Legacy Systems	k. Evolving Roles and responsibilities within IT and Automation	l. Key Performance Indicators - Metrics	m. Competitive Advantage of Information
Concepts 20. Leidigh C. Convergence in the Automation Space. 2005 21. Le Plasterier M. Your worst fears – unrealised. 2005 22. Le Plasterier M. Way into 2005 – time for a reality check. 2005 23. Madren F. Redundancy with Standards in Industrial Ethernet LAN's. 2003 24. Martin. P. Metrics that matter. 2005 25. Messe H. Will Industrial Ethernet render Field bus Systems Obsolete. 2006 26. Müller M. The future of information in Intelligent Devices. 2005	✓	✓	✓		✓			✓				✓	

<p style="text-align: center;">References</p>	<p style="text-align: center;">a. IT and Engineering Convergence</p>	<p style="text-align: center;">b. Enterprise System Integration</p>	<p style="text-align: center;">c. Data Integration</p>	<p style="text-align: center;">d. MES Software</p>	<p style="text-align: center;">e. Networking</p>	<p style="text-align: center;">f. Security</p>	<p style="text-align: center;">g. Computer Integrated Manufacturing</p>	<p style="text-align: center;">h. Field Integration & Management</p>	<p style="text-align: center;">i. Industrial Automation</p>	<p style="text-align: center;">j. Legacy Systems</p>	<p style="text-align: center;">k. Evolving Roles and responsibilities within IT and Automation</p>	<p style="text-align: center;">l. Key Performance Indicators - Metrics</p>	<p style="text-align: center;">m. Competitive Advantages of Information</p>
<p>33. Pinto J. The future of Industrial Automation. 2004</p>									✓				
<p>34. Pinto J. The 3 technology Laws. 2004</p>					✓								
<p>35. Pinto J. Fully Automated Factories. 2005</p>									✓				
<p>36. Pinto J. Managing Enterprise Performance with Web Services. 2005</p>			✓									✓	
<p>37. Pinto J. New Growth in Old Markets. 2001</p>									✓				
<p>38. Porat. Manufacturing in the 19th Century. 2002</p>							✓				✓		
<p>39. Porter M & Millar V - How information gives you competitive advantage. 1984</p>													✓

Concepts	a. IT and Engineering Convergence	b. Enterprise System Integration	c. Data Integration	d. MES Software	e. Networking	f. Security	g. Computer Integrated Manufacturing	h. Field Integration & Management	i. Industrial Automation	j. Legacy Systems	k. Evolving Roles and responsibilities within IT and Automation	l. Key Performance Indicators - Metrics	m. Competitive Advantage of Information
References 40. Rogge. Production and performance management – the key to controlled profitability. 2006 41. Scheepers S. Device Integration for interoperability with the control system. 2006 42. Smith F. Worlds in Collision – or cooperation. 2006 43. Smith F. MES: From Device to Decision. 2005 44. Smith F. Building Bridges to the Enterprise. 2006b 45. Thomas G. Introduction to Virtual LANs. 2006 46. Tindill D. OPC Consideration for Network Security. 2003	✓	✓	✓	✓	✓	✓		✓			✓		

References	a. IT and Engineering Convergence	b. Enterprise System Integration	c. Data Integration	d. MES Software	e. Networking	f. Security	g. Computer Integrated Manufacturing	h. Field Integration & Management	i. Industrial Automation	j. Legacy Systems	k. Evolving Roles and responsibilities within IT and Automation	l. Key Performance Indicators - Metrics	m. Competitive Advantage of Information
47. Tock. The use of Orchestra for Plant wide data integration. 2004		✓	✓									✓	
48. Tweedie J. Unified enterprise with DPM. 2005a			✓									✓	
49. Tweedie J. Integrating processes brings big benefits. 2005b	✓	✓											
50. Volckmar F. Why Industrial Information Management (IIM) and .Net is the Answer. 2002			✓										
51. Woodriddle S. SCADA/Business Network Separation. 2006						✓							
52. Zabel R. The Lord of the Industrial Ethernet Ring. 2006					✓								

Table 5: Concept Matrix
Source: Klopper and Lubbe, 2005

Appendix III – Questionnaire

VOLUNTARY QUESTIONNAIRE FOR IT OR PLANT AUTOMATION PERSONNEL IN A MANUFACTURING COMPANY

"What is the relationship between traditional IT and Plant Automation"
"What are the key determinents of success in your organisation that you have direct impact upon and which gives competitive advantage"

Researcher	Thanesh Marimuthu
Supervisor	Professor Sam Lubbe
Program	MBA - IT Stream
Institution	University of Kwa-Zulu Natal

Note to the respondent

We need your help to understand the current relationship between IT and plant

Automation in your company.

Although we would like you to help us, you do not have to take part in this survey.

If you do not want to take part, ignore this message.

What you say in this questionnaire will remain private and confidential. No one will be able to trace your opinions back to you as a person.

How to complete the questionnaire

1. Please answer the questions as truthfully as you can. Also, please be sure to read and follow the directions for each part. If you do not follow the directions, it will make it harder for us to do our project.

2. We are only asking you about things that you and your colleagues should feel comfortable telling us about. If you don't feel comfortable answering a question, you can indicate that you do not want to answer it. For those questions that you do answer, your responses will be kept confidential.

3. You can either select your options from the drop down list where provided
Fill in an appropriate response in the free text boxes.

Thank you very much for participating in this study.

Part 1: Permission to use my responses for academic research

I hereby give permission that my responses may be used for research purposes provided that my identity is not revealed in the published records of the research.

Postal address:

Postal code:

Contact numbers

Home:

Cell:

Signature:

Part 2: General Personal Particulars

Please tell us a little bit about yourself

1 I am between years old

2 I am

3 I am

4 Name of company

5 Company Size employees

6 Industry Classification
if other specify

7 Years of work experience

8 Level in the organisation

9 Your Job Title

10 Primary Focus Area
if other specify

Part 3: Relationship between Traditional IT and Automation

11 In comparing the fields of Industrial Automation and Information technology in a manufacturing organisation

11.1 There is no relationship between the two functions in my organisation.

11.2 There is some overlap between the two functions and grey areas exist in terms of responsibility.

11.3 The two functions operate in conjunction with and are hence complimentary to each other.

12 In terms of structures within your organisation the following are true for the Industrial Automation function and the Information Technology function

12.1 They operate independently of each other within separate structures/departments.

12.2 These functions are shared across one or many structures/departments.

12.3 The two functions operate within one structure in my organisation.

13 In terms of the network infrastructure in you organisation, comment on the following:

13.1 There is a separate (Physical) Industrial Automation and IT/office network

13.2 VLAN's are utilised in segregation of Industrial Automation and Office networks

13.3 Industrial Automation and office networks are combined

14 What communications Protocols are in use in your Industrial Automation Network?

15 In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.

16 There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

17 If agree what are these?

18 My job function within the field of Industrial Automation has changed significantly in the past 2 years?

19 If yes in what manner do you believe that this has been the case?

**Part 4: Key determinants of Success
and Strategic Competitive Advantage**

20 What is/are the key determinant/s of success (KPI/s) in your organisation that you have direct influence upon?

21 If other specify below

KPI1:
KPI2:
KPI3:

22 I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

23 What are the key factors that provide your organisation with competitive advantage over its competitors?

24 If other specify below

SCA1:
SCA2:
SCA3:

25 The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

Thank you for assisting us in this survey

Appendix IV – SPSS Variable Information

Variable	Position	Label	Measurement Level	Missing Values
part2q1	1	Age(years)	Ordinal	0
part2q2	2	Gender	Nominal	0
part2q3	3	Race	Nominal	0
part2q5	4	Company Size	Ordinal	0
part2q6	5	Industry Classification	Nominal	0
part2q7	6	Years of work experience	Ordinal	0
part2q8	7	Level in the organisation	Nominal	0
part2q10	8	Primary Focus Area	Nominal	0
part3q11.1	9	There is no relationship between the two functions in my organisation.	Nominal	0
part3q11.2	10	Q11.2	Nominal	0
part3q11.3	11	Q11.3	Nominal	0
part3q12.1	12	They operate independently of each other within separate structures/departments.	Nominal	0
part3q12.2	13	These functions are shared across one or many structures/departments.	Nominal	0
part3q12.3	14	The two functions operate within one structure in my organisation.	Nominal	0
part3q13.1	15	There is a separate (Physical) Industrial Automation and IT/office network	Nominal	0
part3q13.2	16	VLAN's are utilised in segregation of Industrial Automation and Office networks	Nominal	0
part3q13.3	17	Industrial Automation and office networks are combined	Nominal	0
part3q15	18	Q15	Nominal	0
part3q16	19	q16	Nominal	0
part3q18	20	q18	Nominal	0
part4q20	21	q20	Nominal	0
part4q22	22	q22	Nominal	0
part4q23	23	q23	Nominal	0
part4q25	24	q25	Nominal	0

Variables in the working file

Variable Values

Value	Label
part2q1	0(a) Did not answer
	1 Do not want to answer
	2 0 - 25
	3 26 - 35
	4 36 - 45
	5 46 - 55
	6 56 - 65
part2q2	0(a) Did not answer
	1 Do not want to answer
	2 Male
	3 Female
part2q3	0(a) Did not answer
	1 Do not want to answer
	2 African
	3 Asian
	4 Coloured
	5 Jewish
	6 Oriental
	7 White
part2q5	0(a) Did not answer
	1 Do not want to answer
	2 < 10
	3 < 100
	4 < 1000
	5 > 1000
part2q6	0(a) Did not answer
	1 Do not want to answer
	2 Chemicals
	3 Electronic and other Electric Equipment
	4 Food
	5 Industrial Machinery
	6 Instrumentation, Measurement and control analysis
	7 Medical Instrumentation and Systems
	8 Petroleum Refining and related industries
	9 Pharmaceuticals
	10 Primary Metals
	11 Paper, Pulp and allied Products
	12 Rubber and Miscellaneous Plastics
	13 Semiconductors and Electronic Equipment
	14 Textiles
	15 Tobacco

	16	Other
part2q7	0(a)	Did not answer
	1	Do not want to answer
	2	< 5
	3	< 10
	4	< 20
	5	> 20
part2q8	0(a)	Did not answer
	1	Do not want to answer
	2	Apprentice
	3	Artisan
	4	Technician
	5	Engineer
	6	Supervisor
	7	Manager
part2q10	0(a)	Did not answer
	1	Do not want to answer
	2	IT
	3	Automation
part3q11.1	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
part3q11.2	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
part3q11.3	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
part3q12.1	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree

	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q12.2	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q12.3	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q13.1	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q13.2	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q13.3	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree

	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q15	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q16	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part3q18	0(a)	Did not answer
	1	Do not want to answer
	2	Strongly Agree
	3	Agree
	4	Tend to agree
	5	Tend to disagree
	6	Disagree
	7	Strongly Disagree
	8	Do not know
part4q20	0(a)	Did not answer
	1	EVA
	2	Factory Efficiency
	3	Machine Operating Efficiency
	4	OEE
	5	Production Plan Variance
	6	Sales Volumes
	7	Fixed Cost Variance
	8	Utilities Variance
	9	Systems Uptime
	10	Product Quality Rating
	11	Other
part4q22	0(a)	Did not answer
	1	Do not want to answer
	2	I have no influence
	3	I have some influence
	4	I have much influence
	5	I have major influence

	6	Do not know/Cannot quantify
part4q23	0(a)	Did not answer
	1	EVA
	2	Factory Efficiency
	3	Machine Operating Efficiency
	4	OEE
	5	Production Plan Variance
	6	Sales Volumes
	7	Fixed Cost Variance
	8	Utilities Variance
	9	Systems Uptime
	10	Product Quality Rating
	11	Other
part4q25	0(a)	Did not answer
	1	Do not want to answer
	2	Some/Minor Negative Effects
	3	Major Negative Effect
	4	No effect what so ever
	5	Some/Minor positive effect
	6	Major positive effect
	7	Do not know/Cannot quantify

a Missing value

Appendix V – Data Set

Case No.	Part2q1	Part2q2	Part2q3	Part2q5	Part2q6	Part2q7	Part2q8	Part2q10	Part3q11.1	Part3q11.2	Part3q11.3	Part3q12.1	Part3q12.2	Part3q12.3	Part3q13.1	Part3q13.2	Part3q13.3	Part3q15	Part3q16	Part3q18	Part4q20	Part4q22	Part4q23	Part4q25
1	4	2	7	4	9	5	7	4	3	7	7	3	3	3	4	4	5	7	7	7	3	5	3	6
2	2	2	7	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	3	5	0	0	6	5
3	4	2	2	3	9	4	7	2	6	3	3	3	6	6	3	3	6	3	3	1	9	3	2	2
4	3	3	4	5	6	2	5	3	6	3	6	3	4	6	6	3	4	4	4	5	10	3	6	5
5	3	3	3	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	4	5	10	3	6	5
6	2	2	7	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	4	5	10	3	6	5
7	3	2	3	5	16	2	5	3	2	2	2	2	2	7	7	2	2	2	2	8	2	4	11	6
8	3	2	3	5	16	2	5	3	2	2	2	2	2	7	7	2	2	2	2	8	2	4	11	6
9	5	2	3	3	9	5	7	3	7	4	2	2	4	7	5	5	2	2	2	3	2	3	2	6
10	5	2	2	3	9	4	7	2	6	3	3	3	6	6	3	3	6	3	3	1	9	3	2	2
11	3	2	3	5	16	2	5	3	2	2	2	2	2	7	7	2	2	2	2	8	2	4	11	6
12	5	2	3	3	9	5	7	3	7	4	2	2	4	7	5	5	2	2	2	3	2	3	2	6
13	4	2	3	3	9	4	7	2	6	3	3	3	6	6	3	3	6	3	3	1	9	3	2	2
14	3	2	3	3	16	3	6	1	6	3	3	3	6	6	2	8	7	3	3	6	5	1	10	5
15	3	2	3	4	16	2	5	3	3	3	5	3	3	6	3	6	3	6	6	6	9	4	3	2
16	4	2	7	3	9	4	4	3	3	6	3	3	6	5	8	6	3	6	3	3	2	3	11	5
17	3	2	3	2	8	2	3	2	6	3	2	3	3	6	3	4	6	3	5	5	2	5	9	7
18	4	2	3	3	9	4	7	2	6	3	3	3	6	6	3	3	6	3	3	1	9	3	2	2
19	3	2	3	3	16	3	6	1	6	3	3	3	6	6	2	8	7	3	3	6	5	1	10	5
20	3	2	3	4	16	2	5	3	3	3	5	3	3	6	3	6	3	6	6	6	9	4	3	2
21	4	2	7	3	9	4	4	3	3	6	6	3	3	6	5	8	6	3	6	3	2	3	11	5
22	3	2	3	2	8	2	3	2	6	3	2	3	3	6	3	4	6	3	3	5	2	5	9	7

Case No.	Part2q1	Part2q2	Part2q3	Part2q5	Part2q6	Part2q7	Part2q8	Part2q10	Part3q11.1	Part3q11.2	Part3q11.3	Part3q12.1	Part3q12.2	Part3q12.3	Part3q13.1	Part3q13.2	Part3q13.3	Part3q15	Part3q16	Part3q18	Part4q20	Part4q22	Part4q23	Part4q25
23	4	2	7	4	9	5	7	4	3	7	7	3	3	3	4	4	5	7	7	7	3	5	3	6
24	2	2	7	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	3	5	0	0	6	5
25	4	2	3	3	9	5	7	3	7	4	2	2	4	7	5	5	2	2	2	3	2	3	2	6
26	4	2	2	3	9	4	7	2	6	3	3	3	6	6	3	3	6	3	3	1	9	3	2	2
27	3	3	4	5	16	2	5	3	6	3	6	3	4	6	6	3	4	4	3	5	10	3	6	6
28	3	3	3	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	3	5	10	3	6	5
29	2	2	7	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	3	5	10	3	6	5
30	3	2	3	5	16	2	5	3	2	2	2	2	2	7	7	2	2	2	2	8	2	4	11	6
31	5	2	3	3	9	5	7	3	7	4	2	2	4	7	5	5	2	2	2	3	2	3	2	6
32	4	2	3	3	9	4	7	2	6	3	3	3	6	6	3	3	6	3	3	1	9	3	2	2
33	3	2	3	3	16	4	6	1	6	3	3	3	6	6	2	1	7	3	3	6	5	1	10	5
34	3	2	3	4	16	2	5	3	3	3	5	3	3	3	3	6	3	6	6	6	9	4	3	2
35	4	2	7	3	9	4	4	3	3	6	6	3	3	6	5	8	6	3	6	3	2	3	11	5
36	3	2	3	2	8	2	3	2	6	3	2	3	3	6	3	4	6	3	5	5	2	5	9	7
37	4	2	7	4	9	5	7	4	3	7	7	3	3	3	4	4	5	7	7	7	3	5	3	6
38	2	2	7	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	3	5	0	0	6	5
39	4	2	3	3	9	4	7	2	6	3	3	3	6	6	3	3	6	3	3	1	9	3	2	2
40	3	2	3	3	16	3	6	1	6	3	3	3	6	6	2	8	7	3	3	6	5	1	10	5
41	3	2	3	4	16	2	5	3	3	3	5	3	3	6	3	6	3	6	6	6	9	4	3	2
42	4	2	7	3	9	4	4	3	3	6	6	3	3	6	5	8	6	3	6	3	2	3	11	5
43	3	2	3	2	8	2	3	2	6	3	2	3	3	6	3	4	6	3	5	5	2	5	9	7
44	4	2	7	4	9	5	7	4	3	7	7	3	3	3	4	4	5	7	7	7	3	5	3	6
45	2	2	7	5	16	2	7	3	6	3	6	3	4	6	6	3	4	4	3	5	0	0	6	5

Appendix VI – Results Frequency Tables

Q1 - Age(years)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0 - 25	6	13.3	13.3	13.3
	26 - 35	20	44.4	44.4	57.8
	36 - 45	15	33.3	33.3	91.1
	46 - 55	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q2 - Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	41	91.1	91.1	91.1
	Female	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q3 - Race

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	African	3	6.7	6.7	6.7
	Asian	26	57.8	57.8	64.4
	Coloured	2	4.4	4.4	68.9
	White	14	31.1	31.1	100.0
	Total	45	100.0	100.0	

Q4 - Company Size

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 10	4	8.9	8.9	8.9
	< 100	19	42.2	42.2	51.1
	< 1000	8	17.8	17.8	68.9
	> 1000	14	31.1	31.1	100.0
	Total	45	100.0	100.0	

Q5 - Industry Classification

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Instrumentation, Measurement and control analysis	1	2.2	2.2	2.2
	Petroleum Refining and related industries	4	8.9	8.9	11.1
	Pharmaceuticals	19	42.2	42.2	53.3
	Other	21	46.7	46.7	100.0
	Total	45	100.0	100.0	

Q6 - Years of work experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	< 5	22	48.9	48.9	48.9
	< 10	3	6.7	6.7	55.6
	< 20	12	26.7	26.7	82.2
	> 20	8	17.8	17.8	100.0
	Total	45	100.0	100.0	

Q7 - Level in the organisation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Artisan	4	8.9	8.9	8.9
	Technician	4	8.9	8.9	17.8
	Engineer	10	22.2	22.2	40.0
	Supervisor	4	8.9	8.9	48.9
	Manager	23	51.1	51.1	100.0
	Total	45	100.0	100.0	

Q8 - Primary Focus Area

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Do not want to answer	4	8.9	8.9	8.9
	IT	11	24.4	24.4	33.3
	Automation	26	57.8	57.8	91.1
	Cannot differentiate	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q11.1 - There is no relationship between the two functions in my organisation.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	4	8.9	8.9	8.9
	Agree	12	26.7	26.7	35.6
	Disagree	25	55.6	55.6	91.1
	Strongly Disagree	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q11.2 - There is some overlap between the two functions and grey areas exist in terms of responsibility

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	4	8.9	8.9	8.9
	Agree	29	64.4	64.4	73.3
	Tend to agree	4	8.9	8.9	82.2
	Disagree	4	8.9	8.9	91.1
	Strongly Disagree	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q11.3 - The two functions operate in conjunction and are hence complimentary to each other

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	12	26.7	26.7	26.7
	Agree	12	26.7	26.7	53.3
	Tend to disagree	4	8.9	8.9	62.2
	Disagree	13	28.9	28.9	91.1
	Strongly Disagree	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q12.1 - They operate independently of each other within separate structures/departments.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	8	17.8	17.8	17.8
	Agree	37	82.2	82.2	100.0
	Total	45	100.0	100.0	

Q12.2 - These functions are shared across one or many structures/departments.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	4	8.9	8.9	8.9
	Agree	15	33.3	33.3	42.2
	Tend to agree	14	31.1	31.1	73.3
	Disagree	12	26.7	26.7	100.0
	Total	45	100.0	100.0	

Q12.3 - The two functions operate within one structure in my organisation.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	4	8.9	8.9	8.9
	Tend to disagree	1	2.2	2.2	11.1
	Disagree	32	71.1	71.1	82.2
	Strongly Disagree	8	17.8	17.8	100.0
	Total	45	100.0	100.0	

Q13.1 - There is a separate (Physical) Industrial Automation and IT/office network

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	4	8.9	8.9	8.9
	Agree	15	33.3	33.3	42.2
	Tend to agree	4	8.9	8.9	51.1
	Tend to disagree	7	15.6	15.6	66.7
	Disagree	10	22.2	22.2	88.9
	Strongly Disagree	4	8.9	8.9	97.8
	Do not know	1	2.2	2.2	100.0
	Total	45	100.0	100.0	

Q13.2 - VLAN's are utilised in segregation of Industrial Automation and Office networks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Do not want to answer	1	2.2	2.2	2.2
	Strongly Agree	4	8.9	8.9	11.1
	Agree	17	37.8	37.8	48.9
	Tend to agree	8	17.8	17.8	66.7
	Tend to disagree	4	8.9	8.9	75.6
	Disagree	5	11.1	11.1	86.7
	Do not know	6	13.3	13.3	100.0
	Total	45	100.0	100.0	

Q13.3 - Industrial Automation and office networks are combined

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	8	17.8	17.8	17.8
	Agree	5	11.1	11.1	28.9
	Tend to agree	10	22.2	22.2	51.1
	Tend to disagree	4	8.9	8.9	60.0
	Disagree	14	31.1	31.1	91.1
	Strongly Disagree	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focused.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	8	17.8	17.8	17.8
	Agree	18	40.0	40.0	57.8
	Tend to agree	10	22.2	22.2	80.0
	Disagree	5	11.1	11.1	91.1
	Strongly Disagree	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q16 - There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	8	17.8	17.8	17.8
	Agree	22	48.9	48.9	66.7
	Tend to disagree	4	8.9	8.9	75.6
	Disagree	7	15.6	15.6	91.1
	Strongly Disagree	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q18 - My job function within the field of Industrial Automation has changed significantly in the past two years?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Do not want to answer	7	15.6	15.6	15.6
	Agree	8	17.8	17.8	33.3
	Tend to disagree	14	31.1	31.1	64.4
	Disagree	8	17.8	17.8	82.2
	Strongly Disagree	4	8.9	8.9	91.1
	Do not know	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Q20 - What is/are the key determinant/s of success (KPI/s) in your organisation that you have direct influence upon?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Factory Efficiency	16	35.6	39.0	39.0
	Machine Operating Efficiency	4	8.9	9.8	48.8
	Production Plan Variance	4	8.9	9.8	58.5
	Systems Uptime	11	24.4	26.8	85.4
	Product Quality Rating	6	13.3	14.6	100.0
	Total	41	91.1	100.0	
Missing	Did not answer	4	8.9		
Total		45	100.0		

Q22 - I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Do not want to answer	4	8.9	9.8	9.8
	I have some influence	21	46.7	51.2	61.0
	I have much influence	8	17.8	19.5	80.5
	I have major influence	8	17.8	19.5	100.0
	Total	41	91.1	100.0	
Missing	Did not answer	4	8.9		
Total		45	100.0		

Q23 - What are the key factors that provide your organisation with competitive advantage over its competitors?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Factory Efficiency	11	24.4	24.4	24.4
	Machine Operating Efficiency	8	17.8	17.8	42.2
	Sales Volumes	10	22.2	22.2	64.4
	Systems Uptime	4	8.9	8.9	73.3
	Product Quality Rating	4	8.9	8.9	82.2
	Other	8	17.8	17.8	100.0
	Total	45	100.0	100.0	

Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Some/Minor Negative Effects	11	24.4	24.4	24.4
	Some/Minor positive effect	17	37.8	37.8	62.2
	Major positive effect	13	28.9	28.9	91.1
	Do not know/Cannot quantify	4	8.9	8.9	100.0
	Total	45	100.0	100.0	

Appendix VII – Cross Tabulation Results

Q1 - Age (years) * Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.

Crosstab

			In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.					Total
			Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Age(years) 0 - 25	Count		0	0	6	0	0	6
	Expected Count		1.1	2.4	1.3	.7	.5	6.0
26 - 35	Count		4	8	4	4	0	20
	Expected Count		3.6	8.0	4.4	2.2	1.8	20.0
36 - 45	Count		1	9	0	1	4	15
	Expected Count		2.7	6.0	3.3	1.7	1.3	15.0
46 - 55	Count		3	1	0	0	0	4
	Expected Count		.7	1.8	.9	.4	.4	4.0
Total	Count		8	18	10	5	4	45
	Expected Count		8.0	18.0	10.0	5.0	4.0	45.0

Crosstab

Count

		Q15					Total
		Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Age(years) 0 - 25		0	0	6	0	0	6
26 - 35		4	8	4	4	0	20
36 - 45		1	9	0	1	4	15
46 - 55		3	1	0	0	0	4
Total		8	18	10	5	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	45.056 ^a	12	.000
Likelihood Ratio	43.652	12	.000
Linear-by-Linear Association	.585	1	.444
N of Valid Cases	45		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by	Phi	1.001	.000
Nominal	Cramer's V	.578	.000
	Contingency Coefficient	.707	.000
N of Valid Cases		45	

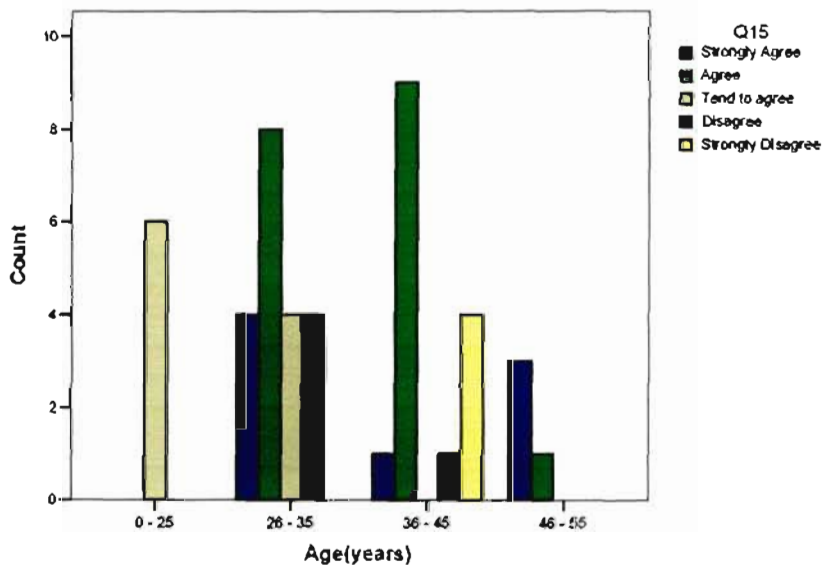
- Not assuming the null hypothesis.
- Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.578

This suggests that a moderate degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q1 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{0.05, 12} = 21.0261$
Decision Rule	if (Test Statistic) $\chi^2 > 21.0261$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd Ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 45.056$

Step 5

The test statistic $\chi^2 = 45.056 > \chi^2_{0.05, 12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q15 are dependent. This suggests that there is a significant relationship between Q1 and Q15

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q1 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule: If P-Value < 0.05 then reject H_0 ,

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q15 are dependent. This suggests that there is a significant relationship between Q1 and Q15.

Q1 - Age (years) * Q16 - There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

Crosstab

			There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?					Total
			Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Age(years)	0 - 25	Count	0	6	0	0	0	6
		Expected Count	1.1	2.9	.5	.9	.5	6.0
	26 - 35	Count	4	8	4	4	0	20
		Expected Count	3.6	9.8	1.8	3.1	1.8	20.0
	36 - 45	Count	1	7	0	3	4	15
		Expected Count	2.7	7.3	1.3	2.3	1.3	15.0
	46 - 55	Count	3	1	0	0	0	4
		Expected Count	.7	2.0	.4	.6	.4	4.0
Total		Count	8	22	4	7	4	45
		Expected Count	8.0	22.0	4.0	7.0	4.0	45.0

Crosstab

Count

	Q16					Total
	Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Age(years) 0 - 25	0	6	0	0	0	6
26 - 35	4	8	4	4	0	20
36 - 45	1	7	0	3	4	15
46 - 55	3	1	0	0	0	4
Total	8	22	4	7	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	28.543 ^a	12	.005
Likelihood Ratio	29.797	12	.003
Linear-by-Linear Association	.193	1	.660
N of Valid Cases	45		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.796	.005
	Cramer's V	.460	.005
	Contingency Coefficient	.623	.005
N of Valid Cases		45	

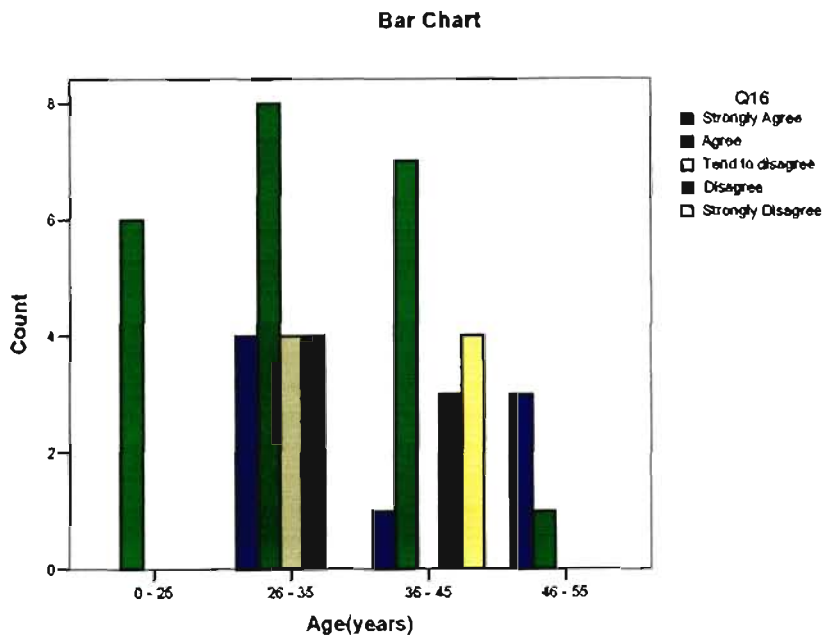
a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.46

This suggests that a low degree of association exists.



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q1 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{0.05,12} = 21.0261$
Decision Rule	if (Test Statistic) $\chi^2 > 21.0261$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 28.543$

Step 5

The test statistic $\chi^2 = 28.543 > \chi^2_{0.05,12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q16 are dependent. This suggests that there is a significant relationship between Q1 and Q16.

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q1 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.005

Decision Rule: If $P\text{-Value} < 0.05$ then reject H_0 .

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q16 are dependent. This suggests that there is a significant relationship between Q1 and Q16.

Q1 - Age (years) * Q18 - My job function within the field of Industrial Automation has changed significantly in the past 2 years?

Crosstab

		My job function within the field of Industrial Automation has changed significantly in the past 2 years?						Total	
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know		
Age(years)	0 - 25	Count	0	0	6	0	0	0	6
		Expected Count	.9	1.1	1.9	1.1	.5	.5	6.0
26 - 35	Count	0	0	8	8	0	4	20	
		Expected Count	3.1	3.6	6.2	3.6	1.8	1.8	20.0
36 - 45	Count	6	5	0	0	4	0	15	
		Expected Count	2.3	2.7	4.7	2.7	1.3	1.3	15.0
46 - 55	Count	1	3	0	0	0	0	4	
		Expected Count	6	.7	1.2	7	.4	.4	4.0
Total	Count	7	8	14	8	4	4	45	
		Expected Count	7.0	8.0	14.0	8.0	4.0	4.0	45.0

Crosstab

Count

		Q18						Total
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know	
Age(years)	0 - 25	0	0	6	0	0	0	6
	26 - 35	0	0	8	8	0	4	20
	36 - 45	6	5	0	0	4	0	15
	46 - 55	1	3	0	0	0	0	4
Total		7	8	14	8	4	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	62.638 ^a	15	.000
Likelihood Ratio	73.489	15	.000
Linear-by-Linear Association	11.584	1	.001
N of Valid Cases	45		

a. 23 cells (95.8%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.180	.000
	Cramer's V	.681	.000
	Contingency Coefficient	.763	.000
N of Valid Cases		45	

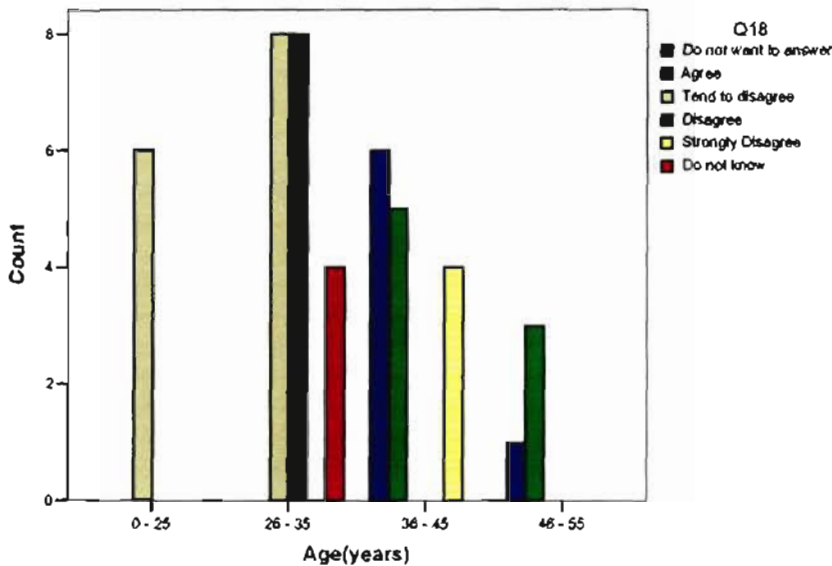
- Not assuming the null hypothesis.
- Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.681

This suggests that a moderate degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q1 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 15

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{0.05, 15} = 24.9958$
Decision Rule	if (Test Statistic) $\chi^2 > 24.9958$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1. 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 62.638$

Step 5

The test statistic $\chi^2 = 62.638 > \chi^2_{0.05,15} = 24.9958$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q18 are dependent. This suggests that there is a significant relationship between Q1 and Q18

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q1 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If *P-Value* ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q18 are dependent. This suggests that there is a significant relationship between Q1 and Q18.

Q1 - Age (years) * Q22 - I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

Crosstab

			I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above				Total
			Do not want to answer	I have some influence	I have much influence	I have major influence	
Age(years) 0 - 25	Count		0	2	0	0	2
	Expected Count		.2	1.0	.4	.4	2.0
26 - 35	Count		4	4	8	4	20
	Expected Count		2.0	10.2	3.9	3.9	20.0
36 - 45	Count		0	11	0	4	15
	Expected Count		1.5	7.7	2.9	2.9	15.0
46 - 55	Count		0	4	0	0	4
	Expected Count		.4	2.0	.8	.8	4.0
Total	Count		4	21	8	8	41
	Expected Count		4.0	21.0	8.0	8.0	41.0

Crosstab

Count		Q22				Total
		Do not want to answer	I have some influence	I have much influence	I have major influence	
Age(years)	0 - 25	0	2	0	0	2
	26 - 35	4	4	8	4	20
	36 - 45	0	11	0	4	15
	46 - 55	0	4	0	0	4
Total		4	21	8	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.192 ^a	9	.008
Likelihood Ratio	28.326	9	.001
Linear-by-Linear Association	.001	1	.970
N of Valid Cases	41		

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .20.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.736	.008
	Cramer's V	.425	.008
	Contingency Coefficient	.593	.008
N of Valid Cases		41	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

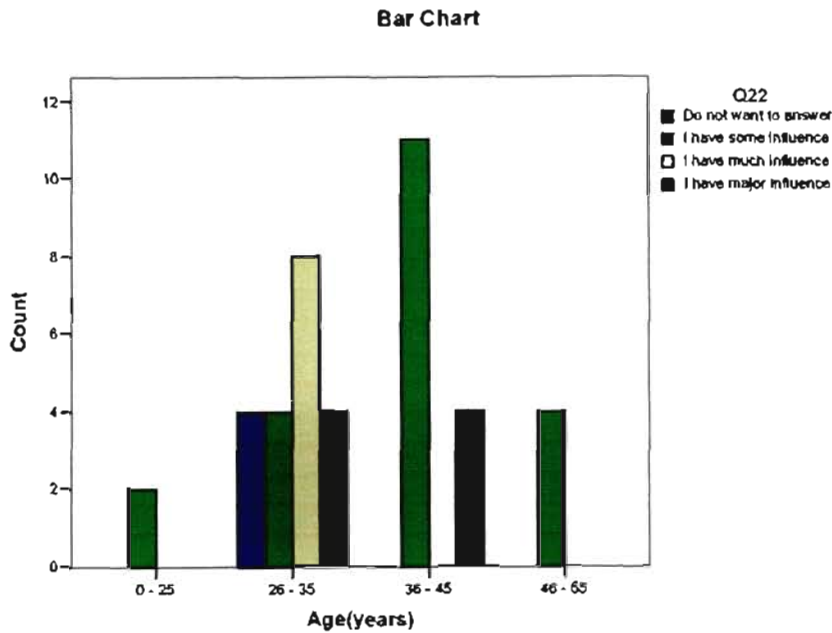
Comment on the strength of dependence:

Cramer's V = 0.425

This suggests that a low degree of association exists.

Contingency Coefficient = 0.593

This suggests that a moderate degree of association between the row and column variables exists.



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q1 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{0.05,9} = 16.9190$
Decision Rule	if (Test Statistic) $\chi^2 > 16.9190$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 22.192$

Step 5

The test statistic $\chi^2 = 22.192 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q22 are dependent. This suggests that there is a significant relationship between Q1 and Q22

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q1 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.008

Decision Rule : If *P-Value* ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q22 are dependent. This suggests that there is a significant relationship between Q1 and Q22.

Q1 - Age (years) * Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

Crosstab

		The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:				Total
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Age(years) 0 - 25	Count	0	6	0	0	6
	Expected Count	1.5	2.3	1.7	.5	6.0
26 - 35	Count	4	7	5	4	20
	Expected Count	4.9	7.6	5.8	1.8	20.0
36 - 45	Count	6	4	5	0	15
	Expected Count	3.7	5.7	4.3	1.3	15.0
46 - 55	Count	1	0	3	0	4
	Expected Count	1.0	1.5	1.2	.4	4.0
Total	Count	11	17	13	4	45
	Expected Count	11.0	17.0	13.0	4.0	45.0

Crosstab

Count		Q25				Total
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Age(years)	0 - 25	0	6	0	0	6
	26 - 35	4	7	5	4	20
	36 - 45	6	4	5	0	15
	46 - 55	1	0	3	0	4
Total		11	17	13	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.189 ^a	9	.012
Likelihood Ratio	24.372	9	.004
Linear-by-Linear Association	.827	1	.363
N of Valid Cases	45		

a. 13 cells (81.3%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.686	.012
	Cramer's V	.396	.012
	Contingency Coefficient	.566	.012
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

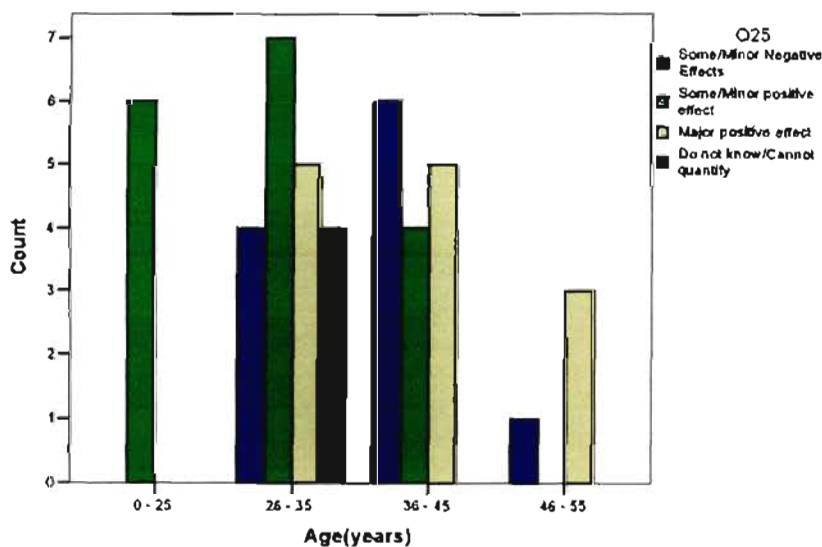
Cramer's V = 0.396

This suggests that a low degree of association exists.

Contingency Coefficient = 0.566

This suggests that a moderate degree of association between the row and column variables exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q1 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{\alpha=0.05,9} = 16.9190$
Decision Rule:	if (Test Statistic) $\chi^2 > 16.9190$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution," *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 21.189$

Step 5

The test statistic $\chi^2 = 21.189 > \chi^2_{\alpha=0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q25 are dependent. This suggests that there is a significant relationship between Q1 and Q25

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q1 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.012

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q1 and Q25 are dependent. This suggests that there is a significant relationship between Q1 and Q25.

Q2 - Gender * Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.

Crosstab

			In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed					Total
			Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Gender	Male	Count	8	18	6	5	4	41
		Expected Count	7.3	18.4	9.1	4.6	3.6	41.0
	Female	Count	0	0	4	0	0	4
		Expected Count	.7	1.6	.9	.4	.4	4.0
Total		Count	8	18	10	5	4	45
		Expected Count	8.0	18.0	10.0	5.0	4.0	45.0

Crosstab

Count		Q15					Total
		Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Gender	Male	8	18	6	5	4	41
	Female	0	0	4	0	0	4
Total		8	18	10	5	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.366 ^a	4	.004
Likelihood Ratio	13.536	4	.009
Linear-by-Linear Association	.134	1	.715
N of Valid Cases	45		

a. 7 cells (70.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.584	.004
	Cramer's V	.584	.004
	Contingency Coefficient	.505	.004
N of Valid Cases		45	

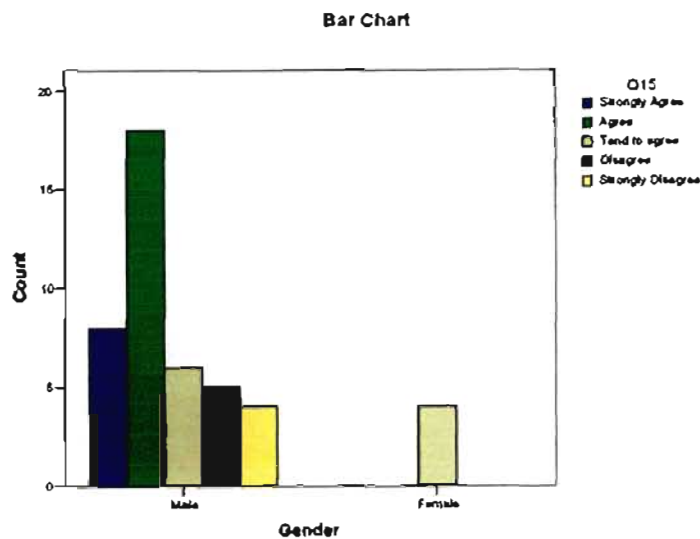
a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.585

This suggests that a moderate degree of association exists.



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q2 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 4

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{0.05,4} = 9.48773$
Decision Rule	if (Test Statistic) $\chi^2 > 9.48773$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 15.366$

Step 5

The test statistic $\chi^2 = 15.366 > \chi^2_{0.05,4} = 9.48773$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q2 and Q15 are dependent. This suggests that there is a significant relationship between Q2 and Q15

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q2 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.004

Decision Rule : If *P-Value* ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q2 and Q15 are dependent. This suggests that there is a significant relationship between Q2 and Q15.

Q2 - Gender * Q16 - There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

Crosstab

			There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?					Total
			Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Gender	Male	Count	8	18	4	7	4	41
		Expected Count	7.3	20.0	3.6	6.4	3.6	41.0
	Female	Count	0	4	0	0	0	4
		Expected Count	.7	2.0	.4	.6	.4	4.0
Total		Count	8	22	4	7	4	45
		Expected Count	8.0	22.0	4.0	7.0	4.0	45.0

Crosstab

Count		Q16					Total
		Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Gender	Male	8	18	4	7	4	41
	Female	0	4	0	0	0	4
Total		8	22	4	7	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.590 ^a	4	.332
Likelihood Ratio	6.134	4	.189
Linear-by-Linear Association	1.083	1	.298
N of Valid Cases	45		

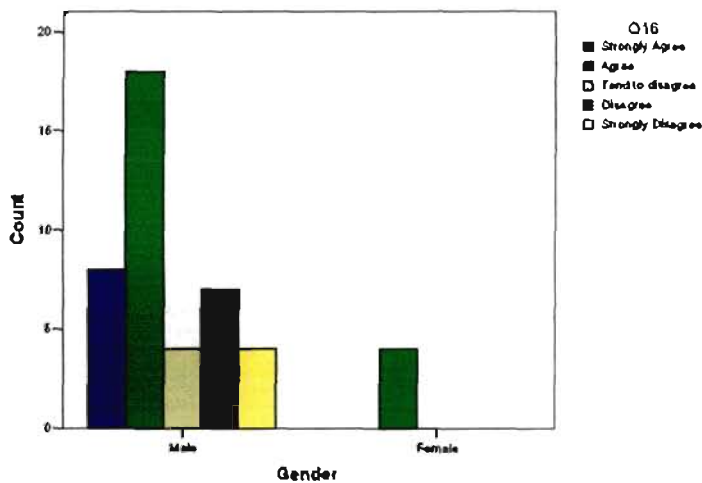
a. 7 cells (70.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.319	.332
	Cramer's V	.319	.332
	Contingency Coefficient	.304	.332
N of Valid Cases		45	

- Not assuming the null hypothesis.
- Using the asymptotic standard error assuming the null hypothesis.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q2 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 4

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,4} = 9.48773$
 Decision Rule: if (Test Statistic) $\chi^2 > 9.48773$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians I*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 4.590$

Step 5

The test statistic $\chi^2 = 4.590 < \chi^2_{0.05,4} = 9.48773$ so we cannot reject H_0 .

Step 6 : Conclusion

Since we cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q16 are dependent. This suggests that there is not a significant relationship between Q2 and Q16

We are simply unable to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q2 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.332

Decision Rule : If *P-Value* ≤ 0.05 then reject H_0

Conclusion: Cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q16 are dependent. This suggests that there is not a significant relationship between Q2 and Q16.

Q2 - Gender * Q18 - My job function within the field of Industrial Automation has changed significantly in the past 2 years?

Crosstab

			My job function within the field of Industrial Automation has changed significantly in the past 2 years?					Total	
			Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree		Do not know
Gender	Male	Count	7	8	10	8	4	4	41
		Expected Count	6.4	7.3	12.8	7.3	3.6	3.8	41.0
	Female	Count	0	0	4	0	0	0	4
		Expected Count	.6	.7	1.2	.7	.4	.4	4.0
Total		Count	7	8	14	8	4	4	45
		Expected Count	7.0	8.0	14.0	8.0	4.0	4.0	45.0

Crosstab

Count		Q18						Total
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know	
Gender	Male	7	8	10	8	4	4	41
	Female	0	0	4	0	0	0	4
Total		7	8	14	8	4	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	9.721 ^a	5	.084
Likelihood Ratio	10.245	5	.069
Linear-by-Linear Association	.123	1	.726
N of Valid Cases	45		

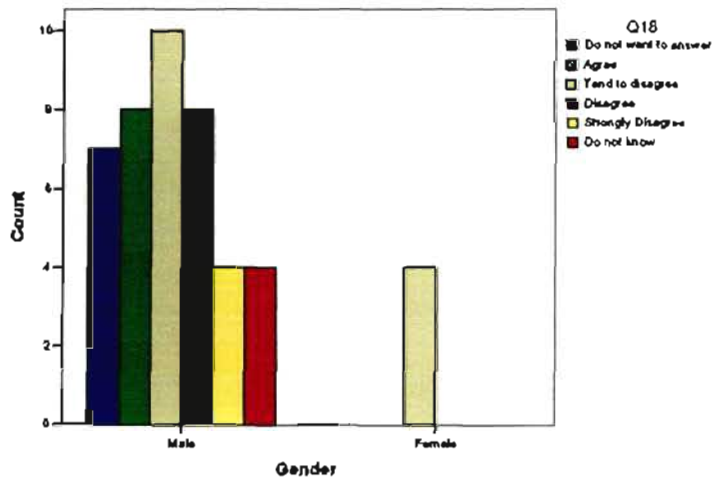
a. 8 cells (66.7%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.465	.084
	Cramer's V	.465	.084
	Contingency Coefficient	.421	.084
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q2 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 5

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,5} = 11.0705$
 Decision Rule if (Test Statistic) $\chi^2 > 11.0705$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 9.721$

Step 5

The test statistic $\chi^2 = 9.721 < \chi^2_{0.05,5} = 11.0705$ so we cannot reject H_0 .

Step 6 : Conclusion

Since we cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q18 are dependent. This suggests that there is not a significant relationship between Q2 and Q18

We are simply unable to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q2 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.084

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q18 are dependent. This suggests that there is not a significant relationship between Q2 and Q18.

Q2 - Gender * Q22 - I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

Crosstab

		I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above				Total	
		Do not want to answer	I have some influence	I have much influence	I have major influence		
Gender	Male	Count	4	17	8	8	37
		Expected Count	3.6	19.0	7.2	7.2	37.0
	Female	Count	0	4	0	0	4
		Expected Count	.4	2.0	.8	.8	4.0
Total		Count	4	21	8	8	41
		Expected Count	4.0	21.0	8.0	8.0	41.0

Crosstab

Count		Q22				Total
		Do not want to answer	I have some influence	I have much influence	I have major influence	
Gender	Male	4	17	8	8	37
	Female	0	4	0	0	4
Total		4	21	8	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.221 ^a	3	.239
Likelihood Ratio	5.764	3	.124
Linear-by-Linear Association	.543	1	.461
N of Valid Cases	41		

a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .39.

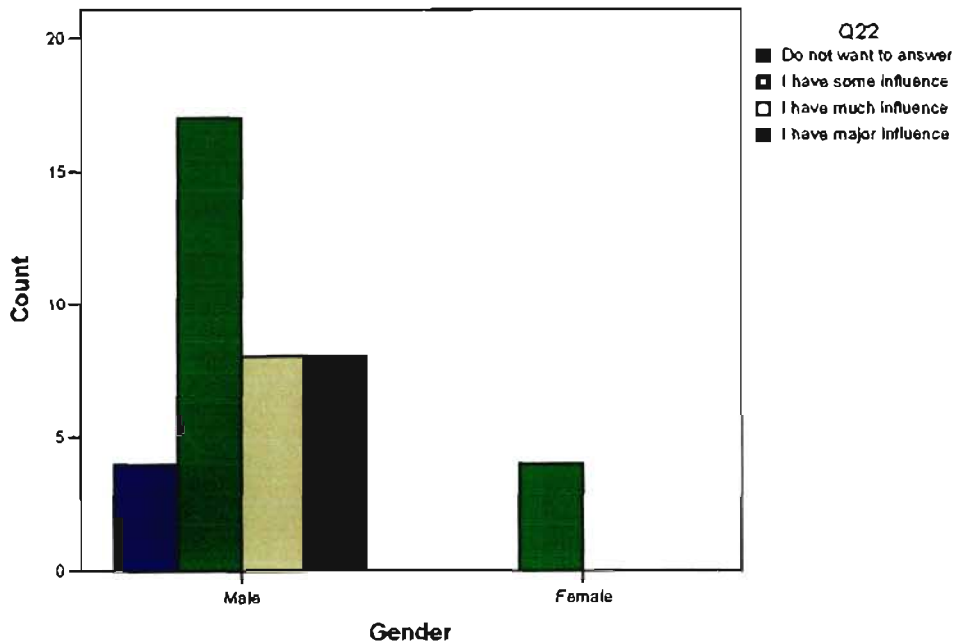
Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.321	.239
	Cramer's V	.321	.239
	Contingency Coefficient	.306	.239
N of Valid Cases		41	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q2 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 3

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,3} = 7.81473$
 Decision Rule: if (Test Statistic) $\chi^2 > 7.81473$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 4.221$

Step 5

The test statistic $\chi^2 = 4.221 < \chi^2_{0.05,3} = 7.81473$ so we cannot reject H_0 .

Step 6 : Conclusion

Since we cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q22 are dependent. This suggests that there is not a significant relationship between Q2 and Q22

We are simply unable to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q2 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.239

Decision Rule : If *P-Value* ≤ 0.05 then reject H_0

Conclusion: Cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q22 are dependent. This suggests that there is not a significant relationship between Q2 and Q22.

Q2 - Gender * Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

Crosstab

			The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:				Total
			Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Gender	Male	Count	11	14	12	4	41
		Expected Count	10.0	15.5	11.8	3.6	41.0
	Female	Count	0	3	1	0	4
		Expected Count	1.0	1.5	1.2	.4	4.0
Total		Count	11	17	13	4	45
		Expected Count	11.0	17.0	13.0	4.0	45.0

Crosstab

Count

		Q25				Total
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Gender	Male	11	14	12	4	41
	Female	0	3	1	0	4
Total		11	17	13	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.097 ^a	3	.377
Likelihood Ratio	4.101	3	.251
Linear-by-Linear Association	.413	1	.520
N of Valid Cases	45		

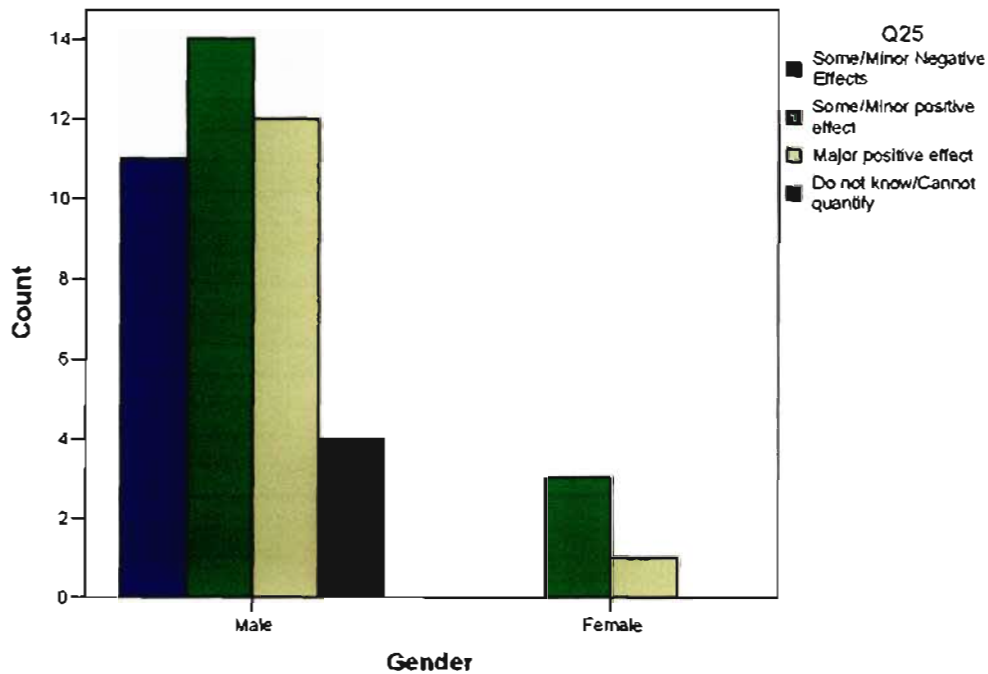
a. 5 cells (62.5%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by	Phi	.262	.377
Nominal	Cramer's V	.262	.377
	Contingency Coefficient	.254	.377
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q2 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 3

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,3} = 7.81473$
 Decision Rule: if (Test Statistic) $\chi^2 > 7.81473$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 3.097$

Step 5

The test statistic $\chi^2 = 3.097 < \chi^2_{0.05,1} = 7.81473$ so we cannot reject H_0 .

Step 6 : Conclusion

Since we cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q25 are dependent. This suggests that there is not a significant relationship between Q2 and Q25.

We are simply unable to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q2 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.377

Decision Rule : If *P-Value* ≤ 0.05 then reject H_0

Conclusion: Cannot Reject H_0 and conclude that there is insufficient evidence to prove that Q2 and Q25 are dependent. This suggests that there is not a significant relationship between Q2 and Q25.

Q5 - Company Size * Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focused.

Crosstab

		In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focused.					Total	
		Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree		
Company Size	< 10	Count	0	4	0	0	0	4
		Expected Count	.7	1.6	.9	.4	.4	4.0
< 100	Count	4	14	0	1	0	19	
	Expected Count	3.4	7.8	4.2	2.1	1.7	19.0	
< 1000	Count	0	0	0	4	4	8	
	Expected Count	1.4	3.2	1.8	.9	.7	8.0	
> 1000	Count	4	0	10	0	0	14	
	Expected Count	2.5	5.6	3.1	1.6	1.2	14.0	
Total	Count	8	18	10	5	4	45	
	Expected Count	8.0	18.0	10.0	5.0	4.0	45.0	

Crosstab

Count

	Q15					Total
	Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Company < 10	0	4	0	0	0	4
Size < 100	4	14	0	1	0	19
< 1000	0	0	0	4	4	8
> 1000	4	0	10	0	0	14
Total	8	18	10	5	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	75.071 ^a	12	.000
Likelihood Ratio	77.292	12	.000
Linear-by-Linear Association	2.586	1	.108
N of Valid Cases	45		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.292	.000
	Cramer's V	.746	.000
	Contingency Coefficient	.791	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

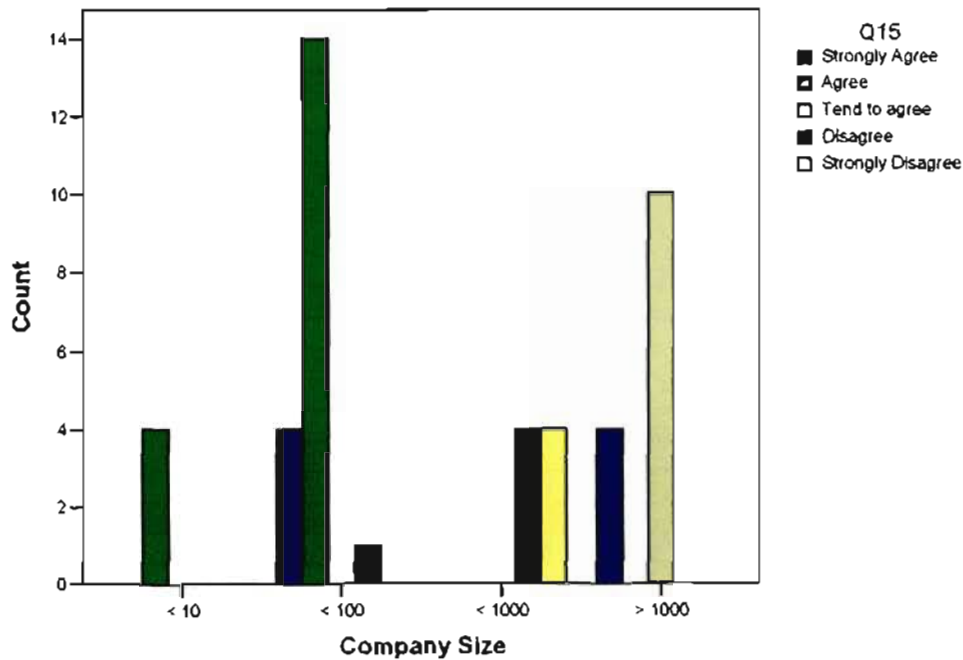
b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.746

This suggests that a moderate to high degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q5 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,12} = 21.0261$
 Decision Rule: if (Test Statistic) $\chi^2 > 21.0261$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 75.071$

Step 5

The test statistic $\chi^2 = 75.071 > \chi^2_{0.05,12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q15 are dependent. This suggests that there is a significant relationship between Q5 and Q15

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q5 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-value = 0.000

Decision Rule : If *P-value* ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q15 are dependent. This suggests that there is a significant relationship between Q5 and Q15.

Q5 - Company Size * Q16 - There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organization?

Crosstab

			There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?					Total
			Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Company Size	< 10	Count	0	0	4	0	0	4
		Expected Count	.7	2.0	.4	.6	.4	4.0
	< 100	Count	4	12	0	3	0	19
		Expected Count	3.4	9.3	1.7	3.0	1.7	19.0
	< 1000	Count	0	0	0	4	4	8
		Expected Count	1.4	3.9	.7	1.2	.7	8.0
	> 1000	Count	4	10	0	0	0	14
		Expected Count	2.5	6.8	1.2	2.2	1.2	14.0
Total		Count	8	22	4	7	4	45
		Expected Count	8.0	22.0	4.0	7.0	4.0	45.0

Crosstab

Count

		Q16					Total
		Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Company Size	< 10	0	0	4	0	0	4
	< 100	4	12	0	3	0	19
	< 1000	0	0	0	4	4	8
	> 1000	4	10	0	0	0	14
Total		8	22	4	7	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	79.680 ^a	12	.000
Likelihood Ratio	61.488	12	.000
Linear-by-Linear Association	1.652	1	.199
N of Valid Cases	45		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.331	.000
	Cramer's V	.768	.000
	Contingency Coefficient	.799	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

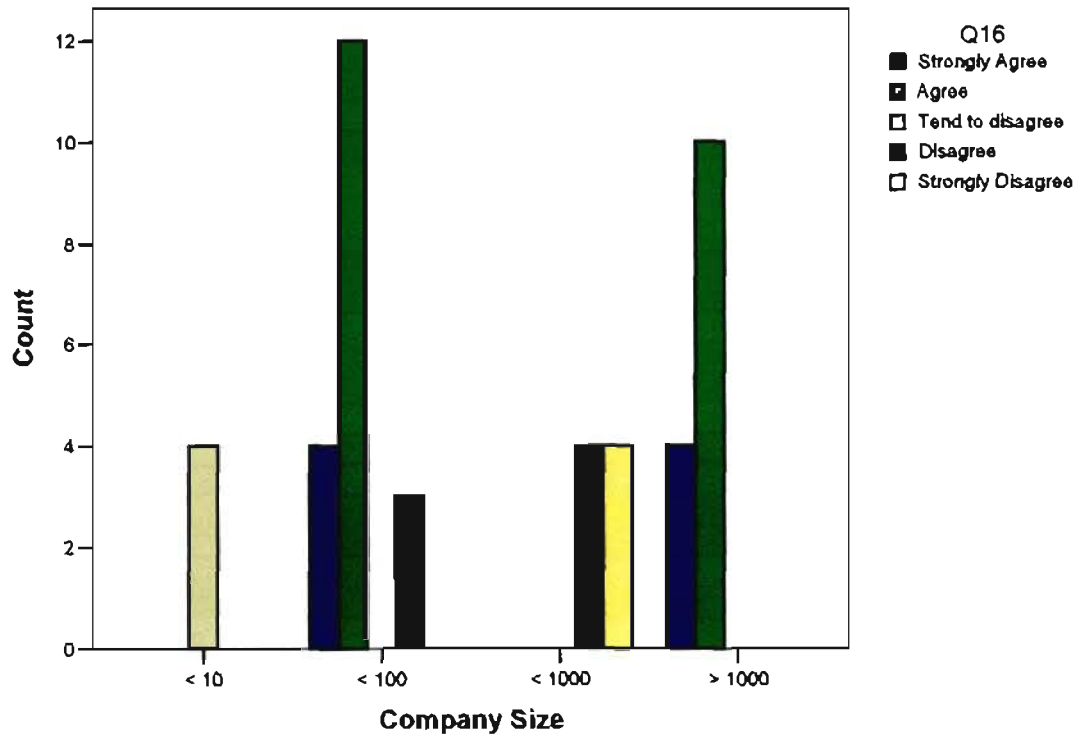
b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.768

This suggests that a moderate to high degree of association exists.

Bar Chart



I. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q5 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step3

Critical Value: $\chi^2_{0.05,12} = 21.0261$
 Decision Rule if (Test Statistic) $\chi^2 > 21.0261$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution," *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 79.680$

Step 5

The test statistic $\chi^2 = 79.680 > \chi^2_{0.05,12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is **sufficient** evidence that proves that Q5 and Q16 are dependent. This suggests that there is a **significant** relationship between Q5 and Q16

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q5 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or **associated** in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If *P-Value* ≤ 0.05 then reject H_0 .

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q16 are dependent. This suggests that there is a significant relationship between Q5 and Q16.

Q5 - Company Size * Q18 - My job function within the field of Industrial Automation has changed significantly in the past 2 years?

Crosstab

		My job function within the field of Industrial Automation has changed significantly in the past 2 years?						Total	
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know		
Company Size	< 10	Count	0	0	4	0	0	0	4
		Expected Count	.6	.7	1.2	.7	.4	.4	4.0
	< 100	Count	7	8	0	4	0	0	19
		Expected Count	3.0	3.4	5.9	3.4	1.7	1.7	19.0
	< 1000	Count	0	0	0	4	4	0	8
		Expected Count	1.2	1.4	2.5	1.4	.7	.7	8.0
	> 1000	Count	0	0	10	0	0	4	14
		Expected Count	2.2	2.5	4.4	2.5	1.2	1.2	14.0
Total		Count	7	8	14	8	4	4	45
		Expected Count	7.0	8.0	14.0	8.0	4.0	4.0	45.0

Crosstab

Count

		Q18					Total	
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree		Do not know
Company Size	< 10	0	0	4	0	0	0	4
	< 100	7	8	0	4	0	0	19
	< 1000	0	0	0	4	4	0	8
	> 1000	0	0	10	0	0	4	14
Total		7	8	14	8	4	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	77.687 ^a	15	.000
Likelihood Ratio	84.614	15	.000
Linear-by-Linear Association	11.008	1	.001
N of Valid Cases	45		

a. 23 cells (95.8%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.314	.000
	Cramer's V	.759	.000
	Contingency Coefficient	.796	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.759

This suggests that a moderate to high degree of association exists.

1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q5 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

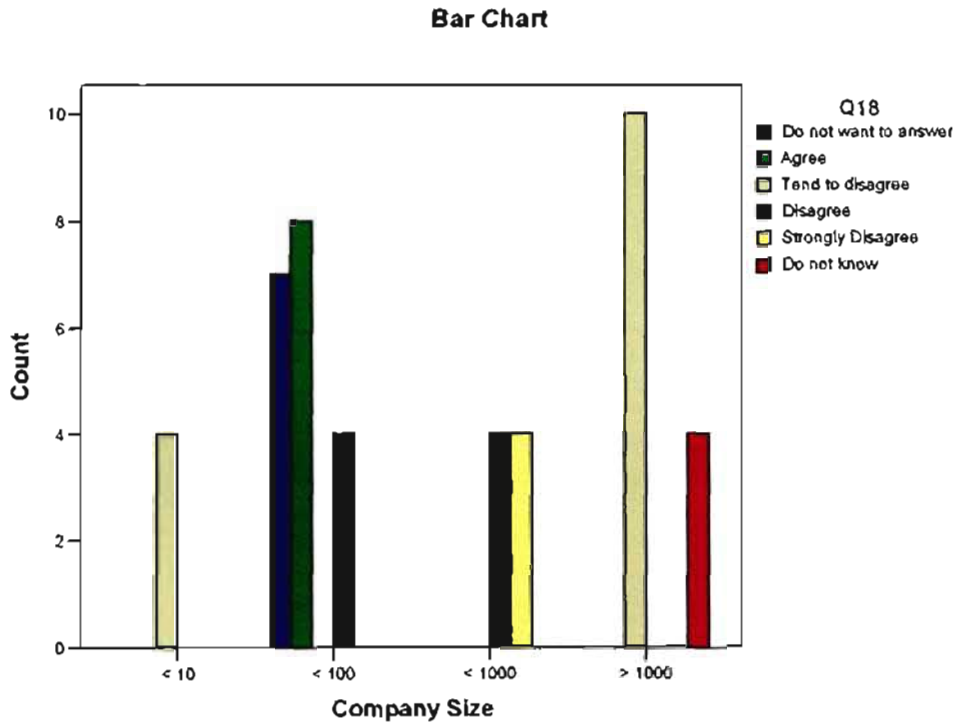
Degrees of freedom = 15

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value:

Decision Rule $\chi^2_{0.05,15} = 24.9958$
if (Test Statistic) $\chi^2 > 24.9958$
then reject H_0



SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 77.687$

Step 5

The test statistic $\chi^2 = 77.687 > \chi^2_{0.05, 15} = 24.9958$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q18 are dependent. This suggests that there is a significant relationship between Q5 and Q18

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q5 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If *P-Value* \leq 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q18 are dependent. This suggests that there is a significant relationship between Q5 and Q18.

Q5 - Company Size * Q22 - I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

Crosstab

			I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above				Total
			Do not want to answer	I have some influence	I have much influence	I have major influence	
Company Size	< 10	Count	0	0	0	4	4
		Expected Count	.4	2.0	.8	.8	4.0
	< 100	Count	4	15	0	0	19
		Expected Count	1.9	9.7	3.7	3.7	19.0
	< 1000	Count	0	0	4	4	8
		Expected Count	.8	4.1	1.6	1.6	8.0
	> 1000	Count	0	6	4	0	10
		Expected Count	1.0	5.1	2.0	2.0	10.0
Total		Count	4	21	8	8	41
		Expected Count	4.0	21.0	8.0	8.0	41.0

Crosstab

Count

		Q22				Total
		Do not want to answer	I have some influence	I have much influence	I have major influence	
Company Size	< 10	0	0	0	4	4
	< 100	4	15	0	0	19
	< 1000	0	0	4	4	8
	> 1000	0	6	4	0	10
Total		4	21	8	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	46.980 ^a	9	.000
Likelihood Ratio	54.903	9	.000
Linear-by-Linear Association	.147	1	.701
N of Valid Cases	41		

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .39.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.070	.000
	Cramer's V	.618	.000
	Contingency Coefficient	.731	.000
N of Valid Cases		41	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

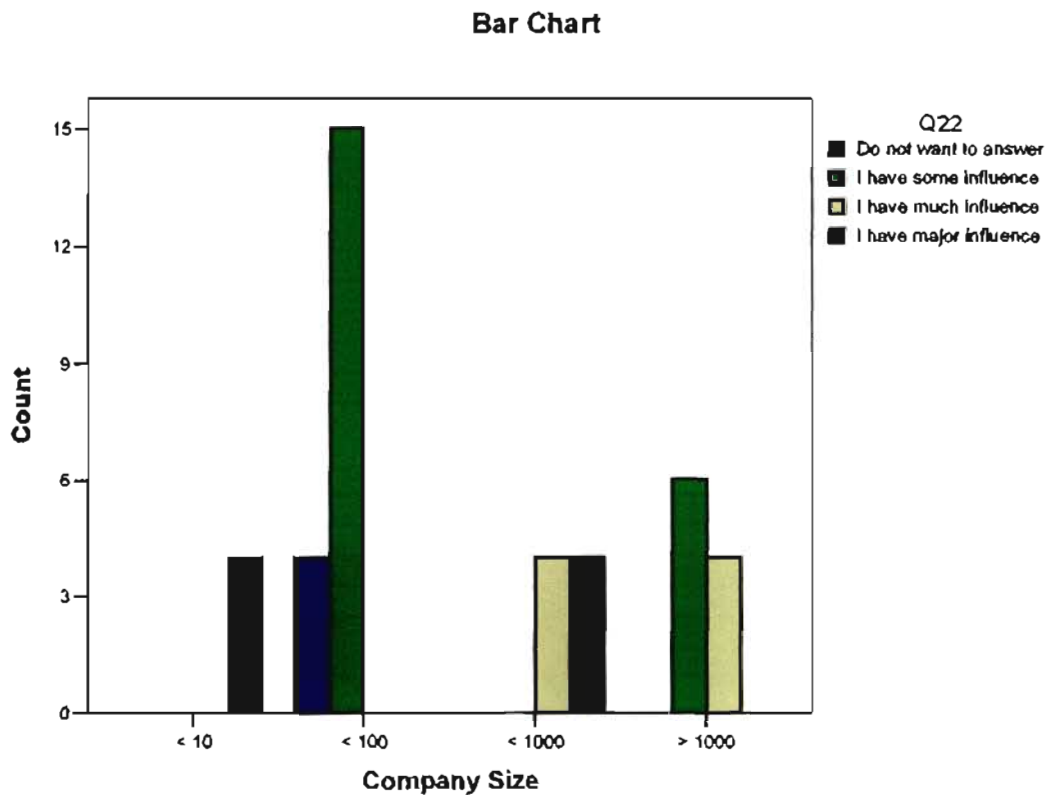
Comment on the strength of dependence:

Cramer's V = 0.618

This suggests that a moderate degree of association exists.

Contingency Coefficient = 0.731

This suggests that a moderate to high degree of association between the row and column variables exists.



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q5 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,9} = 16.9190$
 Decision Rule: if (Test Statistic) $\chi^2 > 16.9190$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 46.980$

Step 5

The test statistic $\chi^2 = 46.980 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q22 are dependent. This suggests that there is a significant relationship between Q5 and Q22

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q5 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-value = 0.000

Decision Rule : If *P-value* ≤ 0.05 then reject H_0 .

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q22 are dependent. This suggests that there is a significant relationship between Q5 and Q22.

Q5 - Company Size * Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

Crosstab

		The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:				Total	
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify		
Company Size	< 10	Count	0	0	0	4	4
		Expected Count	1.0	1.5	1.2	.4	4.0
< 100	Count	7	8	4	0	19	
	Expected Count	4.6	7.2	5.5	1.7	19.0	
< 1000	Count	4	0	4	0	8	
	Expected Count	2.0	3.0	2.3	.7	8.0	
> 1000	Count	0	9	5	0	14	
	Expected Count	3.4	5.3	4.0	1.2	14.0	
Total	Count	11	17	13	4	45	
	Expected Count	11.0	17.0	13.0	4.0	45.0	

Crosstab

Count		Q25				Total
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Company Size	< 10	0	0	0	4	4
	< 100	7	8	4	0	19
	< 1000	4	0	4	0	8
	> 1000	0	9	5	0	14
Total		11	17	13	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	58.983 ^a	9	.000
Likelihood Ratio	46.114	9	.000
Linear-by-Linear Association	.050	1	.823
N of Valid Cases	45		

a. 13 cells (81.3%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.145	.000
	Cramer's V	.661	.000
	Contingency Coefficient	.753	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.661

This suggests that a moderate degree of association exists.

Contingency Coefficient = 0.753

This suggests that a moderate to high degree of association between the row and column variables exists.

1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q5 is independent of Q25 (not related)

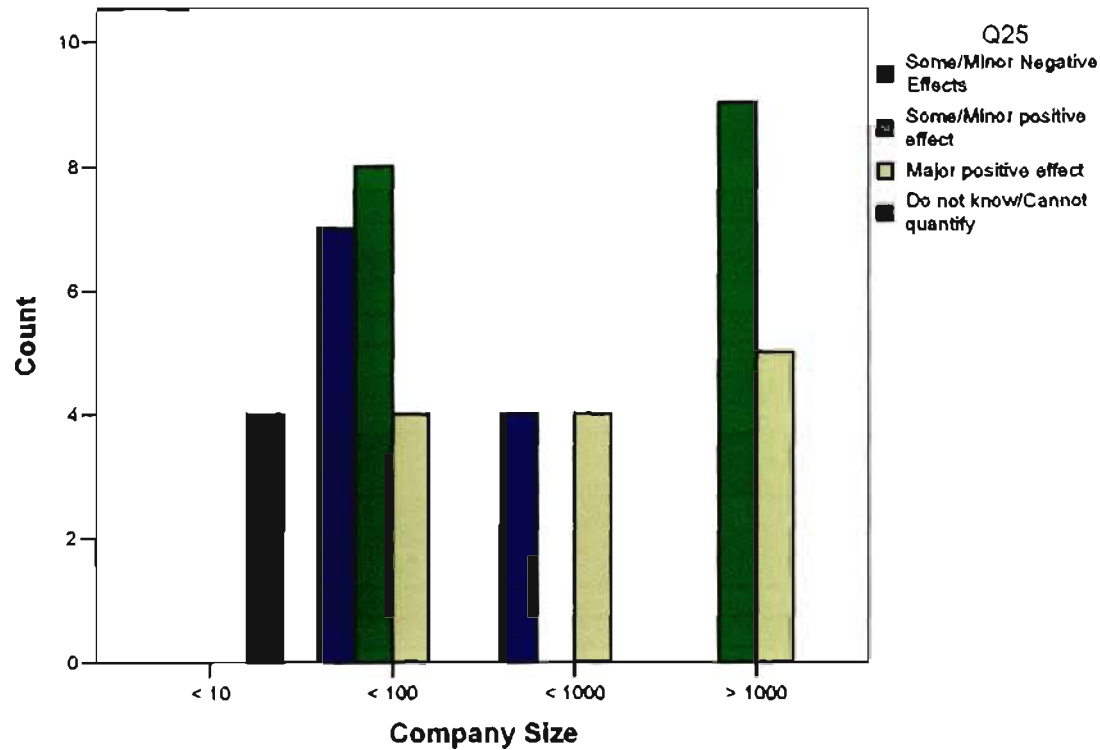
H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Bar Chart



Step 3

Critical Value: $\chi^2_{0.05,9} = 16.9190$
 Decision Rule: if (Test Statistic) $\chi^2 > 16.9190$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 58.983$

Step 5

The test statistic $\chi^2 = 58.983 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q25 are dependent. This suggests that there is a significant relationship between Q5 and Q25

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q5 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule: If $P\text{-Value} \leq 0.05$ then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q5 and Q25 are dependent. This suggests that there is a significant relationship between Q5 and Q25.

Q7 - Years of work experience * Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focused.

Crosstab

			In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.					Total
			Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Years of work experience	< 5	Count	4	4	10	4	0	22
		Expected Count	3.9	8.8	4.9	2.4	2.0	22.0
	< 10	Count	0	3	0	0	0	3
		Expected Count	.5	1.2	.7	.3	.3	3.0
	< 20	Count	0	11	0	1	0	12
		Expected Count	2.1	4.8	2.7	1.3	1.1	12.0
	> 20	Count	4	0	0	0	4	8
		Expected Count	1.4	3.2	1.8	.9	.7	8.0
Total	Count	8	18	10	5	4	45	
	Expected Count	8.0	18.0	10.0	5.0	4.0	45.0	

Crosstab

Count

		Q15					Total
		Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Years of work experience	< 5	4	4	10	4	0	22
	< 10	0	3	0	0	0	3
	< 20	0	11	0	1	0	12
	> 20	4	0	0	0	4	8
Total		8	18	10	5	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	55.117 ^a	12	.000
Likelihood Ratio	57.381	12	.000
Linear-by-Linear Association	.139	1	.709
N of Valid Cases	45		

a. 19 cells (95.0%) have expected count less than 5. The minimum expected count is .27.

Symmetric Measures

		Value	Approx. Sig.
Nominal by	Phi	1.107	.000
Nominal	Cramer's V	.639	.000
	Contingency Coefficient	.742	.000
N of Valid Cases		45	

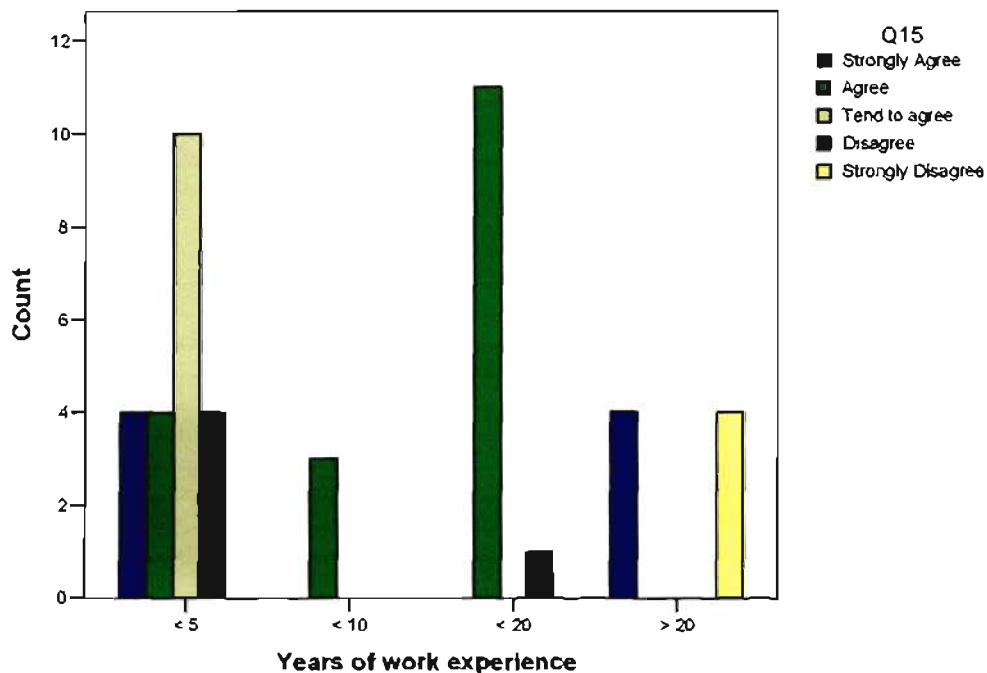
- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0,639

This suggests that a moderate degree of association exists.

Bar Chart



I. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q7 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step3

Critical Value: $\chi^2_{0.05, 12} = 21.0261$
 Decision Rule if (Test Statistic) $\chi^2 > 21.0261$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 55.117$

Step 5

The test statistic $\chi^2 = 55.117 > \chi^2_{0.05, 12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q15 are dependent. This suggests that there is a significant relationship between Q7 and Q15

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q7 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q15 are dependent. This suggests that there is a significant relationship between Q7 and Q15.

Q7 - Years of work experience * Q16 - There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

Crosstab

		There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?					Total	
		Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree		
Years of work experience	< 5	Count	4	10	4	4	0	22
		Expected Count	3.9	10.8	2.0	3.4	2.0	22.0
	< 10	Count	0	3	0	0	0	3
		Expected Count	.5	1.5	.3	.5	.3	3.0
	< 20	Count	0	9	0	3	0	12
		Expected Count	2.1	5.9	1.1	1.9	1.1	12.0
	> 20	Count	4	0	0	0	4	8
		Expected Count	1.4	3.9	.7	1.2	.7	8.0
Total		Count	8	22	4	7	4	45
		Expected Count	8.0	22.0	4.0	7.0	4.0	45.0

Crosstab

Count		Q16					Total
		Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Years of work experience	< 5	4	10	4	4	0	22
	< 10	0	3	0	0	0	3
	< 20	0	9	0	3	0	12
	> 20	4	0	0	0	4	8
Total		8	22	4	7	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	39.760 ^a	12	.000
Likelihood Ratio	42.630	12	.000
Linear-by-Linear Association	.815	1	.367
N of Valid Cases	45		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .27.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.940	.000
	Cramer's V	.543	.000
	Contingency Coefficient	.685	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.534

This suggests that a moderate degree of association exists.

1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q7 is independent of Q16 (not related)

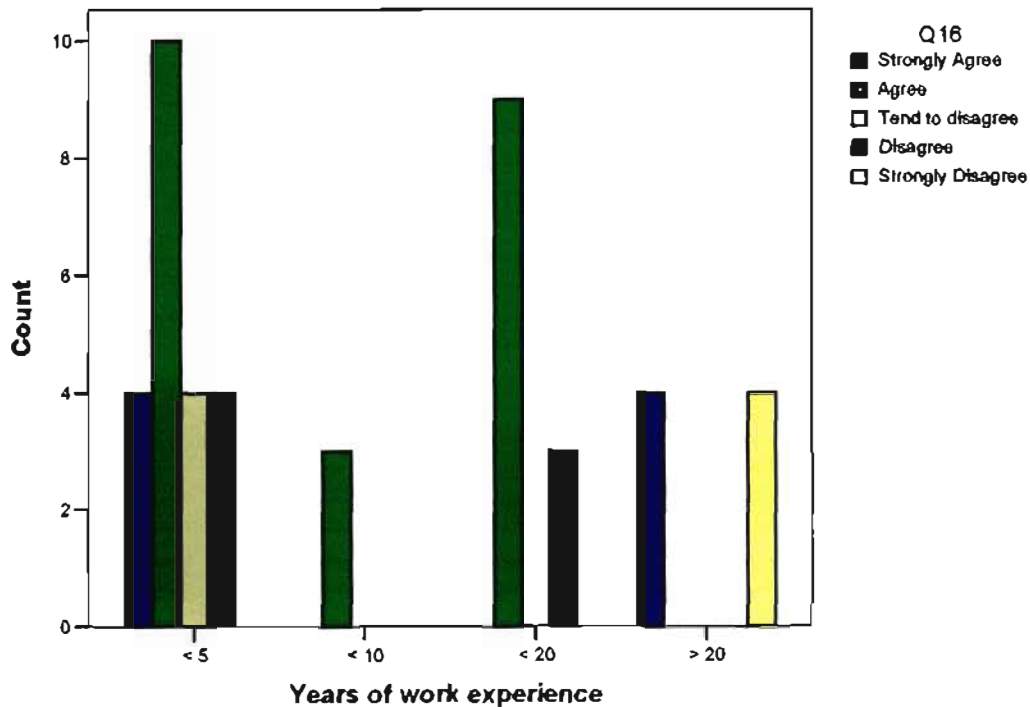
H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Bar Chart



Step 3

Critical Value: $\chi^2_{0.05, 12} = 21.0261$
 Decision Rule: if (Test Statistic) $\chi^2 > 21.0261$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 39.760$

Step 5

The test statistic $\chi^2 = 39.760 > \chi^2_{0.05, 12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q16 are dependent. This suggests that there is a significant relationship between Q7 and Q16

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q7 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

$P\text{-Value} = 0.000$

Decision Rule: If $P\text{-Value} < 0.05$ then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q16 are dependent. This suggests that there is a significant relationship between Q7 and Q16.

Q7 - Years of work experience * Q18 - My job function within the field of Industrial Automation has changed significantly in the past 2 years?

Crosstab

		My job function within the field of Industrial Automation has changed significantly in the past 2 years?						Total	
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know		
Years of work experience	< 5	Count	0	0	14	4	0	4	22
		Expected Count	3.4	3.9	6.8	3.9	2.0	2.0	22.0
	< 10	Count	0	0	0	3	0	0	3
		Expected Count	5	.5	.9	.5	3	.3	3.0
	< 20	Count	7	4	0	1	0	0	12
		Expected Count	1.9	2.1	3.7	2.1	1.1	1.1	12.0
	> 20	Count	0	4	0	0	4	0	8
		Expected Count	1.2	1.4	2.5	1.4	7	.7	8.0
Total		Count	7	8	14	8	4	4	45
		Expected Count	7.0	8.0	14.0	8.0	4.0	4.0	45.0

Crosstab

Count

		Q18						Total
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know	
Years of work experience	< 5	0	0	14	4	0	4	22
	< 10	0	0	0	3	0	0	3
	< 20	7	4	0	1	0	0	12
	> 20	0	4	0	0	4	0	8
Total		7	8	14	8	4	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	80.753 ^a	15	.000
Likelihood Ratio	80.414	15	.000
Linear-by-Linear Association	8.126	1	.004
N of Valid Cases	45		

a. 23 cells (95.8%) have expected count less than 5. The minimum expected count is .27.

Symmetric Measures

		Value	Approx. Sig.
Nominal by	Phi	1.340	.000
Nominal	Cramer's V	.773	.000
	Contingency Coefficient	.801	.000
N of Valid Cases		45	

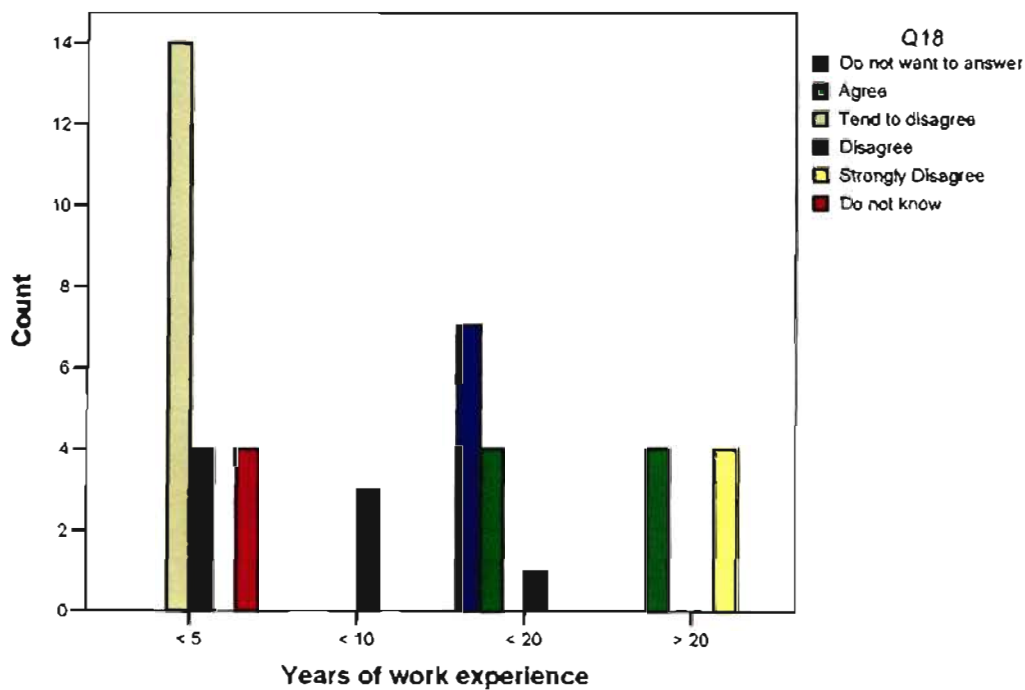
- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.773

This suggests that a moderate to high degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q7 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 15

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,15} = 24.9958$
 Decision Rule: if (Test Statistic) $\chi^2 > 24.9958$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians I*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 80.753$

Step 5

The test statistic $\chi^2 = 80.753 > \chi^2_{0.05,15} = 24.9958$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q18 are dependent. This suggests that there is a significant relationship between Q7 and Q18

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q7 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q18 are dependent. This suggests that there is a significant relationship between Q7 and Q18.

Q7 - Years of work experience * Q22 - I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

Crosstab

		I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above				Total	
		Do not want to answer	I have some influence	I have much influence	I have major influence		
Years of work experience	< 5	Count	0	6	8	4	18
		Expected Count	1.8	9.2	3.5	3.5	18.0
	< 10	Count	3	0	0	0	3
		Expected Count	.3	1.5	.6	.6	3.0
	< 20	Count	1	11	0	0	12
		Expected Count	1.2	6.1	2.3	2.3	12.0
	> 20	Count	0	4	0	4	8
		Expected Count	.8	4.1	1.6	1.6	8.0
Total	Count	4	21	8	8	41	
	Expected Count	4.0	21.0	8.0	8.0	41.0	

Crosstab

Count		Q22				Total
		Do not want to answer	I have some influence	I have much influence	I have major influence	
Years of work experience	< 5	0	6	8	4	18
	< 10	3	0	0	0	3
	< 20	1	11	0	0	12
	> 20	0	4	0	4	8
Total		4	21	8	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	51.128 ^a	9	.000
Likelihood Ratio	42.845	9	.000
Linear-by-Linear Association	.470	1	.493
N of Valid Cases	41		

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .29.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.117	.000
	Cramer's V	.645	.000
	Contingency Coefficient	.745	.000
N of Valid Cases		41	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.645
This suggests that a moderate degree of association exists.

Contingency Coefficient = 0.745
This suggests that a moderate to high degree of association between the row and column variables exists.

1. Chi-Square Test

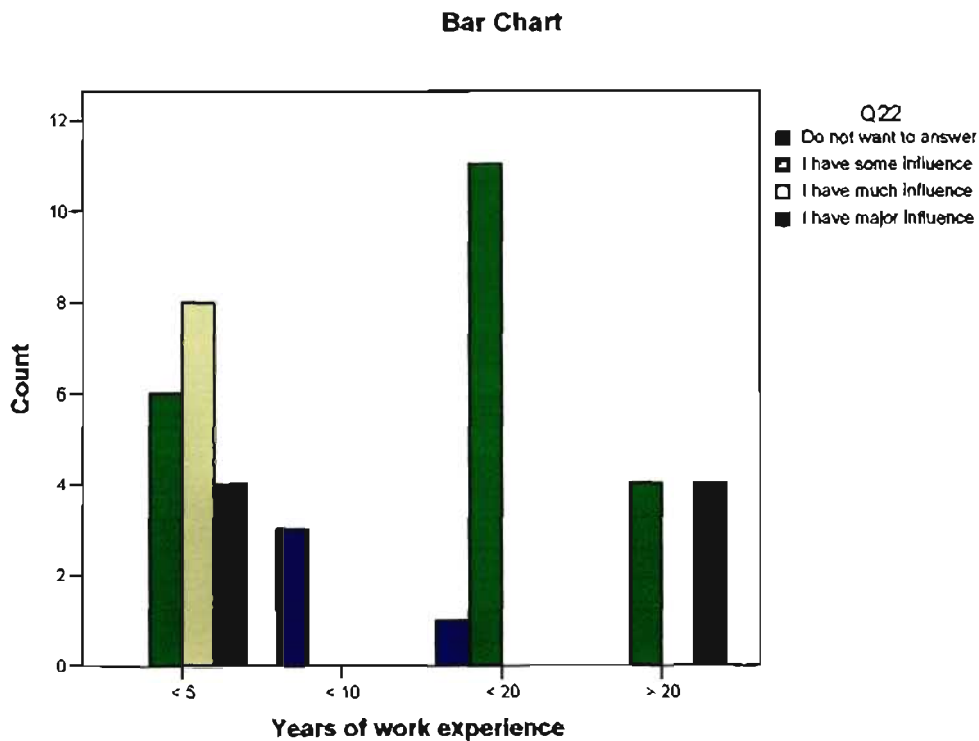
Step 1

The hypotheses are:

- H_0 : Q7 is independent of Q22 (not related)
- H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9
Using a 5% Level of significance $\alpha = 0.05$



Step 3

Critical Value: $\chi^2_{0.05,9} = 16.9190$
 Decision Rule: if (Test Statistic) $\chi^2 > 16.9190$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 51.128$

Step 5

The test statistic $\chi^2 = 51.128 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q22 are dependent. This suggests that there is a significant relationship between Q7 and Q22

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q7 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-value = 0.000

Decision Rule : If *P-value* \leq 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q22 are dependent. This suggests that there is a significant relationship between Q7 and Q22.

Q7 - Years of work experience * Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

Crosstab

		The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:					
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	Total	
Years of work experience	< 5	Count	4	9	5	4	22
		Expected Count	5.4	8.3	6.4	2.0	22.0
	< 10	Count	0	3	0	0	3
		Expected Count	.7	1.1	.9	.3	3.0
	< 20	Count	7	5	0	0	12
		Expected Count	2.9	4.5	3.5	1.1	12.0
	> 20	Count	0	0	8	0	8
		Expected Count	2.0	3.0	2.3	.7	8.0
Total	Count	11	17	13	4	45	
	Expected Count	11.0	17.0	13.0	4.0	45.0	

Crosstab

Count

		Q25				
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	Total
Years of work experience	< 5	4	9	5	4	22
	< 10	0	3	0	0	3
	< 20	7	5	0	0	12
	> 20	0	0	8	0	8
Total		11	17	13	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	37.689 ^a	9	.000
Likelihood Ratio	41.256	9	.000
Linear-by-Linear Association	.105	1	.746
N of Valid Cases	45		

a. 13 cells (81.3%) have expected count less than 5. The minimum expected count is .27.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.915	.000
	Cramer's V	.528	.000
	Contingency Coefficient	.675	.000
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

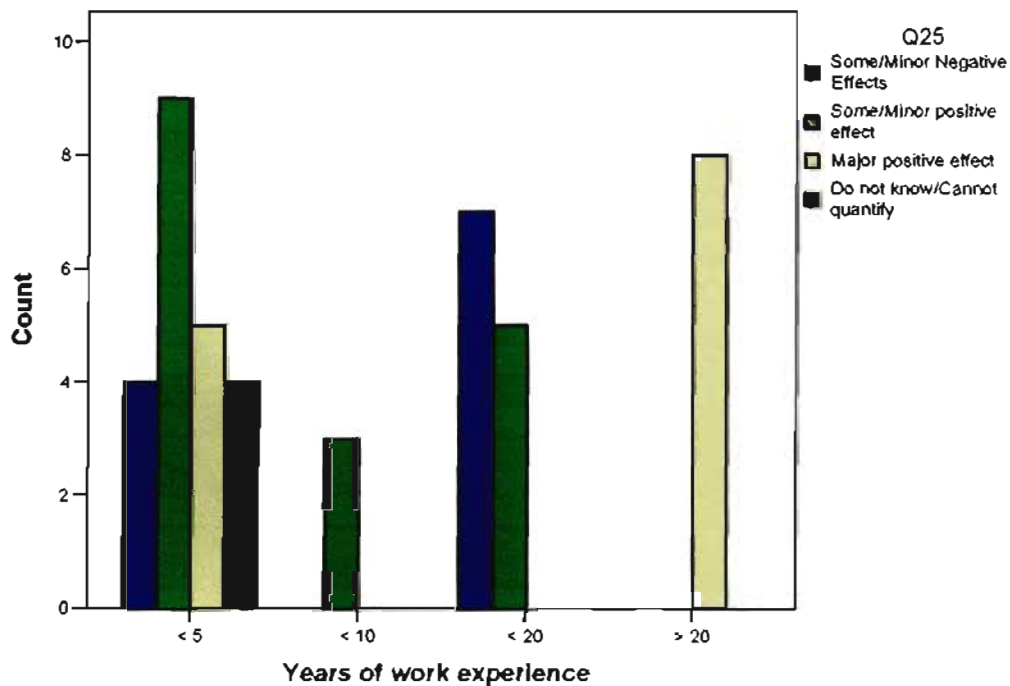
Cramer's V = 0.528

This suggests that a moderate degree of association exists.

Contingency Coefficient = 0.675

This suggests that a moderate degree of association between the row and column variables exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q7 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,9} = 16.9190$
 Decision Rule if (Test Statistic) $\chi^2 > 16.9190$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 37.689$

Step 5

The test statistic $\chi^2 = 37.689 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q25 are dependent. This suggests that there is a significant relationship between Q7 and Q25

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q7 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q7 and Q25 are dependent. This suggests that there is a significant relationship between Q7 and Q25.

Q8 - Level in the organisation * Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.

Crosstab

			In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.					Total
			Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Level in the organisation	Artisan	Count	0	4	0	0	0	4
		Expected Count	.7	1.6	.9	.4	.4	4.0
	Technician	Count	0	3	0	1	0	4
		Expected Count	.7	1.6	.9	.4	.4	4.0
	Engineer	Count	4	0	2	4	0	10
		Expected Count	1.8	4.0	2.2	1.1	.9	10.0
	Supervisor	Count	0	4	0	0	0	4
		Expected Count	.7	1.6	.9	.4	.4	4.0
	Manager	Count	4	7	8	0	4	23
		Expected Count	4.1	9.2	5.1	2.6	2.0	23.0
Total		Count	8	18	10	5	4	45
		Expected Count	8.0	18.0	10.0	5.0	4.0	45.0

Crosstab

Count		Q15					Total
		Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Level in the organisation	Artisan	0	4	0	0	0	4
	Technician	0	3	0	1	0	4
	Engineer	4	0	2	4	0	10
	Supervisor	0	4	0	0	0	4
	Manager	4	7	8	0	4	23
Total		8	18	10	5	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	37.662 ^a	16	.002
Likelihood Ratio	44.903	16	.000
Linear-by-Linear Association	.425	1	.514
N of Valid Cases	45		

a. 23 cells (92.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.915	.002
	Cramer's V	.457	.002
	Contingency Coefficient	.675	.002
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.457

This suggests that a low degree of association exists.

Contingency Coefficient = 0.675

This suggests that a moderate degree of association between the row and column variables exists.

1. Chi-Square Test

Step 1

The hypotheses are:

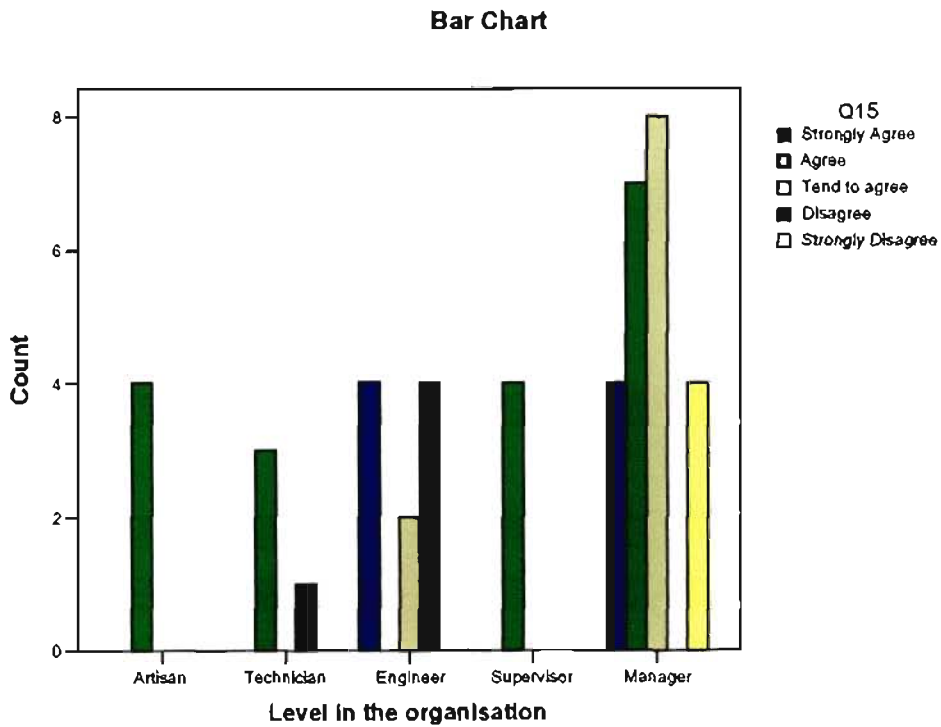
H_0 : Q8 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 16

Using a 5% Level of significance $\alpha = 0.05$



Step 3

Critical Value: $\chi^2_{0.05,16} = 26.2962$
 Decision Rule: if (Test Statistic) $\chi^2 > 26.2962$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 37.662$

Step 5

The test statistic $\chi^2 = 37.662 > \chi^2_{0.05,16} = 26.2962$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q15 are dependent. This suggests that there is a significant relationship between Q8 and Q15

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q8 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If *P-Value* ≤ 0.05 then reject H₀

Conclusion: Reject H₀ and conclude that there is sufficient evidence that proves that Q8 and Q15 are dependent. This suggests that there is a significant relationship between Q8 and Q15.

Q8 - Level in the organisation * Q16 - There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

Crosstab

			There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?					Total
			Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Level in the organisation	Artisan	Count	0	0	4	0	0	4
		Expected Count	.7	2.0	.4	.6	.4	4.0
	Technician	Count	0	1	0	3	0	4
		Expected Count	.7	2.0	.4	.6	.4	4.0
	Engineer	Count	4	2	0	4	0	10
		Expected Count	1.8	4.9	.9	1.6	.9	10.0
	Supervisor	Count	0	4	0	0	0	4
		Expected Count	.7	2.0	.4	.6	.4	4.0
	Manager	Count	4	15	0	0	4	23
		Expected Count	4.1	11.2	2.0	3.6	2.0	23.0
Total		Count	8	22	4	7	4	45
		Expected Count	8.0	22.0	4.0	7.0	4.0	45.0

Crosstab

Count		Q16					Total
		Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Level in the organisation	Artisan	0	0	4	0	0	4
	Technician	0	1	0	3	0	4
	Engineer	4	2	0	4	0	10
	Supervisor	0	4	0	0	0	4
	Manager	4	15	0	0	4	23
Total		8	22	4	7	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	75.010 ^a	16	.000
Likelihood Ratio	57.492	16	.000
Linear-by-Linear Association	4.521	1	.033
N of Valid Cases	45		

a. 24 cells (96.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.291	.000
	Cramer's V	.646	.000
	Contingency Coefficient	.791	.000
N of Valid Cases		45	

- Not assuming the null hypothesis.
- Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

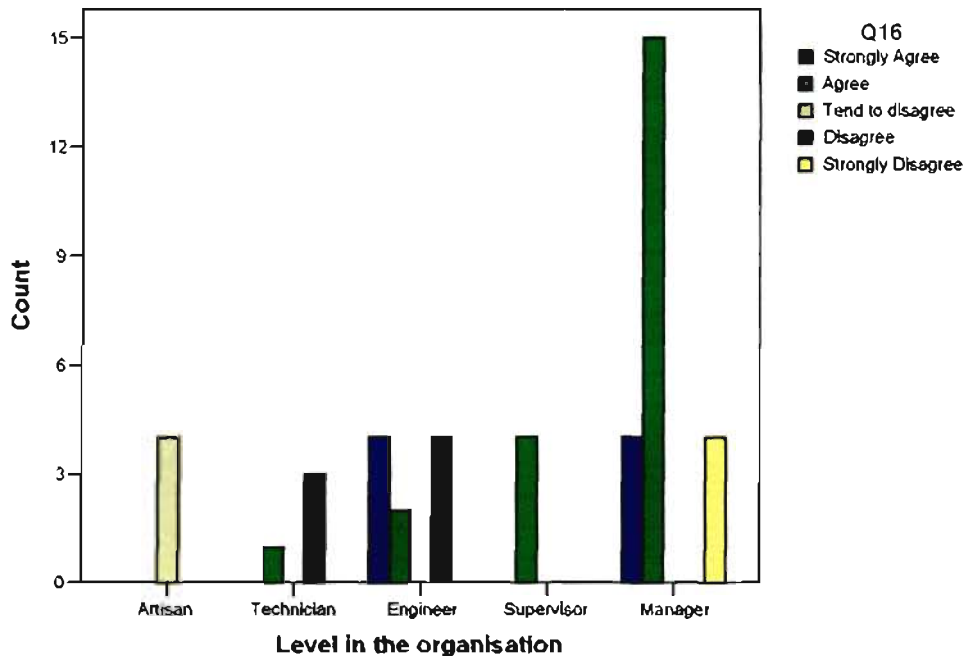
Cramer's V = 0.646

This suggests that a moderate degree of association exists.

Contingency Coefficient = 0.791

This suggests that a moderate to high degree of association between the row and column variables exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q8 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 16

Using a 5% Level of significance $\alpha = 0.05$

Step3

Critical Value: $\chi^2_{0.05,16} = 26.2962$
Decision Rule if (Test Statistic) $\chi^2 > 26.2962$
then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 75.010$

Step 5

The test statistic $\chi^2 = 75.010 > \chi^2_{0.05,16} = 26.2962$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q16 are dependent. This suggests that there is a significant relationship between Q8 and Q16

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q8 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule: If P-Value < 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q16 are dependent. This suggests that there is a significant relationship between Q8 and Q16.

Q7 - Level in the organisation * Q18 - My job function within the field of Industrial Automation has changed significantly in the past 2 years?

Crosstab

			My job function within the field of Industrial Automation has changed significantly in the past 2 years?					Total	
			Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree		Do not know
Level in the organisation	Artisan	Count	0	0	4	0	0	0	4
		Expected Count	.6	.7	1.2	.7	.4	.4	4.0
	Technician	Count	0	4	0	0	0	0	4
		Expected Count	.6	.7	1.2	.7	.4	.4	4.0
	Engineer	Count	0	0	2	4	0	0	4
		Expected Count	1.6	1.8	3.1	1.8	.9	.9	10.0
	Supervisor	Count	0	0	0	4	0	0	4
		Expected Count	.8	.7	1.2	.7	.4	.4	4.0
	Manager	Count	7	4	8	0	4	0	23
		Expected Count	3.6	4.1	7.2	4.1	2.0	2.0	23.0
	Total	Count	7	8	14	8	4	4	45
		Expected Count	7.0	8.0	14.0	8.0	4.0	4.0	45.0

Crosstab

Count		Q18					Total	
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree		Do not know
Level in the organisation	Artisan	0	0	4	0	0	0	4
	Technician	0	4	0	0	0	0	4
	Engineer	0	0	2	4	0	4	10
	Supervisor	0	0	0	4	0	0	4
	Manager	7	4	8	0	4	0	23
Total		7	8	14	8	4	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	75.522 ^a	20	.000
Likelihood Ratio	70.104	20	.000
Linear-by-Linear Association	2.458	1	.117
N of Valid Cases	45		

a. 29 cells (96.7%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.295	.000
	Cramer's V	.648	.000
	Contingency Coefficient	.792	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

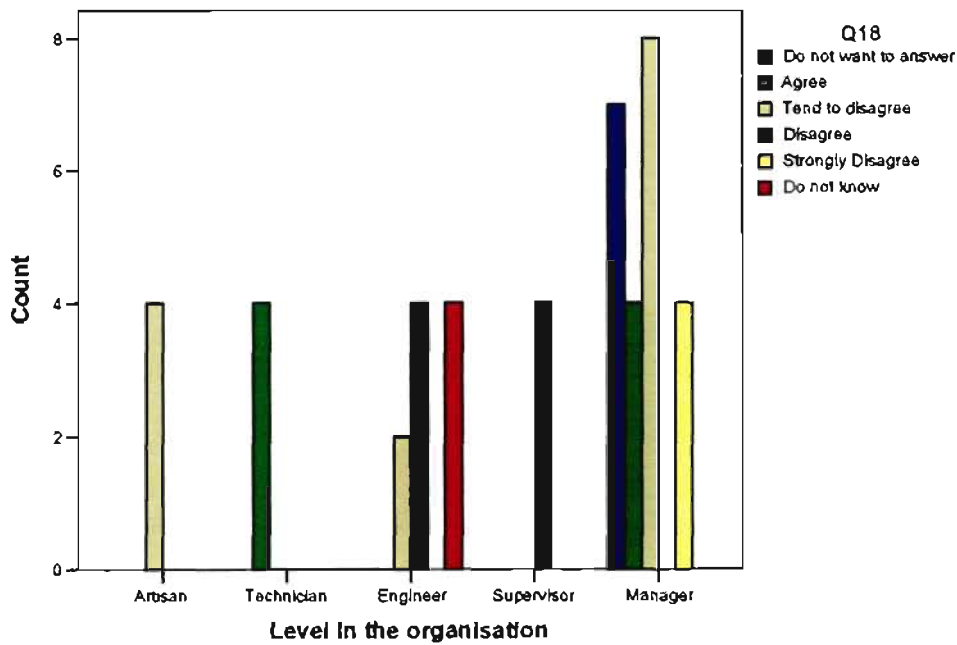
b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.648

This suggests that a moderate degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q8 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 20

Using a 5% Level of significance $\alpha = 0.05$

Step3

Critical Value: $\chi^2_{0.05,20} = 31.4104$
 Decision Rule if (Test Statistic) $\chi^2 > 31.4104$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 75.522$

Step 5

The test statistic $\chi^2 = 75.522 > \chi^2_{0.05,20} = 31.4104$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q18 are dependent. This suggests that there is a significant relationship between Q8 and Q18

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q8 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-value = 0.000

Decision Rule : If *P-value* ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q18 are dependent. This suggests that there is a significant relationship between Q8 and Q18.

Q7 - Level in the organisation * Q22 - I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

Crosstab

			I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above				Total
			Do not want to answer	I have some influence	I have much influence	I have major influence	
Level In the organisation	Artisan	Count	0	0	0	4	4
		Expected Count	.4	2.0	.8	.8	4.0
	Technician	Count	0	4	0	0	4
		Expected Count	.4	2.0	.8	.8	4.0
	Engineer	Count	0	2	8	0	10
		Expected Count	1.0	5.1	2.0	2.0	10.0
	Supervisor	Count	4	0	0	0	4
		Expected Count	.4	2.0	.8	.8	4.0
	Manager	Count	0	15	0	4	19
		Expected Count	1.9	9.7	3.7	3.7	19.0
Total		Count	4	21	8	8	41
		Expected Count	4.0	21.0	8.0	8.0	41.0

Crosstab

Count		Q22				Total
		Do not want to answer	I have some influence	I have much influence	I have major influence	
Level in the organisation	Artisan	0	0	0	4	4
	Technician	0	4	0	0	4
	Engineer	0	2	8	0	10
	Supervisor	4	0	0	0	4
	Manager	0	15	0	4	19
Total		4	21	8	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	89.327 ^a	12	.000
Likelihood Ratio	69.446	12	.000
Linear-by-Linear Association	4.000	1	.045
N of Valid Cases	41		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .39.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.476	.000
	Cramer's V	.852	.000
	Contingency Coefficient	.828	.000
N of Valid Cases		41	

a. Not assuming the null hypothesis.

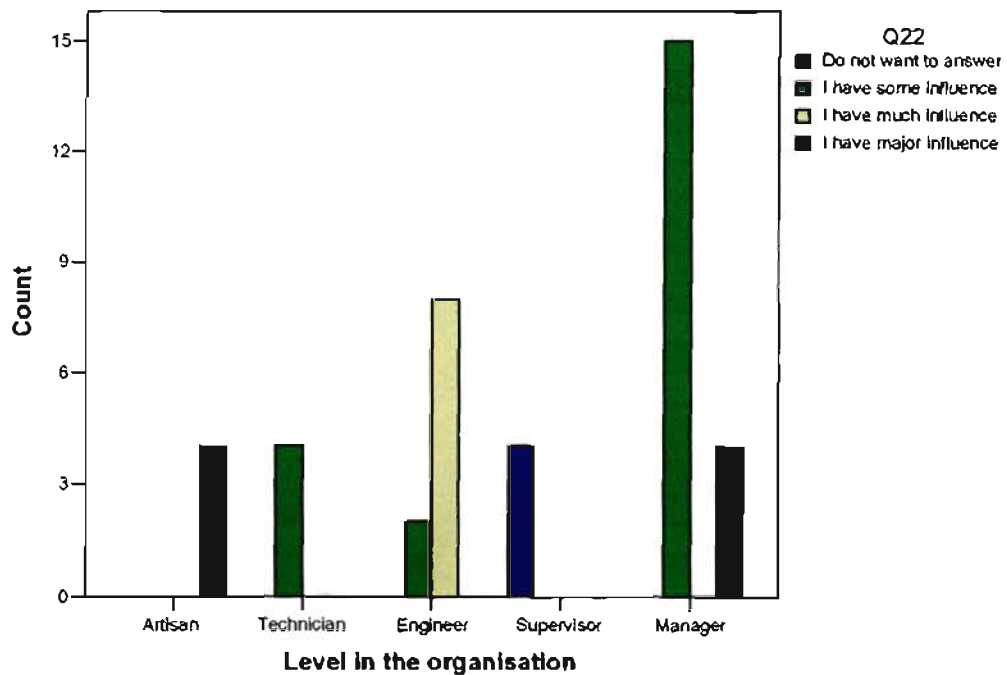
b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.852

This suggests that a high degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q8 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{0.05,12} = 21.0261$
Decision Rule	if (Test Statistic) $\chi^2 > 21.0261$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 89.327$

Step 5

The test statistic $\chi^2 = 89.327 > \chi^2_{0.05,12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q22 are dependent. This suggests that there is a significant relationship between Q8 and Q22

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q8 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q22 are dependent. This suggests that there is a significant relationship between Q8 and Q22.

Q8 - Level in the organisation * Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

Crosstab

			The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:				Total
			Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Level in the organisation	Artisan	Count	0	0	0	4	4
		Expected Count	1.0	1.5	1.2	.4	4.0
	Technician	Count	0	4	0	0	4
		Expected Count	1.0	1.5	1.2	.4	4.0
	Engineer	Count	4	1	5	0	10
		Expected Count	2.4	3.8	2.9	.9	10.0
	Supervisor	Count	0	4	0	0	4
		Expected Count	1.0	1.5	1.2	.4	4.0
	Manager	Count	7	8	8	0	23
		Expected Count	5.6	8.7	6.6	2.0	23.0
	Total	Count	11	17	13	4	45
		Expected Count	11.0	17.0	13.0	4.0	45.0

Crosstab

Count

		Q25				Total
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Level in the organisation	Artisan	0	0	0	4	4
	Technician	0	4	0	0	4
	Engineer	4	1	5	0	10
	Supervisor	0	4	0	0	4
	Manager	7	8	8	0	23
Total		11	17	13	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	62.354 ^a	12	.000
Likelihood Ratio	46.423	12	.000
Linear-by-Linear Association	4.267	1	.039
N of Valid Cases	45		

a. 17 cells (85.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by	Phi	1.177	.000
Nominal	Cramer's V	.680	.000
	Contingency Coefficient	.762	.000
N of Valid Cases		45	

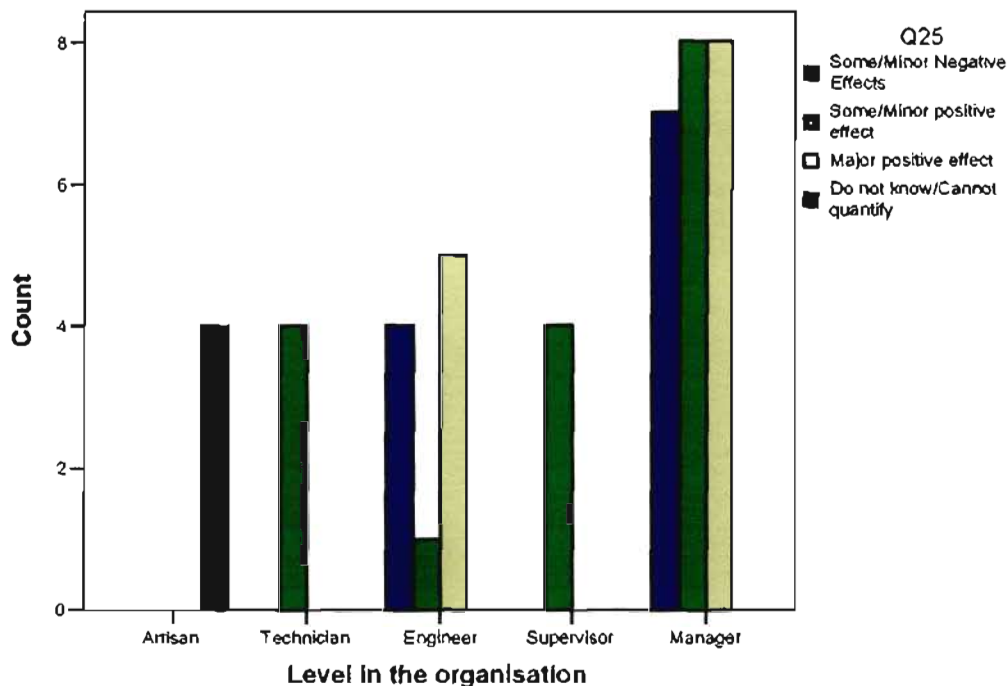
- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.68

This suggests that a moderate degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q8 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step3

Critical Value:

$$\chi^2_{0.05,12} = 21.0261$$

Decision Rule

if (Test Statistic) $\chi^2 > 21.0261$
then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1. 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 62.354$

Step 5

The test statistic $\chi^2 = 62.354 > \chi^2_{0.05, 12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q25 are dependent. This suggests that there is a significant relationship between Q8 and Q25.

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q8 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

p-value = 0.000

Decision Rule : If *p-value* ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q8 and Q25 are dependent. This suggests that there is a significant relationship between Q8 and Q25.

Q10 - Primary Focus Area * Q15 - In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focused.

Crosstab

			In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.					Total
			Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Primary Focus Area	Do not want to answer	Count	0	4	0	0	0	4
		Expected Count	.7	1.6	.9	.4	.4	4.0
	IT	Count	0	11	0	0	0	11
		Expected Count	2.0	4.4	2.4	1.2	1.0	11.0
	Automation	Count	8	3	10	5	0	26
		Expected Count	4.6	10.4	5.8	2.9	2.3	26.0
	Cannot differentiate	Count	0	0	0	0	4	4
		Expected Count	.7	1.6	.9	.4	.4	4.0
	Total	Count	8	18	10	5	4	45
		Expected Count	8.0	18.0	10.0	5.0	4.0	45.0

Crosstab

Count		Q15					Total
		Strongly Agree	Agree	Tend to agree	Disagree	Strongly Disagree	
Primary Focus Area	Do not want to answer	0	4	0	0	0	4
	IT	0	11	0	0	0	11
	Automation	8	3	10	5	0	26
	Cannot differentiate	0	0	0	0	4	4
Total		8	18	10	5	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	78.173 ^a	12	.000
Likelihood Ratio	64.627	12	.000
Linear-by-Linear Association	12.001	1	.001
N of Valid Cases	45		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.318	.000
	Cramer's V	.761	.000
	Contingency Coefficient	.797	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.761

This suggests that a moderate to high degree of association exists.

1. Chi-Square Test

Step 1

The hypotheses are:

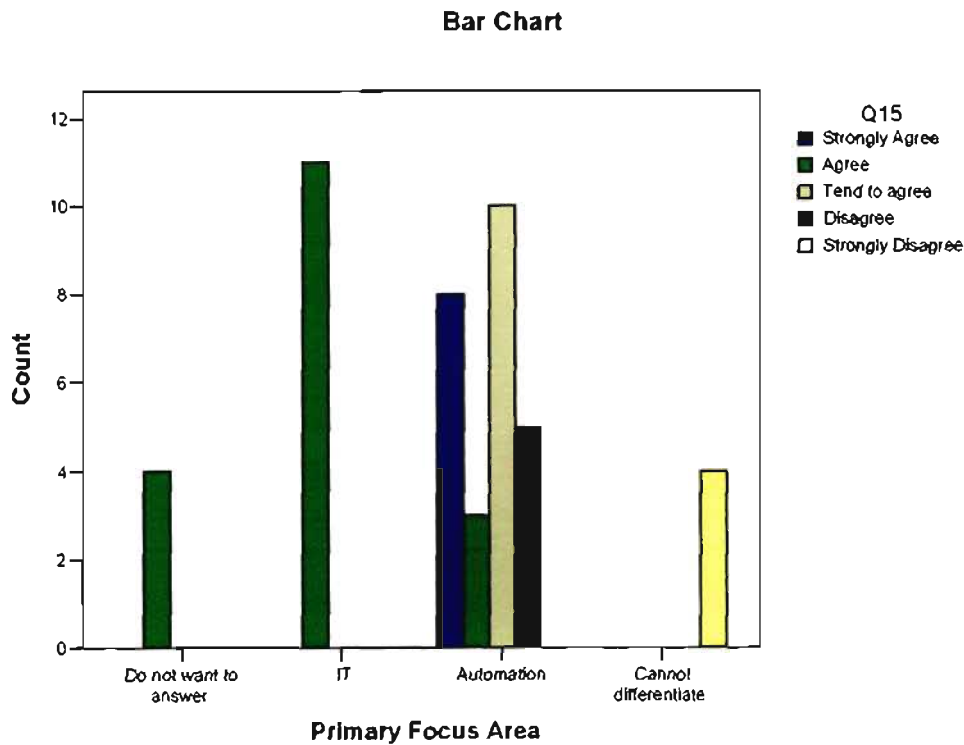
H_0 : Q10 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$



Step 3

Critical Value: $\chi^2_{0.05,12} = 21.0261$
 Decision Rule: if (Test Statistic) $\chi^2 > 21.0261$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution," *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 78.173$

Step 5

The test statistic $\chi^2 = 78.173 > \chi^2_{0.05,12} = 21.0261$ so we reject H_0 .

Step 6: Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q15 are dependent. This suggests that there is a significant relationship between Q10 and Q15

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q10 is independent of Q15 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-value = 0.000

Decision Rule : If $P\text{-value} \leq 0.05$ then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q15 are dependent. This suggests that there is a significant relationship between Q10 and Q15.

Q10 - Primary Focus Area * Q16 - There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

Crosstab

			There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?					Total
			Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Primary Focus Area	Do not want to answer	Count	0	4	0	0	0	4
		Expected Count	.7	2.0	.4	.8	.4	4.0
	IT	Count	0	7	4	0	0	11
		Expected Count	2.0	5.4	1.0	1.7	1.0	11.0
	Automation	Count	8	11	0	7	0	26
		Expected Count	4.6	12.7	2.3	4.0	2.3	26.0
	Cannot differentiate	Count	0	0	0	0	4	4
		Expected Count	.7	2.0	.4	.6	.4	4.0
	Total	Count	8	22	4	7	4	45
		Expected Count	8.0	22.0	4.0	7.0	4.0	45.0

Crosstab

Count		Q16					Total
		Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Primary Focus Area	Do not want to answer	0	4	0	0	0	4
	IT	0	7	4	0	0	11
	Automation	8	11	0	7	0	26
	Cannot differentiate	0	0	0	0	4	4
Total		8	22	4	7	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	69.138 ^a	12	.000
Likelihood Ratio	53.325	12	.000
Linear-by-Linear Association	5.803	1	.016
N of Valid Cases	45		

a. 18 cells (90.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by	Phi	1.240	.000
Nominal	Cramer's V	.716	.000
	Contingency Coefficient	.778	.000
N of Valid Cases		45	

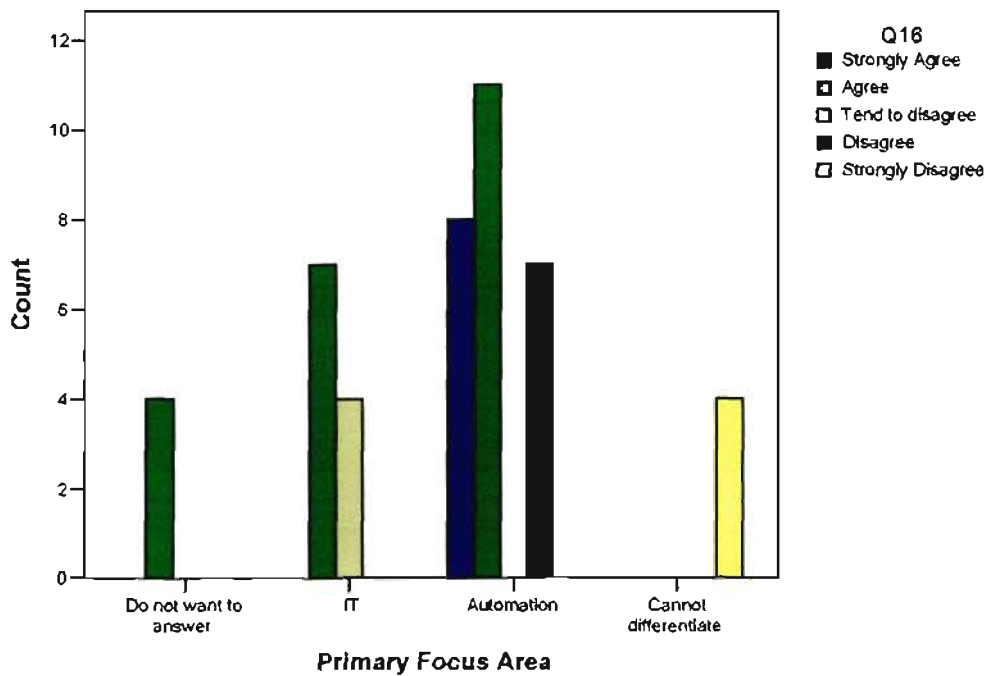
- Not assuming the null hypothesis.
- Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.716

This suggests that a moderate to high degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q10 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 12

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,12} = 21.0261$
 Decision Rule if (Test Statistic) $\chi^2 > 21.0261$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 69.138$

Step 5

The test statistic $\chi^2 = 69.138$ $\chi^2_{0.05,12} = 21.0261$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q16 are dependent. This suggests that there is a significant relationship between Q10 and Q16

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q10 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q16 are dependent. This suggests that there is a significant relationship between Q10 and Q16.

Q10 - Primary Focus Area * Q18 - My job function within the field of Industrial Automation has changed significantly in the past 2 years?

Crosstab

		My job function within the field of Industrial Automation has changed significantly in the past 2 years?						Total	
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know		
Primary Focus Area	Do not want to answer	Count	0	0	0	4	0	0	4
		Expected Count	.6	.7	1.2	.7	.4	.4	4.0
	IT	Count	7	0	4	0	0	0	11
		Expected Count	1.7	2.0	3.4	2.0	1.0	1.0	11.0
	Automation	Count	0	8	10	4	0	4	26
		Expected Count	4.0	4.6	8.1	4.6	2.3	2.3	26.0
	Cannot differentiate	Count	0	0	0	0	4	0	4
		Expected Count	.6	.7	1.2	.7	.4	.4	4.0
Total		Count	7	8	14	8	4	4	45
		Expected Count	7.0	8.0	14.0	8.0	4.0	4.0	45.0

Crosstab

Count		Q18						Total
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know	
Primary Focus Area	Do not want to answer	0	0	0	4	0	0	4
	IT	7	0	4	0	0	0	11
	Automation	0	8	10	4	0	4	26
	Cannot differentiate	0	0	0	0	4	0	4
Total		7	8	14	8	4	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	92.405 ^a	15	.000
Likelihood Ratio	70.402	15	.000
Linear-by-Linear Association	4.384	1	.036
N of Valid Cases	45		

a. 23 cells (95.8%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.433	.000
	Cramer's V	.827	.000
	Contingency Coefficient	.820	.000
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.827

This suggests that a high degree of association exists.

1. Chi-Square Test

Step 1

The hypotheses are:

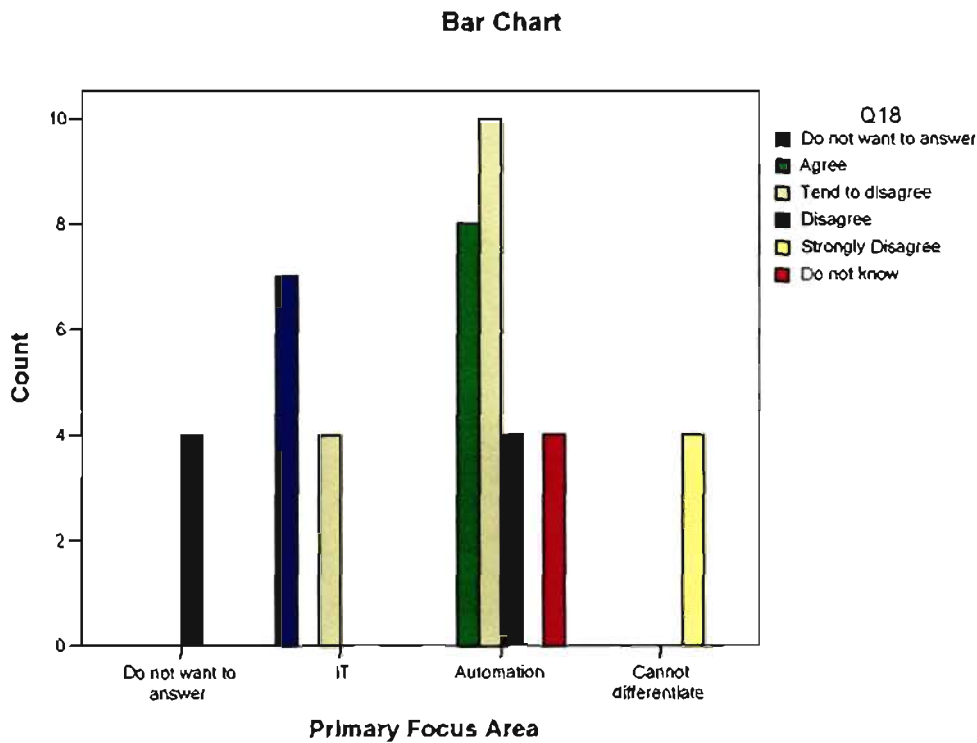
H_0 : Q10 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 15

Using a 5% Level of significance $\alpha = 0.05$



Step 3

Critical Value: $\chi^2_{0.05, 15} = 24.9958$
 Decision Rule if (Test Statistic) $\chi^2 > 24.9958$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 92.405$

Step 5

The test statistic $\chi^2 = 92.405 > \chi^2_{0.05, 15} = 24.9958$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q18 are dependent. This suggests that there is a significant relationship between Q10 and Q18

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q10 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If $p\text{-value} \leq 0.05$ then reject H_0 .

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q18 are dependent. This suggests that there is a significant relationship between Q10 and Q18.

Q10 - Primary Focus Area * Q22 - I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

Crosstab

			I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above				Total
			Do not want to answer	I have some influence	I have much influence	I have major influence	
Primary Focus Area	Do not want to answer	Count	4	0	0	0	4
		Expected Count	.4	2.0	.8	.8	4.0
	IT	Count	0	7	0	4	11
		Expected Count	1.1	5.6	2.1	2.1	11.0
	Automation	Count	0	14	8	0	22
		Expected Count	2.1	11.3	4.3	4.3	22.0
	Cannot differentiate	Count	0	0	0	4	4
		Expected Count	.4	2.0	.8	.8	4.0
	Total	Count	4	21	8	8	41
		Expected Count	4.0	21.0	8.0	8.0	41.0

Crosstab

Count

		Q22				Total
		Do not want to answer	I have some influence	I have much influence	I have major influence	
Primary Focus Area	Do not want to answer	4	0	0	0	4
	IT	0	7	0	4	11
	Automation	0	14	8	0	22
	Cannot differentiate	0	0	0	4	4
Total		4	21	8	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	68.955 ^a	9	.000
Likelihood Ratio	55.749	9	.000
Linear-by-Linear Association	15.049	1	.000
N of Valid Cases	41		

a. 14 cells (87.5%) have expected count less than 5. The minimum expected count is .39.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.297	.000
	Cramer's V	.749	.000
	Contingency Coefficient	.792	.000
N of Valid Cases		41	

- Not assuming the null hypothesis.
- Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

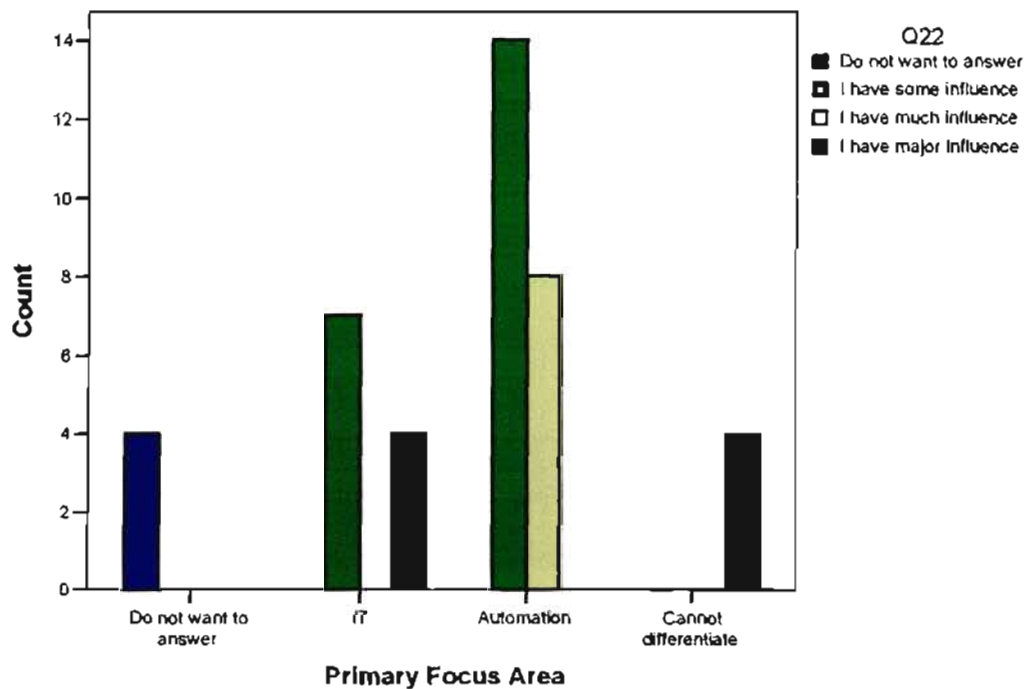
Cramer's V = 0.749

This suggests that a moderate to high degree of association exists.

Contingency Coefficient = 0.792

This suggests that a moderate to high degree of association between the row and column variables exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q10 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,9} = 16.9190$
 Decision Rule if (Test Statistic) $\chi^2 > 16.9190$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 68.955$

Step 5

The test statistic $\chi^2 = 68.955 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q22 are dependent. This suggests that there is a significant relationship between Q10 and Q22

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q10 is independent of Q22 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule: If P-Value < 0.05 then reject H_0 .

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q22 are dependent. This suggests that there is a significant relationship between Q10 and Q22.

Q10 - Primary Focus Area * Q25 - The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:

Crosstab

		The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:				Total	
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify		
Primary Focus Area	Do not want to answer	Count	0	4	0	0	4
		Expected Count	1.0	1.5	1.2	.4	4.0
	IT	Count	7	0	0	4	11
		Expected Count	2.7	4.2	3.2	1.0	11.0
	Automation	Count	4	13	9	0	26
		Expected Count	6.4	9.8	7.5	2.3	26.0
	Cannot differentiate	Count	0	0	4	0	4
		Expected Count	1.0	1.5	1.2	.4	4.0
Total		Count	11	17	13	4	45
		Expected Count	11.0	17.0	13.0	4.0	45.0

Crosstab

Count		Q25				Total
		Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
Primary Focus Area	Do not want to answer	0	4	0	0	4
	IT	7	0	0	4	11
	Automation	4	13	9	0	26
	Cannot differentiate	0	0	4	0	4
Total		11	17	13	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	44.529 ^a	9	.000
Likelihood Ratio	49.225	9	.000
Linear-by-Linear Association	2.292	1	.130
N of Valid Cases	45		

a. 13 cells (81.3%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.995	.000
	Cramer's V	.574	.000
	Contingency Coefficient	.705	.000
N of Valid Cases		45	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.574

This suggests that a moderate degree of association exists.

Contingency Coefficient = 0.705

This suggests that a moderate to high degree of association between the row and column variables exists.

1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q10 is independent of Q25 (not related)

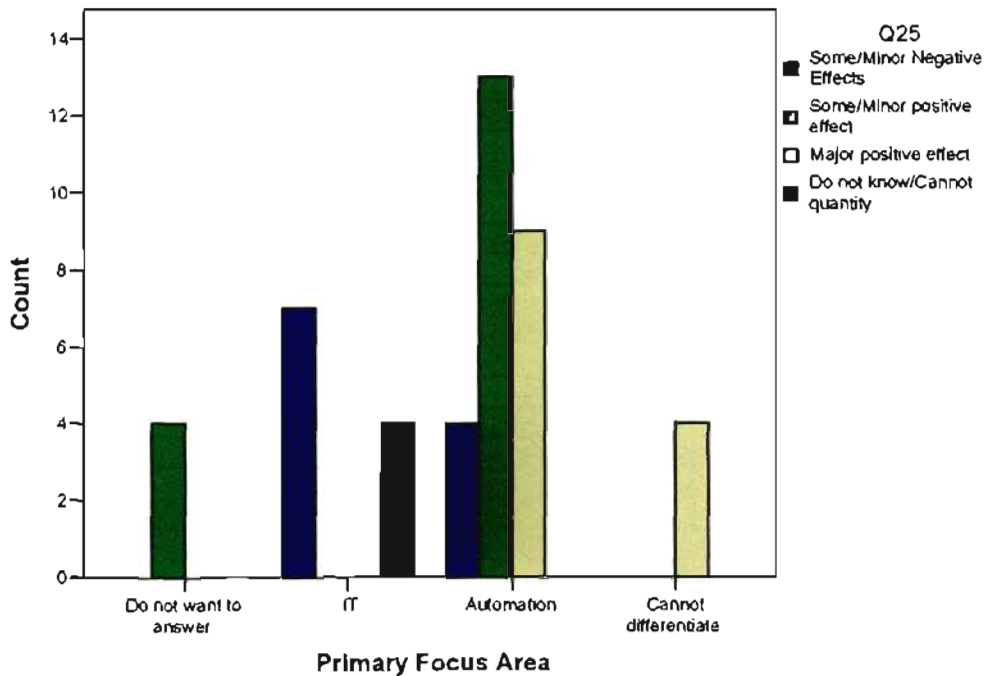
H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Bar Chart



Step 3

Critical Value: $\chi^2_{0.05,9} = 16.9190$
 Decision Rule: if (Test Statistic) $\chi^2 > 16.9190$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 44.529$

Step 5

The test statistic $\chi^2 = 44.529 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q25 are dependent. This suggests that there is a significant relationship between Q10 and Q25

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q10 is independent of Q25 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

$P\text{-Value} = 0.000$

Decision Rule : If $P\text{-Value} \leq 0.05$ then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q10 and Q25 are dependent. This suggests that there is a significant relationship between Q10 and Q25.

In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed. * There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?

Crosstabulation

			There are overlaps in terms areas of responsibility or accountability between Industrial Automation and IT within my organisation?					Total
			Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.	Strongly Agree	Count	8	0	0	0	0	8
		Expected Count	1.4	3.9	.7	1.2	.7	8.0
	Agree	Count	0	11	4	3	0	18
		Expected Count	3.2	8.8	1.6	2.8	1.6	18.0
more IT focussed.	Tend to agree	Count	0	10	0	0	0	10
		Expected Count	1.8	4.9	.9	1.6	.9	10.0
	Disagree	Count	0	1	0	4	0	5
		Expected Count	.9	2.4	.4	.8	.4	5.0
	Strongly Disagree	Count	0	0	0	0	4	4
		Expected Count	7	2.0	.4	.6	.4	4.0
Total		Count	8	22	4	7	4	45
		Expected Count	8.0	22.0	4.0	7.0	4.0	45.0

Q15 * Q16 Crosstabulation

Count

		Q16					Total
		Strongly Agree	Agree	Tend to disagree	Disagree	Strongly Disagree	
Q15	Strongly Agree	8	0	0	0	0	8
	Agree	0	11	4	3	0	18
	Tend to agree	0	10	0	0	0	10
	Disagree	0	1	0	4	0	5
	Strongly Disagree	0	0	0	0	4	4
Total		8	22	4	7	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	113.399 ^a	16	.000
Likelihood Ratio	85.278	16	.000
Linear-by-Linear Association	23.213	1	.000
N of Valid Cases	45		

a. 24 cells (96.0%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.587	.000
	Cramer's V	.794	.000
	Contingency Coefficient	.846	.000
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

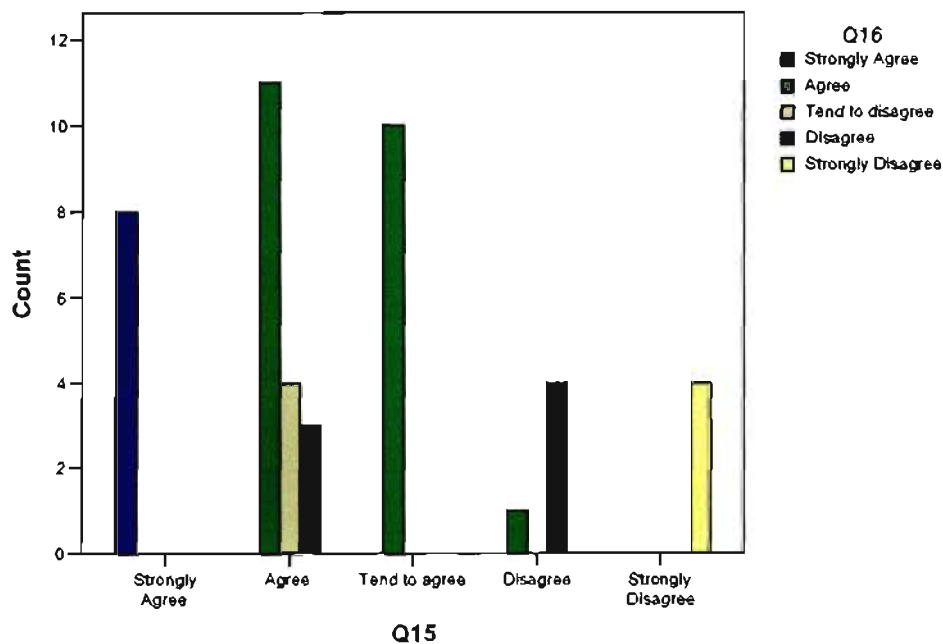
Cramer's V = 0.794

This suggests that a moderate to high degree of association exists.

Contingency Coefficient = 0.846

This suggests that a high degree of association between the row and column variables exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q15 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 16

Using a 5% Level of significance $\alpha = 0.05$

Step 3

Critical Value: $\chi^2_{0.05,16} = 26.2962$
 Decision Rule if (Test Statistic) $\chi^2 > 26.2962$
 then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 113.399$

Step 5

The test statistic $\chi^2 = 113.399 > \chi^2_{0.05,16} = 26.2962$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q15 and Q16 are dependent. This suggests that there is a significant relationship between Q15 and Q16

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q15 is independent of Q16 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule : If P-Value ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q15 and Q16 are dependent. This suggests that there is a significant relationship between Q15 and Q16.

In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.
 My job function within the field of Industrial Automation has changed significantly In the past 2 years?

Crosstabulation

			My job function within the field of Industrial Automation has changed significantly In the past 2 years?						Total
			Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree	Do not know	
In my opinion Industrial Automation/Manufacturing Engineering is becoming more IT focussed.	Strongly Agree	Count	0	4	0	0	0	4	8
		Expected Count	1.2	1.4	2.5	1.4	.7	.7	8.0
	Agree	Count	7	3	4	4	0	0	18
		Expected Count	2.8	3.2	5.8	3.2	1.6	1.6	18.0
	Tend to agree	Count	0	0	10	0	0	0	10
		Expected Count	1.6	1.8	3.1	1.8	.9	.9	10.0
	Disagree	Count	0	1	0	4	0	0	5
		Expected Count	8	.9	1.6	.9	.4	.4	5.0
	Strongly Disagree	Count	0	0	0	0	4	0	4
		Expected Count	.6	.7	1.2	.7	.4	.4	4.0
Total	Count	7	8	14	4	4	4	45	
	Expected Count	7.0	8.0	14.0	8.0	4.0	4.0	45.0	

Q15 * Q18 Crosstabulation

Count		Q18					Total	
		Do not want to answer	Agree	Tend to disagree	Disagree	Strongly Disagree		Do not know
Q15	Strongly Agree	0	4	0	0	0	4	8
	Agree	7	3	4	4	0	0	18
	Tend to agree	0	0	10	0	0	0	10
	Disagree	0	1	0	4	0	0	5
	Strongly Disagree	0	0	0	0	4	0	4
Total		7	8	14	8	4	4	45

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	113.188 ^a	20	.000
Likelihood Ratio	88.608	20	.000
Linear-by-Linear Association	4.514	1	.034
N of Valid Cases	45		

a. 29 cells (96.7%) have expected count less than 5. The minimum expected count is .36.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	1.588	.000
	Cramer's V	.793	.000
	Contingency Coefficient	.846	.000
N of Valid Cases		45	

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.793

This suggests that a Moderate to high degree of association exists.

1. Chi-Square Test

Step 1

The hypotheses are:

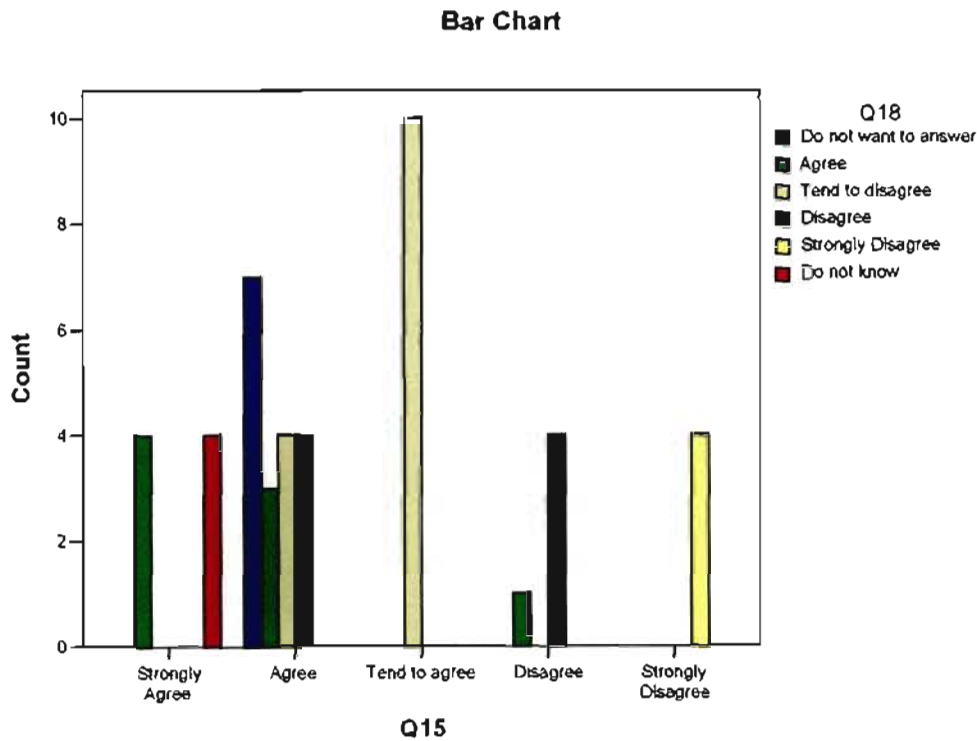
H₀: Q15 is independent of Q18 (not related)

H₁: These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 20

Using a 5% Level of significance $\alpha = 0.05$



Step 3

Critical Value: $\chi^2_{0.05, 20} = 31.4104$
 Decision Rule: if (Test Statistic) $\chi^2 > 31.4104$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 113.188$

Step 5

The test statistic $\chi^2 = 113.188 > \chi^2_{0.05, 20} = 31.4104$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q15 and Q18 are dependent. This suggests that there is a significant relationship between Q15 and Q18

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q15 is independent of Q18 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

$P\text{-Value} = 0.000$

Decision Rule: If $P\text{-Value} < 0.05$ then reject H_0 .

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q15 and Q18 are dependent. This suggests that there is a significant relationship between Q15 and Q18.

What is/are the key determinants of success (KPIs) in your organisation that you have direct influence upon?

* What are the key factors that provide your organisation with competitive advantage over its competitors?

Crosstabulation

			What are the key factors that provide your organisation with competitive advantage over its competitors?					Total	
			Factory Efficiency	Machine Operating Efficiency	Sales Volumes	Systems Uptime	Product Quality Rating		Other
What is/are the key determinants of success (KPIs) in your organisation that you have direct influence upon?	Factory Efficiency	Count	4	0	0	4	0	8	16
		Expected Count	4.3	3.1	2.3	1.6	1.6	3.1	16.0
	Machine Operating Efficiency	Count	0	4	0	0	0	0	4
		Expected Count	1.1	.8	.6	4	.4	.8	4.0
	Production Plan Variance	Count	0	0	0	0	4	0	4
		Expected Count	1.1	.8	.8	.4	.4	.8	4.0
	Systems Uptime	Count	7	4	0	0	0	0	11
		Expected Count	3.0	2.1	1.6	1.1	1.1	2.1	11.0
	Product Quality Rating	Count	0	0	6	0	0	0	6
		Expected Count	1.8	1.2	9	.6	.6	1.2	6.0
	Total	Count	11	8	6	4	4	8	41
		Expected Count	11.0	8.0	6.0	4.0	4.0	8.0	41.0

Q20 * Q23 Crosstabulation

Count

		Q23						Total
		Factory Efficiency	Machine Operating Efficiency	Sales Volumes	Systems Uptime	Product Quality Rating	Other	
q20	Factory Efficiency	4	0	0	4	0	8	16
	Machine Operating Efficiency	0	4	0	0	0	0	4
	Production Plan Variance	0	0	0	0	4	0	4
	Systems Uptime	7	4	0	0	0	0	11
	Product Quality Rating	0	0	6	0	0	0	6
Total		11	8	6	4	4	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	120.035 ^a	20	.000
Likelihood Ratio	93.844	20	.000
Linear-by-Linear Association	9.090	1	.003
N of Valid Cases	41		

a. 30 cells (100.0%) have expected count less than 5. The minimum expected count is .39.

Symmetric Measures

		Value	Approx. Sig.
Nominal by	Phi	1.711	.000
Nominal	Cramer's V	.856	.000
	Contingency Coefficient	.863	.000
N of Valid Cases		41	

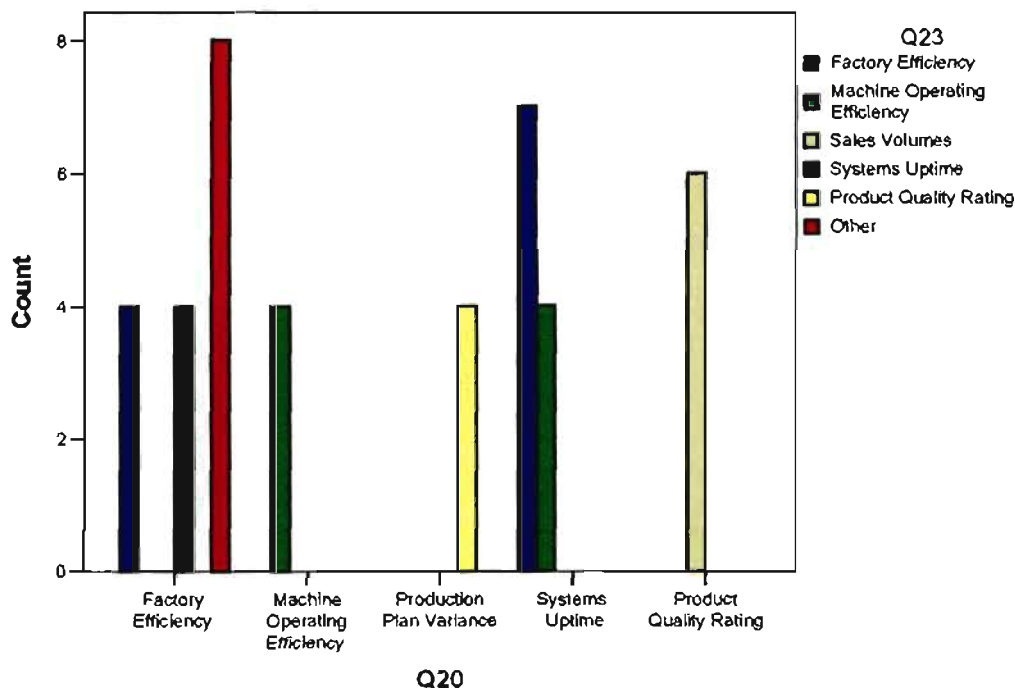
- a. Not assuming the null hypothesis.
 b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.856

This suggests that a high degree of association exists.

Bar Chart



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q20 is independent of Q23 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 20

Using a 5% Level of significance $\alpha = 0.05$

Step 3

<u>Critical Value:</u>	$\chi^2_{0.05,20} = 31.4104$
Decision Rule	if (Test Statistic) $\chi^2 > 31.4104$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians 1*, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 120.035$

Step 5

The test statistic $\chi^2 = 120.035 > \chi^2_{0.05,20} = 31.4104$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q20 and Q23 are dependent. This suggests that there is a significant relationship between Q20 and Q23

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q20 is independent of Q23 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0.000

Decision Rule: If P-Value < 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q20 and Q23 are dependent. This suggests that there is a significant relationship between Q20 and Q23.

I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above

the ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows

Crosstabulation

			The ability to view production information related to the KPI's detailed above has an effect on competitive advantage of my organisation as follows:				Total
			Some/Minor Negative Effects	Some/Minor positive effect	Major positive effect	Do not know/Cannot quantify	
I as an IT/Industrial Automation professional feel that I have the ability to influence the KPI's listed above	Do not want to answer	Count	0	4	0	0	4
		Expected Count	1.1	1.3	1.3	.4	4.0
	I have some influence	Count	7	9	5	0	21
		Expected Count	5.6	6.7	6.7	2.0	21.0
	I have much influence	Count	4	0	4	0	8
		Expected Count	2.1	2.5	2.5	.8	8.0
	I have major influence	Count	0	0	4	4	8
		Expected Count	2.1	2.5	2.5	.8	8.0
Total	Count	11	13	13	4	41	
	Expected Count	11.0	13.0	13.0	4.0	41.0	

Q22 * Q23 Crosstabulation

Count		Q23					Total	
		Factory Efficiency	Machine Operating Efficiency	Sales Volumes	Systems Uptime	Product Quality Rating		Other
q22	Do not want to answer	0	0	0	0	4	0	4
	I have some influence	11	0	6	0	0	4	21
	I have much influence	0	4	0	0	0	4	8
	I have major influence	0	4	0	4	0	0	8
Total		11	8	6	4	4	8	41

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	36.802 ^a	9	.000
Likelihood Ratio	40.128	9	.000
Linear-by-Linear Association	2.763	1	.096
N of Valid Cases	41		

a. 13 cells (81.3%) have expected count less than 5. The minimum expected count is .39.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.947	.000
	Cramer's V	.547	.000
	Contingency Coefficient	.688	.000
N of Valid Cases		41	

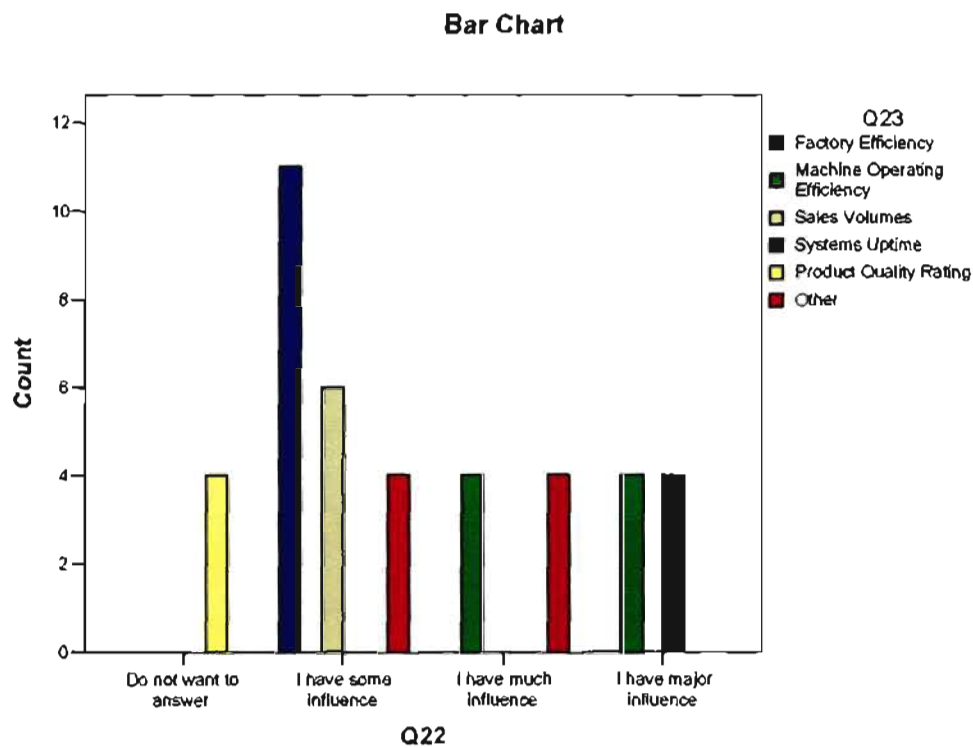
- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.

Comment on the strength of dependence:

Cramer's V = 0.547
This suggests that a moderate degree of association exists.

Contingency Coefficient = 0.688

This suggests that a moderate degree of association between the row and column variables exists.



1. Chi-Square Test

Step 1

The hypotheses are:

H_0 : Q22 is independent of Q23 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Step 2

Degrees of freedom = 9

Using a 5% Level of significance $\alpha = 0.05$

Step 3

$\chi^2_{0.05,9} = 16.9190$
 Decision Rule: if (Test Statistic) $\chi^2 > 16.9190$ then reject H_0

SOURCE: From "Table of the Percentage Points of the χ^2 - Distribution." *Biometrika Tables for Statisticians* 1, 3rd ed (1996).

Step 4

Referring to the contingency Table

Test Statistic: $\chi^2 = 36.802$

Step 5

The test statistic $\chi^2 = 36.802 > \chi^2_{0.05,9} = 16.9190$ so we reject H_0 .

Step 6 : Conclusion

Since we Reject H_0 and conclude that there is sufficient evidence that proves that Q22 and Q23 are dependent. This suggests that there is a significant relationship between Q22 and Q23

We are simply able to demonstrate that a relationship exists.

2. Using P-Value

The hypotheses are:

H_0 : Q22 is independent of Q23 (not related)

H_1 : These classifications are Dependent (related or associated in some way)

Using a 5% level of significance $\alpha = 0.05$

P-Value = 0,000

Decision Rule: If *P-Value* ≤ 0.05 then reject H_0

Conclusion: Reject H_0 and conclude that there is sufficient evidence that proves that Q22 and Q23 are dependent. This suggests that there is a significant relationship between Q22 and Q23.

Appendix VIII – Ethical Clearance

Ethical Clearance has been duly obtained from the research office and is shown on the following page.

Ethical Clearance Approval Number: **HSS/07010A**

RESEARCH OFFICE (GOVAN MBEKI CENTRE)
WESTVILLE CAMPUS
TELEPHONE NO.: 031 - 2603587
EMAIL : ximbap@ukzn.ac.za



23 JANUARY 2007

MR. T MARIMUTHU (951041219)
GRADUATE SCHOOL OF BUSINESS

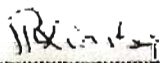
Dear Mr. Marimuthu

ETHICAL CLEARANCE APPROVAL NUMBER: HSS/07010A

I wish to confirm that ethical clearance has been granted for the following project:

"The impact of the convergence of Information Technology and Industrial Automation in operational excellence in the manufacturing environment"

Yours faithfully



MS. PHUMELELE XIMBA
RESEARCH OFFICE

cc. Faculty Officer (Christel Haddon)
cc. Supervisor (Prof. S Lubbe)