Understanding and Improving the Manufacturing Changeover Process in Saudi Arabian Businesses – A Multiple Case Study Approach

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Thesis Summary

The importance of the changeover process in the manufacturing industry is becoming widely recognised. Changeover is a complete process of changing between the manufacture of one product to manufacture of an alternative product until specified production and quality rates are reached. The initiatives to improve changeover exist in industry, as better changeover process typically contribute to improved quality performance. A high-quality and reliable changeover process can be achieved through implementation of continuous or radical improvements. This research examines the changeover process of Saudi Arabian manufacturing firms because Saudi Arabia's government is focused on the expansion of GDP and increasing the number of export manufacturing firms. Furthermore, it is encouraging foreign manufacturing firms to invest within Saudi Arabia. These initiatives, therefore, require that Saudi manufacturing businesses develop the changeover practice in order to compete in the market and achieve the government's objectives. Therefore, the aim of this research is to discover the current status of changeover process implementation in Saudi Arabian manufacturing businesses. To achieve this aim, the main objective of this research is to develop a conceptual model to understand and examine the effectiveness of the changeover process within Saudi Arabian manufacturing firms, facilitating identification of those activities that affect the reliability and high-quality of the process.

In order to provide a comprehensive understanding of this area, this research first explores the concept of quality management and its relationship to firm performance and the performance of manufacturing changeover. An extensive body of literature was reviewed on the subject of lean manufacturing and changeover practice. A research conceptual model was identified based on this review, and focus was on providing high-quality and reliable manufacturing changeover processes during set-up in a dynamic environment. Exploratory research was conducted in sample Saudi manufacturing firms to understand the features of the changeover process within the manufacturing sector, and as a basis for modifying the proposed conceptual model. Qualitative research was employed in the study with semi-structured interviews, direct observations and documentation in order to understand the real situation such as actual daily practice and current status of changeover process in the field. The research instrument, the Changeover Effectiveness Assessment Tool (CEAT) was developed to evaluate changeover practices. A pilot study was conducted by examining the CEAT, proposed for the main research. Consequently, the conceptual model was modified and CEAT was improved in response to the pilot study findings. Case studies have been conducted within eight Saudi manufacturing businesses. These case studies assessed the implementation of manufacturing changeover practice in the lighting and medical products sectors. These two sectors were selected based on their operation strategy which was batch production as well as the fact that they fulfilled the research sampling strategy. The outcomes of the research improved the conceptual model, ultimately to facilitate the firms' adoption and rapid implementation of a high-quality and reliability changeover during the set-up process. The main finding of this research is that Quality's factors were considering the lowest levels comparing to the other factors which are People, Process and Infrastructure. This research contributes to enable Saudi businesses to implement the changeover process by adopting the conceptual model. In addition, the guidelines for facilitating implementation were provided in this thesis. Therefore, this research provides insight to enable the Saudi manufacturing industry to be more responsive to rapidly changing customer demands.

Keywords: Changeover, Set-up time, Set-up process, Manufacturing, Saudi Arabia.

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GLOSSARY OF TERMS

AMT	Advanced Manufacturing Technology
CAD	Computer Aided Design
CNC	Computer Numerical Control
ERP	Enterprise Resource Planning
SFDA	Saudi Food and Drug Authority
FMEA	Failure Mode And Effect Analysis
FMS	Flexible Manufacturing System
ISO	International Organisation for Standardisation
JIT	Just In Time
QA	Quality Assurance
QC	Quality Control
QFD	Quality Function Deployment
QI	Quality Improvement
QM	Quality Management
SAR	Saudi Arabian Riyal
SASO	Saudi Arabian Standards Organisation
SMED	Single Minute Exchange of Die
SPC	Statistical Process Control
SUR	Setup Reduction
TPM	Total Preventive Maintenance
TPS	Toyota Production System
TQC	Total Quality Control
TQM	Total Quality Management
WTO	World Trade Organisation

CHAPTER 1 : RESEARCH OVERVIEW

1.1 Introduction

Achieving customer satisfaction is not an easy task (Dale et al., 2007). Customers require reliability, quality and delivery on time (Dale et al., 2007). In addition, competition has been growing rapidly through the global market and that requires companies to enhance their customer service, quality performance and productivity in order to survive and grow (Al-Khalifa and Aspinwall, 2000). Quality Management (QM) helps to improve companies' efficiency and competitiveness through improving quality of products (Flynn et al., 1994; Kumar et al., 2009), and today QM is recognised globally as a strategic weapon for international competition and trade. Kumar et al. (2009) stated that improved quality reduces waste, cost and increased productivity, while Flynn et al. (1995a, p.342) defined QM as "an integrated approach to achieving and sustaining high quality output, focusing on the maintenance and continuous improvement of process and defect prevention at all levels and in all functions of the organisation in order to meet or exceed customer expectations". According to Flynn et al. (1994), QM is a key element in the World Class Manufacturing (WCM) for being competitive in the markets and able to design and provide quality product.

Turbulent markets and rapid developments in technology have forced manufacturing firms to enhance their ability to change. The dynamic environment leads to changes in the manufacturing product or process and firms need to understand the main drivers of change in order to take necessary action (ElMaraghy and Wiendahl, 2009). Firms need to respond quickly to dynamic customer demands in order to maintain a competitive advantage over others (Singh and Khanduja, 2011). Thus, manufacturing changeover can influence the flexibility of a firm to meet the customers' demands. McIntosh et al. (2001a, p. 5) defined changeover as "a complete process of changing between the manufacture of one product to manufacture of an alternative product until reaching specified production and quality rates". The changeover concept has been associated with lean manufacturing as it refers to a business philosophy that eliminates waste in all manufacturing processes, and the extent of the relationship between product quality and changeover performance can affect a firm's performance (McIntosh et al., 2001a). Schonberger (1992) indicated that changeover and start-up time

are considered as one principle in Total Quality Management (TQM). Furthermore, Flynn et al. (1994) presented the relationship between QM and setup time reduction within the context of World Class Manufacturing (WCM). High changeover performance allows for short production runs, moderate inventory levels and a fast response to customer needs (Singh and Khanduja, 2011). Furthermore, shorter changeover time allows for reducing setup scrap, decreasing setup labour costs, and the reducing of lead time and manufacturing cost. According to McIntosh et al. (2001a), the benefits of achieving better changeover performance are reduced equipment downtime, reduced inventory, reduced resource requirement, and enhanced flexibility and process control of the operation. Thus, the changeover concept is an important element of the manufacturing process that must be highlighted in this research.

ElMaraghy and Wiendahl (2009) discussed how the drivers of change in the manufacturing process can be internal or external. The *internal* driver could be that the performance of a firm is not profitable, or that there are quality problems. The *external* driver is focused on the product and adding value to a firm's customers, markets, supply chain, regulations and economy (ElMaraghy and Wiendahl, 2009). To cope with these demands, a capable production system is required to facilitate an effective changeover process between products. The changes - whether internally or externally - are needed to suit the QM perspective of firms concerned. The change can enable firms to develop a manufacturing strategy and procedures that enhance their QM and changeover manufacturing practices.

Many manufacturing companies in Saudi Arabia want to follow western companies' practice by adopting an advanced QM and lean manufacturing concept. However, those companies do not know which activities are important to improve their practice in the manufacturing, and how to implement them. Alsmadi et al. (2012) reported that the greatest barrier to and difficulty in implementing lean manufacturing and QM in Saudi Arabian manufacturing firms was lack of knowledge about these concepts. However, the Saudi government is now paying attention to encourage individuals to invest in the industrial sector. In recent years, the industrial sector has grown significantly with around 32 industrial cities that are located in different regions in the country. (Detailed background information on Saudi Arabia and its development within the manufacturing industry is given in Appendix 1).

Therefore, Saudi manufacturing firms should benefit from the findings this research, which will help them to enhance their current manufacturing changeover practice.

1.2 Research area

The study is focused on the manufacturing changeover process that takes place whenever product line or manufacturing operations change. A reliable implementation of a quality process enhances the changeover process and increases productivity (McIntosh et al., 2001a). Oakland (2003, p.11) defined a quality process as "the transformation of a set of inputs into outputs that satisfy customer needs and expectation, in the form of products or services". Therefore, the QM concept plays a key role for evolving firms to achieve a competitive advantage (Al-Khalifa and Aspinwall, 2000). Flynn et al. (1994) indicated the relationship between QM and Just In Time (JIT) which includes the changeover concept and setup time reduction, while Cua et al. (2001) defined JIT as a manufacturing program that could lead to the continuous reducing and eliminating of all forms of waste. Vuppalapati et al. (1995) affirmed that JIT and TQM should be treated as one approach since JIT is viewed as a component of the TQM philosophy of improving operational performance. Also, changeover concept and setup time are associated with the lean production concept (Shah and Ward, 2003; 2007). Lean manufacturing comprises management practices such as JIT, quality systems, work teams, supplier management, and cellular manufacturing (Shah and Ward, 2003). It has been suggested that an effective implementation of lean manufacturing needs employees' involvement in the improvement process (White et al., 1999). The improvement process of lean production encompasses changeover and setup time reduction concepts.

McIntosh et al. (2001a) illustrated the movement of changeover from product A to product B, as shown in Figure 1.1, particularly while the changing in the production between manufacturing operations. The process contains three stages; these are run-down period, set-up period, and run-up period until the target productivity is reached. The definition of 'set-up period' is all the activities that take place to set a machine up (McIntosh et al., 1996; 2001a). Van Goubergen and Van Landeghem (2002, p. 205) provided a definition for set-up as "the elapsed time between the last product A leaving the machine and the first good product B coming out". McIntosh et al. (2001a, p.5) defined 'run-up period' as "when production is commenced again and continues until consistent output at full capacity

occurs". Henry (2013) divided changeover components into three activities - clean-up, setup and start-up. Clean-up is removing all materials from the previous process; in some extreme cases, such as the pharmaceutical industry it is required to clean and wash the machine at changeover. Set-up is a key part of the changeover for the machine to be ready for the next product. After the clean-up and setup processes, start-up or run-up comes next which means that the line begins to produce at normal speed and efficiency (Henry, 2013).

The evolution of changeover with the reliable implementation of a quality process can lead to the desired level of productivity and quality performance that helps a firm to reduce waste and downtime, and to be competitive. As shown in Figure 1.1, set-up period is a research area of interest; this is due to the importance of changeover practice for achieving low inventory, flexible manufacturing and responsiveness to demands. These key features of a better changeover are impacted by the quality of the setup period and process; thus, it directly influences the finished product. The potential of the research is to examine the current implementation of manufacturing changeover process in Saudi Arabian manufacturing firms. The purpose of the research is to deliver a conceptual model to facilitate implementation of a high quality and reliable changeover process during the setup period. However, there is a lack of research in this area and further study is needed to examine the changeover practice in Saudi Arabian manufacturing firms.

1.3 Research question

The research question considers the changeover process within manufacturing firms aiming to achieve high product quality. The main question in the research is: "How can Saudi manufacturing firms improve the **quality** and **reliability** of the manufacturing **changeover process**"?

Reliability is often interlinked with **quality** which can be defined as "the ability of a firm to perform satisfactorily over a period of time" (Oakland, 2003, p.4). The reliability of the manufacturing changeover can increase the accuracy of accepted product outcomes. McIntosh et al. (1996, p.7) defined **changeover process** as "the activities that occur while the line is halted". Also, quality in the manufacturing context has been defined as conformance to requirements (Dale et al., 2007). In this study, quality and reliability of the set-up process are important mainly for the firm to improve, and to ensure the development of the existing manufacturing process in order to achieve optimum level of quality rates. Reliability and quality together rank as an essential factor since they are the key to reducing failure; each has an impact on the other. Mishra (2009) confirmed the positive relationship between quality and reliability, as reliability of equipment and components used to manufacture a part can increase the quality of the finished product. The study is focused on studying different changeover processes in terms of originality (existing) and new of the products and processes. In order to answer the main question the sub-questions are provided as follows:

- What are the factors that affect the quality outcomes of the changeover process in manufacturing operations?
- What is the current practice of manufacturing changeover process implementation in Saudi firms?
- How can Saudi firms deliver a consistent manufacturing changeover process for long-term implementation?
- How can Saudi firms enhance the quality of the changeover process when considering changing between different changeover processes, such as existing product, new product and new process?

- How can Saudi firms achieve an optimum level of quality performance while transitioning between different changeover processes?

1.4 Research aim and objectives

The aim of this research is to discover the current status of changeover process implementation in Saudi Arabian manufacturing businesses by identifying the factors affecting the quality and reliability of changeover process. The objectives of the research describe the core goals and to provide an answer to the research question. The following objectives form the focus of this research work:

- To critically explore the factors that can be affected by a reliable and quality changeover process in manufacturing operations.
- To develop the conceptual model which helps firms in quickly implementing high quality and reliable changeover processes during the set-up period.
- To highlight the challenges commonly found during the implementation of changeover process within the Saudi Arabian manufacturing businesses.
- To measure the effectiveness of changeover practice implementation in Saudi Arabian manufacturing sector. The term of effectiveness hereby indicates the degree of resulting the desired and accepted quality outcomes.

The significance and importance of this research can be stated as follows:

- By determining the impacts on the quality of the changeover process, the research findings will enhance firms' quality performance to recognise the changeover process and its relationship with quality.
- The research can contribute to the implementation of manufacturing changeover studies in firms in the context of Saudi Arabia's environment where there is a lack of research in this particular field, both locally and globally.
- It contributes to the knowledge by addressing the gap that has been suggested from several authors (McIntosh et al., 2001a; Culley et al., 2003). McIntosh et al. (2001a) revealed a lack of literature in the subject of high quality changeover process and an area of further research is needed. Culley et al. (2003) studied the sustainability of changeover improvement in the

manufacturing firms. The researcher identified a lack of research and changeover improvement of high quality and reliability process in the industry under study.

1.5 The need for research in Saudi Arabian manufacturing firms

Saudi Arabia became a member of the World Trade Organisation (WTO) on 11 December 2005 (WTO, 2012). The WTO defined as "it deals with the global rules of trade between nations; its main function is to ensure that trade flows as smoothly, predictably and freely as possible" (WTO, 2013). The WTO makes competition open to everyone to prove their distinctiveness and their efficiency, and this gives a company an advantage to create viable competition. Hence, this is a positive step as a multinational firm gains access to Saudi Arabia to cope and compete with local firms. Based on that, the Saudi government provides full support and investment incentives for foreign manufacturing companies to invest in the country (Industrial Clusters, 2012). In addition, there is a huge range of investment incentives that are provided, such as tax-free land and personal, customs duty exemption, free trading with 17 countries and low-cost sites in 32 industrial cities. Therefore, the Saudi government stated its objectives and strategy for developing the manufacturing industry by 2020 as follows:

- Expand the manufacturing GDP from 12% to 20%
- Double Saudi industrial employment from 15% to 30%
- Increase industrial exports from 18% to 35%

In fact, these investment incentives will attract multinational firms and create fierce competition with local industries in the market. Accordingly, Saudi firms are required to accelerate their improvement and work hard to raise the level of production and improvement of products. There is a lack of research in the local manufacturing industry, and studies are needed to advise firms on how best to manage their changeover practices. Therefore, the reason of selecting Saudi Arabia as the case under study is to develop the local industries to become more competitive. By introducing the proposed conceptual model, local firms will be better informed in order to compete with multinational firms.

The manufacturing development in Saudi Arabia has been grown rapidly during the last two decades particularly in the private sector (Detailed background information on Saudi Arabia and its

development on manufacturing industry is given in Appendix 1). The number of manufacturing factories rose to 6751 in 2014 compared with 1990, when there were only 2113 factories (Saudi Ministry of Commerce and Industry, 2014). In 2010 the capital investment of the manufacturing sector had grown to SAR 404 billion which is around GB£67.3 billion approximately based on exchange rates of the day (Saudi Industrial Development Fund, 2010). Meanwhile, the number of employees increased to 530,000 in 2010 compared with 1974 when there were just 34,000. Thus, there has been huge development and improvement in Saudi's manufacturing field, followed by infrastructure growth by increasing the number of industrial cities to 32 cities in different regions (Saudi Industrial Property Authority, 2012). Figure 1.2 describes the Gross Domestic Product (GDP) of the manufacturing sector in Saudi Arabia; the total GDP in 2010 was SAR 87.8 billion which is around GB£14.63 billion approximately based on exchange rates of the time, and that has contributed to increase the country's GDP by 12.6% (Saudi Industrial Development Fund, 2010).

1.6 Research layout

This thesis is organised into nine chapters as shown in Figure 1.3. This first chapter has provided a research overview and establishes the need for the research. It highlighted the importance of changeover practice and addressed the research question and objectives.

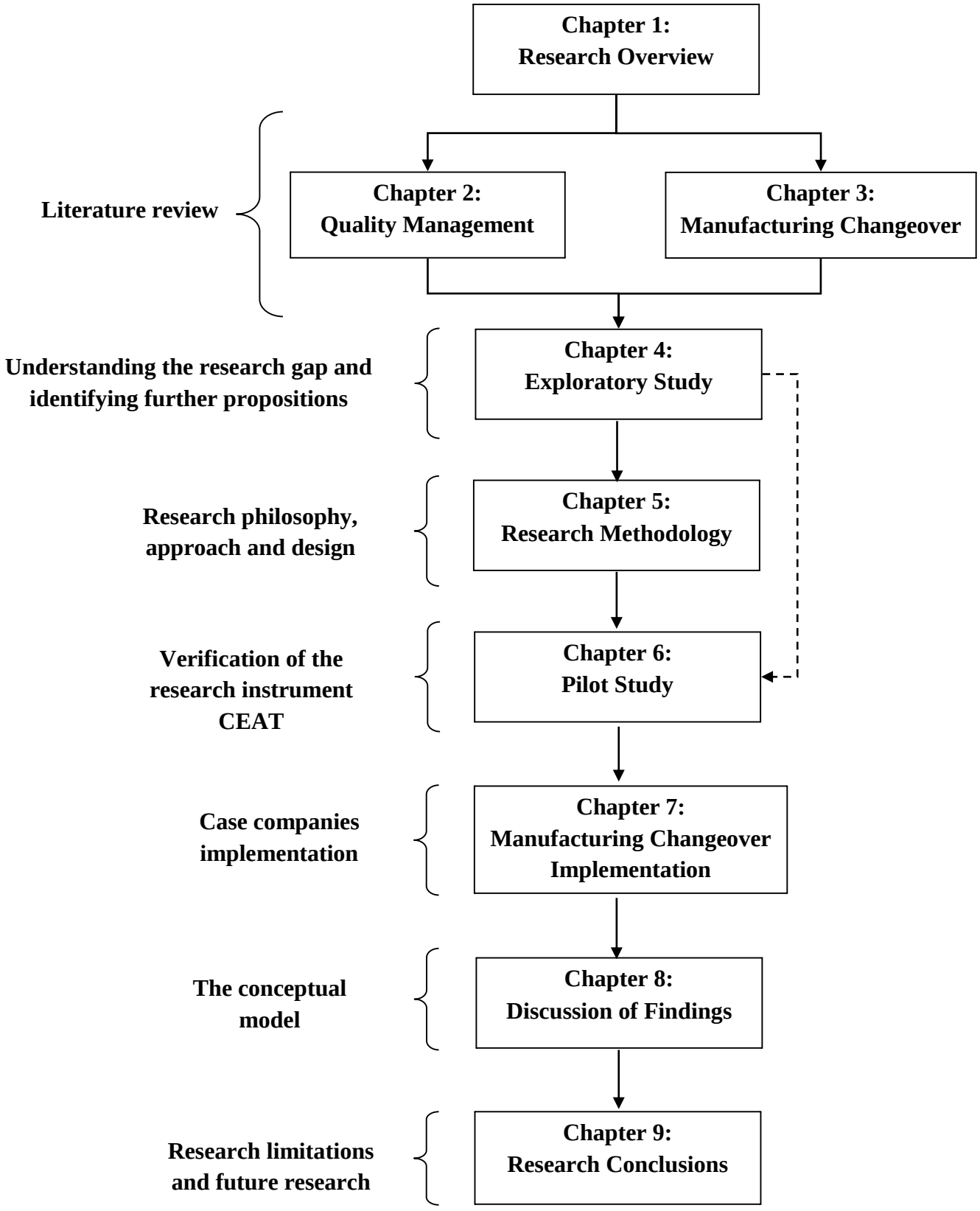

Figure 1.3 Research layout (source: author).

Chapter 2 presents the concept of QM and the evolution of TQM. The chapter reviews the relationship between QM and manufacturing flexibility, firm performance and changeover performance. It reviews the status of QM in Saudi Arabia's manufacturing firms.

Chapter 3 mainly discusses manufacturing changeover practice. It encompasses the lean manufacturing concept that includes Just-in-time (JIT), Total Productive Maintenance (TPM), 5S, Kaizen, and Value Stream Mapping (VSM). Manufacturing changeover literature is critically reviewed with special attention being paid to the difficulties of implementation on the shop floor. Knowledge gap and theoretical conceptual model are identified for the quality and reliable changeover processes. The conceptual model discusses how changeover has evolved in terms of originality (existing) and new of the products and processes.

Chapter 4 examines the exploratory case study of changeover practice implementation in the cable manufacturing industry. The exploratory case study research is conducted for further understanding of the research gap and changeover practice within Saudi Arabian manufacturing firms. The conceptual model was modified based on the results of the exploratory study.

Chapter 5 discusses the research methodology and the rationale employed in the research. A qualitative research methodology was used, employing a case study approach. The research instrument, the Changeover Effectiveness Assessment Tool (CEAT), was developed to evaluate the implementation in the manufacturing firms. The CEAT was mainly based on semi-structured interviews, observations and documentation undertaken and reviewed during company visits and the data collection stage.

The pilot study is conducted in Chapter 6; the main purpose is to validate the research instrument, CEAT. A pilot case study was conducted on the precision components companies in Saudi Arabia and the resulting findings were very helpful in terms of improving the research instrument, CEAT. The conceptual model was customised based on the results of the pilot study.

The main case study is reported in Chapter 7 with cross-case study comparison. The main study was conducted within the lighting and medical products manufacturing sector for the main case studies.

Eight case companies were investigated for the research; four case companies for each sector. The results of manufacturing changeover implementation are reported.

Chapter 8 presents the discussion of findings between case companies. The final conceptual model was modified based on the results of the main case studies. The guidelines for implementing the conceptual model are discussed and set out for further guidance on using the model in a business.

The final chapter, Chapter 9, is the conclusion of the thesis. It addressed the research problem, the main outcomes, and the contributions to the research field. It presents the limitations of the research study, and directions for future research work are discussed.

1.7 Summary

This research examines manufacturing changeover practice in Saudi Arabian manufacturing firms. Through this, the aim of the research was to improve the changeover process and enhance business performance, therefore reducing defective products and optimising changeover effectiveness. This chapter highlighted the research question and objectives that drive the research aim, and explained the need for research in Saudi Arabia's manufacturing firms. This chapter also highlighted the research layout of the thesis, and adding new knowledge in the area of manufacturing changeover practice.

CHAPTER 2 : QUALITY MANAGEMENT

2.1 Introduction

Today, there is tough competition in the market among firms and their products (Dale et al., 2007). Customers are demanding products that satisfy them in terms of quality, cost, and on-time delivery. The Japanese cars and electronics manufacturing industries have provided high-quality and reliable products in the past three decades and set a standard for others to follow (Al-Khalifa and Aspinwall, 2000). These industries supply their products in the global market by producing high-quality products using the concept of Quality Management (QM).

This chapter provides a working definition of quality in the manufacturing context as well as a review of the notion of QM. It describes the evolution of the QM concept from its inception to development, until the attainment of Total Quality Management (TQM). Existing literature has been reviewed in terms of the relation between QM and firm's performance. The sub-section explores the relationship between QM and manufacturing flexibility, particularly considering the changing environment of firms. It also explores the relationship between QM and manufacturing changeover which can have a significant role in ensuring quality. The last section provides an overview of Saudi Arabia and discusses the status of the QM practices within firms in the country.

2.2 Defining quality

There are several definitions of quality in the literature. Quality is regularly referred to as an "excellence in products or services" (Oakland, 2003, p.3). The concept of quality has been used as a strategic philosophy within organisations. The gurus of QM, such as Juran, Deming, Crosby and Feigenbaum have proposed the following definitions of quality (Oakland, 2003, p.4):

- "Fitness for purpose or use" – Juran.
- "Conformance to requirements" – Crosby.
- "Quality should be aimed at the needs of the consumer, present and future" – Deming.
- "The total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product and service in use will meet the expectations of the customer" – Feigenbaum.

- "The degree to which a set of inherent characteristics fulfils requirements" – BS EN ISO 9000.

These definitions affirm that quality means conformance to requirements, which implies the ability to produce products that fulfil their purpose. These definitions emphasise customer satisfaction and high-quality products by ensuring a certain level of outcomes, such as reducing rework, scrap and defects. According to Dale et al. (2007, p.10), quality is defined as "the attributes of a product or service which, as perceived by the customer, makes the product or service attractive to them and gives them satisfaction". The focus of the definition is the value addition to the product or service in order to satisfy customer needs. In fact, customers drive quality for high-performing firms (Evans, 2005). Currently, customers are more aware of and able to recognise the quality issues of products. Therefore, companies are required to exceed customer expectations in order to compete in the market. Further, Oakland (2003, p.5) defined quality as "meeting the customer requirements". Nowadays, companies maintain quality according to customer requirements and this includes availability, delivery, reliability, maintenance, and cost effectiveness.

Crosby, Deming and Juran were known as the three gurus of QM in the western world (Oakland, 2003; Basu, 2004; Evans, 2005; Dale et al., 2007). Figure 2.1 illustrates the timelines of these quality gurus and their contributions. Edwards Deming proposed 14 points for improving quality and a firm's culture in his management philosophy and also developed the concept of the continuous improvement cycle—Plan, Do, Check and Act (PDCA). Deming affirmed that a higher quality product leads to higher productivity which impacts on the strength of competitiveness (Evans, 2005). Deming's philosophy of best practice is getting the facts, collecting data, setting standard procedures, measuring results, and getting feedback. It emphasises a continuous cycle for improvement. According to Deming, QM is the responsibility of all the employees in a firm (Dale et al., 2007). Basu (2004) discussed Deming's philosophy of employee's participation through understanding the objectives and processes, and contributing to the improvement suggestions.

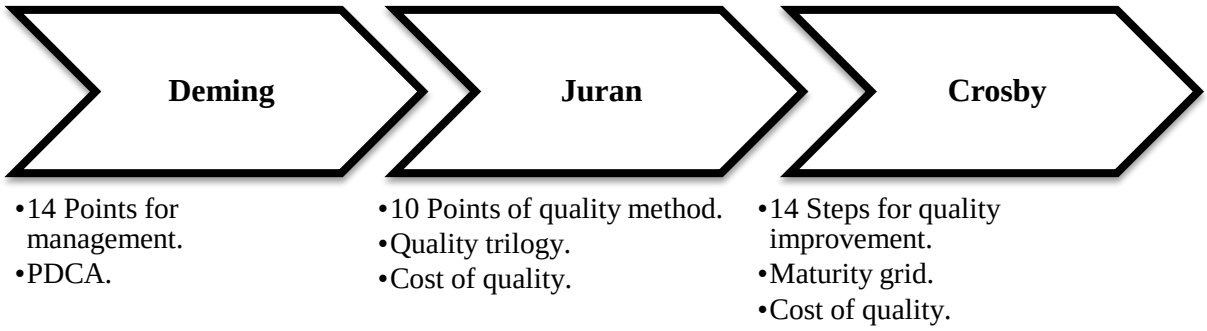

Figure 2.1 Quality gurus and their contributions (adapted and modified from Oakland, 2003; Evans, 2005).

The next quality guru is Joseph Juran, whose approach was to increase conformance to quality parameters to decrease cost and continuous education on quality (Basu, 2004). Juran was a statistician and there are similarities between his work and that of Deming since they both worked in Japan. However, Juran considered as the first quality guru that highlighted quality achieved by communication (Evans, 2005). In this respect, Juran provides a method comprising 10 steps for Quality Improvement (QI). The 10 steps are to build awareness for improvement, set goals for improvement, organise to reach goals, provide training, carry out projects to solve problems, report progress, give recognition, communicate results, keep the score and maintain momentum by making annual improvement of the regular system (Dale et al., 2007, p. 64). Quality Improvement (QI) is defined as "the process for breaking through to unprecedented levels of performance" (Evans, 2005, p. 29). Also, Juran created the quality trilogy which comprises quality planning, control and improvement.

The last quality guru who is discussed here is Philip Crosby; he developed 14 steps in his QI program and developed a QM maturity grid (Dale et al., 2007). Crosby argued that higher quality will reduce cost and increase profits. Also, Crosby introduced the concept of quality costing—the Prevention, Appraisal and Failure (PAF) model for reducing cost and improving quality (Oakland, 2003). Crosby is considered the first quality guru to have highlighted the zero defects concept (Basu, 2004).

Table 2.1 represents the differences and similarities between the views of these three quality gurus and their contributions towards quality. Deming and Juran proposed statistical quality control to Japanese firms after World War II (Evans, 2005). Also, both agreed that quality is a managerial responsibility

(Basu, 2004). However, Juran affirmed that employees in different levels in firms are speaking different languages, such as the ‘money’ language of top management and the ‘things’ language of workers, while Deming considered that all employees should speak the language of ‘statistics’ (Basu, 2004). On the other hand, Crosby notes that culture and behaviour beliefs in an organisation are considered before the statistical approach of Deming is adopted. However, Crosby’s approach was lacking in terms of detailed guidance for using quality tools, systems and techniques (Dale et al., 2007).

2.3 The concept of Quality Management

The state of the world economy creates a lot of uncertainty for businesses due to the amount of changes in the business environment, such as changes in products, rapid changes in technologies, and increasing global competition (Terziovski, 2006). To manage these changes within businesses, QM can drive competitiveness through different manufacturing aspects (Flynn et al., 1995a). According to Chi Phan et al. (2011), when QM practices in manufacturing firms are considered part of the strategic philosophy, it improves competitiveness. Chi Phan et al. (2011, p. 522) defined competitiveness as "the ability of a business to survive in competitive marketplace by offering products or service that attract and satisfy customer". Earlier, Chi Phan and colleagues found that QM practice leads to high performance and competitiveness in terms of conformance quality, manufacturing cost, flexibility, production time and customer service. Reed et al. (2000) and Flynn et al. (1995a) affirmed that TQM has the potential of achieving the sustainability of competitive advantage on cost and differentiation which includes quality, fast delivery, flexibility, and ease of use. This provides an insight into QM practices for dealing with the changing business environment to satisfy customers' requirements. Flynn et al. (1995a, p.342) defined QM as "an integrated approach to achieving and sustaining high quality output, focusing on the maintenance and continuous improvement of process and defect prevention at all levels and in all functions of the organisation in order to meet or exceed customer expectations". The previous definition provides an insight into achieving high-quality performance output by decreasing the amount of defective, rework and scrap products.

Motwani et al. (1994) studied the critical factor of an effective QM in Indian manufacturing organisations, and discussed the constructed factors of an effective QM practice. They found that product design and employee feedback involvement factors have no effect on improving the quality level in Indian manufacturing firms. This is because product design is operated by independent research and development department. Feedback and the employee involvement factors were not significant because although the employee involvement programme was introduced within the firms, it had not been used efficiently. The studied factors of QM practice have been constructed based on the quality gurus and their philosophies as shown in table 2.2.

De Meyer et al. (1989) investigated the most important manufacturing concern of manufacturers in Japan, North America and Europe. The study reported that production in accordance with high-quality standards was the highest concern of Japanese and North American firms, but it was a second priority for European manufacturers as the first was rising overhead costs. In addition, European and North American manufacturers recognised that providing consistent quality to their customers would give them competitive advantage. This reflects the significance of quality outcomes of manufacturing during that period. More recently, Chi Phan et al. (2011) investigated QM practices in Japanese manufacturing firms between the 1990s and 2000s. The study revealed that the QM in Japanese firms

tends to be more focused on customer satisfaction by managing close relationship and enhancing responsiveness to customers' needs. This indicated that the involvement of customers in QM programs was important to the production of high-quality products.

Figure 2.2 shows TQM evolution from a simple inspection activity. The simple inspection can be defined as "conformity evaluation by observation and judgment accompanied as appropriate by measurement, testing or gauging" (Dale et al., 2007, p. 24). This was only one way for ensuring quality at the time—products were examined and tested by visual inspection to fulfil specific quality requirements. Thereafter, simple visual inspection was replaced by Quality Control (QC), which can be defined as "part of quality management focused on fulfilling quality requirements" (Dale et al., 2007, p. 25). Juran and Gryna (1988, Ch. 6, p. 31) defined QC as a "the regulatory process through which we measure actual quality performance, compare it with quality goals and act on the difference". Both definitions referred to quality control as a process that measured for corrective action. By employing seven quality control tools - check sheet, cause-and-effect diagram, Pareto diagram, control chart, histogram, flow chart and scatter diagram - QC enables firms to establish sophisticated production systems (Oakland, 2003). The main goal of QC is preventing non-conforming products from being delivered to customers as well as creating greater process control. QC can employ Statistical Process Control (SPC) for helping top and middle management to understand the capability of the process; whether that process is meeting the requirements and creates an adjustment improvement action if that is required (Mitra, 2012). Basu (2004) discussed the activities that related to QC, which are monitoring process performance, accepting sampling, and maintaining control charts. However, Dale et al. (2007) discussed the disadvantage of implementing QC in the manufacturing sector by arguing that in the QC approach, a systematic approach for planning that prevents the firm from identifying the defective products at the early stage is lacking.

Figure 2.2 Timeline of TQM evolution and its associated practices (adapted and modified from Dale et al., 2007).

Quality control was supplemented by a third stage of QM known as Quality Assurance (QA) that is defined as "part of quality management focused on providing confidence that quality requirements will be fulfilled" (Dale et al., 2007, p. 27). Juran and Gryna (1988, Ch. 9, p. 2) defined QA as "the activity of providing the evidence needed to establish confidence that the quality function is being effectively performed". QA protects perceived quality at the early stages of the manufacturing. This ensures that an extensive QA system would be employed, involving quality costing and process improvement (Dale et al., 2007). QA practice has to meet the requirements of BS EN ISO 9001 of the quality management system. Mitra (2012) stated that QA is ensuring working procedures that are designed and followed; the aim of QA is creating a formal system that surveyed on a regular basis in order to measure the effectiveness of the quality aspects in the company. Basu (2004) discussed the activities that are related to QA, which are an approved supplier scheme, and operator training. Oakland (2003) affirmed that QA is a prevention system rather than a detection system which contributes to the improvement of product quality and productivity by emphasising product and process design. However, QA is distinguished by prevention mistakes, while inspection and QC are based on detection approach.

The last stage of the evolution of QM is TQM. It is a company-wide approach to quality and enables all aspects of organisations, customers and suppliers to be integrated with business processes (Dale et al., 2007). Oakland (2003, p.30) defined TQM as "an approach to improving competitiveness, effectiveness and flexibility of a whole organisation; it is essentially a way of planning organising and understanding each activity, and depends on each individual at each level". Further, TQM emphasises greater use of sophisticated tools and techniques as well as the involvement and empowerment of employees. Moreover, TQM helps to eliminate wastage and activities that do not add value. Basu (2004) stated that TQM is requires the principle of QM and should be applied within firm level of technical, managerial and people. Dahlgaard and Dahlgaard-Park (2006) identified that TQM philosophy emphasised changing company culture from defensive and passive to proactive and open, and the firm is required to identify the appropriate quality strategy in order to build the right culture for successful TQM implementation. Jabnoun and Sedrani (2005) discussed the importance of culture awareness which is considered as a key element of gaining an excellence of quality. However, TQM implementation can lead to changes in organisational culture (Gore Jr, 1999; Jabnoun and Sedrani, 2005; Dahlgaard and Dahlgaard-Park, 2006). Gore Jr (1999) affirmed that TQM helps to increase the focus of the employees' organisational arrangements, and provides an environment that is conducive to building a culture.

2.3.1 The relationship between Quality Management and Firm Performance

A considerable amount of literature has been published on the positive impact of QM practices on the performance of firms (Flynn et al., 1994; 1995a; Mohrman et al., 1995; Terziovski and Samson, 1999; Kaynak, 2003; Lakhal et al., 2006; Terziovski, 2006; Kumar et al., 2009; Parast et al. 2011; Clegg et al. 2013). Saraph et al. (1989) constructed an instrument for measuring critical success factors of QM and found eight variables that are vital for its implementation: the role of management leadership and quality policy, role of the quality department, training, product/service design, supplier quality management, process management, quality data, and employee relations. The research instrument was a comprehensive collection of critical success factors of quality management literature of various authors of quality management gurus. The investigation of 20 companies in the US using this instrument revealed that QM variables have a highly positive influence on quality performance. This instrument offers managers insight into areas that require QI and that need to be developed in order to achieve a beneficial implementation of QM. Badri et al. (1995) used Saraph and colleagues' instrument for measuring QM practices in 424 firms in the UAE. The study revealed that there was a lack of awareness of quality concepts and, thus, these firms did not have a full commitment to meeting and maintaining quality aspects in their quality department. Ahire et al. (1996) constructed an instrument for measuring the application of QM practices in manufacturing plants; the constructed QM instrument has 12 variables, of which some overlap with those in the instrument of Saraph and his colleagues (1989). Further, this instrument focuses on supplier performance, customer needs, TQM tools and techniques—such as Statistical Process Control (SPC)—and benchmarking; it was revealed that the 12 variables of the instrument were positively correlated and this finding is consistent with that reported by Saraph et al. (1989) and Badri et al. (1995). Moreover, Ahire et al. (1996) conducted a survey among 371 automotive firms in the US and found that QM practices have a direct impact on product/service quality and firm performance.

Kaynak (2003) investigated TQM practices in US manufacturing firms and found a positive relationship between TQM implementation and quality, financial, and market performance. Moreover, Kaynak (2003) discussed the direct and indirect effects of TQM practices on firm performance; it was found that open organisations and employee empowerment and involvement facilitate and enhance the

process of change that is involved in TQM. This is because when the work environment encourages open communication among employees, it brings about a positive change in employee performance related to QM. According to Tari et al. (2007), QM practices are directly related to quality outcomes of firms and leadership plays an important role in quality planning, human resource management, learning and customer focus. This reflects the essential role of leadership in ensuring that the firm is fully committed to executing QM practices, which will eventually affect a firm's performance. Studies have confirmed that improved quality is positively related to productivity, which in turn enhances a firm's competitiveness (Deming, 1982; Fisher, 1992) and operational performance (Maani et al., 1994). Table 2.3 summarises the literature review of QM practices that are related to firm performance.

There are, however, a number of studies that reported a negative relationship between TQM and business performance, whether financial or operational (Eskildson 1994; Bergquist and Ramsing, 1999). Eskildson (1994) discussed the reason for not achieving successful TQM implementation in firms; he posited that because of ambiguous definitions of TQM within the firms, this impact negatively on performance. Several studies have discussed the negative relationship between TQM variables and company performance in terms of quality indictor (Bergquist and Ramsing, 1999; Yang et al., 2009) and financial indictor (York and Miree, 2004; Fuentes et al., 2006).

Table 2.3 Literature review of impact of quality management practices on firm performance (Source: author).

Study	Sample	Geographical Area	Performance variables	Major findings
Saraph et al. (1989)	20 manufacturing firms	US	Quality performance	Eight measures of quality management have a direct impact on quality outcomes.
Flynn et al. (1994)	42 manufacturing plants	US	Quality performance	Seven constructs of quality management have a strong relationship with quality performance.
Badri et al. (1995)	424 manufacturing and service firms	United Arab Emirates (UAE)	Quality performance	The study used Saraph et al.'s (1989) instrument and the eight measures of quality management which have a direct impact on quality outcomes.
Ahire et al. (1996)	371 automotive firms	US	Product quality	12 quality management constructs have a positive impact on product quality.
Terziovski and Samson (1999)	962 Australian and 379 New Zealand manufacturing firms	Australia and New Zealand	Quality performance, financial performance and customer satisfaction	40 of the quality variables have a significantly positive effect on quality performance, financial performance and customer satisfaction.
Kaynak (2003)	214 manufacturing and service firms	US	Quality performance, financial performance and inventory management performance	Seven constructs of quality management have a strong relationship with quality performance.
Lakhal et al. (2006)	133 companies from the plastic transforming sector	Tunisia	Financial performance, operational performance and product quality	10 measures of quality management practices have a positive relationship with organisational performance.

Terziovski (2006)	962 Australian and 379 New Zealand manufacturing firms	Australia and New Zealand	Productivity improvement and customer satisfaction	Six quality variables have a positive impact on performance variables.
Tari et al. (2007)	106 firms; 63 from the manufacturing sector	Spain	Quality outcomes	Nine quality management variables were positive related to quality outcomes.
Kumar et al. (2009)	14 firms; 12 firms from the manufacturing sector	Canada	Employee relations, operating procedures, customer satisfaction and financial results	The study proved that positive impact of TQM variables on company performance.
Parast et al. (2011)	61 companies in petroleum industry	Iran	Operational performance	There was a positive association with top management support, employee training and involvement variables on internal quality level.
Clegg et al. (2013)	183 firms; 110 from manufacturing sector	UK and Turkey	Primary and secondary performance	The quality management has a significant impact on both primary (operational) and secondary (financial) performance.

2.3.2 The relationship between Quality Management and Manufacturing Flexibility

There is a large volume of published studies that describe the role of manufacturing flexibility in improving responsiveness of firms (Bolwijn and Kumpe, 1990; Sethi and Sethi, 1990; Upton, 1994; Beach et al., 2000; Garget al., 2003; Gómez-Gras and Verdú-Jover, 2005; Escrig-Tena et al., 2012). Upton (1995a, p.207) defined flexibility as "the ability to change with little penalty in time, effort, cost or performance". Sethi and Sethi (1990, p. 295) defined flexibility in the manufacturing context as "the capability of changing in order to deal with a changing environment", and Lloréns-Montes et al. (2004) affirmed that manufacturing flexibility has a positive relationship with firm performance and competitiveness in dynamic markets.

Bolwijn and Kumpe (1990) explained the transition of firms during the 1980s from producing only high-quality products to the establishment of a highly flexible manufacturing process. The relationship between quality and flexibility is embedded in all areas involved in manufacturing and production; strengthening this relationship can help to achieve the optimum goals of improving quality, cost and performance. It is important to reduce the lead time of manufacturing associated with a low level of inventories and facilitating QI (Bolwijn and Kumpe, 1990). Lloréns-Montes et al. (2004) affirmed that companies that have QI programs have a better understanding of the flexibility perspective and were able to respond quickly to the requirements of the changing environment. QI enables firms to become market-oriented, thereby allowing them to become more flexible (Lloréns-Montes et al., 2004). An approach to facilitate manufacturing flexibility in order to understand market needs is Quality Function Deployment (QFD) (Bouchereau and Rowlands, 2000; Olhager and West, 2002). Basu (2004, p. 157) defined QFD as a "technique that is used for converting the needs of customers into design requirements and follow the concept of voice of the customer drives all the company operations". This approach enables firms to respond promptly to and be capable of handling rapid changes. Olhager and West (2002) discussed the application of QFD which can be used to link market requirements to a manufacturing firm in order to achieve ultimate manufacturing flexibility. Bouchereau and Rowlands (2000) discussed the strengths of QFD application which are reducing development time by 50% of product start-up and reducing the engineering cost by 30%. QFD has been widely used in the manufacturing industry for enabling agility (Vinodh and Kumar, 2011)

integration with Value Stream Mapping (VSM), for enabling lean manufacturing (Mohanraj et al., 2011), for improving manufacturing flexibility (Olhager and West, 2002), and for linking to the measurement of quality costing for decision making (Moen, 1998). According to Garg et al. (2003), the aspects of quality and flexibility have a direct impact on delivery time and product cost. Earlier, Garg et al. (2003) also highlighted that cost reduction, delivery speed and delivery dependability could be improved by enhancing both quality and manufacturing flexibility. A flexible manufacturing system allows for quick changeover, higher machine utilisation, reduced lead time and reduced work-in-process inventory (Garg et al., 2003).

The literature review shows that a positive relationship has been established between manufacturing flexibility and quality (Hill, 1991; Schonberger, 1992; Upton, 1995b; Youssef, 1996; Olhager and West 2002; Garg et al., 2003; Anderson and Vastag, 2004; Chi Phan et al., 2011). Different authors have studied the relationship between flexibility and QI (Lloréns-Monteset al., 2004; Nayak and Ray, 2012). Garg et al. (2003) studied flexibility and quality practices among 44 Indian manufacturing firms; they found that TQM has a positive substantial impact on enhancing flexibility. This is because top management emphasised worker empowerment to deliver better practices. Hence, top management holds the key to successful implementation of quality and flexibility. Also, TQM eliminates waste and activities that do not add value, which leads to an increase in manufacturing flexibility. Lloréns-Montes et al. (2004) examined 417 firms in three sectors in the EU: chemicals, electronics and vehicles. Their study focused on distinguishing between firms that pursue QI and those that do not, and determining whether QI leads to improve manufacturing flexibility. The study revealed that firms that do not pursue QI adapt better to market requirements. However, firms that pursue QI have a high level of manufacturing flexibility but are not always successful in meeting markets' requirements. This is due to excessive flexibility, and does not reflect an improvement in a firm's performance. This finding is consistent with the study of Gómez-Gras and Verdú-Jover (2005) that finds that firms with TQM programs have a positive impact on the level of flexibility; however, there is no direct impact on performance. Escrig-Tena (2012) examined the contribution of QM implementation on strategic flexibility in Spanish firms. They constructed a QM model with seven variables and found that strategic leadership, information and analysis, supplier management and process management

variables contributed positively to flexibility. Further, leadership commitment was found to be vital to enhance changes that were required to be made in order to facilitate flexibility. Process management by establishing working procedures to achieve a high level of flexibility as well as standardisation of process can enable the exclusion of unnecessary processes, thereby promoting necessary change.

The main difference between Western and Japanese approaches to competition and prompt response to market changes is the degree of QI (Zairi, 1993). In the West, the approach that is used to compete in the market relies on technological complexity, while in Japan the approach relies on the improvement process and using the creativity of people (Zairi, 1993). Some existing literature has also been published on Advanced Manufacturing Technology (AMT) for improving responsiveness, productivity level and flexibility of firms (Tracey et al., 1999; Youssef and Al-Ahmady, 2002; Dangayach and Deshmukh, 2005); AMT refers to computer technology, such as Flexible Manufacturing Systems (FMS), Computer Aided Design (CAD) and Statistical Process Control (SPC) (Dangayach and Deshmukh, 2005). Zairi (1993) studied the combination of AMT and TQM in the manufacturing context. The study found a strong link between TQM and AMT, but little emphasis on flexibility and quality in the firms that were studied in terms of achieving competitiveness. Youssef and Al-Ahmady (2002) examined the impact of FMS on certain aspects of quality management in the US manufacturing industry, and found that FMS can increase flexibility, responsiveness, minimise quality costs and improve quality outcomes. The study also revealed that firms with FMS have a better understanding of their QM practices than non-FMS companies have. This is because FMS enables firms to respond promptly to customer and market requirements.

Thus, it is evident that QM provides organisations with quicker learning that leads to the creation of knowledge and innovation; eventually, this is what guides organisations to adapt appropriately to changing market and customer requirements and to remain competitive (Gómez-Gras and Verdú-Jover, 2005).

2.3.3 The relationship between Quality Management and Changeover Performance

Quality management emphasises better quality, prompt response, greater flexibility and lower cost (Schonberger, 1992). Schonberger (1992) indicated that changeover and start-up time is considered as one principle in TQM. The extent of the relationship between product quality and changeover performance can affect a firm's performance (McIntosh et al., 2001a); a high-quality changeover leads to a higher production rate, reduced scrap, greater line reliability and better product quality and process. McIntosh et al. (2001a, p.325) defined changeover quality as "establishing manufacturing parameters to high precision, resulting, for example, in reduced scrap, higher production volume and greater line reliability".

Chiarini (2011) studied the implementation of lean manufacturing in ISO 9001-certified European manufacturing firms. The study suggested that quick changeover was widely used as documented procedure by 89% of the firms investigated. This result implies that ISO 9001-certified firms are more aware and implement a quick changeover process. Changeover significantly impacts quality; therefore, changeovers should be planned and personnel trained in order to ensure a fast process without losing product quality (ElMaraghy and Meselhy, 2009). Shah and Ward (2007) indicated that quick changeover and QA allows companies to predict the outcome more precisely, which increases the reliability of the finished product by ensuring that it is produced within the stipulated time and according to the determined quality. According to McIntosh et al. (1996), some companies would increase changeover time as a trade-off against improved quality rates or productivity; however a long changeover time is a real issue for improving changeover, and is considered a manufacturing waste.

Van Goubergen and Van Landeghem (2002) discussed the three key elements of quality set-up, as shown in Figure 2.3. These elements can be determined as the quality aspects of set-up and are technical aspects of equipment and tools, organisation of work, and the production method employed. Motivation plays an important role in quality set-up by providing appropriate training for operators and other people who are part of the set-up, and these elements have to be optimised in order to enhance changeover performance. Reik et al. (2006a, p.1226) describe changeover quality "as the precision with which the equipment is reset that has a likely impact on each changeover phase—

rundown, set-up and run-up". Moreover, the impact of changeover quality will continue across lost production and the amount of scrap that is produced during changeover as well as after the set-up process into production phase (Reik et al., 2006a; Chi Phan et al., 2011).

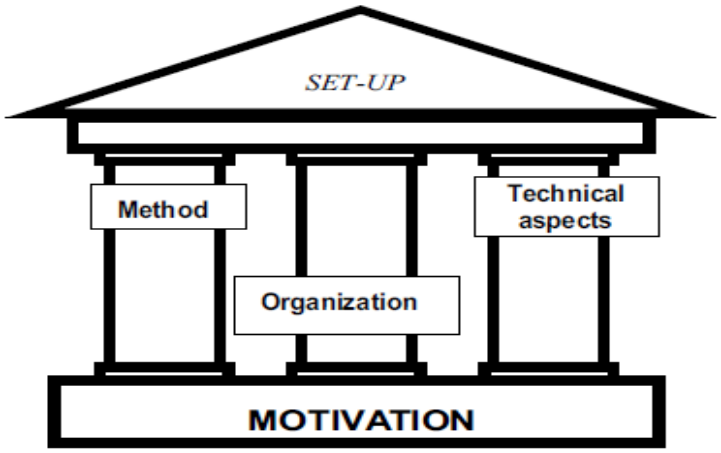

Figure 2.3 Three key elements of a quality setup (Van Goubergen and Van Landeghem, 2002).

Literature exploring the relationship between QM and manufacturing changeover performance is very sparse. Also, only limited studies have examined the implementation of a high-quality changeover process in manufacturing firms. Therefore, having explored a small amount of the literature on high-quality and reliable changeover processes, it can be suggested that there is scope for the work to expand the literature for more in-depth understanding of the phenomenon under study.

2.4 Status of Quality Management in Saudi Arabian manufacturing firms

This section presents an overview of Saudi Arabian firms and discusses the status of QM practices within these firms. It provides an insight into Saudi Arabia's QM applications; there is a lack of existing studies in this particular area.

Many firms in developed countries, such as Japan, the USA and Western Europe, have implemented QM programs to improve customer satisfaction and eliminate processes that do not add value to the work environment (Zairi, 2002). In particular, Saudi industries have raised concerns regarding QM accreditation in their products. Therefore, there are a number of quality accreditations in Saudi Arabia that have been adopted. In the late 1970s, the Saudi government established a Saudi quality accreditation mark that focused on the conformity of the products to certain technical aspects; this sign was granted by the Saudi Arabian Standards Organisation (SASO) which is a reference body responsible for distinguishing all quality aspects at the national and international levels (Alsaleh, 2007). This led to the dissemination of initiatives on quality awareness within the manufacturing industry by the Saudi Quality Council which defined as follow:

"Promoting the mission of quality concepts throughout the community and in drawing the attention to the significance of developing standards and programs of quality control and to the need to establish national awards for quality in order to motivate both organisations and individuals" (Saudi Quality Council, 2012).

Secondly, there is the well-known QM system, known as the International Organisation for Standardisation ISO 9001, which is a system for encouraging the international unification and coordination of industrial standards (Magd, 2006). Recently, the King Abdul-Aziz Quality Award for outstanding organisations was introduced by the Ministry of Industry and Commerce in Saudi Arabia to encourage organisations to apply the QM concept; this award is granted through a long and comprehensive evaluation of QM practices adopted by a particular firm (Alsaleh, 2007). Al-Darrab et al. (2013) examined the accreditation of international standards among 300 Saudi Arabian manufacturing firms. The study revealed that 34% of the respondents' firms were certified with ISO 9001 and 33% were not certified. The rest of the companies were certified with ISO 14001 of Environmental Management System and OHSAS 18001 of the Occupational Health and Safety System with percentages of 4% and 6%, respectively. To sum up, SASO plays a huge role in pursuing

and encouraging Saudi manufacturing firms to obtain international and local quality standard accreditation (SASO, 2015).

There are a number of published studies on QM implementation in Saudi Arabia. Al-Turki and Andijani (1997) studied the quality control practices in 87 firms in the Eastern Province of Saudi Arabia. The study found that 93% of the firms that were surveyed have a quality control department; this reflects the awareness of quality among the firms since that time. Al-Sulimani et al. (2000) indicated that TQM was planned and implemented in Saudi Arabia in well-known organisations, such as Saudi ARAMCO, Saudi Basic Industries Corporation (SABIC) and some public sector organisations. Further, Curry and Kadasah (2002) conducted a survey on the implementation of TQM among a sample of 83 Saudi Arabian companies in the manufacturing sector. The study found that 35% implemented TQM and 65% did not; it was also found that TQM firms provide employees with a better understanding of quality and provide them with appropriate training in TQM's tools and techniques. Further, the implementation of ISO 9000 in the Saudi industry has increased due to the growing access to the global market. Magd (2006) conducted research on ISO 9000 implementation in 175 certified firms in Saudi Arabia. The study revealed that the reason for implementing ISO 9000 was to disseminate awareness of quality concepts. This result was consistent with Mezher and Ramadan (1999) as the main benefit of obtaining an international standard of quality system was because it improves awareness of quality and procedural problems. Mezher and Ramadan (1999) discussed the reasoning of pursuing ISO 9000 certification in the Saudi Arabian manufacturing sector; their study revealed that the first reason was to increase consistency of operations and the second reason was improving product and service quality. Earlier, Mezher and Ramadan (1999) identified the difficulties faced by companies during the certification; the process was time consuming, and accreditation costs were high. Currently, there is a rapid growth in the development of QM due to the highly competitive market and objective of customer satisfaction (Alsaleh, 2007).

2.5 Summary

The chapter explored the major definition of quality and discussed the concept of QM and its evolution. This chapter provides a critical review of relevant literature about QM and its relation to firm's performance, manufacturing flexibility and changeover performance. The chapter also identified the status of QM in Saudi Arabian manufacturing firms. The following chapter is concerned with manufacturing changeover literature and its relation to lean manufacturing concepts.

CHAPTER 3 : MANUFACTURING CHANGEOVER

3.1 Introduction

The previous chapter defined and discussed the concept of QM and its evolution. The practices associated with QM enable evolving firms to be more responsive to the internal and external environments. The relationship between QM and manufacturing changeover performance was also discussed in the preceding chapter. The literature review of QM practices affirmed the positive impact of QM on firm performance.

This chapter reviews the definition of changeover in the manufacturing context and the literature on the lean manufacturing approach related to manufacturing changeover. Further, literature related to the relationship between changeover practice and Just in Time (JIT) as well as Total Productive Maintenance (TPM) is also discussed. The review also encompasses the quick manufacturing changeover literature as interrelated with other aspects, such as Single Minute Exchange of Die (SMED) and Setup Reduction Time (SUR). Further, the proposed conceptual model of quick changeover is presented, which has been generated from existing research on manufacturing changeover.

3.2 Definition of changeover

Achieving effective changeover in manufacturing operations has become a target for industry and academia due to competitiveness in the global manufacturing environment (McIntosh et al., 1996; Mileham et al., 1999; McIntosh et al., 2001a; Elmaraghy and Wiendahl, 2009). Japanese manufacturing techniques have been studied in the UK in order to identify rapid machine set-ups as one of the three principal conditions required for production (Oliver and Wilkinson, 1992, cited in Gilmore and Smith, 1996). This explains the significance of manufacturing changeover on a daily basis. Many authors have attempted to define changeover in the context of the manufacturing process; McIntosh et al. (1996, p.6) for instance defined changeover as “the complete process of changing between the manufacture of one product to the manufacture of an alternative product to the point of meeting specified production and quality rates”, while Reik et al. (2006c, p.122) defined changeover process as “a set of activities necessary to correctly set and/or adjust certain elements of

manufacturing equipment in order to produce the new product at the desired quality at the desired output rate". Henry (2013, p.7) defined changeover time as "the total elapsed time from the last unit of good production at normal speed and efficiency of the preceding run to the first unit of good production of the succeeding run at normal speed and efficiency". Clearly, there is a range of manufacturing changeover definitions which are applicable to the purpose of this thesis; however, the working definition employed in this thesis is the one proposed by McIntosh et al. (1996). A discussion of the features of manufacturing changeover is undertaken in Section 3.4. In order to set the background against which manufacturing changeover is addressed, it is important first to explore the practice of lean manufacturing.

3.3 Lean Manufacturing

The concept of lean manufacturing originated in Japan after the Second World War. It was introduced by Toyota Motor Company in their manufacturing process to minimise waste in all operations (Pavnaskar et al., 2003). Lean manufacturing has been termed the Toyota Production System (TPS), as shown in Figure 3.1. The lean technique is most commonly associated with elimination of waste, such as excess inventory or excess capacity; waste is considered something that does not add value to the product; as Moore (2007, p. 144) explicated, "anything that adds cost, but does not add value". There are different aspects of waste in manufacturing, such as overproduction, time, defects, materials and transport (Pavnaskar et al., 2003). Lean production is a multidimensional approach to management practices that includes QM, JIT, cellular manufacturing, work teams and supplier management (Shah and Ward, 2003). These practices can work together to achieve the main core of lean production: producing high-quality finished products and becoming highly responsive to customer demand. Shah and Ward (2007, p. 791) defined lean production "as an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimising supplier, customer and internal variability". According to Pavnaskar et al. (2003), the benefits of implementing lean production within firms are improved product quality, increased flexibility, reduction in cycle time and reduced work-in-progress. The tools and techniques related to lean production are presented in Figure 3.1; the techniques focus on waste elimination for the improvement of quality, reduction in lead time and lowering of manufacturing cost.

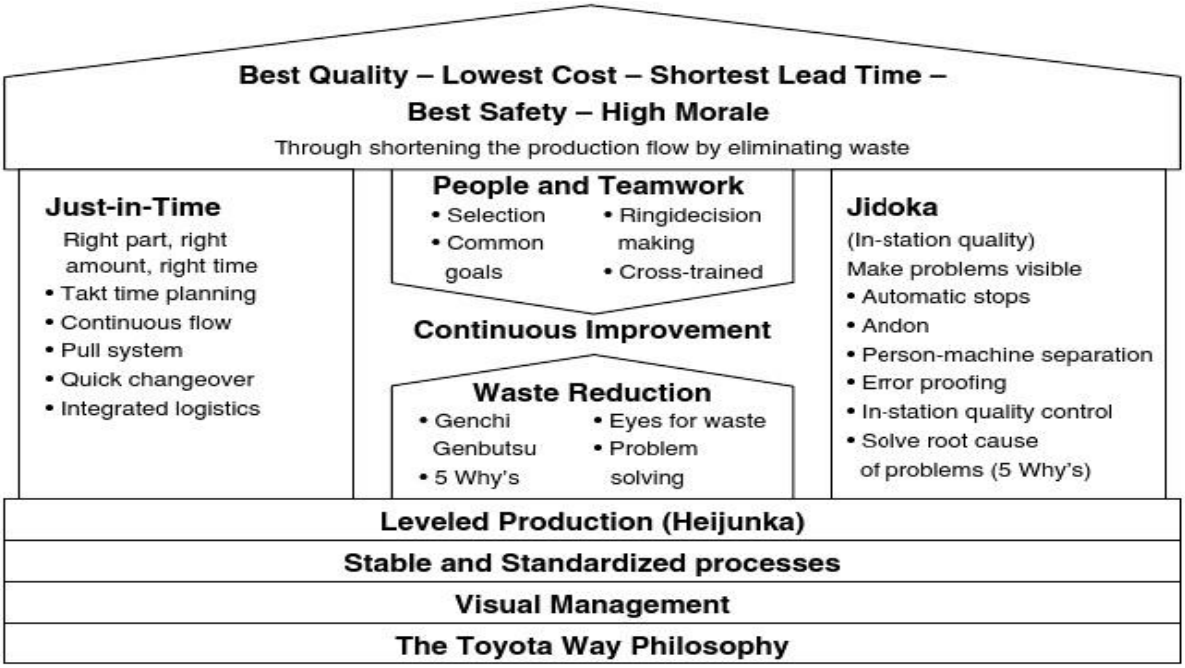

Figure 3.1 Lean Manufacturing known as TPS (Liker, 2004, cited in Moore, 2007).

An extensive literature review by Shah and Ward (2003) found that the most frequently cited aspects in lean production literature were JIT and quick changeover techniques. Therefore, quick changeover is considered as a part of JIT manufacturing practices which lead to prompt response to customer demands, as shown in Figure 3.1. Quick changeover or reduction in set-up time is considered a tool of lean production that helps a firm to identify the processes that must be reduced, eliminated or improved. In other words, the main aim of quick changeover is to eliminate waste during the set-up process.

There is a lack of research in lean implementation in Saudi Arabian manufacturing firms. However, Alsmadi et al. (2012) reported that lean manufacturing was the third most popular program in Saudi firms after TQM and Six Sigma. Karim et al. (2011) studied lean implementation within the Saudi Arabian manufacturing sector. A total of 140 manufacturing firms were selected to participate in the study, and 31 questionnaires were returned. The study investigated the level of lean tools implementation; it was found that TQM and JIT achieved 87% and 65%, respectively, of implementation between firms. However, 5S and lot-size reduction implementation scored the lowest, at 58% and 48%, respectively. Moreover, the study affirmed the manufacturing practices of 5S and lot-size reduction would directly impact on changeover performance. The study revealed that the

difficulties of lean implementation were found to be organisation culture, plant size, lack of management commitment, and lack of skilled manpower, respectively. Beside that the study concluded that the major waste experienced was found to be additional work due to ineffective plan schedule, loss of production due to machine breakdowns, and delay in materials (Karim et al., 2011). No attempt was made to measure the changeover process and practice within Saudi Arabian manufacturing firms. As a consequence of that, this research is timely in order to expand the literature further and to discover the practice of manufacturing changeover.

3.3.1 Just in Time (JIT)

Just in time (JIT) is one of the most commonly employed techniques of lean manufacturing. The main goal of the JIT practice is to reduce and eliminate of waste during manufacturing, and this can be addressed by reduction set-up time (Cua et al., 2001). Mehra and Inman (1992, p. 161) defined JIT as a "production strategy that attempts to achieve excellence in manufacturing by reducing set-up times and lot sizes through the use of group technology, training of employees and preventative maintenance". Group technology is the practice of grouping parts with similar characteristics into 'cell' and 'family' (Mehra and Inman, 1992). Also, Matsui (2007, p. 153) defined JIT as a "process which would produce the necessary items in the necessary quantities at the necessary times and eliminate all operational waste". There are several elements to JIT; some are closely related to the manufacturing changeover and are discussed in the following sections - for example, Total Productive Maintenance (TPM), reduced set-up times, multifunctional employees, and total quality. The nature JIT is actually much broader than that and other areas are considered part of JIT but these are not discussed in this thesis as they are not directly related to the manufacturing changeover; for example, quality circles, focused factory, Kanban, group technology, uniform workload and JIT purchasing (White et al., 1999).

Flynn et al. (1995b) suggested that the dimensions of JIT practices include Kanban, lot-size reduction practices, JIT scheduling and set-up reduction time. The application of JIT principles in the manufacturing context is essential in inventory management and productivity. White et al. (1999) investigated the difference of JIT implementation within small and large US manufacturing firms. The study revealed that better throughput time of converted raw materials into finished products was most

improved in the large and small firms by 88.9% and 82.8%, respectively. The study affirmed that JIT helps firms to cope with the changing external environment and become more responsive to change. Furthermore, the study revealed that the second and third most improved areas of the firms' performance were lower inventory level and better quality outcomes.

According to White (1993), reduced set-up time was the most implemented JIT practice based on research that was conducted among 1035 firms in the US manufacturing sector. The majority of the respondents agreed that JIT helped to decrease throughput time of lead time. In addition, the study indicated that set-up reduction time was often implemented in large firms rather than small firms. The benefits of JIT include decreasing inventory levels, improving employee relations, improving quality, and improving labour productivity (White, 1993; White et al., 1999). Shah and Ward (2003) indicated that the two major forms of waste are delays in flow time and work-in-process inventory. It has been found that quick changeover technique leads to a reduction in work-in-process inventory by reducing lot size and processing time. Earlier, Shah and Ward (2003) studied the relevance of 22 lean manufacturing practices in relation to JIT, TQM, TPM and Human Resource Management (HRM) in the US manufacturing sector. They found that the practice of a quick changeover technique was the one most associated with JIT and moderately associated with TPM. Faster changeover and set-up time have been cited in existing literature on JIT manufacturing and its effect of reducing set-up time and allowing responsive small-batch manufacturing in a range of contexts (White et al., 1999). Matsui (2007) examined the impact of JIT practices on production systems and competitive performance among 46 Japanese manufacturing plants. The study revealed that equipment layout and setup time reduction has a strong impact upon the competitive position of the manufacturing plant (Matsui, 2007). The study affirmed that equipment layout and set-up time strongly correlate with firm's practice, HRM, QM and manufacturing strategy. Greasley (2013) highlighted the influence of manufacturing layout on the plant facilities and equipment in terms of distance travelled by materials and throughput time.

The relationship between JIT and TQM has also been investigated (Flynn et al., 1995b; Cua et al., 2001; Kannan and Tan, 2005). Flynn et al. (1995b) identified that TQM has an impact on reducing inventory level and that contributes to improved JIT practice. In addition, Flynn et al. (1995b)

discussed that JIT focuses on reducing lot size and improving process feedback, which in turn contributes to decreasing defective parts. Lau (2000) examined the joint JIT-TQM implementation in the US manufacturing firms; the study revealed that an extensive overlap between JIT and TQM approaches leads to synergy. Lau (2000) compared the implementation of JIT-TQM and JIT companies and the study result shows that JIT-TQM firms having better quality and business growth performance than JIT firms. The simultaneous implementation of TQM and JIT leads to performance improvement—JIT practices were found to strongly influence quality performance (Flynn et al., 1995b; Lau, 2000). Further, TQM was found to reduce the flow time of the production cycle through a reduction of rework and defective products while maintaining inventory level, which is the main goal of JIT (Cua et al., 2001). Vuppalapati et al. (1995) argued that JIT and TQM are considered as an integrated approach in the manufacturing practice rather than two separate approaches. Figure 3.2 describes the effectiveness of JIT and TQM implementation at the levels of the three different views.

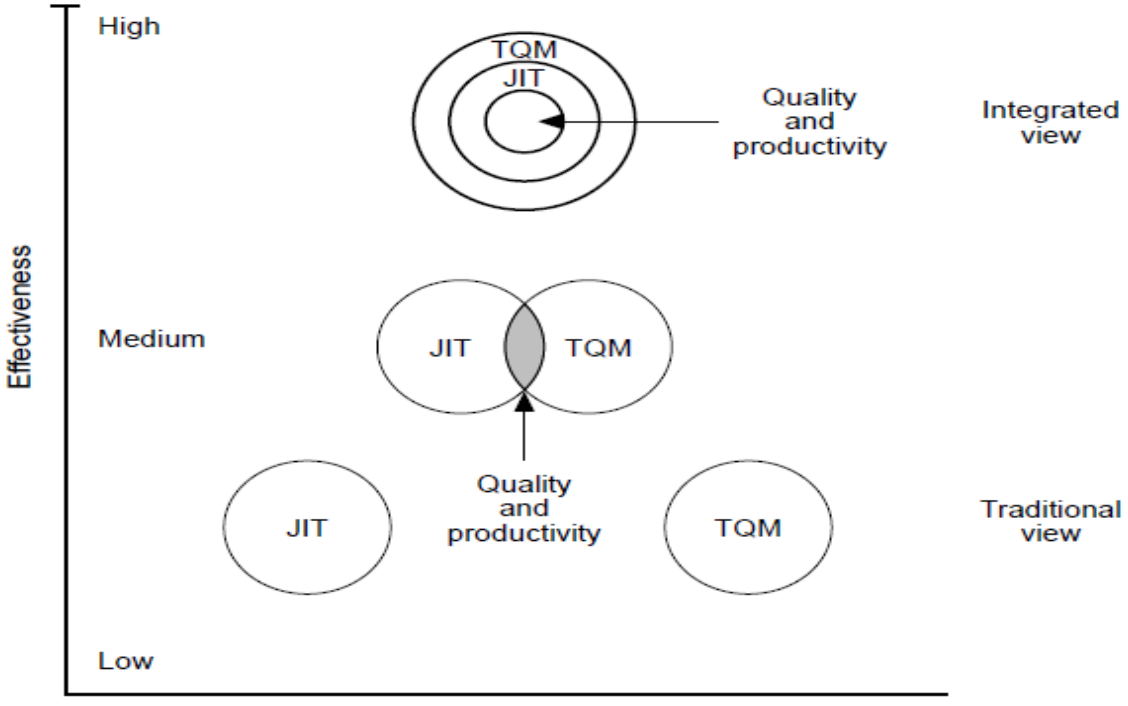

Figure 3.2 Three views of JIT – TQM implementation (Vuppalapati et al., 1995).

3.3.2 Total Productive Maintenance (TPM)

TPM is a partnership approach that brings together maintenance and production in an organisation to improve product quality and contribute towards the success of lean manufacturing (Ahuja and Khamba, 2007). Ahuja and Khamba (2007, p.340) defined TPM as "a maintenance approach that optimises equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day to day activities involving the total workforce". Moreover, TPM is a maintenance approach that enables firms to eliminate wastage of time in terms of equipment breakdowns as well as increase equipment availability (Ahuja and Khamba, 2007). Aspinwall and Elgharib (2013) examined the implementation of TPM in four UK manufacturing firms using a case study approach. The study affirmed that the benefit of implementing TPM was an increase in the productivity and quality. This is because TPM was emphasised in the practical approach and procedure for maximising the equipment effectiveness. Also, the machine availability in the plant increased by around 97% for most of the firms. Kumar et al. (2014) discussed the objectives of Indian companies in pursuing the TPM program; their study revealed that the first objective was improving quality rate and the second was improving productivity and cost effectiveness. The findings from research carried out by Kumar et al. (2014) and Aspinwall and Elgharib (2013) were consistent in terms TPM implementation and its benefits. Attri et al. (2013) discussed the three major barriers of TPM implementation in the manufacturing industry - lack of top management support, training and motivation.

McIntosh et al. (2001b) discussed how maintenance is found to affect the ultimate outcome and changeover performance. The integration of changeover practice and preventive maintenance has been widely reported (Mileham et al., 1997; McIntosh et al., 2001b). By reducing machine downtime, there is an improvement in changeover and this leads to increased line productivity. McIntosh et al. (2001b) discussed that maintenance and changeover are considered as separate processes but together contribute directly to line downtime. The study affirmed that better changeover procedure and practice leads to a reduction in maintenance downtime. Moreover, the study revealed that disruption of steady production and operator while conducting changeover can contribute to poor quality items. Kumar et al. (2014) identified that the importance of TPM implementation was to reduce cost production and

set-up time for faster model changeover, while Ahuja and Khamba (2007) identified that one of the causes of loss of equipment efficiency was set-up and adjustment loss during changeover. Earlier, Ahuja and Khamba (2007) had studied TPM initiatives for enhancing manufacturing practices in Indian steel firms. The study revealed that TPM has an impact on losses: there was a reduction in set-up loss, and the availability of machines was enhanced during the four-year period after the implementation of TPM. Therefore, it can be contended that TPM practices can support firms to be more competitive and become world-class manufacturing firms. TPM embraces a Kaizen technique of continuous improvement in order to improve machine reliability and maintainability (Ahuja and Khamba, 2007).

3.3.3 5S Approach

The 5S approach is based on the Japanese acronyms for organisation, neatness, cleanliness, standardisation and discipline (Gapp et al., 2008). Figure 3.3 explains the elements of the 5S approach. Bayo-Moriones et al. (2010, p. 217) defined 5S as "a system to reduce waste and optimise productivity and quality through maintaining an orderly workplace and using visual cues to achieve more consistent results". A common definition of this approach in Western literature is "Housekeeping" (Gapp et al., 2008; Bayo-Moriones et al., 2010). The 5S approach encourages workers to improve their work conditions by reducing downtime and reducing waste and the inventory process (Warwood and Knowles, 2004; Gapp et al., 2008). Warwood and Knowles (2004) examined the implementation of 5S within 26 UK manufacturing firms; it was found that around 15 companies implemented the 5S approach. Rahman et al. (2010) asserted that 5S is an essential technique as it was found that it improved housekeeping, and maintained health and safety standards on the shop floor. Moreover, Rahman et al. (2010) proposed a systematic checklist for effective implementation of 5S on the shop floor. Top management support, employees' training and standardised procedures were highlighted as key factors for successful 5S implementation (Gapp et al., 2008; Rahman et al., 2010). Singh and Khanduja (2009) discussed the importance of 5S in improving the level of die repairing and die storage area, and Singh and Khanduja (2009) affirmed that 5S was helpful in terms of time saving during die readjustment activities which ensure that the product meets the quality standard.

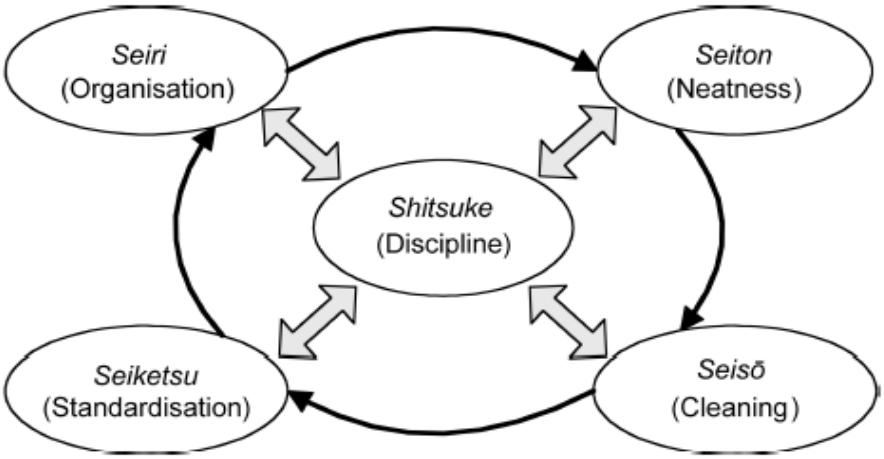

Figure 3.3 The 5S approach (Osada, 1991, cited in Kobayashi et al., 2008).

Bayo-Moriones et al. (2010) investigated the implementation of 5S in 203 Spanish manufacturing plants. The study revealed that firms that adopted the 5S approach were employing a QM system (ISO 9000); this confirmed that 5S is emphasising a continuous improvement culture of the workforce and increasing the level of their involvement, and the study findings also imply that the 5S approach leads to a reduction in the number of defective products and unproductive time. This result contributes to the increased application of the 5S approach for improving performance, particularly in quality and productivity (Bayo-Moriones et al., 2010). Sui Pheng (2001) undertook a comprehensive overview related to similarities between 5S and ISO 9001requirements for QM. The study discussed that the practice of 5S can help to achieve the fulfilment of ISO 9001 certification. Gapp et al. (2008) linked the 5S system to management approaches such as TQM, JIT or TPM which are considered as an integrated management approach rather than simple tools or techniques. Also, 5S is considered the baseline of the TQM approach as it initiates the standardisation process and improves quality performance (Gapp et al., 2008). Moreover, Warwood and Knowles (2004) suggested that 5S should work beside TPM, Kaizen and ISO 9001; thereby 5S practice emphasises better housekeeping and eliminating waste.

3.3.4 Kaizen

Kaizen term refers to the Japanese word which means continuous improvement (Imai, 1986). Kaizen is a philosophy that is related to lean manufacturing operations. Doolen et al. (2008, p.639) defined Kaizen as "a continuous and incremental improvement of all aspects of a company". Moore (2007) identified the major benefits of a Kaizen project as a high quality of finished product, reduced overall cost, improve delivery time. Earlier, Moore (2007) recognised major activities of Kaizen which are standardisation and elimination of waste, such as overproduction, inventory, rework/reject, motion, processing, waiting, and transport. Doolen et al. (2008) stated that Kaizen is considered as an events program which is helpful in order to meet business target objectives. A Kaizen method requires root-cause analysis to identify a potential problem instead of waiting for the problem to happen. Therefore, the Kaizen program team knows that the possible problem needs to be addressed in order to prevent it. García et al. (2013) discussed the reasoning of the abandonment of Kaizen – resistance to change from employees, lack of implementation, and lack of mentoring on the Kaizen program. On the other hand, García et al. (2013) stated the critical success factors of Kaizen implementation – motivation for the company's staff, commitment from senior management, and allocated resources, such as time and space. Kaizen ideally works with other management system – TQM (Imai, 1986; Saleem et al., 2012) and TPM (Ahuja and Khamba, 2007). Saleem et al. (2012) studied the relationship between Kaizen and TQM; the study affirmed that Kaizen is considered as a technique derived from the TQM approach for continuous improvement in terms of quality, productivity and manufacturing process. Ahuja and Khamba (2007) affirmed that Kaizen was helpful in terms of successful TPM implementation. The success of the implementation of Kaizen alongside TPM is recognised as it enhances the participation among employees across the firm, as a result of which cost-saving is achieved in respect to reductions in maintenance cost, defective parts and breakdown.

A number of published studies describe the role of Kaizen activities in improving and reducing changeover time (Moxham and Greatbanks, 2001; Patel et al., 2001; Bednarek and Scibiorek, 2011; Pellegrini et al., 2012). Bednarek and Scibiorek (2011) studied the improvement of changeover time through a Kaizen project. The Kaizen program took place over five days and involved different tasks and events which help to reduce changeover time. Moreover, observations and improvement of

changeover procedure were conducted during the course of the project. Eventually, the project reduced the original changeover time from 62% to 27% after first implementation. The study affirmed that developmental, consciousness and technical benefits were achieved during this project, where workers' engagement and work-out of Kaizen activities on a regular basis create an improvement in the changeover process. Pellegrini et al. (2012) studied the reduction of set-up time in a manufacturing company, where following extensive application of SMED and brainstorming session, the set-up time was reduced from 1 hour and 25 minutes to 47 minutes. The Kaizen program of monitoring set-up process was followed in order to ensure the process was standardised. Moreover, top management supported the Kaizen program and had a sense of shared responsibility to achieve successful implementation of the program.

3.3.5 Agile Manufacturing

Agility is the ability to respond quickly to unpredictable changes in the market or customer demands (Vokurka and Fliedner, 1998). Gunasekaran (1999) stated that agile manufacturing is naturally developed from lean manufacturing, because lean manufacturing emphasises elimination of waste and lead time where agile manufacturing is about becoming more flexible and responsive. Quinn et al. (1996, p. 858) defined agile manufacturing as "the ability to accomplish rapid changeover between the manufacture of different assemblies utilising essentially the same work cell". It is measured by the capability of the manufacturers to react quickly and become more responsive to customer demands for products and creating profits (Quinn et al., 1996). Agile manufacturing embraces the range of flexible production besides TQM, JIT and lean manufacturing. Zelbst et al. (2010) discovered the relationship between TQM, JIT and agile manufacturing. The study revealed that JIT was a necessary predecessor of TQM as it is strongly associated with it; also TQM was a necessary predecessor of agile manufacturing as they are also strongly associated. Thereby, the three management operations strategies build on one another. Inman et al. (2011) affirmed that the relationship between JIT and agile manufacturing was not significant; this is because agile subsumes the lean manufacturing paradigm (Inman et al., 2011). Zelbst et al. (2010) stated the TQM has a significant impact in a firm's ability to respond to customer needs, which is directly correlated to agility as it focuses on responding

to changes in customers' needs. However, Inman et al. (2011) found that agile manufacturing was positively associated with operational performance – customer service, quality and productivity.

Agile focuses on small lot-size production and is driven by changing customer demands. In order to be an agile firm, Vokurka and Fliedner (1998) posited that four competencies need to be merged - quality, dependability, flexibility and cost. Hallgren and Olhager (2009) discussed the difference between lean and agile manufacturing in terms of competitive intensity. The study found that lean manufacturing is strongly correlated with the cost performance of the manufacturing operations while agile manufacturing is strongly correlated with the flexibility of the product mix. However, both lean and agile approaches strongly impact the quality conformance, delivery speed and reliability (Hallgren and Olhager, 2009). Moreover, Dubey and Gunasekaran (2014) found that agile manufacturing was significantly positively related to advanced technology as it is considered an enabler to achieving demand; which helps manufacturing firms to respond rapidly to demand. On the other hand, Dubey and Gunasekaran (2014) discussed that a firm's culture and environment can be negatively associated with agile manufacturing as it can discourage employees from responding quickly to a customer's demand. This is because a firm's culture consists of human values, habits, beliefs and working knowledge that affect agile manufacturing performance.

Total agility means an immediate and quick changeover with no cost (Alves et al., 2012). Thus, it explains that fast changeover is a prerequisite for implementing agile manufacturing.

3.3.6 Value Stream Mapping (VSM)

According to Haefner, Kraemer, Stauss and Lanza (2014), Value Stream Mapping (VSM) is an efficient, simple (but not simplistic) methodology used to illustrate and redesign several value streams. Specifically, Ono (1988) argued that VSM methodology was coined by the Toyota Production System in the mid-80s and initially consisted of two major phases: it dealt with value stream analysis and design where the waste sources (within the production process) were reduced (Ono, 1988). Figure 3.4 is an example of VSM; the illustration shows the number of work stations and the movement of raw materials at each stage until they become a finished product. It shows the process time of the batch and changeover at the current manufacturing state. VSM is helpful in terms of identifying non-value added activities, recognising supplier capability, and planning for the future state.

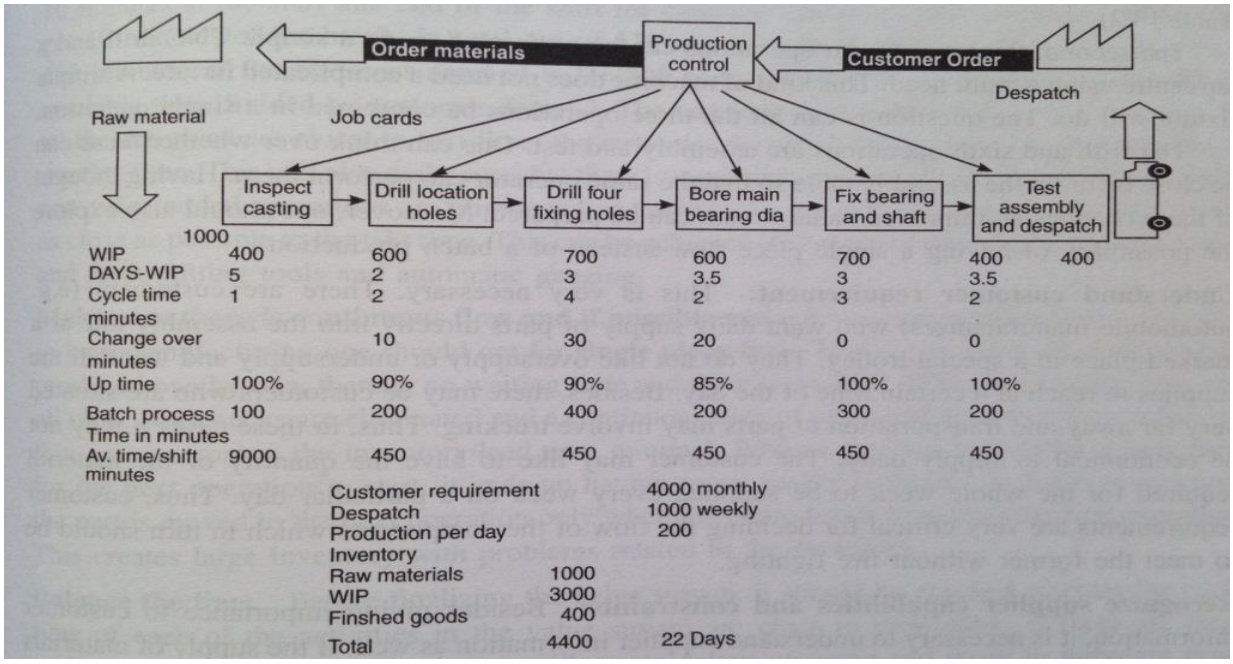

Figure 3.4 Value Stream Map (VSM) (Gopalakrishnan, 2010).

In addition, VSM is not only widely used in industrial practice but is also directly associated with lean manufacturing, reduced inventories and short lead time (Rother, 2003; Nash et al., 2011). Particularly, VSM is an appropriate methodology for lean manufacturing practices as it can approach the entire process flow in three-step methodologies (Sean and Gahagan, 2012). First, VSM generates a diagram showing the 'current state' on how the actual process operates. Second, a 'future state' map is also created to recognise the waste's root causes through a lean process flow to identify the financial impact of the process.Third, an implementation plan is created to achieve any possible project objectives (Rahani and al-Ashraf, 2012). VSM quality defects are only addressed in a very basic manner and its characteristics, inspection processes and present quality loops are not considered in the visualisation (Haefner et al., 2014).

Besides, VSM is associated with changeover practice as well as set-up time. According to Lee-Mortimer (2006) VSM can assist in reducing the lead time and as a result the manufacturers and/or producers can achieve an effective quick changeover practice. Practically, this can be achieved in five steps. First, several reduction concepts are analysed to a group of employees. Second, each set-up activity is timed and documented. Third, the second-step results are shown to the employees. Fourth, the set-up activities are analysed and separated into two categories, internal and external. Fifth, several standardised operating procedures are required to implement the improvements. Lee-Mortimer (2006)

discussed the usage of VSM in a case study of the electronics industry within the UK. A VSM exercise was implemented in the study and helped to identify the internal lead time which was about ten days and the added value to the customer was about 41.5 minutes. In other words, by assisting the setup reduction, VSM eliminates the lead times and the defects while concurrently increasing capacity, productivity and flexibility (Lee-Mortimer, 2006).

3.3.7 Manufacturing Strategy

This section discusses the different aspects of manufacturing and operation strategies that are associated with manufacturing changeover in the literature. The following sub-sections are discussed as follows:

Make to order (MTO) & Make to stock (MTS)

According to Zaerpour et al. (2008), Make-to-order (MTO) is an organisation's operation strategy allowing clients to purchase goods that are tailored to their specifications. It can be considered as a time-consuming strategy, since it manufactures the end-product only when clients place their order. Thus, clients must wait until their product is manufactured. However, MTO has the benefit of allowing more flexibility during the production stage in terms of the product customisation (Zaerpour et al., 2008). Another organisation's operations strategy is the Make-to-stock (MTS) strategy which is used to match the client demand forecasts with the production stage; in other words, MTS forecasts identify the stock volume which has to be produced. The efficiency of this strategy (in regards to cost reduction) depends on how accurately the forecast of the product's demands is conducted; thus avoiding any excessive inventory. However, the MTS dependency on the demand forecasts' accuracy is one of its main drawbacks for many organisations today (Olhager and Prajogo, 2012). Taking into account the fact that lean manufacturing is related with an integrated socio-technical system which eliminates waste (Shah and Ward, 2007) and that lean manufacturing practices are internal tools aiming to create finished goods based on the client's preference and demand pace with little or no waste, MTS is directly associated with lean manufacturing as this particular operations strategy literally mean to produce goods for stock based on demand forecasts in order to eliminate waste and reduce costs (Olhager and Prajogo, 2012).

Lastly, MTO and MTS are also associated with set-up time and changeover practice. On the one hand, some companies are producing their products to order (MTO companies) or producing their products to stock (MTS companies), and on the other hand there are other companies maintaining a middle ground (between the two). In either case, the production environment is characterised by changeover practice and set-up times among the consecutive items' production, since these two usually impact MTO versus MTS decisions. Thus, making a product to order in such an environment might reduce inventory costs for that product; however, at the same time it might increment the lot size and inventory costs for the products made to stock (Rajagopalan, 2002; Olhager and Prajogo, 2012). In addition, this can lead to a complex trade-off as the lead times are increased because of the congestion effects; resulting in a need for higher safety stocks for MTS products and lower service levels for MTO products. A viable solution that could be applied to counter such issues is the creation of an effective and efficient heuristic through the development and implementation of a non-linear, integer programming formulation (Rajagopalan, 2002).

Trade-off strategy

Trade-off was originally introduced as a way to understand the relationships among the components of competitive advantage, such as cost, flexibility, lead time, quality and delivery (Greasley, 2013); however, companies cannot perform all these manufacturing advantages simultaneously. Da Silveira and Slack (2001) described trade-off as operational compromises routinely made by managers. Moreover, improved performance on one factor can be achieved by reducing performance on other factor (Mapes et al., 1997). McIntosh et al. (1996) affirmed that trade-off occurred against changeover time in order to improve production and quality outcomes.

3.4 Manufacturing Changeover

Changeover in the context of the manufacturing industry is considered vital in enabling firms to respond promptly and to fulfil customer requirements. Rapid changeover enhances productivity and reduces lead time (Shingo, 1985). McIntosh et al. (1996) indicated the impact of changeover on performance measures such as scrap, efficiency and reliability. In addition, it has been observed that if quality is not addressed adequately during the set-up period, it will lead to an increase in the run-up period (Mileham et al., 1999). The authors distinguished between the set-up and run-up periods during a changeover time. McIntosh et al. (2001a, p.5) defined run-up period as "when production is commenced again and continues until consistent output at full capacity occurs". Van Goubergen and Van Landeghem (2002, p. 205) provide a definition for set-up as "the elapsed time between the last product A leaving the machine and the first good product B coming out". Brown (2001) provides an example of manufacturing changeover in Honda Motor Company Ltd., a world-class manufacturing company of automobiles and motorcycles. In September 1995, Honda launched an assembly line for the 1995 Honda Civic model. However, every twenty-second car produced was a 1996 Honda Civic model entered in the production line, thereby facilitating a fast changeover. Therefore, Honda saved 30% of the manufacturing cost of the 1996 Civic as compared to the 1992 model change; it also provided the workers with valuable experience in effectively implementing manufacturing changeover. This example provides an insight into the manner in which Honda implemented a rapid changeover. According to Elmaraghy and Wiendahl (2009), rapid manufacturing changeover requires the following prerequisites related to a dynamic environment: resources, plant structures, manufacturing layout and organisational concepts. According to Koss (2011), the reasons for implementing manufacturing changeover are also of significance; for example, a changeover in the beverage industry that comprises lost production units and is characterised by decreased asset utilisation, wastage of raw material and inefficient use of labour would cause loss of time and incur higher manufacturing costs.

Shingo (1985) developed the Single Minute Exchange of Die (SMED) method in order to reduce set-up time during changeover; this is applicable to any factory and any machine. The main goal of the SMED method is to identify the waste and non-adding value tasks while performing changeover. The

SMED concept has three stages of implementation; these stages are discussed in the Shingo conceptual model, as shown in Figure 3.5. SMED was used by Toyota plants and considered as one of the principle elements of TPS. Shingo (1985) distinguishes between internal and external setup during manufacturing changeover activities. Internal setup is defined as the activities that can only be performed when a machine is stopped (Shingo, 1985). Besides that, external setup is defined as the activities that can be performed while a machine is running (Shingo, 1985). As shown in Figure 3.5, it is highly important to address the preliminary stage between internal and external setups. This stage creates a sense of urgency by understanding which and what activities could be external or internal in set-up time. Next stage is separating between internal and external activities in set-up which is important for implementing and achieving SMED technique. Shingo (1985) suggested that during the external setup in the stage-one checklist, performing function checks and improving transportation of parts can be used in the set-up time. Stage two involves converting internal set-up to external set-up by reviewing operations again whether any tasks are incorrectly presumed to be internal. It is extremely important to discover a proper way to transfer these tasks to external set-up. Standardisation of set-up procedure can be used during the second stage. Finally, the third stage involves streamlining all aspects of the set-up operation, which means that a detailed analysis of each element operation is undertaken. This stage can be called an improvement stage and an alternative way to reduce internal set-up time. For example, Toyota Motor Company reduced internal set-up time for making a bolt from eight hours to 52 seconds. Besides that, Mitsubishi Heavy Industries reduced internal set-up time of a boring machine form 24 hours to two minutes and forty seconds (Shingo, 1985).

Criticism has been directed at the SMED method that it is restricted to use only on press systems that relate to an exchange of dies (McIntosh et al., 1996). However, Trovinger and Bohn (2005) discussed the use of the SMED methodology with the auxiliary support of Information Technology (IT) in circuit board electronics assembly; the study achieved an improvement of 80% on reduction of original set-up time, labour saving and quality improvement. Shingo (1985) claimed that SMED is an approach that can be applied in a factory to any machine.

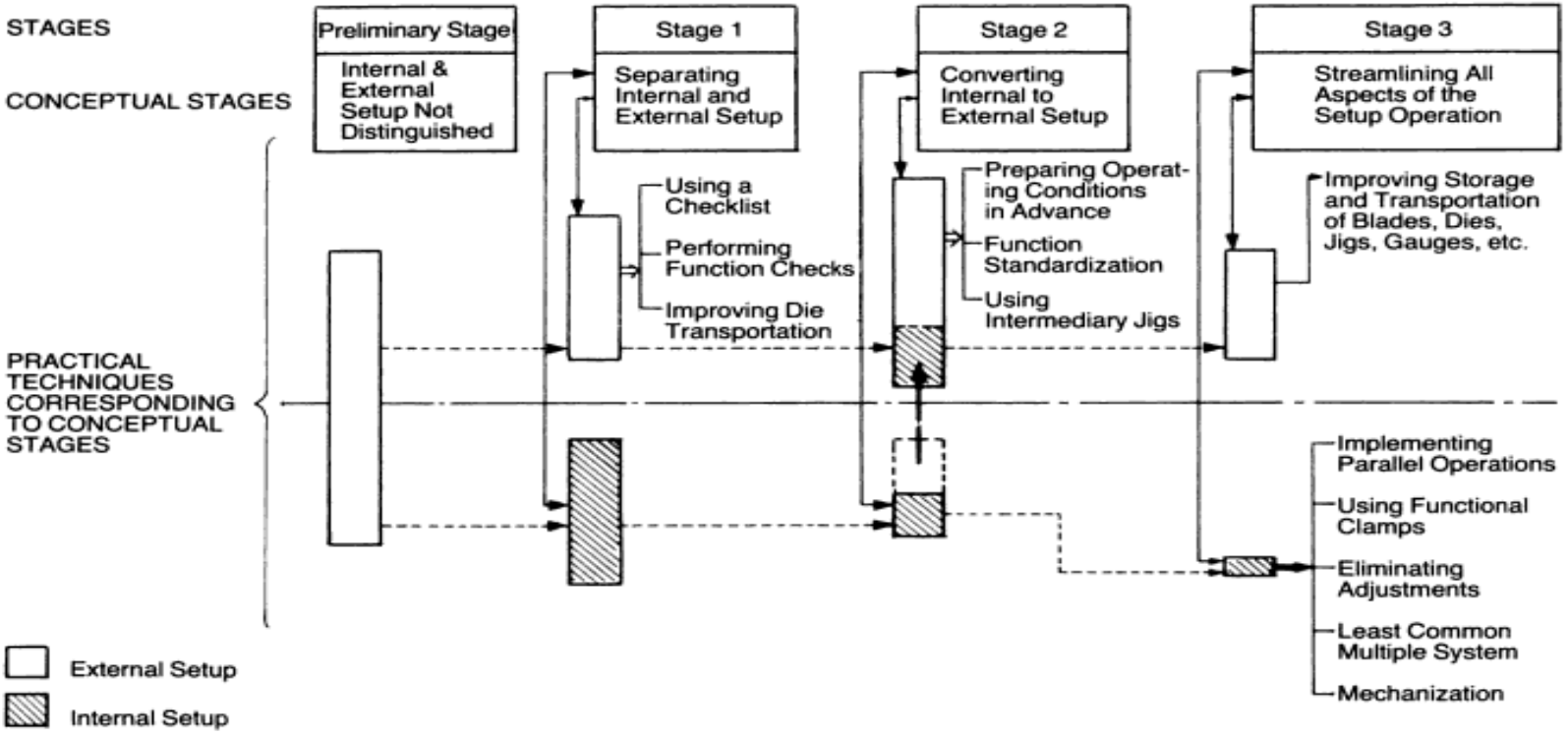

Figure 3.5 Conceptual stages of SMED (Shingo, 1985).

Singh and Khanduja (2009) examined the SMED technique by conducting a case study in the foundry of a small and medium enterprise (SME) in India. The study revealed a 48% reduction in the amount of time taken for changeover of different die parts in the casting machine. The authors suggested that QM tools, such as the Pareto chart and cause-and-effect analysis, help to improve changeover time. Accordingly, QM tools offer an aid to recognise the eliminations, changes and externalisation of set-up activities, and it can be incorporated and developed during the set-up process for better changeover performance and throughput time. McIntosh et al. (2007) studied the improvement in manufacturing changeover by applying the SMED technique. The study emphasised the improvement of changeover by reallocation of tasks and employment of the SMED technique. The summary of the literature review on the correlation between the management approaches –TQM, JIT, TPM, 5S, Kaizen, Agile and changeover/set-up time - is presented in Table 3.1.

Table 3.1 Summary of the relationship between approaches (Source: author).

Management Approach	TQM	JIT	TPM	5S	Kaizen	Agile	Ref.
TQM: an approach to improving competitiveness, effectiveness and flexibility of a whole organisation (Oakland, 2003).							Sec. 2.3
JIT: a production strategy that attempts to achieve excellence in manufacturing by reducing set-up times and lot sizes (Mehra and Inman, 1992).	✓						Sec. 3.3.1
TPM: a maintenance approach that optimises equipment effectiveness and eliminates breakdowns (Ahuja and Khamba, 2007).	✓	✓					Sec. 3.3.2
5S: a system to reduce waste and optimise productivity and quality through maintaining an orderly workplace and using visual cues to achieve more consistent results (Bayo-Moriones et al., 2010).	✓	✓	✓				Sec. 3.3.3
Kaizen: a continuous and incremental improvement of all aspects of a company (Doolen et al., 2008).	✓		✓	✓			Sec. 3.3.4
Agile: the ability to accomplish rapid changeover between the manufacture of different assemblies utilising essentially the same work cell (Quinn et al., 1996).	✓	×	×	×	×		Sec. 3.3.5
Changeover/ Setup time: the complete process of changing between the manufacture of one product to the manufacture of an alternative product (McIntosh et al., 2001a).	✓	✓	✓	✓	✓	✓	Sec. 3.4

✓: indicate the relationship. ×: indicate no relationship.

The SMED methodology has been widely described in existing literature on changeover for reducing set-up time as well as improving the changeover process (Moxham and Greatbanks, 2001; Lee-Mortimer, 2006; McIntosh et al., 2007; Singh and Khanduja, 2009) for productivity improvement (Ani and Shafei, 2013). Carrizo Moreira and Campos Silva Pais (2011) discussed the SMED implementation improvement on a firm's financial performance. The implementation was saving 2.1% of sales volume which equated to around €363,000. Table 3.2 shows the time spent during the set-up process phase and it can be seen that the tuning of parameters accounted for most of the time. As a result, there was a lack of coordination between workers, delay in receiving raw materials on job location, and lack of set-up procedure. Therefore, SMED was implemented for separating and converting internal activities from external operations; the firm achieved reduction on original changeover time after implementing SMED of around 44%.

Table 3.2 Percentage of time spent during set-up (Carrizo Moreira and Campos Silva Pais, 2011).

Set-up process phase	**Percentage of time**
Take out old die	25%
Insert new die	32%
Prepare new die	8%
Tuning new parameters	35%

Benjamin et al. (2013) examined the SMED implementation in order to reduce and eliminate small stop loss. Firstly, internal and external activities of the company were differentiated in order to separate and convert internal activities to external activities. The SMED technique was implemented and the improvement of elimination of overall equipment effectiveness was achieved at 2.08%. Moreover, Nystha et al. (2013) studied the implementation of the SMED in the pressing machine of the production line for quick changeover. It was suggested that the current situation of changeover time and process was analysed; following this it was found that the internal and external activities need to be identified in order to implement the SMED technique. As a result, the firm segregated and shifted the internal to external activities, based on which changeover process was standardised. The study reduced the original changeover time by 66% and increased the availability of the machine by 19% (Nystha et al., 2013).

McIntosh et al. (2001a) discussed the impact of changeover improvement into Economic Order Quantity (EOQ). Kumar and Suresh (2009, p. 94) defined EOQ as "the size of order which minimises total cost of carrying and cost of ordering". Large-lot production reduces costs that are associated with long set-up time and increased costs related to inventories (Shingo, 1985). There are two basic costs that need to be considered; inventory cost and order cost as shown in Figure 3.6. In essence, EOQ is balanced between these two costs. Ordering costs are related to the efficiency of equipment that is being affected by time lost during changeover. However, inventory costs are related to holding works and keeping items on hand, such as storage and handling (Kumar and Suresh, 2009). As a result of changeover improvements in quality and time reduction of changeover practice, order cost and EOQ will be reduced as (McIntosh et al., 2001a). The improvement of the changeover process and time is positively associated with the EOQ model of cost reduction. Reducing inventory level leads to an increase in quality performance. The probability of damage to products during storage and handling will reduce (Flynn et al., 1997). The emphasis on improvement of changeover process and time is associated with inventory level and quality performance.

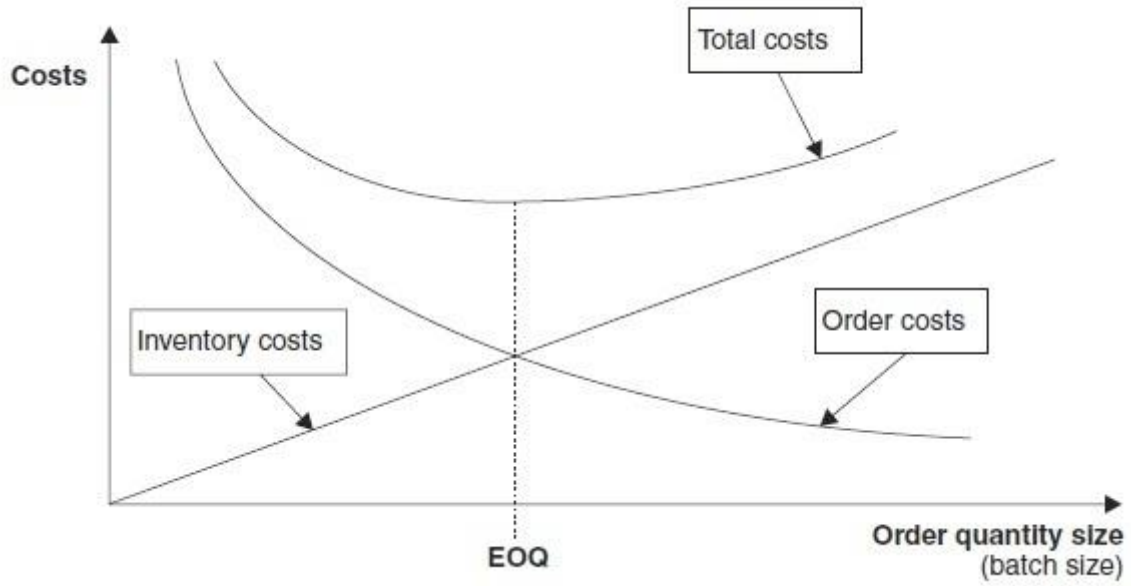

Figure 3.6 Economic Order Quantity (EOQ) (Kumar and Suresh, 2009).

In addition, the benefits of reducing set-up time are increased production speed, faster changeovers and increased competitiveness (Allahverdi and Soroush, 2008). However, the importance of an improved changeover can be highlighted by ensuring line reliability and reduced rejected products.

Klopsic and Houser (1997) conducted a study on improving line productivity and reducing downtime losses during rapid changeover in an aluminium foil and styrene packing plant. The company aimed to increase the output of quality coated products by 25% in six months. In order to improve the productivity, the company had to identify specific priority areas of opportunity for improvement. The company used videotaping for recording changeover process in both shifts; the videotape was helpful in terms of recognising the participation between workers and observing the problems that emerged during the changeover process (Klopsic and Houser, 1997). As a result, it found that there are three types of changeover in the company that needed to be improved: the first type was the changeover in solving the problems that occurred during changes, the second type was the changeover related to procedure, and the third type was a change in the practices of operators per shift. The company eliminated these three types by standardising and revising the changeover process in order to reach to the optimum practice. Moreover, employee involvement was a key for successful changeover improvement in terms of providing valuable suggestion (Klopsic and Houser, 1997). Eventually, the firm achieved its objective of producing a higher quality product. Reik et al. (2006a) identified the generic framework for improving changeover activities in terms of the 4Ps—people, practice, process and products—as shown in Figure 3.7. The 4Ps have been identified as a major influence on changeover activities and changeover performance. This approach can be described in the following manner: people need to be trained and motivated in order to achieve best practices in the production of products. Typically, a product itself may need to be redesigned or the process may need to be revised to enable better changeover.

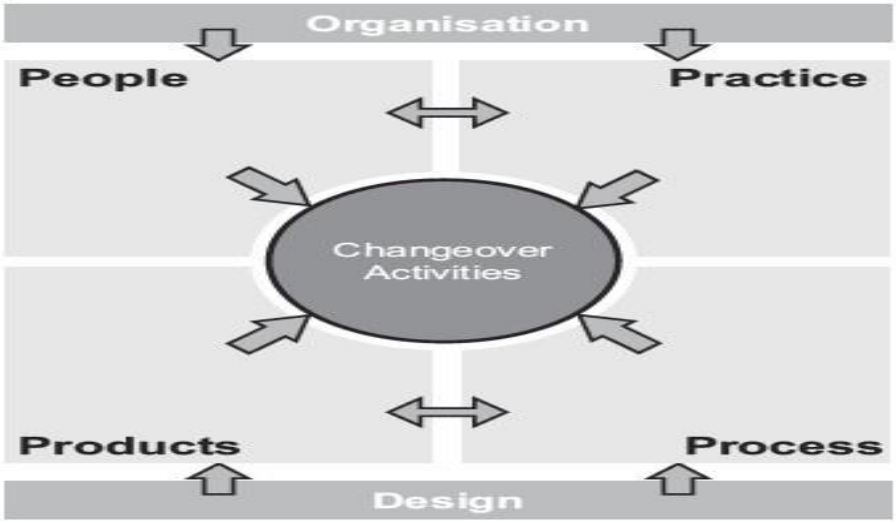

Figure 3.7 The 4Ps of changeover activities (Reik et al., 2006a).

A majority of existing studies have focused on changeover time reduction and this is often termed the set-up reduction time (SUR) (Gilmore and Smith, 1996; Patel et al., 2001; Van Goubergen and Lockhart, 2005; Allahverdi and Soroush, 2008; Bharath and Lokesh, 2008). It can be defined as the total time that a machine remains idle with operators when there is a change in the process for the next job. A reduction in set-up time could result from improvement of production flexibility without affecting production capacity. Patel et al. (2001) examined four precision component manufacturing companies; their study aimed to reduce set-up time by applying the mistake proofing (Poka Yoke) method, which considers quality control tools for achieving zero defects. It was found that employee participation and suggestions as well as management support were important in reducing setup time. The study proved that QM tools, improvement meetings and Statistical Process Control (SPC) all help to reduce set-up time. Patel et al. (2001) affirmed that the integration between QM tools and changeover process eventually leads to an improvement in product quality and reliability of the changeover process. Thus, it is evident that most existing studies focus on set-up time reduction and set-up period. However, the run-up period can also significantly affect changeover—for example, the run-up period can increase changeover time if the set-up process has not been addressed properly (Mileham et al., 1999; 2004). Therefore, the reliable and high quality of the set-up process has a direct impact on run-up, so it is essential to improve the entire changeover process rather than focusing only on one set.

Colour coding is one of the common techniques that are highlighted in the literature for providing a quick changeover process (Mans, 2000; McIntosh et al., 2001a; Standard-Knapp, 2006). Colour coding is defined as guidance for quickly changing parts during changeover and to make the production system extremely operator-friendly (Mans, 2000). Colour coding is an increasingly important technique that helps its users easily identify change parts (McIntosh et al., 2001a). Arizona Beverages reduced changeover time by 50% while implementing the colour coded and friendly process of changeover (Standard-Knapp, 2006). Since the Arizona plant produces beverages in different sizes, frequent changeover was required. Moreover, Mans (2000) affirmed that colour coding parts has a tremendous value for making changeover reliable. Colour coding was used for identifying

bottle size during changeover and that helped to reduce set-up time by an hour and a half within Jack Daniel's bottling factory (Mans, 2000).

A rapid changeover improvement is recognised as a requirement of a firm's responsiveness for flexible and small-batch manufacturing (McIntosh et al., 2007). An improved changeover performance allows a firm to manufacture small-size batches, reduce inventory cost and reduce cycle time (McIntosh et al., 2001a). Batch production is defined as "the form of manufacturing in which the job pass through the functional departments in lots or batches and each lot may have a different routing" (Kumar and Suresh, 2009, p. 5). The machine set-up is required for the production of batch size and changing set-up is a prerequisite for next batch size. This type of production requires a frequent change in set-up machine for the production line; therefore flexibility needs to be accommodated (Kumar and Suresh, 2009). By improving the set-up process in batch production, productivity and quality performance would be increased.

Another aspect of manufacturing changeover that has been addressed in existing studies is the design of changeover for ensuring high performance (McIntosh et al., 1996; Mileham et al., 1999; Van Goubergen and Landeghem, 2002; Reik et al., 2006a; 2006b). Van Goubergen and Landeghem (2002) discussed the design rules for efficient work methods during set-up time; a list of design rules was proposed in terms of technical practice for improving working methods during set-up time. Recent studies have been published on the related subject of the improvement of the outcomes after the changeover (Diaby et al., 2013; Karasu et al., 2014). These studies determine the optimal changeover time and process for reducing defect rate of the outcomes. Diaby et al. (2013) implemented a mathematical model in order to address the problem of quality level and set-up reduction in the JIT environment and two linear models were generated for identifying and improving the outcomes. However, Karasu et al. (2014) proposed the Taguchi model for improving manufacturing changeover in plastic injection in order to ensure that the first product meets the standard. The reason for employing the Taguchi model was to minimise the quality defects, as the Taguchi model of loss function is for determining the level of quality products (Basu, 2004). Twenty six trial production runs were conducted in order to produce of the accepted standard product. The study suggested implementing the SMED technique in terms of reducing changeover time. With the application of the

Taguchi model, the trail run of changeover was reduced to 18 times, thus reflecting an improvement of around 30% and a reduction of 15 minutes of changeover time. The summary of the literature review on improvement of manufacturing changeover improvement is presented in Table 3.3.

Table 3.3 Literature review of manufacturing changeover and improvement of set-up time (Source: author).

Category of literature	Authors	Year	Methodology	Major Finding
Set-up time reduction (SUR)	Gilmore and Smith	1996	Empirical	The study was conducted on a tablet manufacturing pharmaceutical plant by using action research; Set-up time was reduced through improving machine utilisation.
	Mileham et al.	1997	Description	The paper reviewed the potential of SUR within TPM. It was found that TPM has a role in reducing changeover losses. The paper concluded that TPM does not recognise wider implications that contribute to changeover performance.
	Patel et al.	2001	Empirical	The study examined precision manufacturing firms use of SUR and mistake-proofing methods. It was found that the studied companies were reducing set-up time by teamwork, standardisation methods, new machinery technology, empowerment, work study and automatic tool changers. Only a few emphasised the use of SMED methods.
	Van Goubergen and Lockhart	2005	Description	The study developed a framework for evaluating and improving changeover from the ergonomics and human factor points of view.
	Allahverdi and Soroush	2008	Description	The study reviewed 21 research papers regarding the subject of scheduling with set-up times and cost. It was found that different scheduling, such as single, parallel and flow shop scheduling has an impact on set-up time/cost.
	Morgado et al.	2013	Description	The study identified tools for diagnosing set-up performance indicators, such as total time, waiting time, handling and cleaning time. It aims to provide improvement opportunities in the set-up process.
Improvement tool (SMED)	McIntosh et al.	2000	Empirical	The paper discussed the role of SMED methodology in separating internal tasks from external tasks. It was found that SMED can streamline the current task and seek for improvement if applied effectively.
	Moxham and Greatbanks	2001	Empirical	The paper discussed the implementation of SMED within the textile operations industry. It was found that the set-up time reduction is considered as a prerequisite of SMED implementation. Also, team working and visual factory control method can lead to correct implementation.
	Singh and Khanduja	2009	Empirical	The study provided guideline to prepare the standardised set-up procedure in foundry SMEs. SMED was used for eliminating unwanted activities.

Improvement tool (SMED)	Kusar et al.	2010	Empirical	The study looked at reducing setup time by introducing a SMED workshop and achieved reduction on time within 50%.
	Alexa	2011	Description	The study reviewed the SMED method and its benefits for the manufacturing industry as offering a competitive advantage.
	Mohamad et al.	2011	Empirical	The study addressed set-up time reduction in an automotive battery assembly line. The SMED technique was used and saved around 47% of set-up time.
	Moreira and Silva Pais	2011	Empirical	The study provided a case study implementation of the SMED method. It was found that SMED implementation eliminated waste and non-added value by saving 2% of sales volume.
	Benjamin et al.	2013	Empirical	The paper used a case study approach in order to demonstrate the application of the SMED technique. It was found that SMED was useful in tackling big losses and OEE.
Design for changeover (DFC)	McIntosh et al.	1996	Description	The paper discussed the role of design in changeover improvement. It was found that design can be used to fully automate changeover and it was too difficult to sustain best practice.
	Mileham et al.	1999	Empirical	The paper described the rules of design for changeover. A case study approach of action research in a packaging firm was taken. The firm reduced changeover time to more than 50% and that impacted on the firm realising a saving £45k that contributed to increasing the revenue.
	Van Goubergen and Landeghem	2002	Empirical	The study discussed the rules of designing for changeover that contribute to reduce set-up time.
	Reik et al.	2006b	Empirical	The paper provides a formal design for changeover methodology through identification of improvement opportunities. The main aim is to develop a generic method to design flexible and responsive manufacturing equipment.
	Reik et al.	2006a	Description	The paper provides a generic framework for improvement changeover performance. It discussed the change drivers, change elements and changeover equipment design.
	Singh and Khanduja	2011	Empirical	The study aimed to reduce set-up time by redesigning the die and tooling. The reduction was around 25% to 35% in the design phase.

Changeover improvement	Klopsic and Houser	1997	Empirical	The study was conducted at Tenneco Food Company; the improvement project was suggested for improving the quality coated product by 25% in six months. The company achieved that target through employee involvement and standardised changeover process between crew shifts. Videotaping of changeover process was used for training purposes; the changeover time reduced by 15 minutes.
	McIntosh et al.	2001b	Empirical	The paper used a case study method in order to identify whether the maintenance activity can influence changeover performance. The study affirmed the integration between maintenance and changeover performance.
	Culley et al.	2003	Empirical	The paper examined factors that contribute to sustaining changeover improvement. Action research was employed in the study; the revisited sites have investigated over 10 years.
	Mileham et al.	2004	Empirical	The study investigated the impact of run-up in rapid changeover. Action research was employed for case study approach. The study found that setup parameters have an impact on run-up.
	Owen et al.	2007	Description	The paper sought to identify a complexity of changeover problems and the scope of improvement opportunities. The study provides a generic framework for changeover improvement. a
	McIntosh et al.	2007	Empirical	The paper assessed retrospective improvement of changeover performance. It was found that task reallocation and preparation need to convert at external time.
	Singh and Khanduja	2010	Empirical	The study affirmed that the DMAICT Six Sigma approach has reduced die changeover time in the light alloy foundry.
	Karasu et al.	2014	Empirical	The study proposed the Taguchi model in the trial run of changeover in plastic injection, in order to ensure the first product is correct. The total trial error decreased to 18 trials from 26 trials, saving 15 minutes.

3.4.1 Difficulties associated with changeover practice

Some studies identified difficulties that occurred during manufacturing changeover and set-up period (McIntosh et al., 1996; Singh and Khanduja, 2009; 2011). There are certain factors that can negatively impact changeover performance and they are:

- *Measurability of changeover data*

Changeover is a repeatable process that occurs on a regular basis in manufacturing. Singh and Khanduja (2009) and McIntosh et al. (1996) discussed that firms usually collect their data as normal routine process without considering the accuracy of the data. Culley et al. (2003) affirmed that an error occurred during recording manual changeover data. This makes it difficult to improve activities that are associated with understanding the actual improvement and progress.

- *Monitoring the set-up period only*

Many firms only monitored the set-up period without paying any attention to the run-down and run-up periods (McIntosh et al., 1996). The run-up period can also significantly affect changeover—for example, the run-up period can increase changeover time if the set-up process has not been addressed properly (Mileham et al., 1999; 2004). In order to initiative the improvement of changeover as a whole run-down, set-up and run-up period need be monitored effectively.

- *The linkage between changeover data and performance data*

There is a lack of awareness of a quantitative technique that can help to reduce and improve changeover time (Singh and Khanduja, 2009). Quality and production output data of scrap, rework and defect product need to be linked with changeover time in order to improve the output of the quality performance. According to McIntosh et al. (1996), some companies would increase changeover time as a trade-off against improved quality rates or productivity. Therefore, the association between these data will increase the quality rates and ensure that the outcome will meet production standards.

- *Ineffective methodology of conducting changeover*

Less emphasis is being paid to the changeover procedure which causes excessive movement and activities during changeover (Singh and Khanduja, 2011). Lack of changeover procedure creates

complexity and unclear scope of the changeover process lead to inefficiency and lack of clarity, so the changeover procedure needs to be revised on a regular basis and upgraded if any improvements are applied.

3.5 Research gap

Having reviewed the Quality Management concept in Chapter 2 and manufacturing changeover in the current chapter, the implementation of QM has a direct impact on various aspects of firm performance, such as financial, quality and operational aspects, which are summarised in Table 2.3. Changeover has an influence on a manufacturing firm's performance which contributes to the quality of finished products. The changeover process needs to be addressed appropriately, initially to reduce rework, defect and scrap products (McIntosh et al., 1996; 2001a). The relationship between quality performance and the changeover process significantly impacts the performance of firms, as discussed earlier. Chapter 2 discussed that there is a positive relationship between QM and manufacturing flexibility. Furthermore, it was indicated that changeover performance has an influence on manufacturing flexibility; manufacturing flexibility is a key for evolving firms to respond promptly to customer demands in a high-velocity manufacturing environment. However, most of the research has focused on attempts to reduce changeover and set-up time while only a few have focused on the improvements of the changeover process. Studies on the effect of quality and reliable setup process of manufacturing changeover operations are rare; therefore, further research on higher quality of changeover during the set-up process is necessary (Culley et al., 2003). The review of the literature has identified the research gap, and the need to examine the impact of a high quality and reliable changeover process on a firm's performance, such as productivity and quality outcome. There is a lack of a conceptual model that would aid firms in determining a quick and high quality changeover process. In addition, there is also a lack of research on the topic of lean manufacturing and on the implementation of effective manufacturing changeover in Saudi Arabian firms, which are the focus of this work.

3.5.1 The proposed conceptual model of high quality and reliable changeover process

Robson (2011, p. 67) defined a conceptual model as "a representation in the form of a diagram of the important elements involved in the research topic and the relationship between them". Easterby-Smith et al. (2008) discussed the need for conceptual model in research; they stated that it helps to guide the researcher and keeps the investigation focused on specific subject. Developing a framework or conceptual model helps the researcher to understand and answer the research question (Robson, 2011), and also reflects the relationship between the factors and variables that are to be studied in the research. The conceptual model has two major strengths in a research study:

- It explains clearly the research statement and the purpose of the research.
- It explains the research based on the existing knowledge.

An extensive literature review was used to develop a conceptual model for this study. A conceptual model of the changeover process was developed for the implementation of a high quality and reliable process on the shop floor during changeover. Figure 3.8 illustrates the proposed conceptual model for prompt setup process implementation during manufacturing changeover. This model is based on the preceding literature review and empirical literature on the changeover subject. Brown (2001) discussed the changeover to a new product in the Honda Company. This provided an insight into considering the changeover process in new product development. The conceptual model has a matrix on the left that contains the different procedures related to changeover related to both products and processes. The conceptual model highlighted the different stages of changeover in terms of the following aspects:

- Original product and original process
- Original product and new process
- New product and same process
- New product and new process

The model proposes the changeover implementation in terms of a high quality process from the different aspects of People, Process, Quality and Infrastructure. People and Process themes were identified in the literature (See Figure 3.7).

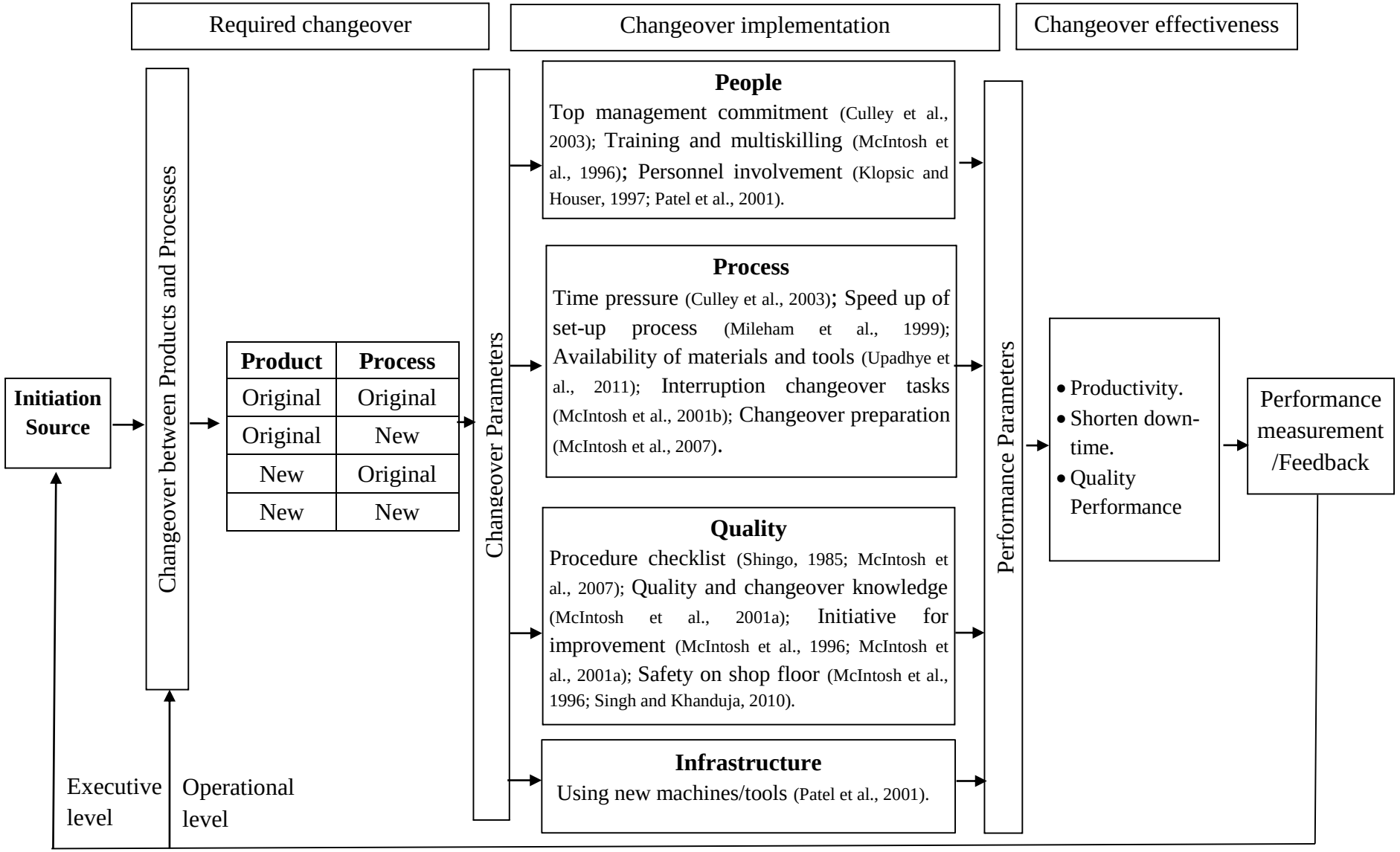

Figure 3.8 Proposed conceptual model of high quality and reliable changeover process (Source: author).

In addition, Quality and Infrastructure were proposed in the conceptual model as the main aim of the study to establish how to implement a high quality and reliable changeover process. Moreover, the factors are directly related to the changeover performance as indicated from the literature. The model aims to guide the research and then become a tool to aid firms in implementing a high quality and reliable changeover process that will optimise product outcomes in terms of reducing scrap, rework and defects. Karasu et al. (2014) discussed the need for confirming the changeover process as the average runs of having the first good part after the changeover was needed to conduct 26 productions runs in the plastic injection unit. The quality of finished products affects overall firm performance in terms of productivity and changeover (McIntosh et al., 2001a). Consequently, improved quality is positively associated with productivity that, in turn, enhances firms' competitiveness (Deming, 1982; Fisher, 1992; Terziovski, 2006) and operational performance (Maani et al., 1994). Better changeover practices enhance productivity (Shingo, 1985), reduce the production run (Singh and Khanduja, 2011) and improve quality (McIntosh et al., 1996). Moreover, prompt analysis of feedback and associated product performance significantly improves quality (Bolwijn and Kumpe, 1990). The conceptual model helps to assess changeover effectiveness in order to improve a firm's output. The four main proposed factors of the changeover process are described below:

People:

The human element is engaged in the changeover process as indicated by Reik et al. (2006a); people's involvement and motivation has an impact on changeover process, which is recognised different sub-factors:

- Top management commitment is required to provide time and resources and to initiate improvement for efficient manufacturing changeover and its sustained implementation (McIntosh et al., 2001a; Culley et al., 2003). Management support encourages shop floor activity by ensuring required improvement in the changeover process. In the context of this study, managers have the capability to facilitate the changeover process. Culture issues in the workplace pave the way for receptive change and further improvement in the changeover process (McIntosh et al., 2001a). Managers play a crucial role in changing the firm culture into one that facilitates change by creating an environment of continuous improvement.

- The requirement of training and multi-skilled operators; training is important in facilitating the changeover process with highly multi-skilled workers (Shingo, 1985; McIntosh et al., 1996; McIntosh et al., 2001a; Culley et al., 2003). Lee-Mortimer (2006) affirmed that a two-day training workshop of SMED implementation was helpful to disseminate and recognise an improvement area of changeover practice within electronic manufacturing in UK. The workshop helped the firm to identify some issues related to changeover practice. However, the lack of defined responsibility for the changeover element and different processes was found between shifts.
- Personnel involvement on the shop floor leads to the provision of valuable suggestions to the firm; regular meetings would be useful to enhance employee contribution towards establishing a better changeover process (Klopsic and Houser, 1997; Patel et al., 2001).

Process:

The process that is involved in changeover practice is indicated by Reik et al. (2006a); this research has recognised different sub-factors which are as follows:

- In manufacturing changeover, time required for finishing the changeover and pressure to deliver affects the quality of the changeover process (McIntosh et al., 2001a; Culley et al., 2003). If production is scheduled with tight time intervals for the changeover process; this can create pressure on the firm. In order to observe the pressure to deliver changeover, the data of changeover time and process must be documented in order to analyse the performance of the changeover (Culley et al., 2003).
- Speeding up the set-up process can increase changeover time during the run-up period and that can have an effect on quality rate of accepted products (Mileham et al., 1999; 2004). According to Cakmakei (2009), the changeover procedure needs to be initiated and identified by firms in order to standardise the process.
- Availability of materials and tools on job resources. Upadhye et al. (2011) examined the lean manufacturing implementation of a medium-sized firm in India. The study reported that in 6% of working time, the machine had to wait for raw materials due to transportation delays. Also

delays occurred on receiving material from the previous manufacturing process due to machine breakdown.

- Interruption in the sequence of changeover tasks discussed by McIntosh et al. (2001a; 2001b). If the operator is distracted by taking another job or by waiting for material to be delivered during the changeover process, this can result in a repeated and improper set-up process that impacts on run-up period. Also, the disruption of a steady state of manufacturing can directly impact on product quality (McIntosh et al., 2001b).
- Changeover preparation before the setting-up of the machine (McIntosh et al., 2007; ElMaraghy and Meselhy, 2009). Shingo (1985) emphasises planning with using the SMED method, as it can reduce the set-up time during changeover by separating and recognising internal and external activities that will allow time for arranging the next job. The effectiveness of implementing tool modification in the machine and the colour-coded technique has a greater impact on improving changeover time (Mans, 2000).

Quality:

The quality process of confirming the changeover activities is considered in the research, which recognised different sub-factors as follows:

- Creating a procedure checklist before or during changeover is rather important in order to proceed smoothly with the changeover; a checklist helps to determine that all tools and equipment are prepared for the changeover (Shingo, 1985; McIntosh et al., 2001a; 2007; Culley et al., 2003). Shingo (1985) suggested using a checklist during the preparation for changeover; the list should contain the name(s) of the practitioner(s) who conducted the changeover, information on technical data, and numeric values for measurements. The checklist enhances the accuracy of the operating conditions with minimal mistakes.
- It is essential to disseminate knowledge on the integration between quality management and the importance of manufacturing changeover to enhance the quality of changeover (McIntosh et al., 2001a). Shingo (1985) affirmed that operators required knowledge relating to the machine.

- The initiative to improve changeover can involve the SMED method or the application of continuous improvement tools (McIntosh et al., 2001a). McIntosh et al. (2007) discussed the mapping of changeover tasks as it is helpful for indicating the sequence of changeover tasks that need to be that conducted, who performs the tasks, and the changeover time. Moreover, changeover can be improved by recording the activities by video tape on a regular basis (Karasu et al., 2014).
- The studies have also indicated that there is a correlation between enhancement in safety on the shop floor and the improvement in changeover performance (McIntosh et al., 1996; 2001a). The level of safety on the shop floor in terms of a clean and tidy workplace while conducting the changeover process is also important (Singh and Khanduja, 2010; Upadhye et al., 2011).

Infrastructure:

Patel et al. (2001) argue that rapid machine technology facilitates the changeover process to improve speed and reliability of outcomes. However, the rapid changing of the technology, such as new machine and tools was highlighted in the research; as follows:

- Existing literature shows that using new machines and tools impacts on changeover performance in terms of quality (McIntosh et al., 2001a). A firm should rigorously test its machines on a regular basis. The rapid change in the technology of machines and tools has both positive and negative impacts on the reliability of changeover performance (Patel et al., 2001).

The idea of the conceptual model is to represent the research theory by providing a visual diagram to facilitate understanding. The aim of the conceptual model discussed above is to guide a high quality and reliable changeover process. Moreover, the conceptual model highlighted different changeover stages of products and processes that have an effect on the research themes – People, Process, Quality and Infrastructure. To sum up, the conceptual model needs to be developed further by examining its impact in the field.

3.6 Summary

This chapter has provided an insight into the manufacturing changeover practice, the purpose being to discover the lean manufacturing concepts and their relation to the manufacturing changeover. This chapter explored the concepts of JIT, TPM, 5S, Kaizen, VSM and agile manufacturing and how they can have an impact on changeover practice. The difficulties associated with changeover practice in the field have also been identified and discussed. Having reviewed the literature, the research gap was identified as the need for a better and higher quality changeover process to improve firms' performance. The proposed conceptual model has been identified from the literature review and is focused on the delivery of a high quality and reliable changeover process during manufacturing set-up in a dynamic environment.

CHAPTER 4 : EXPLORATORY FIELD WORK

4.1 Introduction

This chapter presents the exploratory field work conducted as part of this study. The purpose of this study is to inform the planned research of undertaking a particular research study in the manufacturing changeover process and to develop a relevant proposition for further research. Very few studies have attempted to understand manufacturing changeover in the Saudi Arabian industrial sector. The chapter presents the case studies and the methodology used for the exploratory field work. A qualitative research methodology and a case study approach were employed to facilitate the collection of data. The outline of the case companies on which the case studies were conducted is followed by a discussion of the case studies; the conclusion provides a number of suggestions for the development of the planned research.

4.2 Profile of the companies

The exploratory case studies involve two Saudi Arabian cable firms located in Riyadh 2nd Industrial Area in Saudi Arabia. The Riyadh 2nd Industrial Area has major industries including food, metal and chemical industries (Modon, 2013); it was established in 1976 and has approximately 1050 factories with 120,000 workers (Modon, 2013). Modon is a Saudi Industrial Property Authority that is responsible of development of industry cities and their infrastructure. The author accessed Modon's internet website for the purpose of selection the companies. Modon's internet website provides a comprehensive overview of the industry types that are located in the industrial cities. From the search of Modon's internet website, the cable industry was recognised in the Riyadh 2nd Industrial Area as batch production operation. The cable industry was selected because it is widely recognised for having high quality products and for being a valuable industry as it consumes 500,000 tons of copper annually, valued approximately at £2.5 billion (Almokbily, 2011).

Company A is a subsidiary of a larger organisation. At the time of the study, it employed 450 employees and had nine years of experience in cable manufacturing. The plant operates two shifts every 24 hours. It offers a range of cable products, such as low- and medium-voltage power cables,

communication and data cables, low-voltage control cables, and building wires. The company delivers its products domestically in Saudi Arabia and internationally in Middle Eastern countries only.

At the time of writing, Company B has more than 35 years' experience in the market and is considered one of the biggest cable manufacturers in the Middle East with 2500 employees. The company has 18 local branches and six overseas branches with a turnover of around SAR 5 billion (£833 thousand) in 2010. The company has four major groups that offer different products—communication cables, control cables, low- and medium-voltage cables, high-voltage cables, medium-voltage lead-sheathed cables, and overhead lines. The company produces more than 4000 grades of cables annually. It successfully delivers its products domestically and internationally in Middle East countries, Australia, New Zealand and Cyprus.

4.3 Methodology

The case studies were successfully completed during July and August 2012. Both companies were contacted via email during June 2012 to obtain their consent to participate in the research (Appendix 2-A shows the letter asking the firms to participate in the exploratory research). A qualitative framework was used for the exploratory research as it is helpful in understanding the real situation in the field. A case study approach was chosen since it is an appropriate method for conducting exploratory research that aimed to understand the implementation of the quality process during changeover between products in two sample companies. The case study was selected because it was suitable approach for observing the changeover practice and conducting semi-structure interviews. Yin (2009, p.18) defined a case study as "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon in depth and within its real life context using multiple source of evidence".

In order to collect reliable data, the case study protocol involved semi-structured interviews and visiting the shop floor. The semi-structured interview is considered a flexible instrument that helps to explore further issues in terms of research area that investigated. Saunders et al. (2009) suggested that semi-structured interviews can be suitable for use in exploratory studies for understanding the context of the research. Moreover, visiting the company's shop floor is considered important to help the

researcher understand the company atmosphere in terms of changeover implementation of tool and die preparation. The semi-structured interviews were conducted at the company site, tape recorded, and then transcribed for the purpose of analysis. The quality and production managers were interviewed for half an hour for each company; the reason for interviewing them was that they are directly related to shop floor operations and are significantly involved in the work related to the research question. Apart from the interviews, the shop floors were visited in order to gain a better insight into the working environment.

The aim of the semi-structure interviews was to identify the implementation of the changeover process for different existing products, new products and new processes within manufacturing firms. It was expected that the interviews would support an understanding of the changeover process and the obstacles during the set-up period in Saudi Arabian manufacturing firms. Robson (2011) suggested that the questions asked should be straightforward, in a simple language, and short and meaningful. The first section of the interview contained questions regarding the company background and the products the company offered in the market. The next section dealt with the implementation of the changeover process in the production process of the company. Therefore, it is important to link the changeover process to QM implementation during the set-up period. Moreover, the questions attempted to investigate the quality factors that affect changeover, as the main purpose of the study was to understand this aspect (the exploratory research interview questions are given in Appendix 2-B).

Data triangulation is commonly used to enhance the accuracy of the research when multiple sources are involved (Robson, 2011). The validity of the data triangulation strategy in the research was judged from the shop floor visit, the company's internet website, and the semi-structured interviews. The shop floor visit provided an insight into the fundamentals of the company's culture and infrastructure development as well as work environment. Moreover, the company's website was a valuable resource for identifying and validating the data that have been collected. The company's website was used in terms of finding operational data and specifically changeover data – time and process. Also, the company's brochure was used in terms of validating company background. The reason for using data triangulation is to counter all the threats to the validity of the research (Silverman, 2010).

4.4 Case study A

4.4.1 Company Background

Company A has embarked on acquiring various QM system certifications, including ISO 9001:2008 that is certified by the British Approvals Services for Cables (BASEC) which is an independent body of the accreditation system. Moreover, the company's lab has been certified by the Saudi Standards, Metrology and Quality Organisation (SASO). The company has a Quality Control (QC) department that aims to ensure that the quality specifications of the offered products meet identified quality standards. The QC department has 45 employees who work as quality inspectors, quality control lab technicians and quality engineers. In the last three years, the company has launched the Enterprise Resource Planning (ERP) system that integrates all the processes of finance, manufacturing and supply across the entire firm. The company is planning to implement QA within the next few years. The first impression was that it was well maintained, clean, had safety signs on the shop floor, and had an overall pleasant and cooperative atmosphere. The company has clearly stated their objectives on the notice board of the plant to be shared with employees.

4.4.2 Changeover Implementation

The company has a business strategy of achieving customer requirements and on-time delivery; in production, the company manufactures products based on demand forecasting of the market since the accuracy of forecast will prevent inventory from running out; this strategy is used and called make-to-stock (MTS). On the other hand, the make-to-order (MTO) strategy is used once the order has been placed by the customer; this strategy can help to maintain and customise products as mentioned in the literature review in Chapter 3. The implementation of the changeover process depends on customers' orders; therefore, the company prepares the weekly production planning schedule to be aware of the production process flow. Hence, the average number of changeovers in the company is twice per day since the company is batch production and its key consideration is to meet customers' requirements.

Company A is not satisfied with the changeover time of 36 minutes, as shown in Figure 4.1. Moreover, it takes 15 minutes for the quality sample to be approved by the quality department; thus,

the total time that the company needs to begin production is 51 minutes. Quality sample is a random specimen of product for testing and analysing the quality rate. The company reviewed the quality rate of the product sample in the laboratory in order to start the production, and agreed and aimed to reduce the changeover time by 50%. The top management advised staff to record the changeover process in order to reduce the time taken, and the company assigned one technician and one helper for performing the changeover process. The company is relying on the technician to perform changeover process and helper for bringing tools and parts that needed. From the video record, the company found that the helper did not work with the technician as he should. The reason behind this was that the communication during set-up time was not effectively used and guidance from the technician was lacking.

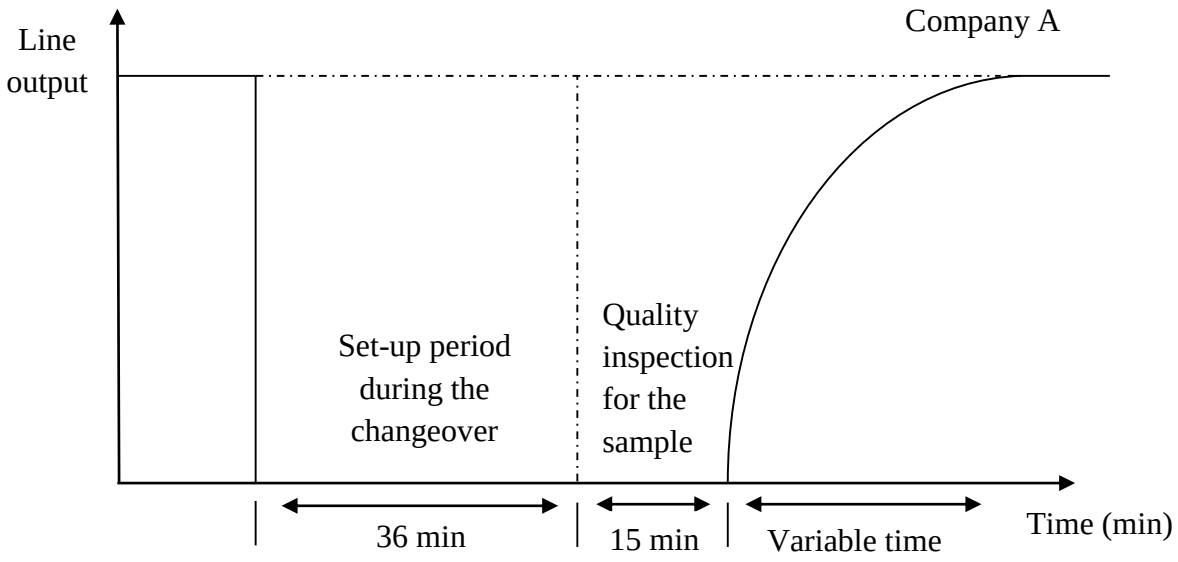

Figure 4.1 Line output during the changeover in company A (Source: author).

The study revealed that time has a direct influence on changeover implementation since the changeover process was not standardised. Time can be a crucial factor in implementing the changeover process and ensuring quality for each product. Moreover, the company has provided training for technicians and worked with the maintenance team for making the availability of machinery efficient. Technician involvement is essential during the changeover to share knowledge and awareness of the changeover process as well as to ease the pressure involved. The company agreed that changeover has an impact on the company's performance in terms of competitiveness and

financial position. Therefore, to ensure a successful changeover process on a daily basis, the company believed that can be achieved by reducing set-up time and ensuring that the technicians gain more experience in the changeover process. Thus, the production process of this company can be improved, thereby leading to the achievement of high quality performance and productivity.

4.5 Case study B

4.5.1 Company Background

The main objective of company B is to provide a high quality product with high productivity and on-time delivery to achieve customer satisfaction. Company B has a Quality Control (QC) department and has the ISO 9001:2008 certification, which is certified by the British Approval Services for Cables (BASEC) as well as the ISO 9001, which is certified by TUV SUD America that is an international service corporation focusing on consulting, testing and accreditation. Their finished product is certified by KEMA Netherland, which is a laboratory of high-power voltage cables that provides assessment and accreditation of cable companies. In 2010, the company claimed that it was close to achieving zero defects in their products, which is a significant achievement considering the large production volumes and complexity of operations.

4.5.2 Changeover Implementation

Figure 4.2 illustrates the manufacturing process of company B during the changeover; the preparation for the changeover is usually planned by the supervisor. The company utilises 60 minutes for the set-up time between different products as this is considered to be fixed time. Without waiting for the final quality sample, a sample can be taken during the first and last runs by the quality inspector. In the middle run of the cable production, the sample is usually inspected visually by the QC department to ensure that production meets the high quality standard. The average number of times a changeover is implemented is four times per day; an increase in the number of changeovers would indicate a large number of orders for different products, but a huge lost production opportunity. The key consideration for the changeover is to achieve customer satisfaction. Before beginning the changeover, the company relies on the supervisor to prepare the tools, equipment and materials that will be used in the process.

The main concern of the company is the input of material coming from the previous process; a lack of this input material would affect the machine due to non-availability of materials from the previous process. Upadhye et al. (2011) reported that Indian manufacturing firms waste 5.93% of working time because of non-availability of input materials from previous operations. Therefore, finished materials from the preceding process should be available for the machine changeover of the next process in order to eliminate the waste.

In 2011, the company established the Process Development Group (PDG) with the aim of identifying processes that do not add value to reducing waste in the manufacturing and changeover processes. By identifying wastage and processes that do not add value, the company can create value for their customers by meeting delivery time. This group will lead the company in eliminating waste and achieving lean manufacturing production.

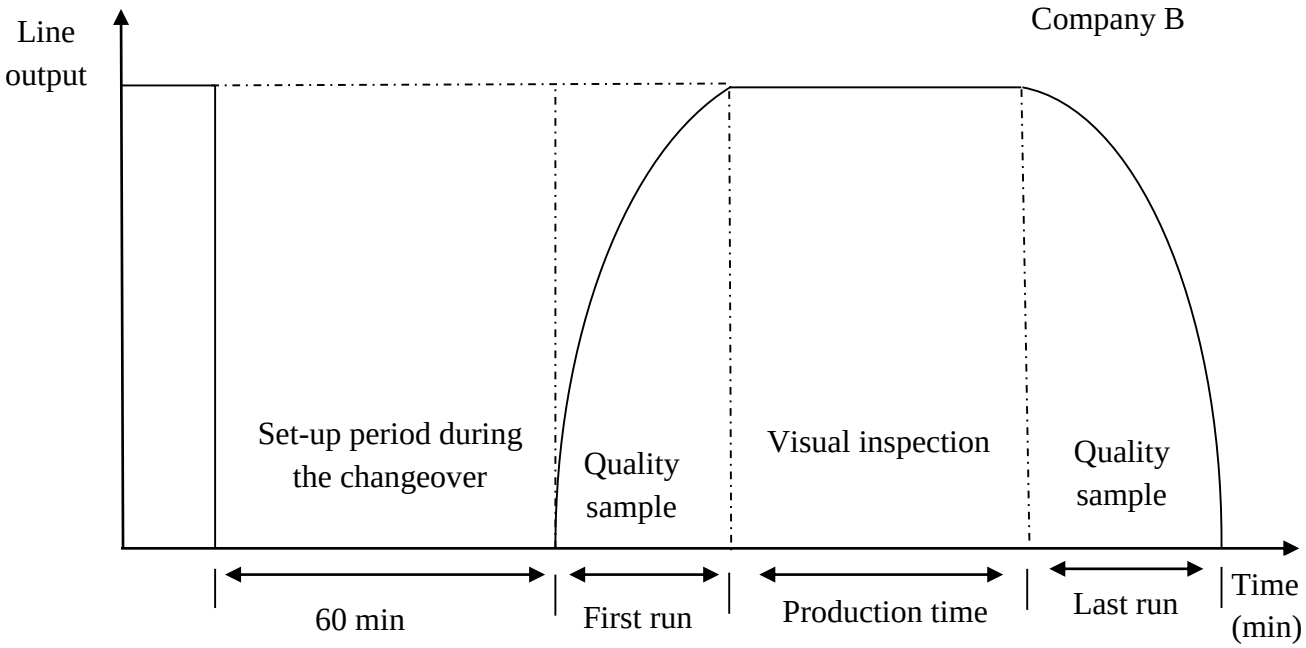

Figure 4.2 Line output during the changeover in company B (Source: author).

4.6 Discussion

Both companies understand the importance of changeover time in the production process, and the managers of both companies were aware of the significance of quality sample implementation during and after the changeover process. However, the interviews revealed some discrepancies between the different managers' knowledge particularly regarding company background in terms of the number of

employees and years of experience. During the changeover process, both companies were relying on a quality inspector for handling the inspection of the produced product. The exploratory research identified the main themes that can affect the quality and reliability of the changeover process. Figure 4.3 presents the cause and effect diagram of the factors that affect the quality and reliability of the manufacturing changeover process: machine, technician, company environment and tools. These themes were found to be most related to the manufacturing changeover process in the study. Moreover, all these factors have been extracted from the interviews and contribute to changeover quality. These factors can be considered in greater detail in further research.

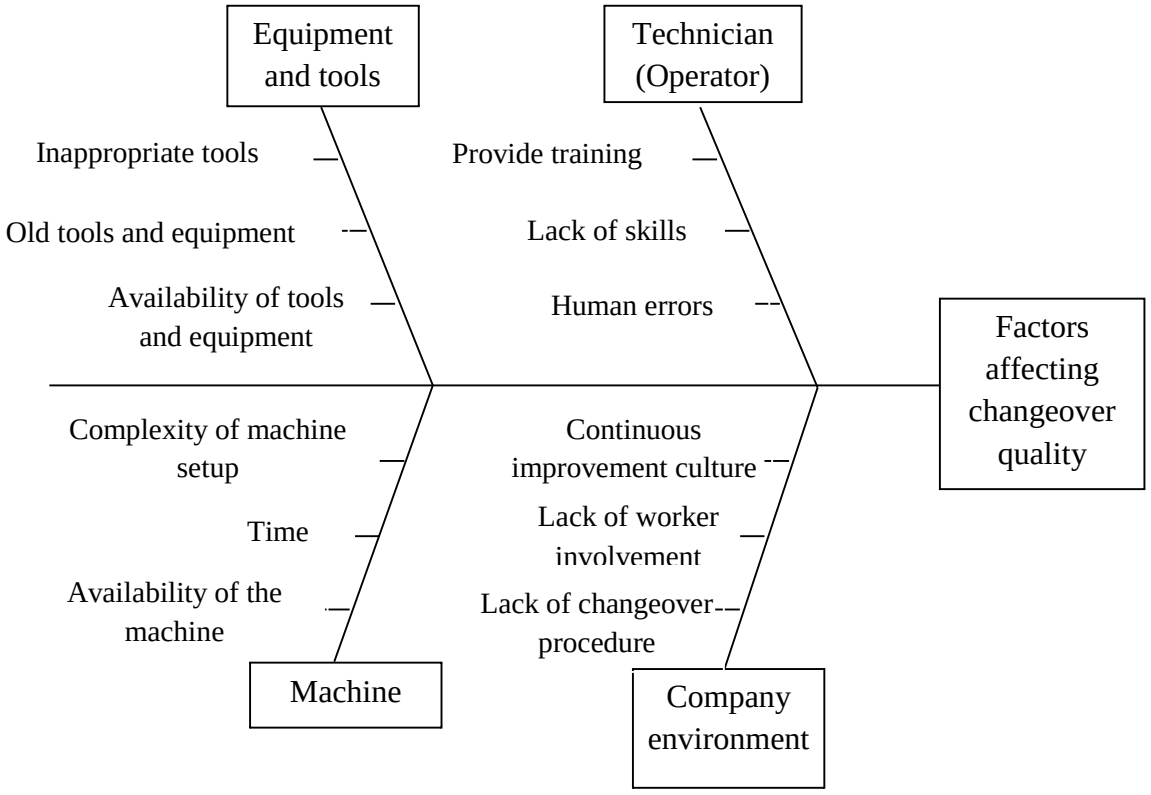

Figure 4.3 Cause and Effect diagram for both case studies (Source: author).

Company A has delegated the implementation of the changeover process among responsible employees in the production department in order to create a sense of urgency. Company A has taken the initiative of improving the changeover process by recording the process; however, this requires the identification of the particular changeover task that requires improvement. Moreover, to develop a more effective changeover process, the company should identify the difficulties that occurred during

the set-up period. During the changeover process, it was found that there were rollers and wires on the ground and close to the machine during set-up time which can affect the efficiency with which the technician performs a reliable changeover process. Moreover, tools were not organised and finding specific tool was time consuming.

Company B has a huge reputation in the local and global markets. It utilised one hour in the changeover process and there is no initiative to reduce it. This is because the company dominates the market so it has no real competitor in the same region. In addition, the production manager admitted that changeover does not add a competitive advantage to the company in terms of meeting customer demand. This is because of the fact that production is governed by producing only high-quality products.

Preliminary recommendation

The changeover time in Company A can be improved by forming a problem-solving team comprising an engineer, a technician and a helper. This team's main responsibility should be to create a changeover procedure with respect to quality standards and to enhance the changeover process. Many authors have suggested that firms can improve the changeover procedure by applying standardisation methods (McIntosh et al., 1996; Patel et al., 2001; Singh and Khanduja, 2011). Moreover, the actions of and time taken by both the technician and helper must be analysed to improve the changeover process. The changeover process video record proved that the company needs to improve changeover performance by adopting the 5S approach—sort, set in order, shine, standardise and sustain—that can facilitate the required improvement for tools and dies cabinets. By watching the video tape, company A should enhance safety requirements in areas that can inhibit the changeover process. For example, it was evident that there were rollers and wires on the ground and close to the machine during set-up time which affects the technician's movement during changeover.

During the interviews, training was identified as not being used effectively during the changeover process. This was because most of the workers in the cable companies were from Asian countries due to the language barrier and low wage demand of such labour. It is necessary for both companies to separate the internal and external set-up processes during or before changeover in order to facilitate SMED implementation. Finally, the companies must embark on a culture of continuous improvement

in order to reduce set-up time and improve the changeover process. This can be achieved by enhancing personal involvement in terms of providing suggestions and solving problems.

The proposed conceptual model

The conceptual model was derived from the results of existing research to be applicable in a dynamic working environment. The proposed conceptual model can be customised after conducting exploratory research on Saudi Arabia's cable firms. As the study was conducted on the changeover process in cable firms, it was discovered that the process of changeover has been used in cable firms in the changeover process for original products and processes only. The reason for this is that the cable industry has fixed manufacturing processes and products. It is rare that this industry launches a new product in the market. The exploratory study has helped to develop the conceptual model based on the practical input. In addition, the factors that affect the quality of changeover have been customised from the proposed conceptual model (See Figure 3.8) in order to be suitable for the Saudi Arabian cable industry environment. One additional factor has been derived from this exploratory case study—the availability of materials from previous processes. The material from earlier processes must be available in time to serve as input for the next machine changeover process. Therefore, the availability of materials from previous processes can be rather important in ensuring a reliable changeover to the next process. In the conceptual model, it was postulated that quality performance affects productivity of the firms and both of that affect the outcomes. The customised conceptual model is presented in Figure 4.4.

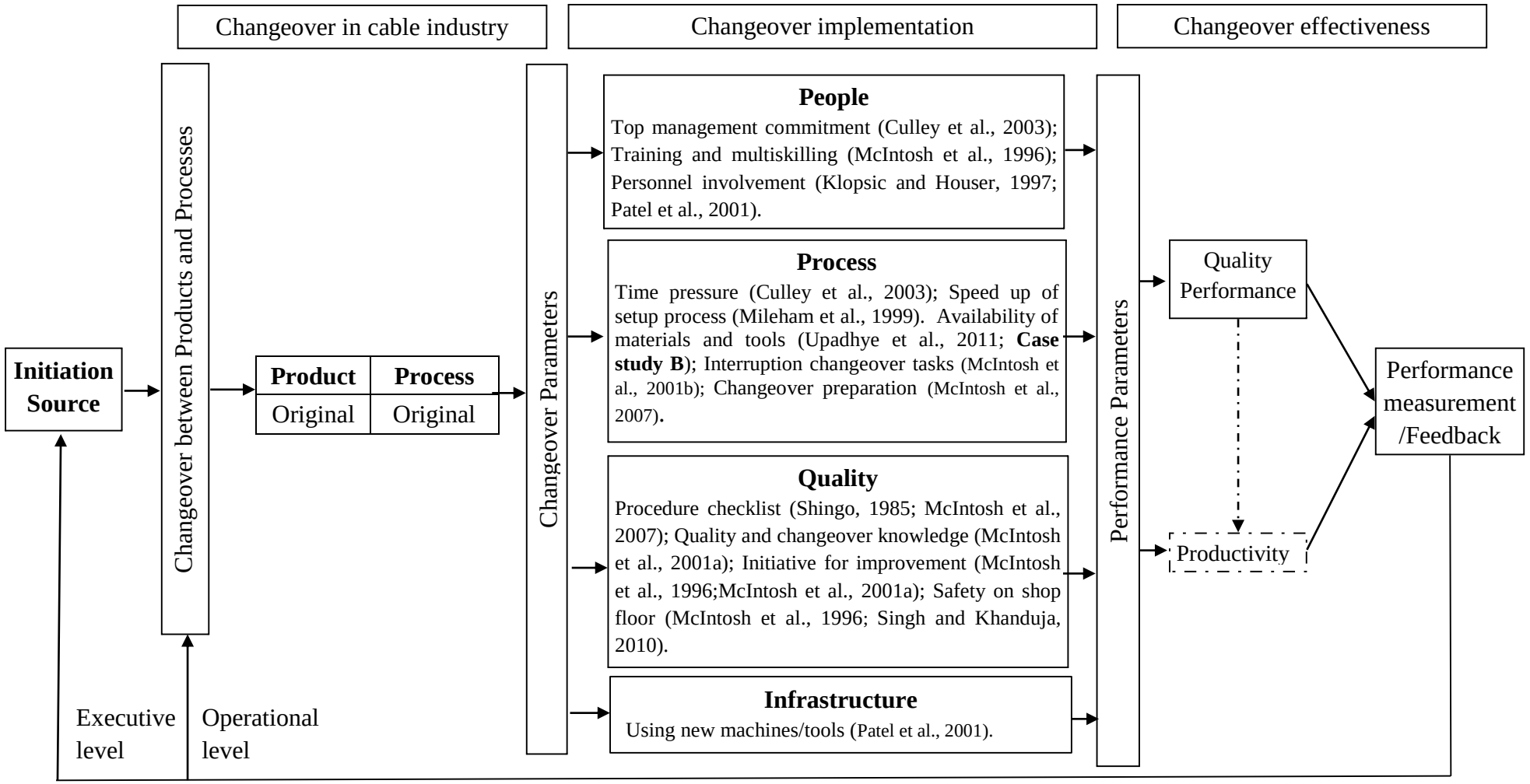

Figure 4.4 Proposed conceptual model for cable companies (Source: author).

Limitations of the exploratory research

Data triangulation of the exploratory study was achieved by visiting a shop floor, the company website and interview data; which were collected in cable firms. Both companies have an internet website for offering their products but these websites did not include valuable information, such as financial and operational data; therefore, companies' websites were not considered a rich resource for validation the data. Data triangulation in the exploratory research was a limitation of the research and data triangulation needs be developed further in the main research.

4.7 Recommendation for future work

This study has provided insight into how manufacturing changeover was implemented in two Saudi Arabian cable firms. The exploratory field work conducted for this study provides a number of details related to quality inspection during changeover in cable manufacturing firms in Saudi Arabia. Each company has a different approach of managing quality during and after set-up time. The study indicated that the companies need to improve their changeover processes in order to meet the customer demand. There are a number of suggestions for further research, the exploratory research investigated aspects of the implementation of the manufacturing changeover process. In the cable industry, the most known and used changeover process is that for an original product and original process; therefore, in order to cover other processes, it may be necessary to examine different changeovers in terms of new product and process. In addition, this study focuses on only the cable industry changeover process rather than examining the manufacturing changeover processes in different industries. It is important to look further afield since quality implementation during the changeover process has a direct effect on the process of the changeover.

In essence, a large number of changeovers will utilise more set-up time and raw materials, which may increase the total price of the product. This may lead firms to lose their competitive advantage in terms of product price.

4.8 Summary

This chapter has explored the changeover practice implementation in Saudi cable manufacturing firms. The exploratory research has provided an insight into the implementation of case companies for set-up time and quality procedure. Also, it discovered the changeover process through the implementation of set-up and run-up periods. The exploratory study was essential to improve the research methodology in terms of the research instruments and data triangulation employed; in essence, the nature of the study was helpful in terms of allowing modification of the conceptual model. The following chapter is the research methodology describing the method that was employed in the research. The next step of the research is to study the effectiveness of the changeover processes among different manufacturing industries in Saudi Arabia.

CHAPTER 5 : RESEARCH METHODOLOGY

5.1 Introduction

The literature review, discussed in Chapters 2 and 3, reveals the efforts that have been made for improving the changeover process by using different techniques, such as SMED and 5S. Therefore, the improvement in changeover activities can help to increase the output rates of finished products. As explained earlier in Chapter 4, exploratory research was conducted in order to improve the research methodology of the main research in terms of the research instruments and data triangulation. Undertaking exploratory field work helped develop the understanding of manufacturing changeover practice within Saudi Arabian cable firms.

This chapter describes the methodology that was used to conduct the research in the dissertation. Having conducted a thorough literature review, it is essential to study the quality and reliability of the changeover process during set-up time. This chapter presents the multi case study approach recommended by Yin (2009), followed by the criteria of identifying selected firms. The discussion of constructed research instrument which is called the Changeover Effectiveness Assessment Tool (CEAT) was given in this chapter. Further, it was followed by the analysis that is used in the research and data coding procedure. Finally, the credibility of the research was explored through validity, reliability and data triangulation.

5.2 Theoretical philosophy

The interpretivist paradigm can be defined as applicable to a research study that involves interpretation of the various different elements of a study (Myers, 2009). It basically integrates the interests of humans into the research study. According to Myers (2009), in interpretivism, it is believed that contact with reality (be it socially constructed or given) happens only through various social constructions like consciousness, language and even shared meanings. Simply put, interpretivism is related to the philosophical location of idealism, and is mainly used for grouping together varied approaches (Collins, 2010). Furthermore, interpretivism-related research studies mostly focus on sense and can employ numerous approaches for reflecting various features of the issue (Myers, 2009).

The interpretivist paradigm has its roots in human sciences and philosophy. According to Myers (2009) the methodology is grounded in the reality of individuals making sense of subjective reality as well as adding meaning to it. Further, qualitative research claims that human experiences are basically context-bound and can never be free from location and time (Collins, 2010). It also states that it is important for researchers to completely understand the socially structured world and discover the way values and interests are merged within the overall research study (Collins, 2010). Also, it is almost impossible to attain complete neutrality and objectivity, and - over the period - the value of participants and individuals becomes the most important part of the study (Myers, 2009).

Interpretivism has been chosen for this research study as it is a powerful means of gathering insights by determining meanings through refining our understanding of the whole research on the manufacturing changeover process. It focuses upon the depth, richness and overall complexity of the phenomenon under study, and helps produce results that are not simply achieved through statistical techniques (Collins, 2010; Saunders et al., 2009). The interpretivist paradigm aids in examining all the needs and, thereby, helps generate a better understanding of the phenomenon (Creswell, 2014). It also facilitates in focusing upon multiple realities and not just a single reality of the phenomenon, and emphasises the fact that realities usually vary based upon place and time as well as integrating the interests of humans into the research study.

The interpretivist-based research approach presents results based upon real-life views of the manufacturing changeover practice as well as the perceptions of the participants (Creswell, 2014). The research is essentially an attempt to understand the impact of individual experience and background on the study area (Myers, 2009).

5.3 Qualitative research approach

Qualitative research is an approach designed to help the researcher to understand the people and context of the firms under analysis (Myers, 2009). Qualitative research involves different strategies, such as action research, case study research and grounded theory, which contribute to finding an answer to the research question. One of the main strengths of qualitative research is that it enables the study of phenomena that is not available elsewhere (Silverman, 2006). In addition, it also facilitates

explanations regarding the experience of people with complex textual descriptions. According to Saunders et al. (2009), qualitative research is interpretive and needs to be understood logically in terms of the phenomenon being studied. In order to interpret qualitative research, it is important to develop an in-depth understanding of the aspects within the boundaries of the research context. Qualitative research is essential when seeking specific information regarding values, opinions and beliefs of particular populations and its main benefit is that it permits researchers to identify intangible factors, such as norms and beliefs. Robson (2011) provides a framework for research design when conducting a research project; and the components of this framework are presented in Figure 5.1. The purpose of the research is to discover the implementation of changeover process in Saudi Arabian manufacturing firms which in turn will the leads to identifying and determining the research question. Hence, the conceptual model was developed based on the existing literature, aiming to answer the research question. Thereafter, the research methods and sampling strategy of the research can be identified for examining the manufacturing changeover implementation in Saudi Arabian firms. The framework represented in Figure 5.1 provides an insight that qualitative research does indeed ensure a strong relationship between its components and the research foundation.

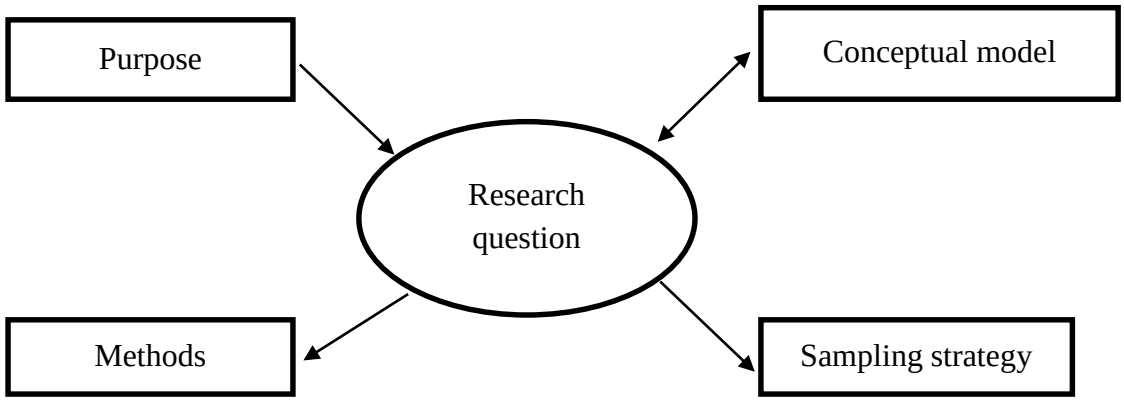

Figure 5.1 Research design framework (adapted and modified from Robson, 2011).

To answer the main research question, qualitative research was chosen since the research question involves indicating and understanding the real situation such as actual daily practice and current status of changeover process in the field rather than numerical results of quantitative research. Moreover, this research focuses on adding contribution to knowledge by identifying patterns or variables that are involved in the changeover process which can be identified by the qualitative approach. This because

that qualitative research is more involved in addressing the practical issues of the changeover process on the shop floor than the quantitative approach.

The data collection for this research used qualitative approach which involves multiple case studies. The research design in Figure 5.2 represents the research process that were carried throughout the study, literature review were undertaken to explore the concept of QM and previous literature of lean manufacturing with focus on changeover literature. Based on reviewing the literature, the proposed conceptual model was developed for providing high-quality and reliable manufacturing changeover process. This was followed by conducting exploratory research due to the lack of manufacturing changeover research in Saudi Arabian firms and to explore the manufacturing changeover practice. Changeover Effectiveness Assessment Tool (CEAT) was developed based on the findings of the exploratory study. CEAT was developed in order to measure the changeover effectiveness among the manufacturing firms. Therefore, a pilot study was vital to inform the research design and examine CEAT as well as the conceptual model was modified in response to the study findings. The main case study was conducted by using CEAT and the outcome of the research improved the conceptual model of high-quality and reliable manufacturing changeover process.

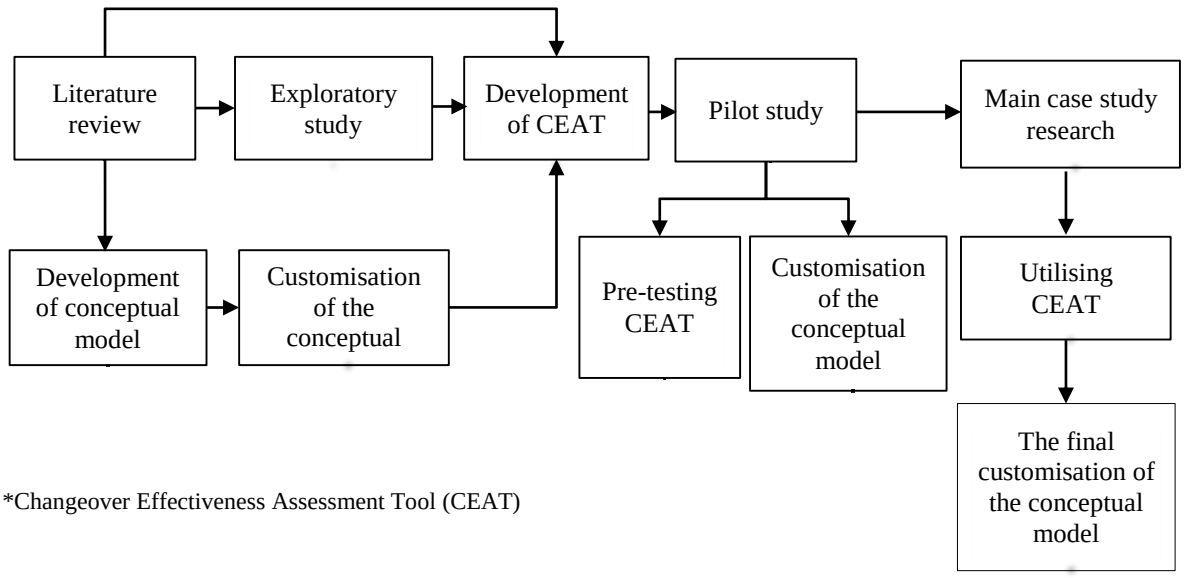

Figure 5.2 The research design (Source: author).

5.3.1 Exploratory field work

Prior to the main study and determining the methodology, exploratory research was conducted for an in-depth understanding of the research problem and is presented in the previous chapter. In addition, it is essential to test the aspects of the research design and to allow necessary adjustment before final commitment to the research (Robson, 2011). The exploratory research was engaged in the investigation of two cable manufacturing firms in Riyadh, Saudi Arabia (See Chapter 4 for more detail). The changeover concept and quick changeover was mainly derived from lean manufacturing as explained in the literature review chapter. Therefore, a lack of literature on changeover was found specifically within Saudi Arabian manufacturing firms. As a result it was therefore vital to conduct the exploratory research in order to understand the aspects and the concept of changeover practice that is being implemented within Saudi Arabian manufacturing firms and to inform the research design.

5.3.2 Pilot study

A pilot study is a small-scale, dummy run of the main study (Robson, 2011) which helps to transfer research design into reality and resolve some upcoming problems. The main purpose of the pilot study is to examine research instruments in terms of wording and ambiguity of the interview questions. Therefore, research instruments can be corrected and made clearer before the main case studies begin. Yin (2009) stated that a pilot study will help to improve the data collection plan with reference to the research procedure and content of the data. The pilot study report should contain an obvious experience learned about research design and field procedure (Yin, 2009).

The use of a pilot study in this research was considered essential for many reasons. Firstly, the research instruments were examined during the pilot study and some efforts made in order to improve and rephrase the research instruments. Moreover, some of the statements have been modified based on the reality of the company's shop floor (See Chapter 6 for more detail). Yin (2009) affirmed that the pilot study is formative research the aim of which is to assess the intended research instrument in term of questions as well as provide clarity for research design. Secondly, the pilot study helps to ensure that the targeted interviewees are the best candidates possible to be interviewed before the main study commences. Finally, it helps to evaluate the convenience and access of the companies that are located

in this geographical area. A pilot study indeed helps to improve the research procedure and instrument for the main study.

5.4 Case study

Myers (2009) stated that a case study is a research strategy which focuses on empirical evidence from actual situations within organisations and contributes to existing knowledge. Yin (2009, p. 18) defined a case study in the following manner:

"A strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon in depth and within its real life context using multiple source of evidence"

Rowley (2002) and Yin (2009) indicated that the case study method is appropriate for asking rational questions of 'how' and 'why'. Robson (2011) explained that case studies help to provide solutions to research problems in different disciplines. One of the main objectives of the case study in the present context is to answer 'how questions' on the reliability and quality of the set-up process during manufacturing changeover and 'why questions' related to improving the changeover process in firms. There are many examples of the case study approach in qualitative research in manufacturing changeover and QM (Klopsic and Houser, 1997; Sha'ri and Aspinwall, 2000; Patel et al., 2001; Singh and Khanduja, 2009). The case study was selected for this research because it is a commonly used methodology in the field which provides insight and variety for the research in terms of the collected sample. The evidence gathered in case-study work is most commonly through documentation, semi-structured interviews and direct observations which are discussed further in the following section. Multiple sources of case study were used in the research rather than relying on a single data source because it helps to ensure that collected data are verified from different sources, which will enhance the consistency of the research.

Figure 5.3 presents the multiple case studies method proposed by Yin (2009). The first stages deal with the definition and design of the case studies, followed by the preparation and collection of data, and then analysis. These stages are all essential as they represent the holistic approach of case studies. Conducting multiple case studies can be described as conducting multiple repetitive experiments (Robson, 2011). Referring to both Rowley (2002) and Yin (2009), case studies can produce similar

results for literal replication and contrasting results for theoretical replication. A multiple case study can enable for comparisons between case studies and facilitate a more comprehensive understanding of the research problem (Wahyuni, 2012). However, it is important to conduct proper number of case studies because there are high costs involved in the research interview and the fact that the amount of data collected cannot be efficiently assimilated. Furthermore, Perry (1998) claimed the maximum number of case studies in one research investigation is twelve, because more than this number of case studies creates an unwieldy study; so it is important to ensure that the sample for the case studies is sufficient for the research. Therefore, eight case studies conducted together which will provide support for research as it provides the diversity and variety of data that allow to comparison for considering this particular gap in the literature.

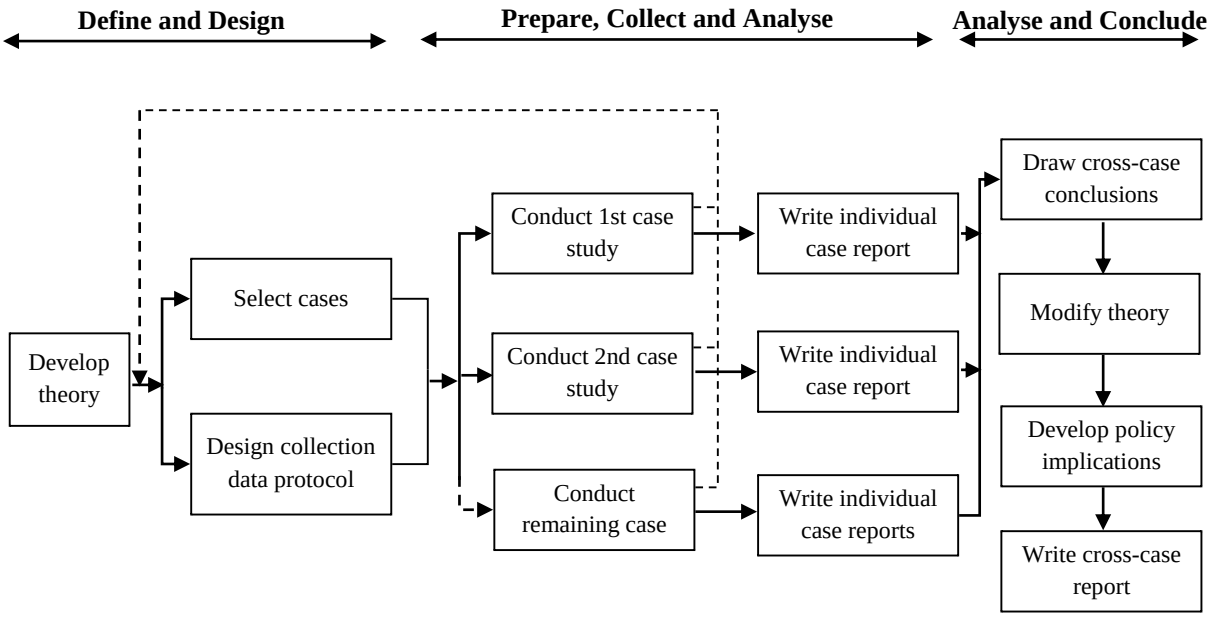

Figure 5.3 Multiple case study method (Yin, 2009).

The research question involves exploring the quality of the changeover process during the set-up period. As has been described in the literature, the study was targeting firms that implemented the batch production type. The reason for this is that a prerequisite for batch production is a set-up process for each batch size production; this frequent changeover in the production takes place on a regular basis. The approach taken by this study aims to understand the changeover practices in some of these firms, for instance lighting, pharmaceutical, packaging, medical products and plastic firms, as they are operating on batch production.

In the literature review in Chapter 3, the proposed conceptual model was provided; to examine the performance of this conceptual model, it is necessary to conduct field work. Since the model needs to be explored, an inductive study approach is adopted as it involves theory building (Rowley, 2002). According to Barratt et al. (2011), a majority of qualitative case studies in Operation Management research have embraced the inductive approach of theory building. Therefore, the case study was selected as the main method for research and data collection.

5.4.1 Semi-structured interview

Semi-structured interviews are part of the case study as they are instruments used in flexible and multi-strategy design research (Robson, 2011). Myers (2009, p. 124) defined a semi-structured interview as "it involves the use of some pre-formulated questions but no strict adherence to them and new questions might emerge during the conversation". In this method of interviewing, the researcher has some structured questions with flexibility to identify issues that are related to the research which emerge during the interview. The researcher provides a list of themes and key questions that need to be covered in the interview, and the main objective is to understand the respondent's opinion by using open-ended questions. This type of questioning is important during an interview to reveal an unclear aspect or clarify an aspect in more detail. It provides the researcher the opportunity to add and include some important insights into the interview. According to Robson (2011), long and leading questions should be avoided as it leads the interviewee in a particular direction when providing answers. Semi-structured interviews are considered an appropriate tool for qualitative research in the following conditions (Robson, 2011; Creswell, 2014):

- It is a flexible and adaptable approach
- Allows the researcher to study the phenomenon more in depth and gain a clear understanding
- Encourages cooperation and rapport
- Enables the assessment of respondents' knowledge

In this case, the themes of the interview questions are the factors that affect the quality and reliability of the changeover process during set-up time as illustrated in Figure 4.4 in the previous chapter. These questions are related directly to the main research question. The semi-structured interviews were

conducted with the quality manager and production manager of Saudi firms for half an hour each; the reason for this is that they are directly related to shop floor operations and the themes of the interview questions. Some Quality Inspectors were interviewed because the firms do not have a Quality Manager position in the organisation chart.

5.4.2 Observation

Observation can be involved in the research through direct observations. This means involving the revealing of the researcher's identity to the participants; however, the researcher does not participate in the activities (Saunders et al., 2009; Robson, 2011). Robson (2011) affirmed that observation is a direct technique as the researcher observes the people and what they do. The reason for choosing this method is to observe the work environment of the firms during the changeover process and the set-up time of the manufacturing process, and this technique facilitates an understanding of the reality of changeover practice in manufacturing firms. Robson (2011) discussed one disadvantage of direct observations which is its time-consuming nature. Nevertheless, the researcher can address that issue by identifying the observation variables before beginning the observation. In order to collect suitable data, the observation variables are identified based on the literature review and were further developed through the pilot study. The observational protocol was engaged during the study in order to record the collected data while observing (the observation check sheet is given in Appendix 4-B). It should be noted that some firms have a high level of regulation before granting access to the shop floor operation, such as medical products companies. However, the researcher gained access to the shop floor after getting approval for the visit from the firms.

As shown in Figure 4.4 in the previous chapter, the conceptual model factors need to be identified and examined further during the observations of changeover practice during the set-up period and the shop floor visit. Also, the researcher asked the firms about changeover documented data procedure and the recording of manufacturing changeover process operation activities. This will improve the data validation of the research by linking the responses of interviews' data and observations. It helps to note the discrepancies that occurred between what people say and what they do particularly in the changeover process (Robson, 2011). The research observation framework is shown in Figure 5.4. The

main observation variables of the research are changeover preparation, changeover practice, and shop floor safety during changeover. Attending changeover practice fully or partially would be essential as two sub-factors that are mainly related to the observations.

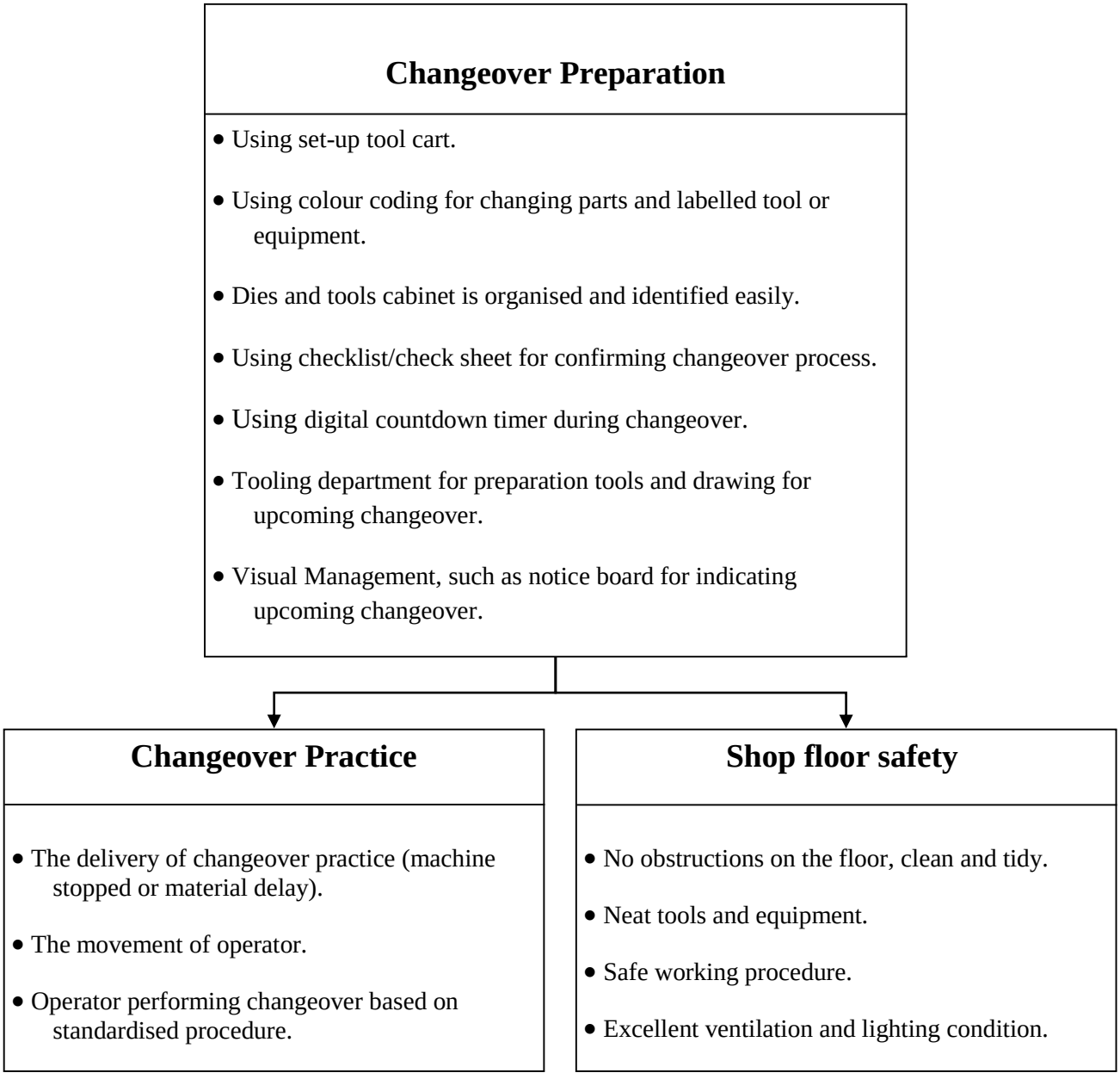

Figure 5.4 Research observation framework (Source: author).

5.4.3 Documentation

The documentation is a crucial part of any data collection in the case study method. Documentation can be classified as public documents, newspapers, journals and diaries of the interviewed companies

(Yin, 2009). The main pages of companies' internet websites can be used as a source for collecting evidence of background presentation and history of case companies. However, the companies' internet website was not resource-rich based on the findings of the exploratory research, so the researcher improved the research collecting data approach by collecting more evidence from case companies. The researcher asked the companies whether they had changeover data documentation and what sorts of data were recorded if they had such records. Furthermore, the researcher tried to collect evidence of companies' documentation in terms of changeover time and activities sheet. The value of the documentation to the research is that it assists in understanding the level of awareness of the changeover process in the firms and its importance. Also, it is to identify the opportunity for improvement using changeover data. However, the Daily Production and Batch Record Report sheet can be gathered if the changeover time is included in these sheets (The different sheets for the case companies are given in Appendices 6-B, 6-C, 6-E and 6-H). A few case companies successfully submitted organisation charts to the researcher.

Creswell (2014) discussed the significance of utilising and examining audio and visual materials in qualitative research. Visual materials were taken by the researcher after gaining the agreement of the company. The pilot studies and main case studies involved the use of visual material in the form of photographs of the shop floor, for further explanation and examination. It is a good opportunity for researcher to share directly company's reality and is an unobtrusive method of data collection (Creswell, 2014). It should be noted that the visual material required companies' approval; therefore some companies refused the taking of photographs on the shop floor.

5.4.4 Data triangulation

The data triangulation approach enhances the credibility of the research findings (Wahyuni, 2012). Data triangulation involves the engagement of different sources of the firm which include shop floor visit/observation of work environment, changeover documentation, and the data collected from interviews as shown in Figure 5.5. Documents have been used in social science research as a source of rich information and resources (Yin, 2009). Based on the exploratory research, companies' websites were the main limitation of data triangulation; therefore changeover documentation was required instead of companies' websites in the data triangulation method.

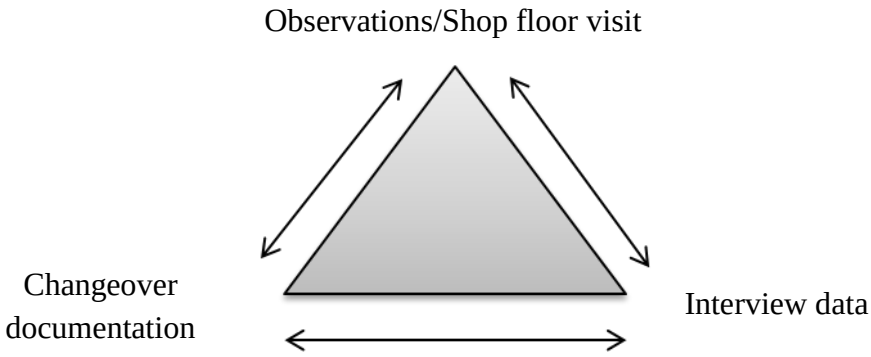

Figure 5.5 Data triangulation (Source: author).

Robson (2011) affirmed that data triangulation helps to ensure that collected data are verified from different sources, which will enhance the consistency of the research. The reason for using data triangulation is to increase the level of confidence in the data (Robson, 2011). Rowley (2002) stated that the case study method has strength as evidence can be collected from multiple sources.

5.4.5 Sampling in the case studies

It is necessary to identify appropriate firms from which to gather reliable data. Common indicators should be considered within selected batch production firms in Saudi Arabia; this would facilitate data collection as the research is about the quality of changeover during the set-up period and requires the investigation of a dynamic firm. There are a range of indicators that can be used, such as financial and growth indicators. However, in order to make the study focused and provide a meaningful result, the following indications were decided upon:

- *Quality management indicator*

The study targets firms that deal with quality programs, such as QC, QA and TQM. Firms should undertake initiatives and be aware of quality and the need for continuous improvement. This leads the research to target suitable companies in order to collect reliable data. Motwani et al. (1994) suggested that the quality department is required to provide quality procedures for manufacturing, purchasing and distribution departments. Also, Henry (2013) discussed the role of the quality department in the changeover process, as quality representative needs to be involved and inspected pre- and post-changeover settings.

- *Export indicator*

One of the indicators is that the firm distributes their products globally. The exporting firms can face demand for frequent changes in products due to the fierce competition with local and multinational companies. Thus, it is required that product quality is met and customer requirements are fulfilled, which can be achieved by implementing a fast changeover process between products with an assurance of high quality requirements.

- *Size of the plant indicator*

Large-sized organisations are more likely to implement changeover consistently than small manufacturers are (White et al., 1999; Shah and Ward, 2003), because large companies are involved in continuous improvement processes to meet new demands. In addition, the growth of firms can be measured by increasing profits against the cost of the product and by using internal resources. However, the exploratory research revealed that large-sized firms consumed a great deal of time during changeover process. Based on the exploratory research, firms were less to apply improvements to the changeover process. As a result, a sample of different sized firms is needed in order to understand the reality of Saudi manufacturing firms depending on size. Moreover, the selected eight firms are representative of the Saudi manufacturing industry.

The Saudi Industrial Development Fund (2010) defined small enterprises as those that have an annual income of around US$1.3 million which is approximately GB£784,000 based on exchange rate and the number of employees, ranging from between 2 and 49. On the other hand, medium-sized enterprises are defined as firms that have an annual income of around US$13.3 million, or GB£8 million approximately based on exchange rate and the number of employees, between 50 and 200s. It should be noted that this SME definition is only valid for Saudi Arabia.

- *One geographical area indicator*

The objective of gathering data from one geographical area can be crucial as it keeps the research more focused in order to answer the question (Sha'ri and Aspinwall, 2000; Saunders et al., 2009). The research concentrated on Riyadh in Saudi Arabia; it then focused on one geographical industrial area within Riyadh which was the 2nd Industrial area. The reason for selecting Riyadh, as it leads the cities

in having the highest number of manufacturing factories, and this is because Riyadh city has three industrial cities.

The lighting and medical products sectors were selected for the main case studies. The selection of these two sectors was based on the sampling strategy that has been discussed previously, and the protocol of using eight case companies discussed above; four case companies for each sector. Also, two semi-structured interviews were undertaken with Production and Quality Manager, and the researcher was also involved in direct observations of changeover practice and shop floor visit. Documentation used in the research related to changeover data and archival records, if available. After identifying the selected firms in the study, firms were contacted to invite them to participate in the research. An introductory research letter containing the research aim and methodology was sent to the firms; this helped firms and particularly interviewees to be prepared to provide the required information. All companies were contacted via email during April 2013 for the lighting sector and January 2014 for the medical product sector in order to obtain their consent to participate in the whole study (Appendix 6-A shows the letter asking firms to participate in the main case study research). The lighting firms' case studies were successfully completed during July to August 2013 and the medical product firms' case studies were completed during February to March 2014.

5.5 Research instrument – Changeover Effectiveness Assessment Tool (CEAT)

The research instruments were the tools used in the research for collecting primary data through semi-structured interviews, observations and documentation. The extensive literature review was undertaken, in addition to conducting exploratory field work that helped to identify and refine the proposed conceptual model and the pilot questions of the research tool. The main reasoning behind constructing the research instrument which named as Changeover Effectiveness Assessment Tool (CEAT) was based on the findings of the exploratory research - that each cable company has a different procedure of managing the changeover process during and after set-up time (the copy of CEAT is given in Appendix 3). Moreover, the process of accepting products through quality department during and after the changeover process was completely different between the companies. However, the exploratory study affirmed that the cable companies that participated have different processes of manufacturing changeover practice for each company. As a result, the research tool,

CEAT, was constructed in order to understand and examine the effectiveness of changeover practice. CEAT was mainly based on a maturity model approach that has been used in different subjects, such as Project Management (Cooke-Davies and Arzymanow, 2003; Brookes et al., 2014) and Knowledge Management (Serna, 2012). Maturity model was developed from TQM subject as emphasise on the continuous improvement approach (Cooke-Davies and Arzymanow, 2003). CEAT refers to the different of the effectiveness of the changeover process towards improvement and excellence, and the instrument was constructed based on the main factors of the conceptual model which are People, Process, Quality and Infrastructure. These main factors have then been divided into sub-factors that relate to the changeover practice. The CEAT comprises three sections:

- The first section of the CEAT instrument was gathering general background information about a respondent's experience and education level. Questionnaire was used before the interview started in order to collect the company's background data, such as company size, when the company was established, any quality program that it has implemented and how many years they have used this program.
- The second section of the instrument was to understand the status of the manufacturing changeover process based on semi-structured interview. It focused particularly on understanding the manufacturing changeover practice problems within the firm. Also, it examined the documentation procedure relating to changeover data and the results of the first outcomes after conducting changeover.
- The third section of CEAT attempted to examine the research sub-factors through the selection of five levels which indicate the firm's practice in the changeover process (the copy of CEAT is given in Appendix 3). CEAT incorporates 13 sub-factors from the main research factors; 11 sub-factors are mainly associated with the semi-structured interviews questions and two sub-factors are mainly related to the direct observations of changeover practice in the shop floor. CEAT indicates five levels of manufacturing changeover process which are described below:

  Level 1 Changeover primitive process: poor process and lack of attention given to improve changeover practice.

Level 2 Changeover managed and controlled process: changeover is recognised but is not standardised and improved.
Level 3 Changeover initiative process: changeover process is recognised and standardised but is not often improved.
Level 4 Changeover standardised process: changeover process is standardised and initiated the opportunity for improvement.
Level 5 Changeover optimising and sustainable process: continuous improvement cycle for changeover process.

During the semi-structured interviews and observations on the shop floor, the researcher used interview and observation matrix sheet in order to collect the respondent's answers to the questions (A copy of the interviews and observations matrix sheet is given in Appendix 4-A). The national language of Saudi Arabia is Arabic, although English is widely spoken in most of the firms. The research instrument, CEAT, was discussed in the English language during the interviews. Some conversations and discussion during the interviews were carried in the Arabic language in order to enable the interviewee to express his ideas fluently and in greater detail. However, the semi-structured interviews and the research interview transcript were translated into the English language.

Figure 5.6 describes the data collection stages - gathering, preparing, organising and finalising. The primary stage was gathering data from participating firms through interviewing the respondents, observation note-taking and collecting documentation that was associated with changeover data and practice. This was followed by the stage whereby the data prepared which involved the transcribed interviews and arranged observation notes as well as visual materials of the shop floor. These data have to be organised in relation to the research themes in order to be organised for coding. Therefore, coding and sub-coding can generate labelling and the assigning of words or phrases for each category of the data. This helps to provide a comprehensive insight of the current problems regarding the changeover practice between companies. Also, coding becomes the root of developing the research analysis. Finally, sorting, organising and preparing the data in advance would be essential for the beginning of analysing and presenting the results of the research findings.

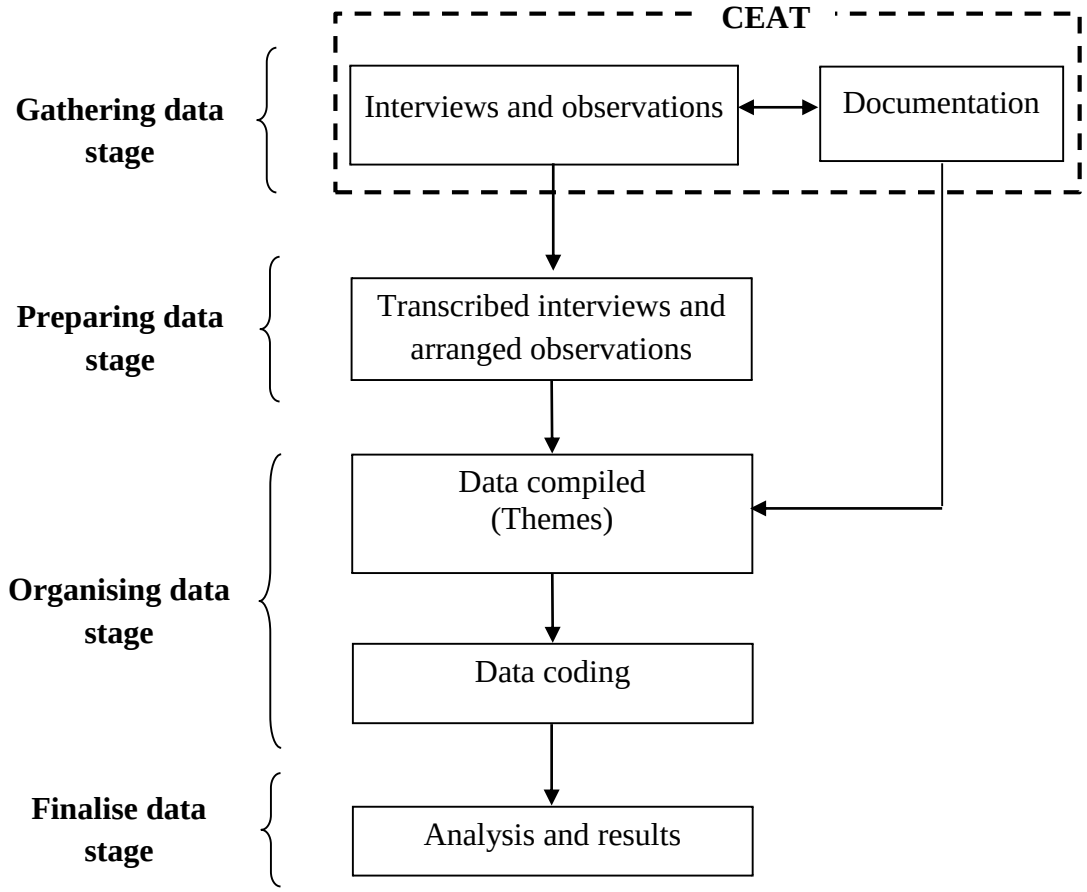

Figure 5.6 The process of collected raw data (Source: author).

Figure 5.7 describes the role of CEAT instrument in assessing the implementation of the current changeover practice whether it is new or existing product in terms of People, Process, Quality and Infrastructure. The study examines the differences between the required changeover of existing and new product, however CEAT considered as an assessment tool for identifying the weaknesses and strengths towards the changeover practice in the manufacturing firms. The result of CEAT can provide a valuable feedback to improve the practice by evaluating the research factors related to changeover. Moreover, CEAT evaluates the changeover implementation and its effectiveness particularly on the status of the quality of the first outcomes.

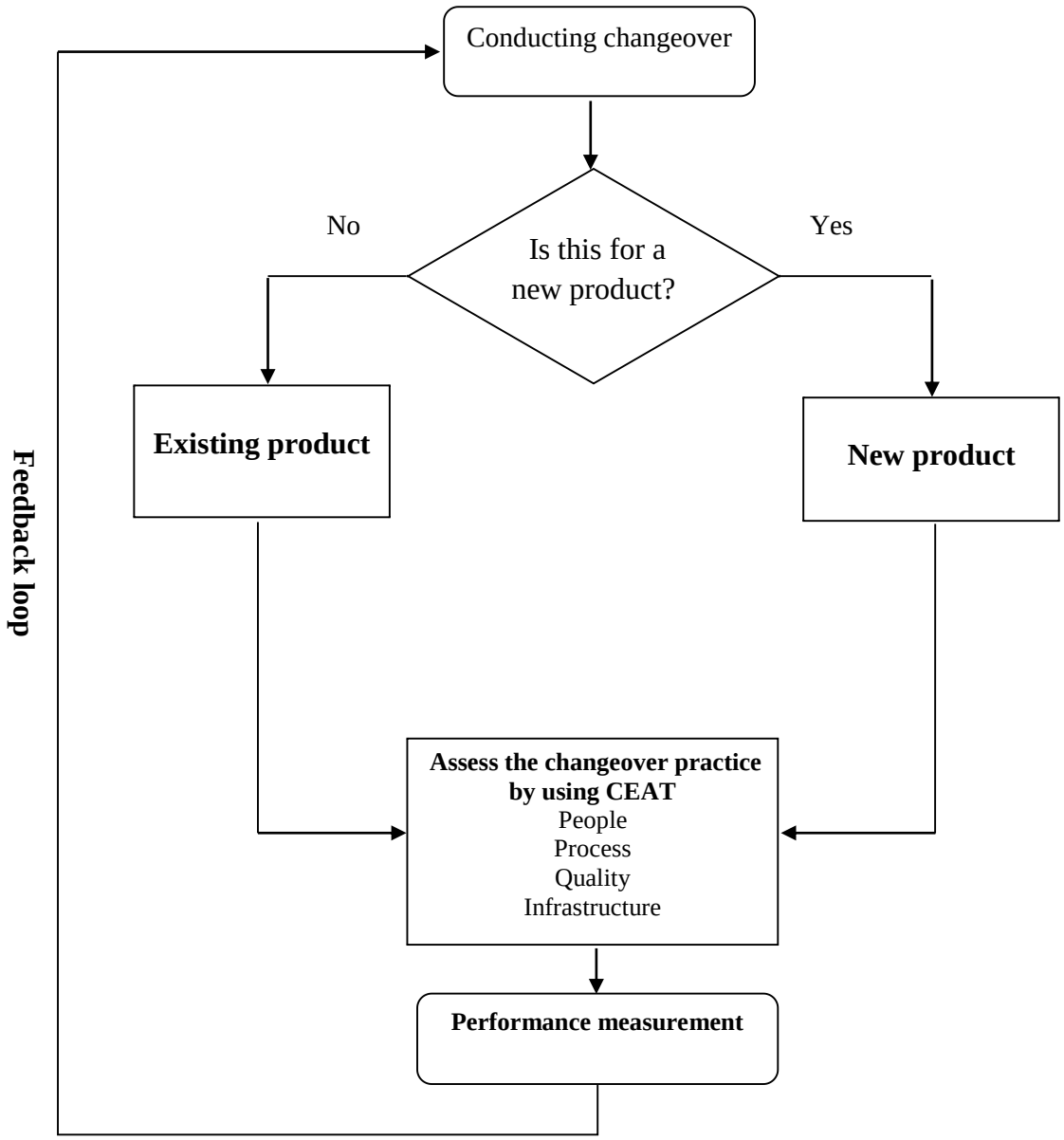

Figure 5.7 The implementation of CEAT (Source: author).

5.6 Analysing data

Thematic analysis is a generic approach to the analysis of qualitative data (Robson, 2011), and is undertaken to identify, evaluate and report themes (patterns) within the given data set. It was defined by Robson (2011, p. 474) as "a realistic method which reports experiences, meanings and the reality of participants which examines the ways in which events, realities, meanings and experiences are the effects of a range of discourses operating within society". Qualitative research usually deals with understanding various different aspects of data and thematic analysis offers an opportunity to better comprehend and deal with each issue (Myers, 2009). Also, in thematic analysis, there is a strong opportunity to relate opinions and concepts and then undertake comparisons with the collected data.

Thematic analysis helps to comprehend several aspects of the selected research area (Creswell, 2014). One of the biggest advantages of thematic analysis is the flexibility (Robson, 2011); it can be applied to both the constructionist and interpretivist paradigms.

Thematic analysis is considered most suitable for this research study as it will helps the researcher focus upon interpretations of the data. It aids the systematic analysis of the data as well as linking the theme frequency to the entire content and, thereby, making the entire research accurate. Further, allows the researcher to precisely determine the relations between the patterns and themes of changeover process. Furthermore, thematic analysis strongly focuses upon interpreting the data and is best suited for generating theory (Corbin and Strauss, 2008).

The data collected from semi-structured interviews and observations has to be coded and analysed using computer software. Robson (2011) suggested an approach that can be used for analysing data by identifying themes, patterns, relationships and differences among subgroups. Also, categorising data involved into developing categories that are derived from terms used by participants or existing literature is part of this approach (Saunders et al., 2009). This helps to conduct a more focused and in-depth analysis of data. The study involves the comparison of prompt high quality and reliable changeover process implementation in the manufacturing operations.

5.6.1 Taping and transcribing

The research interviews can be audio recorded in order to enable the researcher to concentrate in greater depth on what is being said. After the interview, it is important to transcribe the interviews in order to analyse the collected data in an appropriate manner (a sample of transcripts of the main case studies is given in Appendix 6-I). Silverman (2006) stated the advantages of having tapes and transcripts of interviews; audio records can be replayed and that would help to improve the quality of transcripts. Another advantage is that the recording of sequences of conversation may help the researcher to analyse sequences of utterances. Also, the researcher can focus on the interview rather than on taking notes and that helps to produce a better interview.

5.6.2 Data coding

Corbin and Strauss (2008) describe data coding as fracturing the data and rearranging them into categories to facilitate analysis; subsequently, data coding was used in this research in order to help organise the amount of collected qualitative data. Coding is the process of focusing on the collected data for refining themes and patterns (Hahn, 2008). The main terminology of coding the data is generating different levels of coding in order to recognise the relationship between the data as shown in Figure 5.8. First, the process of coding was undertaken to create the initial coding that has a large quantity of qualitative data. The second level focused more on coding in order to narrow down the data categories. Next, the third level of the process was refining the thematic codes of the data to fit with the proposed conceptual model. Hahn (2008) suggested that theoretical concepts could emerge from the themes and categories that established in the previous level (the coding template sheet that used in the research is given in Appendix 4-C). Figure 5.8 explains the data coding process that was used in the research.

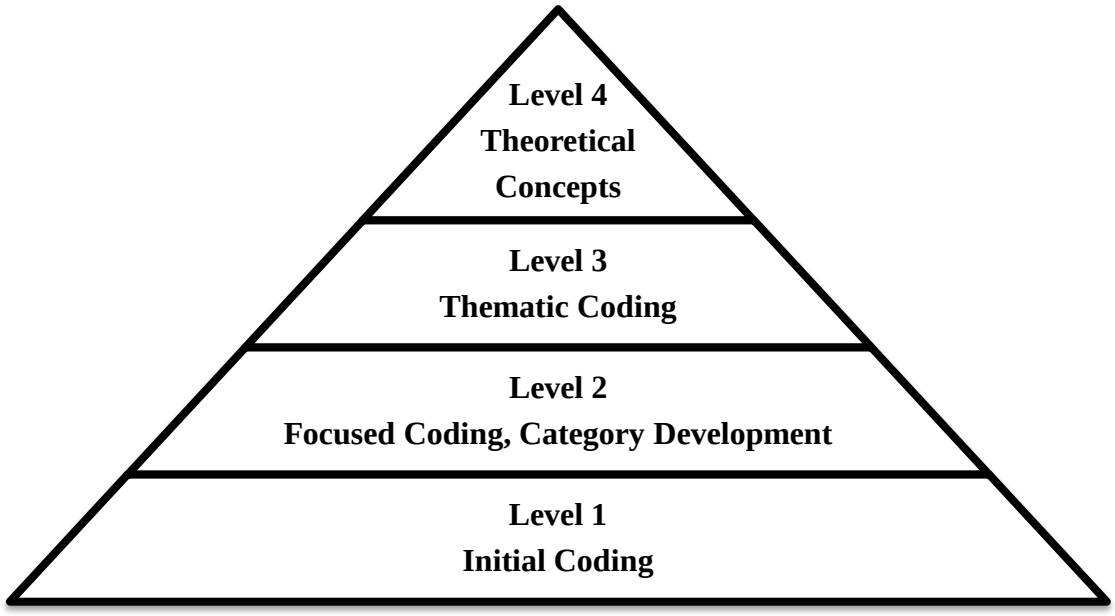

Figure 5.8 Data Coding (Hahn, 2008).

Microsoft Excel Software was used for coding and analysing the data; this was suggested by different authors (Hahn, 2008; Meyer and Avery, 2009), and others suggested Microsoft Word Software (La Pelle, 2004; Hahn, 2008). Meyer and Avery (2009) affirmed the advantages of using Excel in that it can handle large amounts of data, has multiple attributes, and offers a range of techniques. The

researcher did not use NVivo Software for coding and analysing the qualitative data due to the time constraints.

5.7 Validity and reliability of the research

The credibility of the research can be emphasised in the research design by establishing the validity and reliability of the research (Rowley, 2002; Silverman, 2006; Saunders et al., 2009; Yin, 2009). Wahyuni (2012, p. 77) defined credibility as "accuracy of data to reflect the observed social phenomena". Also, reliability is defined as the degree of consistency of data collection and analysis technique that will yield consistent findings despite using different observations (Silverman, 2006; Saunders et al., 2009). Data analysis methods and research strategy must indicate the transparency and reliability of the research process (Silverman, 2006). Robson (2011) and Saunders et al. (2009) described the four threats to reliability, which are participant error, participant bias, observer error, and observer bias. These threats can have a significant effect on the reliability of the research.

Rowley (2002) defined construct validity as the establishment of appropriate measures for the concepts being studied. This could be a measure that validates the research question in terms of data collection. In Chapter 3, the conceptual model was proposed from a review of the existing literature; this conceptual model is needed to investigate further the constructed sub-factors during data collection. External validity is the generalisation of the study findings based on replication logic (Rowley, 2002). It involves the generalisation of the study by analysing two or more cases, developing theory and proposing a high quality and reliable changeover process for the implementation of the conceptual model.

5.7.1 Research ethics

Saunders et al. (2009, p. 226) defined ethics as "the standards of behaviour that guide your conduct in relation to the rights of those who become the subject of your work, or are affected by it", and Robson (2011, p.197) defined it as "the rules of conduct; typically to conformity to a code or set of principles". Since management research involves human participants, it is necessary to understand ethical requirements for the research (Saunders et al., 2009). The ethical approval gained prior to

commencement of the research in order to ensure that the practice of ethical standards is employed during data collection. This gives a commitment to participants and also protects the researcher and ensures that ethical requirements are met (Robson, 2011). The researcher is aware of and respects the confidentiality of firms' data. This research involves an interview technique that is limited to within the firms and the researcher understands the ethical constraints of Saudi Arabia. It is important for the researcher to realise that the participants' identity remains confidential according to the ethical codes of scientific research. The personal information of all firms should be encoded in order to keep data confidential, so the researcher assigns a code or reference number to each firm to ensure that the data are stored against their codes rather than their names and only the researcher knows the full details.

5.8 Challenges in getting access and collecting field data

There were some challenges in getting access which was observed during asking the firms to participate in the research. The task of asking the company to participate in the research was not easy. Two medical products companies and one lighting company declined to participate; the most common reasons for this were: "We are too busy" and "We are moving to new premises". Therefore, a possibility might be that the firms did not value the importance of the research outcomes. Finally, it was easier to gain access to large firms than to SME firms, due to the fact that large firms are more open to the external environment and understand the potential positive outcomes of the research.

While collecting the field data, it became apparent to the researcher how important it was to communicate the research objectives effectively, as cultural aspects can impact on the outcomes when people are involved. In addition, there were some challenges to collecting field data which was observed during the company visits. There was a lack of manufacturing research in this geographical area and firms did not conduct research on a regular basis; subsequently, the researcher observed some hesitation in allowing the conducting of research interviews. For example, the researcher contacted Company F (Medium size) in advance by email in order to invite them to participate in the research. The company owner was the person contacted; they agreed to participate and the research interviews were scheduled. The researcher was pleased with the high speed response of the company. On the day of the interview, however, the Production Manager (PM) was hesitant about being interviewed by the researcher, although this had been agreed with the company owner, as the PM was in the position to

provide some unique information about the manufacturing changeover process to the researcher. The researcher totally understood that and explained that the response would remain strictly confidential; the researcher also explained the meaning of the research and its importance for Saudi manufacturing firms. The PM contacted the company owner to ask again if the company could participate in the research; following which he eventually agreed to participate. Also, for instance, the Production Manager of Company H (small size) was hesitant about being interviewed as it was the first such research experience for the company. To conclude, some of the manufacturing firms were not aware of the meaning and the potential of the academic research therefore some hesitation was initially observed during field data collection.

5.9 Summary

The research methodology employed to collect data including a multi case study and qualitative research approach which involves semi-structured interviews, direct observations and documentation has been discussed in detail in this chapter. The research instrument - CEAT - was developed and discussed in this chapter. Chapter 6 is the pilot study which presents the finding of the case studies and outcomes for improving CEAT. Also, an effort has been made to customise the conceptual model to establish a high quality and reliable manufacturing changeover process. This model will ultimately improve a firm's practices in the particular area of manufacturing changeover between products as a daily procedure.

CHAPTER 6 : PILOT STUDY

6.1 Introduction

In Chapter 5, the multi case study approach taken by this research in order to achieve the aim of the study was discussed. As explained earlier, the main purpose of the research methodology chapter is to explicate the research designs and methods used in the study. Also, the research instrument, CEAT, was introduced and discussed.

This chapter presents the pilot work conducted as part of this study. The purpose of this study is to investigate of undertaking a particular research study in manufacturing changeover in Saudi Arabian firms and to examine the proposed research instrument - CEAT - that was developed for further research. To date, only very few studies have attempted to understand manufacturing changeover in Saudi Arabian firms. The chapter present the pilot case studies and the methodology used for the study. A qualitative research methodology and a case study approach were employed to facilitate the collection of data. The outline of the companies on which the case studies were conducted is followed by a discussion of the case studies; the conclusion provides a number of suggestions for future research.

6.2 Methodology

The precision components company was selected for pilot study as their manufacturing type is batch production, based on the research sampling strategy which is implementing of QM programs, location at one geographical industrial area, and exporting of their products. Companies C and D are located in the 2nd industrial area of Riyadh, Saudi Arabia. A qualitative research approach was used for the pilot study; a semi-structured interview was involved in the study and direct observations were undertaken on the shop floor in terms of changeover practice and safety during changeover in order to examine the performance of the research instrument, CEAT (the copy of CEAT is given in Appendix 3). The preparation level of changeover was observed in order to assess the firm's performance in its operations activities. Data triangulation was engaged in the pilot study in terms of interview data, observations and documentation as discussed in the previous chapter.

A case studies approach was employed in this study. Both companies are Saudi-owned and their products have certified by SASO. Companies agreed to participate in the research following email contact in April 2013. The precision components companies offer a variety of products, such as gear, pump, pipe, valve and machined components (Products offered by Company D are given in Appendix 5-A). The Production Manager (PM) and the Quality Manager (QM) for both companies were targeted to interview as they relate directly to the shop floor manufacturing activities. The case studies of the pilot study were successfully completed during June 2013.

6.3 Profile of the companies

The details about the participant companies are given in Table 6.1. Both precision components companies have quality departments which are implementing QC and QA in their manufacturing practices. One large-sized company and one medium-sized company formed the pilot case studies, and both companies were established for more than 15 years.

Table 6.1 Pilot case companies profile (Source: author).

Companies	Company Size	Company established	Quality program	Years of implementing quality program
Company C	More than 200 > Large size	More than 15 years	Quality Control (QC) and Assurance (QA)	More than 15 years
Company D	50-200 > Medium size	More than 15 years	Quality Control (QC) and Assurance (QA)	10-15 years

Company C

The company was accredited with the ISO 9001:2008, and also certified with TS 29001:2003 which is for petroleum, petrochemical and natural gas industries. Specifically the company uses batch and mass production in their manufacturing. Table 6.2 shows the respondents of Company C based on their experience in the manufacturing industry, and education level. The company has three manufacturing cells which are:

- Cell-1: Computer Numerical Control (CNC) machine with production capacity 60%
- Cell-2: Conventional machine with production capacity 30%
- Cell-3: Big part products with production capacity 10%

Table 6.2 Respondents' experience and education level of Company C (Source: author).

Respondents	Education level	Experience in manufacturing industry
Production Manager	Bachelor degree	5-10 years
Quality Manager	Master degree	More than 15 years

Company D

As was the case with the previous company, the PM and QM were interviewed in order to ensure consistency of the study sample. Company D was founded in 1987. The company has been certified ISO 9001:2008 for Quality Management System and has also upgraded the certification of Quality Management System TS 29001. The company claims itself as the only approved local supplier for Saudi ARAMCO in the Middle East.; Saudi ARAMCO is considered one of the biggest companies in the country and their main business is exploration and producing to refine oil and natural gas. Table 6.3 shows the respondents of Company C based on their experience in the manufacturing industry and education level. The company has two manufacturing cells which are:

- Cell-1: Computer Numerical Control (CNC)
- Cell-2: Conventional machine

Table 6.3 Respondents' experience and education level of Company D (Source: author).

Respondents	Education level	Experience in manufacturing industry
Production Manager	Bachelor degree	More than 15 years
Quality Manager	Diploma degree	More than 15 years

6.4 Pilot case studies

The interviews were conducted on the company site in order to assess and observe their practice in terms of changeover preparation and manufacturing changeover. Respondents were asked to categorise the most common problems that occurred during manufacturing changeover in their companies (The copy of CEAT is given in Appendix 3). Availability of raw materials is considered the area of greatest concern in both companies while performing changeover, as shown in Table 6.4. This is due to a range of reasons, such as supplying of raw material abroad and lack of raw materials management software that controls inventory level. Skill of manpower emerged as the second problem that companies faced in implementation of manufacturing changeover. Both companies affirmed that resigning and retaining of skilled manpower is very high in Saudi Arabia. This is as a result of reaching the threshold limit of workers' salaries. After a certain length of time, a worker gains experience and knowledge; therefore companies cannot retain them due to the disparity between the high skill level and low wages paid. It should be noted that the majority of manpower in Saudi Arabia is from Asian countries, such as India, Nepal and Pakistan.

Table 6.4 Changeover problems that occur in Companies C and D (Source: author).

Company	Respondent	Problems that occur during manufacturing changeover
C	Production Manager	Availability of the tools
	Quality Manager	Availability of the raw material
		Lack of skilled manpower
D	Production Manager	Availability of the supply of raw materials from outside the country.
		Lack of raw materials management software impacts on availability of raw materials
		Lack of skilled manpower
		Lack of awareness of changeover/set-up time
	Quality Manager	Lack of training

Based on their answers the objectives of improving the changeover process can be summarised as follows:

- To be more efficient and effective, therefore to compete in the market
- To reduce man hours working and so to enhance productivity

The respondents were asked what they considered were the major obstacles to improving the changeover process, which were cited as:

- Financial difficulties
- Retaining skilled people
- Clear strategy for improving productivity
- Employees' motivation

According to the respondents of both companies, the production department was responsible for recording changeover data. Both companies have an explicit and documented production time; therefore changeover time will be calculated as an indirect way from starting and ending of batch production time. However, these data were recorded by the supervisor and the operator as a daily routine process and have not been used for improving changeover practice. It seems to be that both companies focused on recording production time in order to determine the production cost and little emphasis was put on using the changeover data to improve the setup. All respondents admitted that changeover data have not been used or linked with performance and first outcomes. In addition, the Quality Manager of Company C stated that the problem after set-up of the machine is that the first piece will always get rejected.

The outcomes of the interviews and observations that conducted in both companies can be seen in Table 6.5; the sub-factors in this research are grouped in into four categories - People, Process, Quality and Infrastructure - as showed in the conceptual model in Chapter 3 at Figure 3.8. The conceptual model of the research discussed different changeover in terms of product and process. It should be noted that the pilot study only examined the changeover of original product and original process. The studied sub-factors are denoted by "F" (i.e. F1 to F13) as stated in the legend below the table. The respondents' answers are represented as L1 to L5 where "L" refers to their implementation level towards changeover practice. The levels that indicated respondents' answers from L1 to L5 were based on the research instrument CEAT. The respondents of both companies are referred to as Production Manager (PM) and Quality Manager (QM) in the table. The sub-factors from F1 to F11 were mainly based on the selected by the respondents as suitable level during the semi-structured interviews while sub-factors F12 and F13 were mostly related to direct observation of changeover practice and preparation as well as the safety procedure during changeover process. The selected levels of these two sub-factors were based on the researcher's observations. The last column of the table indicates the attendance of the researcher at changeover practice and preparation for each company.

Table 6.5 The interviews and observations matrix of pilot study (Source: author).

Interview & Observation Matrix		Interview											Observation		
		People			Process				Quality			Infra.	Process	Quality	Overall
Firm		F 1	F 2	F 3	F 4	F 5	F 6	F 7	F 8	F 9	F 10	F 11	F 12	F13	Attending changeover
C	PM	L4	L2	L4	L4	L2	L4	L2	L2	L1	L3	L5	L4	L4	Partially
	QM	L4	L3	L3	L5	L3	L4	L5	L1	L3	L2	L5			
D	PM	L2	L1	L2	L3	L1	L3	L2	L1	L1	L2	L1	L2	L3	Fully
	QM	L3	L2	L3	L4	L1	L5	L2	L1	L1	L3	L4			

F1 (Factor 1) Top management support changeover process
F2 (Factor 2) Training for changeover practice
F3 (Factor 3) Employee involvement during changeover
F4 (Factor 4) Time cause an undue pressure
F5 (Factor 5) Speed up the set-up process (standardisation)
F6 (Factor 6) Availability of the materials
F7 (Factor 7) Interruption of the sequence of changeover tasks
F8 (Factor 8) Using checklist (Preparation)
F9 (Factor 9) Awareness of changeover and QM
F10 (Factor 10) Initiative for changeover improvement
F11 (Factor 11) Using new machines and tools
F12 (Factor 12) Changeover preparation
F13 (Factor 13) Safety and facilities on shop floor (clean and lighting)

6.4.1 Company C

The company has 20 years' experience of manufacturing precision components and it distributes its products to both the local and international markets. The main aim of the company is to provide a consistent quality, and reliable delivery at competitive prices. The company has a sand-casting iron foundry which feeds the plant with manufactured castings for producing a wide range of pumps, valves and heavy equipment. During the interview, the Production Manager discussed how the company records changeover data:

"I believe we are still very weak in some areas of collecting some data, for example set-up time, how long it will take".

Changeover data were not recorded directly but the set-up time was calculated as a part of production time data. The company is using ERP software in order to provide advance planning and scheduling, product lifecycle, supply chain management and financial management. The company claims that ERP software elevates the manufacturing operations to be more flexible and to meet business challenges and opportunities. The following sub-sections discuss People, Process, Quality and Infrastructure based on the data collected.

People

Top management identified the importance and scope of the changeover and set-up time to the firm, as the company has the concept of the preparation of changeover, such as tooling and drawing preparation. The company has a daily morning meeting for discussing the problems that happened the previous day. Top management were involved in this meeting to provide suggestions and feedback for general manufacturing operations problems. However, this meeting was not enough to deliver feedback on the subject of changeover process improvement. Besides that there was no follow-up meeting to discuss changeover improvements with management. Both respondents affirmed that top management did not directly participate and a there was not a smooth cycle of feedback to production and quality personnel for improving the changeover process.

General basic training is provided for all the new workers in order to familiarise them with the working environment. It should be noted that the worker who is performing changeover is called the lead-man; the lead-man originally was an operator and already has operational experience within the

company. The lead-man enhances his experience of being specialised on a certain machine and there was a short internal training course about the set-up of the machine. The lead-man and the operator inform their supervisor about past problems; however the lead-man was not involved in decision making relating to the changeover improvement process. This is because the managers did not encourage decision making as a result of a lack of a documented feedback and suggestion system.

Process

The production department is totally responsible for performing the set-up process. The QM department was not engaged in the changeover process as its main role was to inspect the outcomes of the machines. Moreover, it seems that in terms of involvement in the set-up parameters, the QM department strategy is reactive rather than proactive; as the Quality Manager stated:

"Whatever parameter changes the production department has done, we are not aware. We will check the outcome of that one. If it is OK, we will give the green signal, "Please go ahead." In case of any deviation, we will say, "This particular dimension is out of tolerance. Please control it"".

The company normally works two shifts, one in the morning and the other at night. The notice board was implemented in order to maintain the communication between crews' shifts. Figure 6.1 shows that the notice board based on an hourly daily set-up schedule as well as output efficiency tracker for the machines. This helps to keep all shop floor workers informed of the preparation for the next set-up period. In addition, the company has a strategy of reducing time pressure on the lead-man during changing over between the machines at the same time. For example, two machines are required to do set-up at the same time; management decided to do changeover on one machine while keeping the other one running. As a result, the set-up was segregated between two machines and the products that are produced will be sold based on the forecasting of customers' demand.

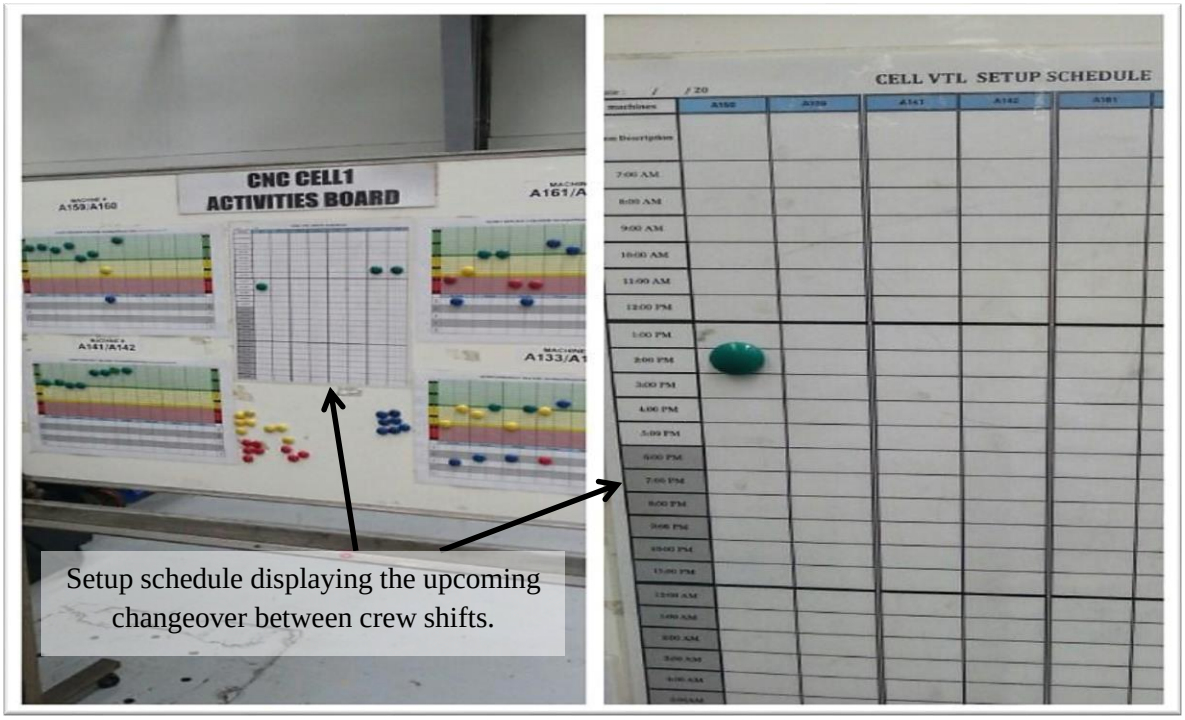

Figure 6.1 Visual activities board of machines performance and setup time (Source: author).

Normally, the time pressure created on the shop floor is due to the machine breakdown and maintenance. Both respondents affirmed that changeover standardisation procedures existed but they were not very robust. The reason for that is the set-up process might change, as a result of buying new machines, since the procedures have not been updated and not fully documented because of lack of follow-up in the development of the changeover procedure. Changeover preparation has been identified in the firm as an essential process for having high productivity and for being more flexible. The firm established a tooling department which prepare the tools in advance for upcoming jobs. The tools preparation process is presented in Figure 6.2. The process can be discussed as follows: The lead-man prepares the drawing of the next manufactured product based on the production plan. The drawing is then handed over to the tooling department in order to prepare the tools based on the drawing. Then, tools and drawing are ready for collection in advance before changeover commences within an hour. However, some difficulty is experienced during the preparation which is the availability of tools as these may be in use with the other machine. The value of the tooling department is to reduce the time taken for tool preparation for the upcoming changeover, and thereby to eliminate waste. In terms of new product changeover, the company highlighted the importance of preparing tools, raw materials and drawing in order to progress towards changeover effectively.

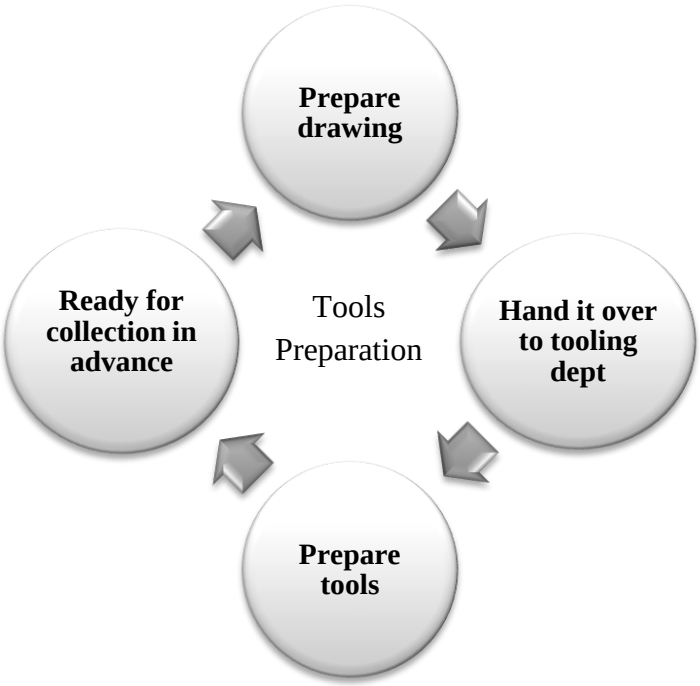

Figure 6.2 Tools preparation (Source: author).

The major advantage of the company having its own foundry is the availability of raw material. The company is relying on itself to produce raw material rather than relying on a supplier which is generally out of their control. A two-week advance schedule is submitted to the foundry in order for it to prepare the raw materials for the upcoming changeover. The company has an alternative raw material to run the machine in case they faced a delay or rejection in the scheduling of raw materials, which maintains the progression of the changeover as well as improves machine utilisation. During changeover, the lead-man is often interrupted by having to deal with other jobs; which means that the changeover process have to be repeated. On the shop floor, there was a dies cabinet which was organised, and where all die and tool have part numbers and were easily identifiable.

Quality

It has been observed that there was no use of a simple checklist or procedure checklist for confirming changeover activities on the shop floor. Therefore, the firm was relying on the lead-man's experience for preparing raw materials and tasks. The firm identified safety requirements on the shop floor by using safety signs, based on the observations of the researcher. Changeover is usually conducted without constraints, such as an unclean shop floor that might interrupt and affect the lead-man. It was observed that the company was not providing knowledge about changeover and QM through

communication channels, such as book, notice board or leaflet. The firm mostly disseminated the knowledge of changeover and the QM verbally only, via the engineer. Moreover, the link between the QM and changeover process on the shop floor was not being made as the quality department was not responsible for the changeover parameters.

The company has a policy of initiating continuous improvement between its departments. Each individual division has to produce a minimum of one continuous improvement that would be discovered from their prospective area. Top management evaluate all the improvements that are presented by the departments. Eventually, the major improvement on the shop floor, or cost-saving achieved will be awarded based on the value of contribution to work practice. There was no specific changeover process improvement conducted on the shop floor but the firm had recently introduced a changeover data sheet for recording set-up time in order to create a database for the changeover. It seems to be that the changeover process itself has not been improved; rather the firm has started to motivate the shop-floor workers to make improvements.

Infrastructure

The company had experience of changing and replacing the machines. The old machines are becoming obsolete and require changing; this is due to high rejection and rework rates. However, the complexity of the new machines led to an increase in changeover time. Company C has not reviewed the impact of its new machine on changeover time since purchasing it. The compromise between old and new machine occur at the changeover time; the company claims that the outcomes of the new machine are always better than old machine, and that there is also a high acceptance rate of the products as they meet their quality standards and requirements. The company put great trust in the performance outcomes of these new machines as sometimes quality inspection was not required for the outcomes.

The overall changeover effectiveness within the company is shown in Figure 6.3. Based on the respondents' answers and observations, the score was 3.6. This indicates that the company is working towards achieving level 4 for standardising its changeover process. There were some discrepancies within the respondents' answers, particularly on Factor 7 - interruption of the sequence of changeover tasks and on Factor 9 - Quality Management and changeover knowledge. In terms of Factor 7, the Quality Manager affirmed earlier that quality department was not involved in the changeover

parameter and process during set-up time. This indicated that the quality department was only concerned about the outcomes after the set-up time. Therefore, a there was a general lack of quality department involvement and awareness of the activities as well as tasks that were undertaken during the set-up period. In terms of Factor 9 discrepancy, and based on observation, the researcher did not observe a notice board on the shop floor which introduced the QM concept and changeover knowledge.

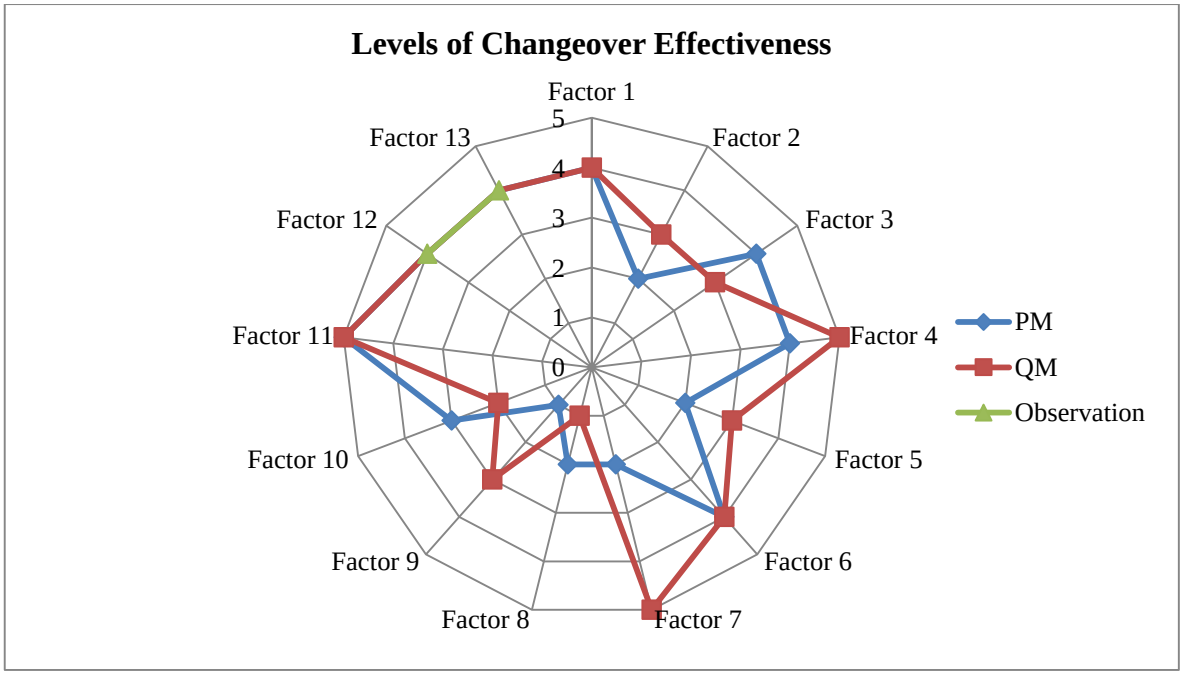

Figure 6.3 Levels of changeover effectiveness - Company C (Source: author).

6.4.2 Company D

Company D production relies on supplying contracts to local and global companies. The company claims itself as tailor-made industry which means that the manufactured product should meet customers' exact requirements. The main goal is to meet delivery time and customers' requirements. During the interview, the Production Manager discussed manufacturing changeover implementation within the company as:

"Actually we did not reach this level to reduce set-up time and therefore return it back to production capacity. We have major problems that need to be fixed first before starting to think how to reduce set-up time. Set-up time has not yet been studied here as it is a minor problem".

In the previous quote, the Production Manager discussed the main problems that the company faced, described in Table 6.4, section 6.4. However, the PM pointed out that the manufacturing changeover process was less important and seen as a minor issue for improving manufacturing practice of the company due to the fact that the firm tends to operate at a low level of changeover practice. While, maintaining a better changeover practice requires a higher level of quality and improvement process as well as a lack of understanding and awareness of the importance of changeover practice within the firm. The company's main focus is on solving major issues in the plant warehouse and their current lack of a documentation system. Recently, the company introduced EPICOR software which it considers an ERP system. This software will help the company calculate the actual cost and time for products as well as becoming more responsive to change. The company's organisation chart can be seen in Figure 6.4. Based on the organisation chart, the changeover process is related to the production department; however the quality assurance department does not consider changeover a part of the quality department; rather it is a completely different area in this respect. The following section evaluates their changeover practice based on four categories - People, Process, Quality and Infrastructure.

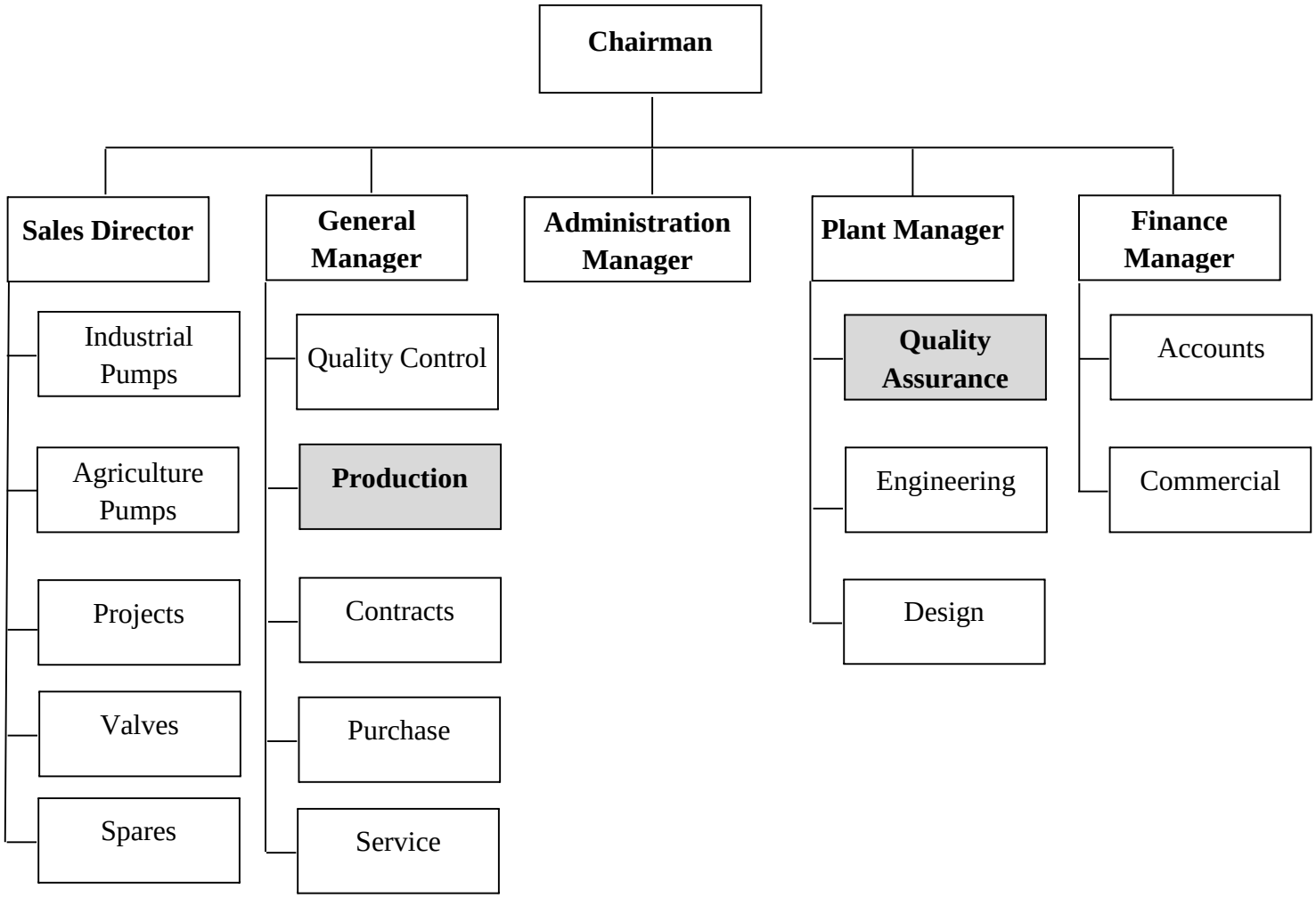

Figure 6.4 Organisation Chart of Company D (Source: author).

People

Top management plays an important role in facilitating improvement by providing their support and commitment to, and involvement in, the manufacturing practice; however, their involvement in improving changeover is lacking. As a result, there is no follow-up meeting to study particular improvement opportunities of the manufacturing operation or changeover process, and top management are not involved in providing feedback or suggestions for improving the changeover process.

A two-week general training programme is provided for new operators by observing existing workers and supervisors while conducting manufacturing operations. There is no lean principle training given to the operators, such as 5S or Seven Deadly Wastes. The informal training procedure is not defined, can create some ambiguity for new workers. Therefore, the training given to the new operators will be different for upcoming operators. The PM suggested that top management should establish a new training centre for workers in order to improve their skills. The QM refers to the level of workers' skill within the company:

"If we get a highly qualified worker, that means we have to pay a high salary".

Company D employed new workers for having an advantage of low wages. Workers are involved in the feedback of the changeover process loop with management by verbal communication. Some difficulties occurred at the shop-floor level between workers because of the language barrier which results in a lack of communication. Consequently, workers need to learn one common language in order to overcome communication difficulty.

Process

Company D affirmed that the changeover process performs under less pressure. Based on the researcher's observation, the operator conducted changeover without having the pressure of exceeding an average changeover time. The company does not emphasise improving and reducing changeover time as the operator mainly performs inefficiently when it comes to changeover activities. Besides that, the performance of the operator can be described as a waste of time; for example, using a cell phone or talking with the other operator during the changeover process. This is based on the

observation during the changeover; the operator was uncommitted to finishing the changeover on time since there was no pressure from top management to reduce the set-up time. Accordingly, the company has not standardised changeover procedure as they are mostly relying on some experienced workers only.

Due to the small scale of the plant, the company does not have an issue with transportation of the materials into the location for the next changeover. There is some delay in purchasing raw materials because of financial difficulties. Recently, the company established a planning department to draw up a materials plan in advance for the production department. Through establishing this department, the company will maintain the communication channel between production and the planning department more effectively.

Workers were often interrupted during the changeover process to undertake another job; this happened two or three times during the process. Both respondents affirmed that interruptions were normal during the changeover process. Distracting operators and preventing activities required during the changeover process occurred due to the supervisor asking the operator to take on another job that was to be delivered soon.

Quality

Using a checklist for confirming the changeover process before set-up activities commence can enhance the reliability of the process. However, there was no extended use of the procedure checklist, or use of a simple checklist to confirm the set-up process within the company. The QM responded in that regard:

"The same people have not changed for a long time from the workers and engineers in the field. Since I am here for 17 years, we do the same practice – it never changes. Therefore, the same practice of changeover has been in place since that time".

There were no tools or techniques for confirming changeover process before starting the activities where the company was completely reliant on the operator's experience. In addition, there was no specific improvement of set-up time or changeover process based on the respondents' answers, this is because the company was satisfied with its changeover practice and felt it did not need to be improved. The company depends on the supervisor to disseminate the knowledge of changeover and

quality management to the workers, as knowledge is disseminated verbally based on the understanding of the supervisor. The Quality Department was not involved in the changeover practice and parameters as these are handled completely by the Production Department. This is because the Quality Department was only responsible for inspection of the outcomes after the set-up process was conducted. Moreover, there was a lack of communication and consistency between the Production and Quality Departments towards the changeover process.

Infrastructure

There has been no review of the impact of the use of new machines on setup time and changeover process since they have been purchased by the company. The company believes that a new technology reduces and improves the set-up time of the machines; the Quality Manager stated that the company is going to use plasma technology for cutting and that would improve set-up time. However, the Production Manager claimed that the company has not bought new machines since the plant was established and had no intention of buying new machines. The contradiction between the Production and Quality Managers was clear in their different answers for Level 1 and Level 4 relating to technology (Factor 11).

The levels of changeover effectiveness are shown in Figure 6.5 which is based on respondents' answers and observations. The overall changeover effectiveness within the company based on the respondents and observation was 2.3; this indicates that the company is on a level managed and controlled changeover process. There were discrepancies within the respondents' answers particularly on availability of materials for job resources (Factor 6) and using new machines/tools "technology" (Factor 11). Obviously, there was a lack of communication between Quality and Production Departments in terms of raw materials availability (Factor 6). Therefore, the Production Department established a planning department to provide a materials plan in advance for the Production Department in order to improve raw materials handling to the shop floor. According to the Factor 11 discrepancy and based on the observation on the shop floor, there were no new machines used on the shop floor since the plant was established.

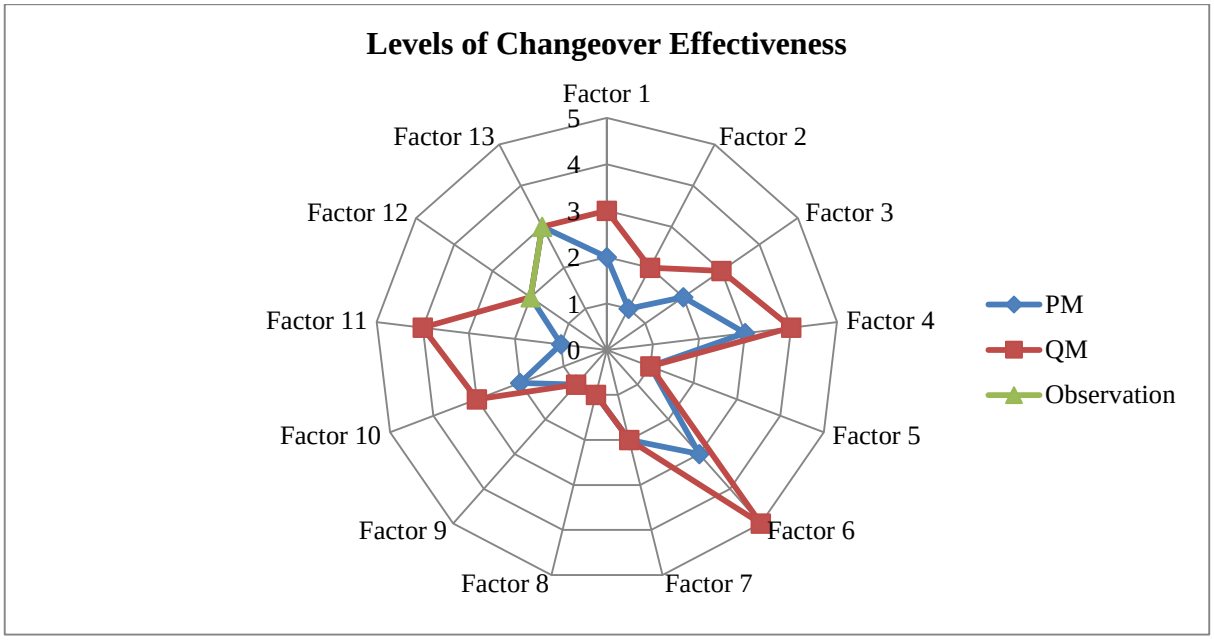

Figure 6.5 Levels of changeover effectiveness - Company D (Source: author).

6.5 Discussion

The companies are fully committed to collecting production data, such as production time and produced quantity in order to calculate production cost of manufactured product. The firms were calculating changeover time by determining the difference in production time between ending manufacturing the previous product to beginning manufacturing the next product. As a result of that, changeover data were not collected in a direct way, which can create some ambiguity and inaccuracy of the calculations for the exact time of the next changeover. As the main focus on their recording data was on the production time; this result shows a lack of interest in recording changeover time and activities. Besides that, the calculated changeover data were not used for initiatives relating to the continuous improvement of the changeover as they were collected daily routine process.

Company C has clearly identified their approach to the manufacturing strategy by implementing Make-To-Stock (MTS) and trade-off strategy on the shop floor. The trade-off strategy is described as operational compromises to understand the relationship between competitive advantages (Da Silveira and Slack, 2001). Company C has been applied the MTS strategy for reducing time pressure on the lead-man while conducting two changeovers at the same time. This result indicates the poor production planning scheduling that is releasing two jobs simultaneously. In addition, Company C has implemented a trade-off strategy between set-up time and high-quality rate of the outcomes. The

company replaced the old machines in order to reduce the rejection rate; however the new machine does take more set-up time although with high-quality output. The trade-off occurred between set-up time and product quality; this happened during conforming of the set-up process for a longer time so that a lot to attention was focused on the details of achieving the quality product. According to McIntosh et al. (1996), manufacturing companies allow for increasing set-up time in order to improve quality rates; as stated by the Quality Manager of Company C:

"The companies will go for new technology or a new machine to drastically reduce their set-ups. Here in our case, we have gone so far to replace the older machine, or to reduce the rejections. We don't mind spending more time on the set-up provided we get the right quality at the end of the day".

Company D has a training issue with its new operators as there no specific training was given to them. Normally, the operator exercises and learns the manufacturing practice from his colleague, but this can lead to some non-conformity within the accurate working procedures that need to be followed. A training programme must be identified to ensure that those new operators are undergoing the same training procedure. Moreover, the firm was not bringing in that many educated people because of financial constraints which would have an impact on the level of awareness changeover and QM. Also, a lack of communication on the shop floor was caused by language barriers between operators of different nationalities. Undoubtedly, there was a problem with human resources in terms of improving operator skill, in order to enhance changeover practice. The company had not established a sense of preparation for upcoming changeover; there was no indicated level of changeover preparation, such as drawing, materials and tools preparation.

The absence of training for existing operators of both companies was indicated. A general training programme of manufacturing practice was lacking as well as specific training on changeover improvement. SMED and 5S programs were not trained or implemented on the shop floor. Both firms lacked a standardised changeover procedure and simple checklist for confirming the changeover process. These serious problems were initiated by both companies as they established non-written changeover procedures based on long experience on the shop floor. Companies need to establish standardisation of changeover procedure, in order to initiate the improvements in the changeover practice. The study revealed that the availability of materials for changeover depends on the level of planning and preparation. The difference between Company C and Company D in terms of

changeover preparation level was obvious, and it is evident that Company C has a tooling department for helping to eliminate the waste during changeover time.

Table 6.6 describes the mean changeover process factors of each category within the firms based on the collected data of the research instrument, CEAT. It seems that Company C has better practice of delivering high-quality changeover than Company D has, with overall scores of 3.65 and 2.25, respectively. Undoubtedly, the category of quality had the lowest mean for both companies. This is because of a low level implementation of quality factors as neither company was using a checklist for confirming the changeover process before it began, and instead relied on experiences of the supervisor or the operator to perform the process. Moreover, there was a lack of awareness of the importance of the changeover improvement to business as there was not much of an improvement made towards set-up time.

Table 6.6 The mean of construct factors between Companies C and D (Source: author).

Categories	Company C	Company D
People	3.3	2.2
Process	3.7	2.5
Quality	2.5	1.9
Infrastructure	5	2.5
Overall	**3.6**	**2.3**

Drawing these results together, the conceptual model has been customised based on the study of the precision components industry and findings of the pilot study. This modification helps to keep the model updated and identify further sub-factors that affect the reliability of the changeover process in this industry. Figure 6.6 represents the proposed conceptual model. The most common changeover between product and process within the precision components industry was the original changing of the existing product and process. One additional factor has been derived from Company C which is changeover preparation. The advance preparation of upcoming changeover was clearly indicated in the tool department. Also, the preparation of the drawing for identifying the most suitable tools during the early stage of the production was recognised in order to make changeover time quicker and simpler. The conceptual model needs to be explored further in terms of identifying additional sub-factors and different manufacturing changeover in terms of originality (existing) and new of the products and processes.

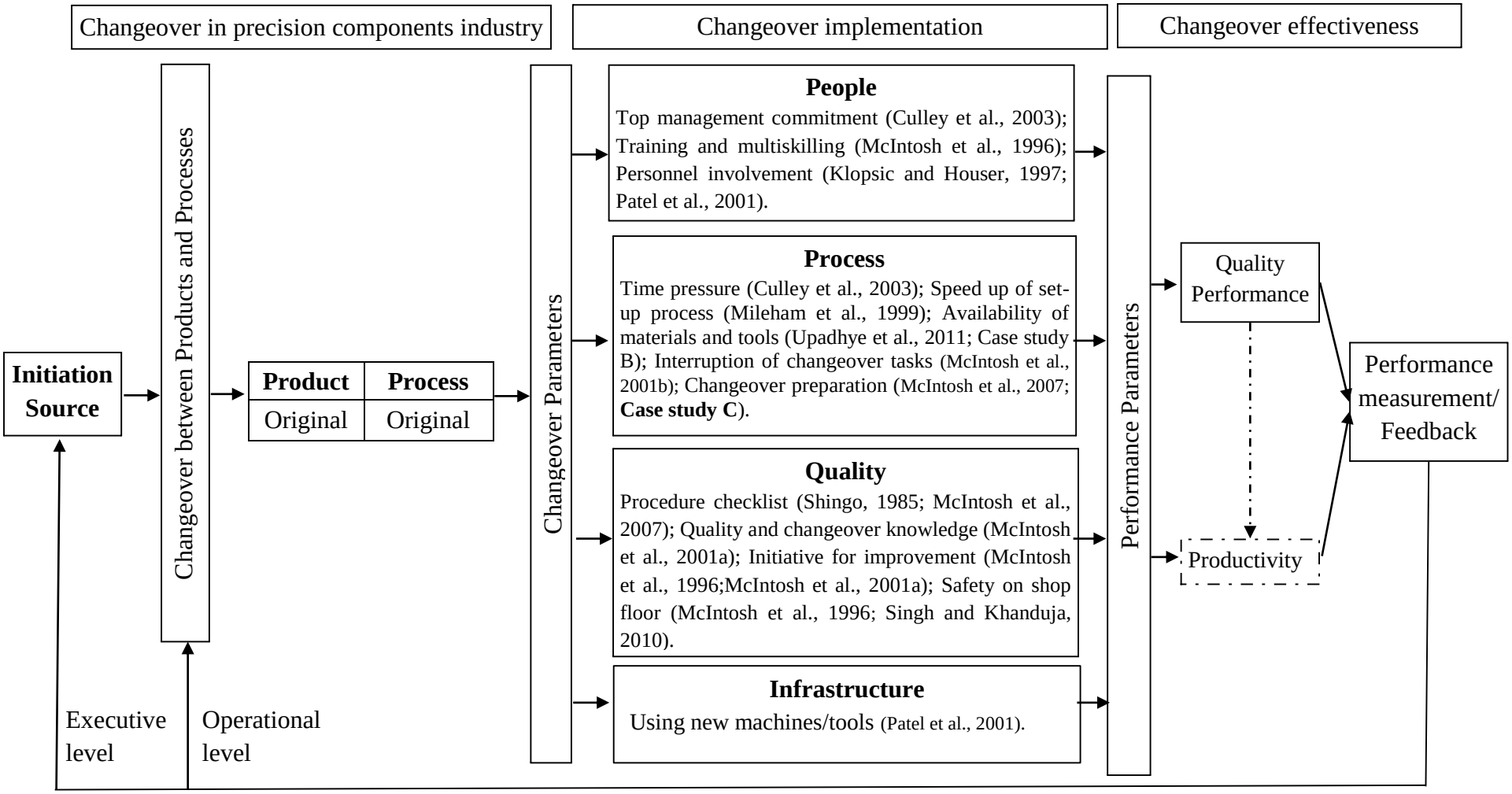

Figure 6.6 Proposed conceptual model for precision components companies (Source: author).

6.6 Pilot study outcomes

The importance of the pilot study is to test and improve the research design and tools before collecting data in the main cases. The research design and tools in the pilot study have proved effective. The pilot study was very helpful in terms of improving and rectifying the statements of the research instrument, CEAT. Certain levels had to be changed in order to make the levels clearer for the respondents of the main case studies. Some levels have changed, or been added and revised in order to eliminate ambiguity at those levels. Table 6.7 indicates the number of each level that has been changed, added and revised. Moreover, the table shows the difference between the old and new versions as well as the reasoning for each amendment (The research instrument CEAT is given in Appendix 3). In addition, there are some improvements to CEAT that contributed directly to the research design. The pilot study helped to ensure that the research design works well before conducting the main study. It is essential for recognising some developments in the research tool. The changes in the research instrument CEAT are:

- Factor 6: availability of tools has been added to the materials availability; based on the pilot study of Company C this indicates that the preparation of tools needs to be identified in advance before conducting the changeover. The availability of tools can impact on changeover progression as this was a problem of Company C.
- Factor 11: using new machines and tools "technology" has been changed and revised to the statement levels 1, 2, 3 and 5. The modification of this factor was based on reviewing changeover time while and before purchasing new machines. Increasing set-up time of a new machine contributes directly to the progression of changeover.
- Factor 12: changeover preparation has been modified after the pilot study. Based on the shop floor visit and attending of changeover practice, the researcher perceived the shop floor aspects in Saudi Arabian firms, such as using of the colour-coding technique, tooling preparation, and die cabinet. The combination of the literature review as well as observations in the field of changeover preparation contributes to construct this factor's levels.

Table 6.7 Sub-factors and levels that changed in the research instrument (CEAT) after conducting the pilot study (Source: author).

Factor and level no.	Old version	New version	Reason
Top management commitment Level 3	Top management is encouraging changeover practice by providing adequate tools and equipment	Top management is encouraging changeover practice by providing adequate tools and equipment; provides suggestions for improving the changeover process	It was found that top management supported changeover process by providing suggestions
Training and multiskilling Level 2	Operators will have training only in changing or introducing of new machine and production line	New operators will have short introduction training for plant facilities	Paraphrasing
Availability of materials and tools "on job resource" Level 5	Better communication channel between production and planning departments	Better communication channel between production and planning departments by using software; planning department disseminated the production plan in advance to the responsible departments	Identifying the role of planning department towards delivering production plan
Procedure checklist Level 1	Firm do not have procedure checklist or simple check sheet for preparation changeover	Firm does not have a procedure checklist or simple check sheet for changeover preparation; operator relying on his experience and memory to prepare tools and materials for the changeover	It was found from the pilot studies that companies were relying on operator experience for changeover preparation
Quality Management and changeover knowledge Level 1	No knowledge disseminated of Quality Management (QM) and changeover among shop floor workers by firm	No knowledge disseminated to Quality Management (QM) and changeover among shop-floor workers by firm but sometimes it relies on the supervisor to disseminate knowledge to the operator through verbal communication	It was found from the pilot studies that companies were relying on verbal communication to disseminate knowledge

Using new machines/tools "Technology" Level 1	New machines compromised on changeover time and effectiveness	Firm not reviewing the impact of new machines on changeover time and effectiveness while purchasing them	Identifying the reviewing process while purchasing
Using new machines/tools "Technology" Level 2	Occasionally when the firm used new machines this compromised on changeover time and effectiveness; new machines were tested once installed; updated and latest machines/tools are provided	Firm giving priority of buying new machines to the high quality rates output more than considering less changeover time; new machines were tested once installed; updated and latest machines/tools are provided.	Understanding the occurrence of the trade-off between quality outcomes and changeover time
Using new machines/tools "Technology" Level 3	New machines help to improve set-up time	Sometimes the firm revises the impact of new machines on changeover time and effectiveness while purchasing them	Identifying the reviewing process while purchasing
Using new machines/tools "Technology" Level 5	Adding new sentence	Firm reviewed the impact of new machines on changeover time and effectiveness while purchasing them	Identifying the reviewing process while purchasing

6.7 Conclusion and recommendations for future work

The outcomes of the pilot study have undoubtedly indicated that many difficulties are experienced in the changeover practice within Saudi Arabian firms. Changeover data need to be record the actual set-up time and related activities in order to create continuous improvement of changeover practice. Top management need to enhance the role they play in training, particularly in relation to the changeover process. Also, lean manufacturing and SMED training are required to enhance the changeover practice in order to be more consistent and standardised. Also, the improvement of changeover practices can enhance manufacturing flexibility (McIntosh et al., 2001a). A high quality and reliable changeover process can contribute directly to production and eliminate wasteful activities. The recommendation for future work is to undertake case studies within different industries in order to examine the changeover practice within Saudi Arabian manufacturing firms, as each manufacturing sector and each firm has different methods in practicing the changeover process. CEAT was examined in precision industries in order to be more robust and valid for further research. Moreover, as the main aim of the research is to provide a vigorous conceptual model of high-quality and reliable changeover process, the main cases studies need to be examined at different changeover stages of product and process.

6.8 Summary

This chapter has investigated and established the implementation of changeover within precision components industries in Saudi Arabian firms. CEAT was examined while conducting semi-structured interviews and direct observations for further improvement. The improvement of CEAT was discussed and presented in this chapter. Also, the constructed sub-factors and levels were improved and paraphrased based on the pilot study, and the customised conceptual model for the pilot study was provided in order to be valid throughout the research. Changeover practice within the companies was discussed in this chapter and further recommendations were given. The following chapter discusses the main case studies and how they implement towards changeover practice, and also examines and compares the implementation of manufacturing changeover within the main case companies.

CHAPTER 7 : MANUFACTURING CHANGEOVER IMPLEMENTATION

7.1 Introduction

The previous chapter presented the pilot research; the researcher discussed the implementation of the changeover process within Saudi Arabian precision components firms. The research instrument, CEAT, was improved based on the pilot study findings of the precision components firms. The conceptual model has been customised based on the results of the pilot study.

This chapter represents the main case studies of the research. The case studies were conducted within Saudi Arabian manufacturing firms. Firms from both the Lighting sector and the Medical Products sector were selected based on their manufacturing operation type which was batch production which requires frequent changeovers on a daily basis. As stated previously, the objective of the study was to assess and discover the current status of the manufacturing changeover effectiveness within Saudi firms. The term *effectiveness* hereby indicates the degree to which the desired outcomes are achieved. The cross-case studies comparison was followed in order to obtain more comprehensive understanding of the manufacturing changeover practice.

7.2 Case Studies

This section represents the case studies of two different manufacturing industries. The lighting sector and the medical products sector were selected for the main cases of the research. The lighting sector is represented by Companies E, F, G and H, and the medical products sector is represented by Companies I, J, K and L. The case studies of the lighting sector were successfully completed between June and August 2013, and the remaining case studies were completed between February and March 2014. The main reason for the selection of these industries was based on the sampling strategy discussed in Chapter 5. The selection of the main case companies was based on each one's manufacturing operation of batch production, implementation of QM programs, location at one geographical industrial area, and exporting of their products.

7.2.1 Lighting Sector

The demand for the lighting market in Saudi Arabia has grown based on the demand from the massive infrastructure construction being carried out as well as from the home owner. According to Thomas (2013), the expected growth of demand on lighting fixtures is around 8% to 10% annually. The lighting industry is seeing rapid technology development in Saudi Arabia and the industry has targeted new technology which is the Light Emitting Diode (LED). The high growth and variety of projects in the lighting market provides sufficient opportunities and will attract new market entrants, both foreign and local investors.

Figure 7.1 shows the basic manufacturing process of the lighting sector; this comprises five stages which are cutting, pressing, welding, painting and assembly line. The process begins with cutting of the raw material of stainless steel sheet roll. The next stage of the process is the pressing which involves punching and bending of the sheet roll, in two separate processes. Spot welding is the next process where metal surfaces are welded before going to the painting process. Finally, the assembly line is the last stage of the manufacturing process for assembled electric wiring and cable. It should be noted that the punching and bending processes of pressing were studied in the research. These two processes were selected based on the frequent changing of the lighting models because it requires more changeovers.

Figure 7.1 Manufacturing process of the lighting sector (Source: author).

Companies' profiles

The profiles of the lighting companies are described in Table 7.1. The table shows the participating firms in terms of company size, when the company was established, quality programs and for how long these have been implemented. It can be noted that small and medium size (SME) Companies F and H had only used QC for the last five years while the large Companies E and G had implemented both QC and QA for more than 15 years.

Table 7.1 The main characterises of the lighting companies (Source: author).

Companies	**Company Size**	**Company established**	**Quality program**	**Years of implementing quality program**
Company E	More than 200 > Large size	More than 15 years	Quality Control (QC) and Assurance (QA)	More than 15 years
Company F	50-200 > Medium size	More than 15 years	Quality Control (QC)	Less than 5 years
Company G	More than 200 > Large size	More than 15 years	Quality Control (QC) and Assurance (QA)	More than 15 years
Company H	Less than 50 > small size	More than 15 years	Quality Control (QC)	Less than 5 years

The interviews and observations matrix of the lighting sector can be seen in the Table 7.2. The sub-factors F1 to F13 were studied in Table 7.2; these sub-factors indicated the level of changeover effectiveness and were grouped into four categories - People, Process, Quality and Infrastructure - as shown in the proposed conceptual model. The sub-factors from F1 to F11 were mainly based on the selected by the respondents as suitable level during the semi-structured interviews, while the sub-factors F12 and F13 were mostly related to the direct observation of changeover practice and preparation. The research instrument, CEAT, tool was implemented in order to measure their practice in terms of providing a high quality and reliable changeover process (The copy of CEAT is given in Appendix 3). The respondents' answers are represented as L1 to L5 which "L" refers to their implementation level towards changeover practice. The levels that indicated respondents' answers from L1 to L5 were explained in Chapter 5 in the CEAT research instrument section 5.5. The Production Manager (PM) and the Quality Manager (QM) were involved in semi-structured interviews for approximately 45 minutes. In some companies, such as Company G and Company E for Mass Production Factory (MPF), the Quality Inspector (QI) was interviewed as they do not have a Quality Manager position. It should be noted that Company E was interviewed for small batch factory and Mass Production Factory (MPF) in order to draw comparisons between and assess the two factories. The last column of the table indicates the researcher's attendance at the changeover practice within the participant firms.

Table 7.2 The interviews and observations matrix of lighting firms (Source: author).

Interview & Observation Matrix		**Interview**											**Observation**		
		People			**Process**				**Quality**			**Infra.**	**Process**	**Quality**	**Overall**
Firm		**F 1**	**F 2**	**F 3**	**F 4**	**F 5**	**F 6**	**F 7**	**F 8**	**F 9**	**F 10**	**F 11**	**F 12**	**F 13**	**Attending changeover**
E	PM	L2	L3	L1	L3	L1	L4	L2	L1	L1	L2	L3	L3	L5	Fully
	QM	L3	L2	L2	L4	L1	L2	*N/A	L1	L3	L3	L2			
	PM (MPF)	L3	L4	L3	L3	L2	L4	L4	L1	L1	L3	L2	L2	L4	Fully
	QI (MPF)	L3	L3	L3	L3	L2	L4	L3	L1	L3	L2	L3			
F	PM	L4	L2	L2	L5	L1	L5	L4	L1	L1	L2	L5	L2	L3	Fully
	QM	L3	L2	L3	L3	L1	L4	L2	L1	L2	L1	L4			
G	PM	L3	L3	L3	L3	L1	L4	L3	L1	L1	L3	L4	L3	L4	Partially
	QI	L4	L4	L4	L4	L1	L4	L2	L1	L1	L3	L3			
H	PM	L4	L4	L4	*N/A	L2	L4	L4	L1	L1	L1	L2	L1	L2	Partially
	QM	L3	L4	L3	L3	L1	L2	L2	L1	L1	L1	L2			

***N/A: No answer**

MPF: Mass Production Factory

F1 (Factor 1) Top management support changeover process
F2 (Factor 2) Training for changeover practice
F3 (Factor 3) Personnel involvement during changeover
F4 (Factor 4) Time cause undue pressure
F5 (Factor 5) Speed up the set-up process (standardisation)
F6 (Factor 6) Availability of the materials and tools
F7 (Factor 7) Interruption of the sequence of changeover tasks
F8 (Factor 8) Using checklist (Preparation)
F9 (Factor 9) Awareness of changeover and QM
F10 (Factor 10) Initiative for changeover improvement
F11 (Factor 11) Using new machines and tools “Tech”
F12 (Factor 12) Changeover preparation
F13 (Factor 13) Safety and facilities on shop floor (clean and lighting)

Companies' respondents

The respondents of the research interviews are shown in Table 7.3. The table describes the interviewees in terms of job position, experience in the manufacturing industry and education level. Some of the interviewed companies did not have the position of a Quality Manager; therefore the Quality Inspector (QI) was interviewed instead.

Table 7.3 Respondents profile of lighting companies (Source: author).

Companies	Respondent position	Education level	Experience
Company E	Production Manager	Bachelor degree	Less than 5 years
	Quality Manager	Diploma	More than 15 years
Company E (MPF)	Production Engineer	Bachelor degree	More than 15 years
	Quality Inspector	Diploma	Less than 5 years
Company F	Production Manager	Bachelor degree	5 - 10 years
	Quality Manager	Bachelor degree	5 - 10 years
Company G	Production Manager	Bachelor degree	Less than 5 years
	Quality Inspector	Diploma	Less than 5 years
Company H	Production Manager	Bachelor degree	10 - 15 years
	Quality Manager	Bachelor degree	More than 15 years

MPF: Mass Production Factory.

Objectives for and obstacles to improving changeover process

Both respondents from the Quality and Production Departments were identified the objectives for, and obstacles to, improving the changeover process within the lighting sector which are shown in Table 7.4. Undoubtedly, the most commonly reported reason was to increase the production and save time as the main objective of improving the changeover process. On the other hand, financial difficulty and lack of initiative towards changeover process improvement were the main reasons that inhibited the improvement of the changeover process based on the respondents' answers.

Table 7.4 The objectives for and obstacles to improving the changeover process of lighting companies (Source: author).

Companies	Respondents	Objectives of improving changeover process	Obstacles to improving changeover process
Company E	Production Manager	Direct impact on the utilisations, production and the indirect impact of utilising the foreign resources	Tools rack was not organised and very far from the machines.
	Quality Manager	Achieve customer demand and satisfaction	Documentation system of changeover activities
Company E (MPF)	Production Engineer	To save time	Unavailability of the auxiliary equipment, such as forklift
	Quality Inspector	To increase production	Lack of skilled technicians
Company F	Production Manager	To increase production capacity	Lack of awareness and understanding of changeover process improvement
	Quality Manager	To increase production	Lack of documentation of changeover data and improvement
Company G	Production Manager	Improving productivity and time. Reducing working hours for the operator and keeping him focused on production	Lack of management and engineers' staff that will help to initiative improvement of changeover
	Quality Inspector	Enhance product quality	1) Procedure of changeover process 2) Difficulty of paying for new die (Financial)
Company H	Production Manager	To increase product, quality and production. Better quality product to the customer. Reduce rejection as well	There is no objection on production
	Quality Manager	Save time	Lack of financial resource

Company E

Company Background

Company E was founded in 1978 and started to produce outdoor lighting fixtures with the participation of a Foreigner Company as a joint venture. In 1989, the company merged with another Saudi Company to cooperate in manufacturing lighting indoor fixtures. It employed 1000 employees and has more than 15 years of experience in the lighting manufacturing industry. The plant operates two shifts every 24 hours. The company claims itself as one of the biggest producers of indoor and outdoor lighting within the Middle East and North Africa (MENA) region by delivering millions of lighting fixtures each year. In addition, Company E has two factories in Egypt and the United Arab Emirates (UAE). The company launched a factory for high-volume orders which are between 50,000 and 100,000 units. The main factory is for small batch production in order to meet customers' requirements for different products. The small batch factory and Mass Production Factory (MPF) of Company E have been investigated as part of the study. Company E offers a range of lighting products, such as commercial, residential, hospital, emergency, industrial, hazardous, central battery system and roads. The company has an advanced laboratory of testing luminaire and lighting design of new product development. The company lab and products are certified by the Saudi Standards, Metrology and Quality Organisation (SASO), and the company lab has been certified by Underwriters Laboratories (UL) for safety, testing and inspection. The process of testing is to maintain the efficiency and safety of the products as well as to ensure their ability to resist hot temperature, dust and rain. Moreover, it implemented QC and QA for maintaining and ensuring the quality of products that it offered. The company has been accredited with ISO 9001 for Quality Management System which is certified by the British Standard (BSI). Also, the BSI certified the company by ISO 14001 of Environmental Management and OHSAS 18001 of Occupational Health and Safety. The company was twice (1986 and 1998) awarded the King Abdulaziz Award of ideal factory by the Ministry of Industry and Electricity in Saudi Arabia. In 2001, Company E started to implement the ORACLE System for better maintaining of its business process. The company claims that ORACLE is a resource-planning system that helps it to plan for the next job order and being more flexible. The company has a new product development group for studying and providing new opportunities for the business. Recently, the company provided different training for each employee's level in the

manufacturing department. Lean awareness and lean green-belt training were provided to foremen and engineers as the company started to implement lean manufacturing. The lean green-belt training is defined as a continuous improvement cycle by implementing Define-Measure-Analyse-Improve-Control (DMAIC) which is considered as a core tool for the Six Sigma approach. Moreover, top management, such as managers and directors, were attended this training, which was conducted on the company site by an external consultant provider.

In September 2012, Company E purchased entire lighting manufacturing companies in East Asia at an estimated cost of £36.6 million pounds (based on exchange rates at the time). The reasoning of that acquisition as it targets fast-growing economies in the world. The company will enhance their brand name and the distributions of their products within East Asia, such as Vietnam, Indonesia, Singapore, Malaysia and Australia. Relating to this acquisition, the CEO of Company E claims:

"The acquisition comes as a perfect complement to our company product offering, fitting with the requirements of our core Middle East and Africa markets. Also, a number of opportunities exist to extract synergies from the combination of our two organisations".

The company planned to go into the manufacturing and assembly line of LED as a new technology of interior and exterior lighting by the end of 2013. This new technology will enhance their ability to meet customer demand and requirements for that technology. The organisation chart of the company can be seen in Figure 7.2; the company has a comprehensive large-scale organisational hierarchy. It can be clearly seen that the Manufacturing Director is involved with all factories that the company owned. However, the Quality Manager is linked to the Shared Service Department.

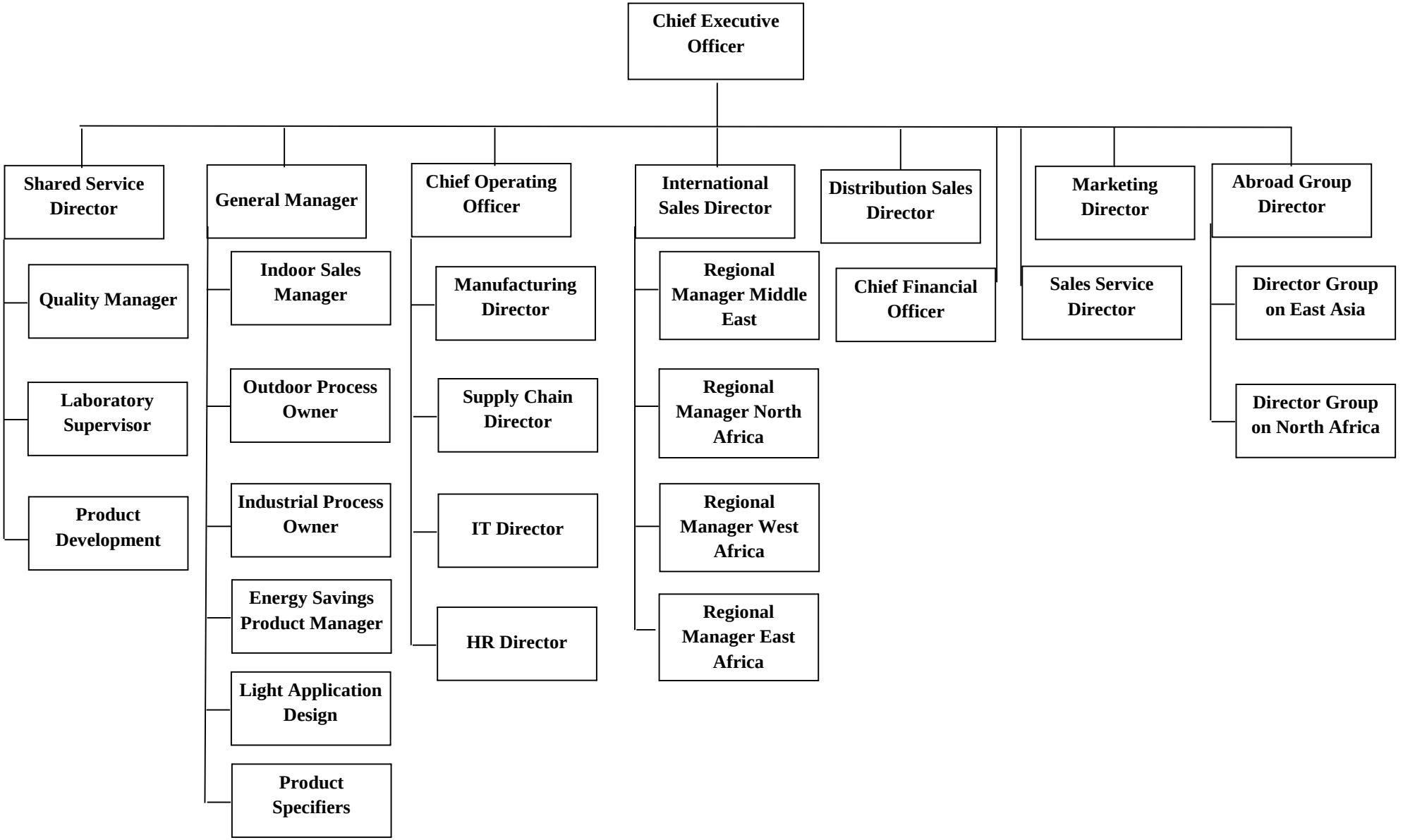

Figure 7.2 Organisation chart of Company E (Source: author).

Challenges in changeover practice

Changeover practice is considered part of the daily process of frequent changes between manufacturing products for small batch production within the company. The interviewees of the company discussed the challenges that they face with the changeover process. Based on the respondents' answers the most common problems are as follows:

- Lack of skilling operators for conducting the changeover of machines.
- Proper monitoring of the availability of tools and machines. For example, production planning releases two job orders simultaneously for one machine or for the same tool. Therefore, it leads to delays which can be more than five to six hours.
- High degree of variation in changeover time between morning and night shifts because there was no proper monitoring and supervising of operators during the night shift. Thus, it would impact on operators' performance.

In terms of changeover data documentation, over the last 10 years, the company calculated the time taken for the set-up time for all the machines in the shop floor and recorded it in the ORACLE system. The reason for that was to calculate the estimated time of the production and to determine estimated production cost (The copy of the Daily Production Report of Company E is given in Appendix 6-B). The set-up time study was taken based on the machine types only, while ignoring other factors that would impact directly on the set-up time. Furthermore, the company has not recorded the actual changeover time or specific set-up time in the shop floor; instead it is totally reliant on old data recorded in the system. In addition, the rejections rates of products after set-up cannot be determined precisely by the quality department. Hence, there is no extended data collection regarding acceptance or rejection of the first outcomes after changeover. Both respondents were just estimating the rejected quantity of the first outcomes which was between three to five pieces.

New Product Development (NPD) and its relation to changeover process

Company E operated on batch production which is based on customer requirements. In 2013, the company launched around 38 new products based on the customer requirements of some enormous

projects in Saudi Arabia. According to Millson and Wilemon (2008) the New Product Development (NPD) process includes preliminary design and manufacturability assessment, development of prototype, in-house product testing, trial production and full-scale production start-up. The stages of the new product development of the company are as follows: Firstly, the company receives the requirement of the new product based on the customers; therefore the NPD department has to set product specifications based on that requirement. The feasibility study is required to examine the production cost and durability before launch of the product. Consequently, the company sets the plan for the product development and builds the product in terms of concept design, 3D design and modelling. Rapid prototype was created based on CAD drawing in the factory or it can be formed abroad if that requires a complex plastic and casted part. Finally, the sample of the actual product will be produced for test and validation within the company laboratory. Figure 7.3 shows the new product development of Company E. Phase 4 of the new product trial runs stage was the transitional process of practicing the changeover process on the shop floor before production commences. During the trial run or pilot production, the company was not monitoring the changeover practice in terms of process, time and effectiveness.

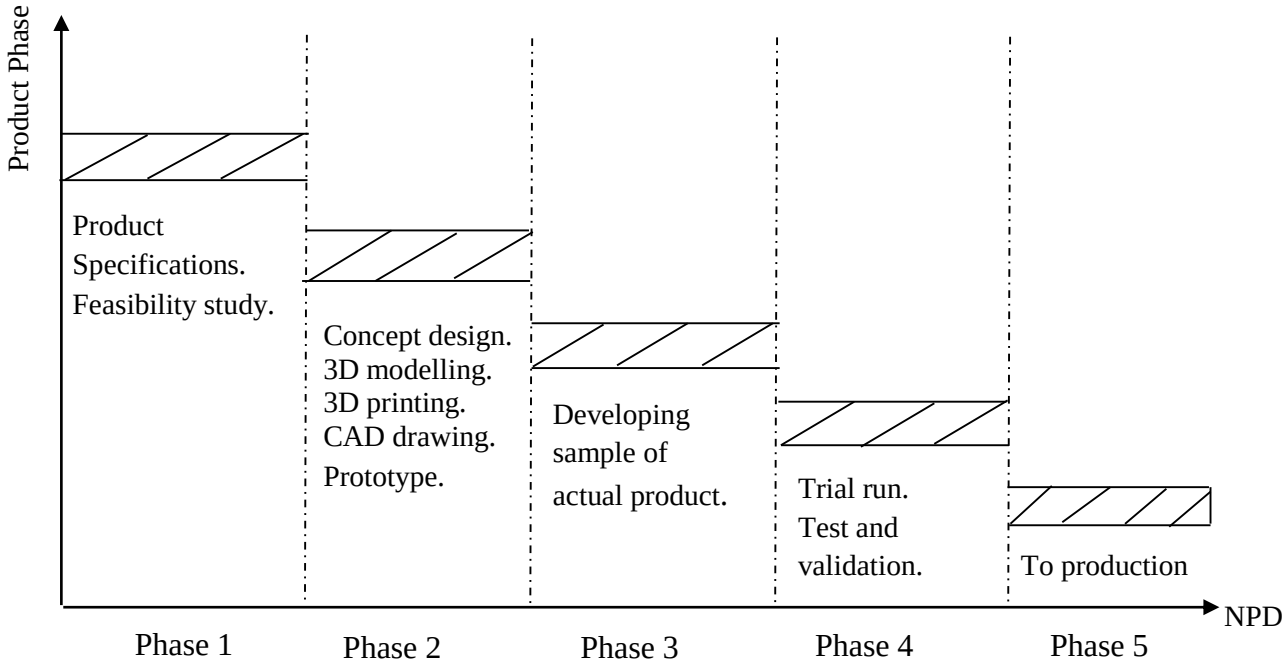

Figure 7.3 New product development of Company E (Source: author).

The NPD department takes into account manufacturing criteria during the product development stage, such as manufacturing process of the production and changeover of set-up time, as described below:

"When we develop a new product, we think about the manufacturing process. We enter this product into the system. Okay, how do we make it, which processes do we employ? Which is the best for them? For example, I want to make this part. So, I'm not making it just like this. I'm thinking, which process? Do you go to slitting? Okay, better go to slitting. What should we consider here?"

The NPD department sets up meetings with the manufacturing department in order to discuss the production challenges of a new product in terms of raw materials availability, machine tools and measurement procedure of acceptance product after the changeover. The benefit of the production trial run reduces the human mistakes of the operator before it goes to production. Annacchino (2003) discussed the trial run as verification of manufacturing infrastructure, testing manufacturing capability, and process documentation. The first production of the trial run of the new product has to involve each company department, such as production, laboratory and quality. The trial run production will produce between 100 and 200 pieces or, in a few cases this reached 1000 pieces which is based on the complexity of the product and can increase the confidence of operator for manufacturing changeover process. Also, the main purpose of the high volume production trial was to ensure that the new product has met the quality requirements and specifications. The quantity of trial run will be used for process review, final feasibility study and production approval for accepting the product. The following sub-sections discuss People, Process, Quality and Infrastructure based on the data collected.

People

Top management were committed to providing tools and machines for enhancing the productivity. Also, top management provided continuous feedback and suggestion for improvement production and changeover process through a daily meeting. However, a lack of attention was paid by top management to define the importance of changeover to the manufacturing process. The company was relying on the old and historic changeover data that were recorded in the ORACLE system rather than recording up-to-date data on the shop floor. The Production Manager discussed the delay and inaccuracy of the time study that was taken 10 years ago for changeover time, as follows:

"The time study for our product A, that takes me 20 minutes in the system. Then it takes me extra time. It takes me 30 minutes. I don't know how this time is studied. Maybe they take the time study and

everything is available to the operator and he just starts the set-up and finishes the set-up. They did not consider the operator movement and the time of tool selecting during the time study".

The firm's training only targeted Foremen and Engineers. Therefore, the company was relying on the Foremen to deliver the instructions and guidance to the operator during the changeover process. A visual observation of existing operators and non-formality training was given to new operators to learn the manufacturing and changeover process within the company. Hence, there was no formal training provided to the new and existing operators. In term of operator involvement, there was a lack of operator involvement during the changeover process. For example, operator involvement for conducting changeover before at the end of the shift was missing as it would be transferred and conducted in the next shift. Clearly, it is time-consuming for the next shift to perform the changeover process rather than conducting it on the previous shift. In fact, the involvement of top management and engineers was crucial to evolve the changeover process into an improved process. The Production Manager discussed this as:

"I am not asking more questions about the changeover to operators and, like I said, my changeover in the system is 30 minutes. I'm not asking them and I'm not getting the feedback from the operator".

Besides that, the Quality Manager affirmed that the operator was partially involved on giving feedback improvement on changeover and production practice to the top management and engineers. The feedback process is informal and based on operator's willingness to inform the supervisor and engineer. However, these ideas were not accelerated from top management to be implemented on the shop floor.

Process

Changeover performs under less time pressure between crews' shifts, although there was a medium degree of variability of changeover processes between crews' shifts. This is due to non-conformity of changeover process between the shifts. The firm has not established standardised procedures for the changeover process. Recently, the company has been working to implement the Standard Operating Procedure (SOP) for machines start up and operation in order to be more systematic and consistent in performing the task. The company has introduced signs for some improvement on the machine shop floor; these indicate when machines are in service which is in green colour and non-working or standby machine which is in red colour. These signs are considered a form of visual management and

it helps the company to begin lean implementation. It aids the workers on the shop floor to indicate the machines that are at the preparation stage or changeover process before commencing production.

In term of raw materials availability, there was a minor delay on transportation of raw materials due to the company having four warehouses in different locations. Also, occasionally, materials were delayed from the supplier due to non-availability of raw materials. The person responsible for preparing the materials for the next job order was the Supervisor/Foreman. During changeover preparation, raw materials and previous process materials were prepared through the internal time while the machine was not working. The sequence of changeover process was usually interrupted by asking operator to take another job. This was because of no time pressure to finish the existing changeover and set-up activities; consequently that caused the repeat of the changeover task again. In terms of changeover preparation, the company has organised tools and dies cabinets and each die was identified by name and part number as shown in Figure 7.4. The production department was responsible for arranging the die and tool cabinets for easy identifying of the required tool and die. However, there was no tooling and die department in the company for preparation of upcoming changeover; instead, the Supervisor/Foreman was responsible for preparing the tool or die and informing workers on the upcoming changeover.

Figure 7.4 Tools rack for bending machines (Source: author).

Quality

The company was not using assessment tools and techniques, such as checklists for confirming the changeover process before commencement. Company E was totally reliant on the Supervisor's experience for confirming the changeover process. On the subject of QM and changeover knowledge, the company was providing quality and safety seminars to the management employees only. Disseminated knowledge was missing at the operators' level as the company was depending on the Supervisor/Move-man to spread it by verbal communication to the shop floor workers. The company tried to disseminate the lean knowledge of 5S and Seven Deadly Wastes within the company's office, as shown in Figure 7.5. However, the access of the lean manufacturing poster was limited due to its location in the plant manager's office.

Figure 7.5 Lean manufacturing posters (Source: author).

The company made an improvement in the setup process by locating dies and tools cabinets near the machines. Figure 7.6 shows the improvement of the tools cabinet by identifying die part numbers and indicating the name of the machine that used the tool. Figure 7.7 shows the organisation of tools and dies rack for easier and quick identification. However, the company does not take changeover improvement very seriously as there was no improvement made in regards to improve set-up process and changeover data recording. The Production Manager discussed the improvement of set-up time as:

"In the daily production, there is a start time and a finish time of the job. But there is no improvement made with the set-up process and changeover data recording".

Figure 7.6 Dies cabinet (Source: author).

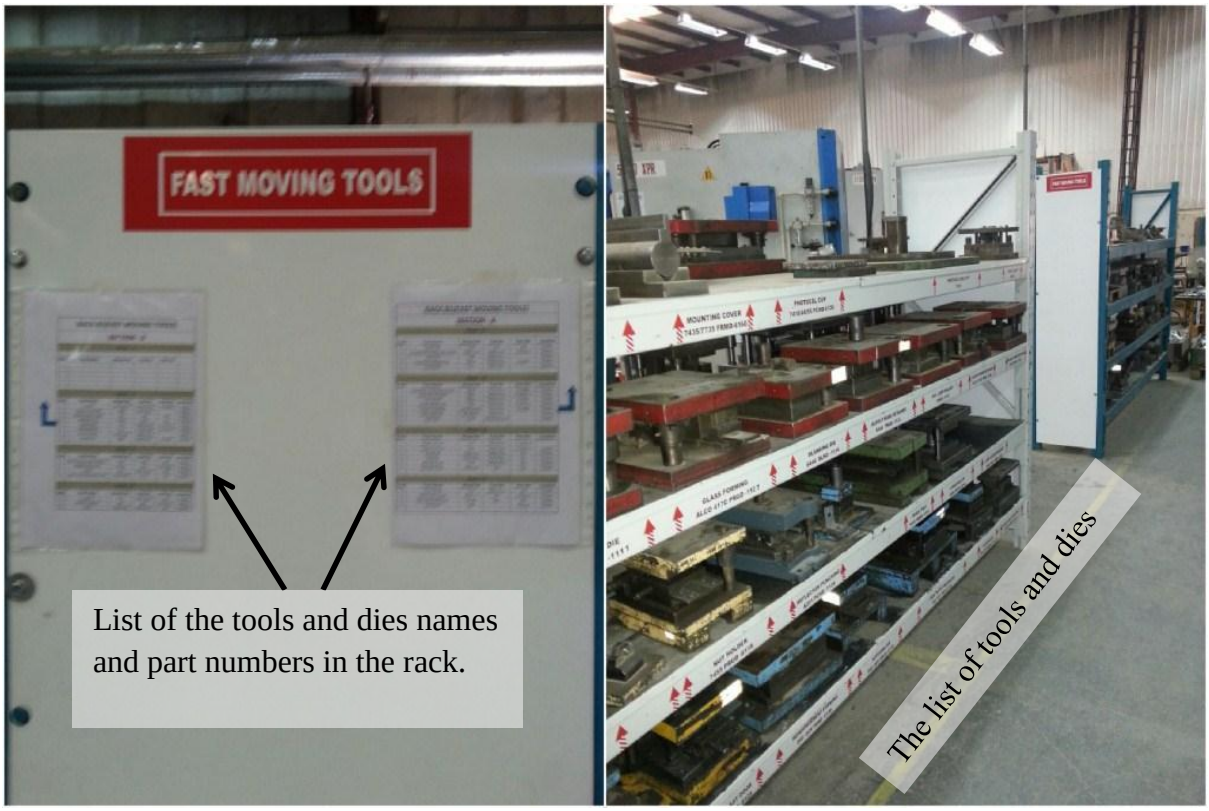

Figure 7.7 Fast moving tools and dies rack (Source: author).

In terms of safety on the shop floor, the working area was clean and there were no remains of scrap or materials from the previous job. Besides that, there were no hindrances of materials in the floor to operators during the conducted changeover process; tools and equipment were neatly stored during the set-up period.

Infrastructure

The company's policy is to achieve customers' demand by investing in and purchasing new machines that would fulfil the firm's requirements in the market. The Quality Manager claims that Company E is always looking for a highly sophisticated new machine that enhances the quality of the product. The Production Manager discussed that the main aim of buying new machines is to improve productivity not the set-up time:

"We purchased new machines to achieve customer demand. We are not thinking about the set-up time. We are just thinking about the production or performance here".

The levels of changeover effectiveness can be seen in Figure 7.8. Based on the respondents' answers and the researcher's observations, the score of changeover effectiveness was 2.4; this indicates that the company is working towards achieving level 3 of initiative changeover process. The lowest practice of changeover process was in the people factor which was overall 2.25, which can consider as a managed and controlled changeover process level. There were contradictory answers particularly relating to the availability of raw materials and tools on job resources (Factor 6); this is due to lack of involvement of the Quality Department on the shop floor, particularly at the changeover preparation stage. In terms of QM and changeover knowledge (Factor 9) discrepancy and based on the observation, the researcher did not observe a notice board on the shop floor for introducing the Quality Management concept and changeover knowledge. Posters and leaflets were posted in the plant manager's company office only.

It should be noted that the Quality Manager was not able to answer the question of interruption to the sequence of changeover tasks (Factor 7). This is due to the unavailability of the information regarding interruptions to the operator while performing the changeover task.

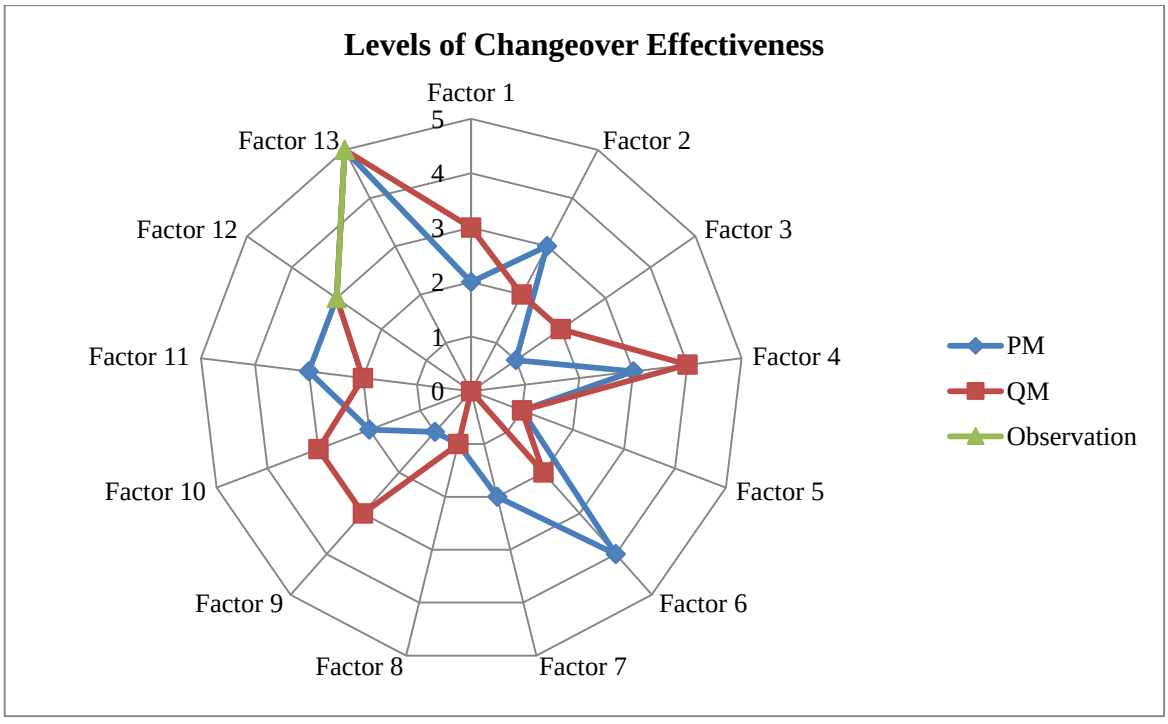

Figure 7.8 Levels of changeover effectiveness, Company E (Source: author).

Company E Mass Production Factory (MPF)

The Mass Production Factory (MPF) of Company E has around 1000 employees and workers on the shop floor. It produces a high volume product which is between 50,000 to 150,000 units. As a high volume producer the changeover occurs on a weekly basis and in some cases more than twice a week. Normally, changeover time consumes two hours for changing the die and installing the raw material of the steel sheet. During the researcher's visit to the company, top management of Company E suggested and advised the researcher to visit and examine the Mass Production Factory (MPF). Company E was very helpful and cooperative with the researcher during the data collection and the visit to both factories. The Company E (MPF) interviews with the Production Engineer and Quality Inspector as the company does not have a Quality Manager position. This case study can be an example of mass production type.

Challenges in changeover practice

Respondents were asked to identify the main problems that they faced during changeover practice within the company. The challenges can be described as follows:

- Machine and tool failure. Some punching and slitting processes were incomplete due to tool or die failure; therefore they had to be sent to the maintenance department.
- Feeding of the machine is not efficient during changeover and contributes to the inconsistencies in the first outcomes.

The company does not record changeover time. The Production Manager affirmed that the Foreman will start to record changeover time and activities in the few next weeks as the company has started to implement lean manufacturing in the shop floor. However, the researcher attended the changeover process and there was no existence of recording the data of changeover time and its activities. The Quality Inspector was not involved with changeover documentation data as he answered:

"*I don't know about the recording changeover data within the company*".

The interviewees discussed the scrapped products of first outcomes after the set-up time; this is due to the confirming of the product measurement and at least three to five pieces are scrapped. Normally

changeover is conducted within two hours before reaching stable production. Both respondents agreed that reducing changeover time will impact directly to increase the productivity.

Recently, a third-party company was involved in providing shop-floor workers, such as operators and helpers. The company is outsourcing the shop-floor activities and relying on the supervisors/foremen to provide guidance and instructions for maintaining working conditions. This is due to a lack of manpower within the company. The Quality Inspector discussed the shortage and lack of skilled manpower as:

"Nowadays we are facing a shortage of workers. Top management and third party don't provide the skilled manpower. That's the main problem".

People

Top management were providing suitable tools and equipment for consistent manufacturing changeover practice. Top management also delivered suggestions for improving the changeover process. However, top managers were not involved with changeover activities on the shop floor; as they were relying on the communication channel through the engineer and the foreman. Recently, lean manufacturing training was delivering to engineers and foremen only; however, the SMED technique was not introduced in this training. In term of operator involvement, feedback of past problems of changeover process was provided by the operator to the foreman or engineers. However, there was no regular meeting for improving changeover process and even the operator was not involved in changeover or set-up improvement. This is because the company was satisfied with the current practice of changeover process and time.

Process

The foreman was responsible for informing operators of the upcoming changeover as well as informing the next shift by verbal communication. Also, a notice board was used on the shop floor to inform workers of the current task of manufacturing projects. Changeover performs under less time pressure as it is conducted on a weekly basis. Both respondents affirmed that the changeover procedure was established for certain manufacturing processes. However, the company has not revised the changeover procedure as it costs money and time. In terms of material availability, raw materials

were always available due to adequate time available for the next changeover. The plant manager was involved in issuing a weekly plan for a specific project. Through a week the company prepared raw material by slitting metal sheet and placed it near to the machines. Figure 7.9 shows that the metal sheet was feeding the die in order to form the sheet to the required product. The changeover process can be described by loading a coil sheet then replacing the die kit. Following that comes replacing the roller, cropping and raft for forming the shape of the metal sheet to specific product.

Figure 7.9 Mass Production Factory (MPF) Steel Section (Source: author).

Changeover preparation can take place after distributing the weekly plan to the production plant departments. The activities of preparation can take place through checking material and die status. Dies cabinet were organised and easy to identify. Changeover was performed without interrupting the sequence of activities and a minor variation of set-up time, since the company was limited to changing between products as well as the maximum of two hours of changeover time. During the changeover, the operator conducted the activities of the changeover process and the foreman provided consistent instructions to the operator.

Quality

The company was not using a checklist for changeover preparation. The Production Manager affirmed the importance of a checklist or check sheet to the shop floor. The company distributed knowledge only to foremen and engineers through a one-day session of quality awareness; therefore it relies on foremen to disseminate the knowledge of QM and changeover to operators. The company was not implementing any techniques or methods for improving set-up time. The company was not recording the changeover data; but the production department made a weekly effort to improve the set-up time by observing and monitoring the changeover time and comparing it with previous performance of the changeover practice. However, there was no particular technique or method used for improving changeover time. In term of the safety on the shop floor during changeover, the company was able to deliver a safe working environment for conducting the process.

Infrastructure

The company strategy of buying new machines is by providing high quality products and achieving customer demand. However, the company was due to install a new machine that combined two manufacturing processes, to eliminate the waste of conducting another changeover. The Production Manager discussed this as follows:

"Actually we are doing efforts for this point because we are doing refurbishment of two machines and also we will bring one new machine that will produce simultaneously, the core plates and the housing rather than doing changeover of one and a half hours".

The levels of changeover effectiveness are shown in Figure 7.10. Based on the respondents' answers and the researcher's observations the score was 2.7; this indicates that the company is working to achieve level 3 of the initiative changeover process. Moreover, it can be seen that the lowest practice of changeover process was on quality factors, which was overall 2.3 and that can considered as a managed and controlled changeover process level. This is because of having low-level quality implementation of the ensuring changeover process.

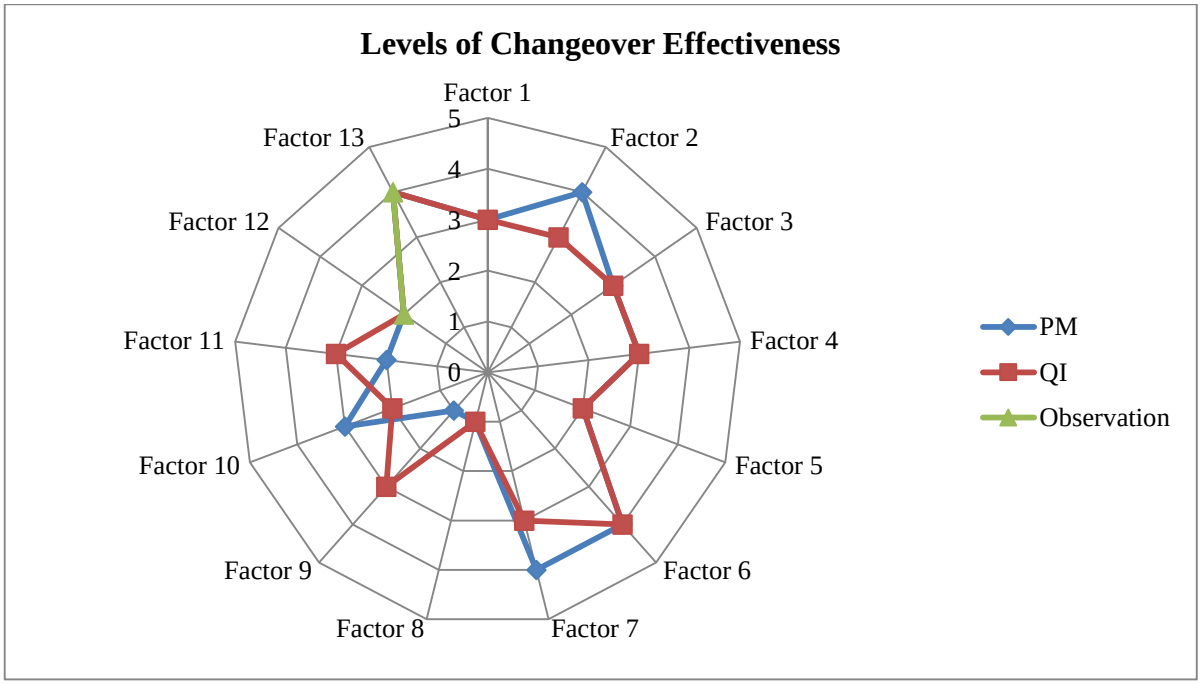

Figure 7.10 Levels of changeover effectiveness, Company E (MPF) (Source: author).

Company F

Company Background

Company F was established in 1998 and is considered as a medium size (SME) company with 100 employees. The company distributes its products globally and locally as it has more than four sales branches within Saudi Arabia. The company has successfully accomplished and delivered certain different projects within the Western and Central regions of Saudi Arabia. The plant operates on one shift per a day. Company F has a steel section and assembly line section. The QC department was founded in the last five years as it was certified for ISO 9001: 2000 for Quality Management System and SASO in 2011. Company F manufactures residential, landscape, exit signs, flood, hospital, industrial, and air handling luminaire products. The company has six manufacturing sections - steel, welding, painting and three assembly line sections.

Challenges in changeover practice

Respondents were asked to identify the main problems facing changeover practice within the company on a daily basis. The challenges can be described as follows:

- The most common scenario was die failure, particularly during or before starting the production. Minimum prevention maintenance of the die and machine which halts the production and start of the changeover.
- Availability of raw materials during changeover process was an issue to the company before solving the problem and installing new software. Previously, the company faced a shortage of raw materials - this is due to non-availability of materials planning software.

In terms of changeover data documentation, the discrepancy occurred between two respondents for recording the data. The Production Manager admitted that the firm recorded changeover data within the shop floor and the other respondent claimed that as they were not recording it at all. Based on the observation of the changeover activities, the firm did not record changeover data or set-up time at all. In normal conditions, the changeover consumed around an hour. In fact, the firm does not have a changeover sheet for recording the changeover tasks and time. The company affirmed that the most significance for their production was the productivity per day. The firm always has one to three pieces

as scrap or repair items after set-up; also there were no recorded data of the first outcomes of the rejected items.

People

Top management were encouraging changeover practice by providing adequate tools and machines; in addition, top management understand the role of the changeover process within manufacturing as it appears in the daily process. However, there was a lack of follow-up meeting by top management after identifying the problems for which led to suggestions for further improvement to the production and changeover process. Top management mainly emphasises improving the productivity but placed less emphasis on improving the changeover process. Additionally, the production department management was not concerned about enhancing changeover process, changeover documentation and improvement. For example, the company was not recording set-up time and its activities on the shop floor. The Production Manager sees the changeover practice as follows:

"The changeover meaning for me is changing the dies only".

Within the last two years, the firm started to provide a short introductory training to new operators only since it is a requirement to obtain ISO 9001: 2000 certification. The changeover was normally conducted by the supervisor with some help from the operator. Indeed, the company is relying on supervisor and operator experience for performing the changeover process. The company planned to provide training for new and existing workers within the next year, and that will be located in the company on level 3 of the training and multiskilling factor. The supervisor and operator have maintained the communication channel with management regarding the changeover issues; for instance die damaged and repaired.

Process

Changeover performs under less time pressure and there was no necessity from the operator to deliver it at the earliest time. This is due to the lacking of monitoring of and involvement in the changeover activities from middle levels of management, such as engineers and managers. Regarding to the operators' understanding of changeover tasks, the Quality Manager claims:

"The changeover for the operators - it's not in their mind to do it very fast for the period of time. No, they only do it fast when the Production Manager asks for it".

The company does not have a changeover procedure to follow; instead it relies on operator and supervisor experience. The reasoning for not having changeover procedure within the company, as the Production Manager believes, is that changeover is an easy task to perform and not required for the procedure. Also, there was no delaying of raw materials transportation and availability to the location for the next changeover due to the small scale of the plant. In terms of changeover interruption, the operator is committed to finish the task without taking another job. Only the Production Manager and the engineer can interrupt the changeover task as they have permission for interruption changeover activities. The company is producing production plans in advance a day before; therefore a daily production plan is distributed to the responsible departments in order to be prepared for next orders. In terms of changeover preparation, the company has tools and dies cabinets in the production department but these were not identified. Also, there was no existence of a tooling department for changeover preparation.

Quality

The firm was not using a checklist for assertion of changeover process before it commenced. This is due to fact that the company was relying on the supervisor's memory and experience to conduct the changeover preparation. The Quality Manager discussed the importance of having a changeover procedure and checklist:

"It makes the work more organised. If you have this check sheet, you can see at the end of the day what is normally missing during the changeover process. You can see that in the check sheet. If not sometimes you will forget. In the check sheet, you can always see and it is documented as well. Changeover procedure is needed first, then checklist or sheet after that. If you have these techniques, you just check to confirm the process, and then continue to work the job".

The company was totally dependent on the supervisor to disseminate the knowledge of QM and changeover through verbal communication. In the previous year the company conducted a seminar of how to properly store the dies in the storage rack and that was targeting different levels of management positions. Since that the die failure was the main issue of the production department. This

seminar helped to establish dies cabinets on the shop floor in order to ensure easy and safe access to the dies. However, the cabinet did not identify each die name and part number within the dies cabinet.

Based on the respondents' answers the company was not studying the supervisor's and operator's movements during changeover process. In terms of changeover improvement, there was a lack of impetus for improving set-up and changeover process, the reason for that was due to unavailability of changeover data to start an improvement from. In terms of safety on the shop floor, there was a safety sign and safety requirements were attended to while conducting the changeover process.

Infrastructure

Two years ago the company bought new machines for its steel section to enhance the production capacity. Top management was involved in studying which new machine to buy. The Production Manager discussed the process of buying new machines as the following:

"I remember once we decided to buy a new machine; we did a full study of buying a new machine that included the time of changing the die. We asked the manufactured company to visit their factory in China in order to examine the new machine from different categories, that including changeover time, maintenance and productivity. We brought our supervisor there to test the machine and that was our procedure for buying a new machine".

The company claims that the impact of changeover time on the new machine was reviewed while purchasing it. Different categories were reviewed, such as productivity, maintenance and improving changeover time. Moreover, to eliminate changeover time and manual set-up the company considered buying a new machine with specific criteria that can combine different processes at the same time. However, despite the high consideration of buying new machines that have more developed set-up, there was a lack in the production department in valuing and using set-up features in the new machines.

Figure 7.11 describes the levels of changeover effectiveness within the company. Based on the respondents' answers and the researcher's observations, the score was 2.9; this indicates that the company is working to achieve level 3 of initiative changeover process. It can be seen that the lowest practice of changeover process overall was on quality factors which was 1.75, which can be considered as a managed and controlled changeover process level. There were contradictory answers

particularly relating to interruption to the sequence of changeover tasks (Factor 7); this is due to less involvement on the shop floor activities between the respondents. There were also contradictory answers relating to time pressure to deliver changeover process (Factor 4); this is due to a lack of engagement in and observation of the changeover process by the Production Manager, who considered that the changeover practice is a very simple task.

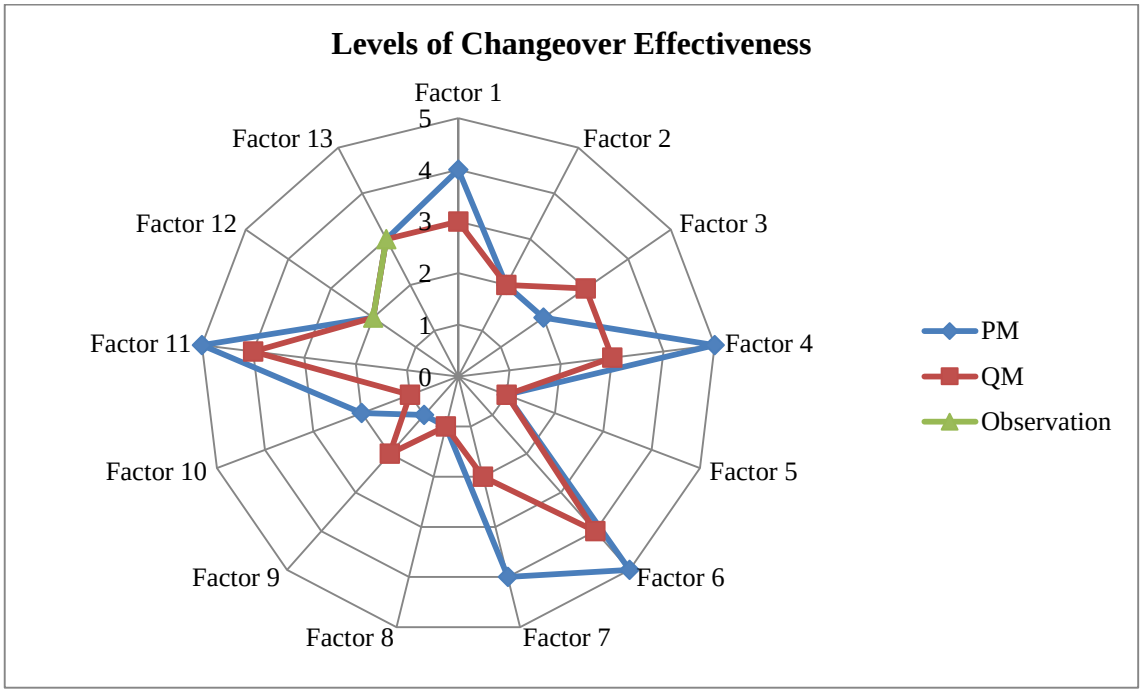

Figure 7.11 Levels of changeover effectiveness, Company F (Source: author).

Company G

Company Background

Company G was founded in 1982 and it employs around 200 people, with more than 15 years of experience in lighting manufacturing. The company offers a range of lighting products, such as commercial, residential, emergency sign, industrial and outdoor. When the company was first established, the production capacity was 75,000 units per a year. In 2005, the company expanded their factory by launching a new assembly line. Currently, the company production capacity has been rapidly growing to reach 2,700,000 million of lighting units per a year. The plant operates two shifts, 12 hour each. The company launched the ORACLE system for planning resources 10 years ago and has had QC and QA departments for more than 15 years. It embarked on obtaining a range of QM system certifications; ISO 9001: 2000 for Quality Management System standard and procedures. The company products gained the SASO certificate of Saudi quality accreditation. In 2004, the company lab was certified by Underwriters Laboratories (UL) for safety, testing and inspection. Company G is exporting 15% of the manufacturing lighting products to the Gulf Countries and North Africa.

Challenges in changeover practice

The interviewees of the company were asked about the challenges and problems they faced during changeover process in the company. Based on the respondents' answers the most common problems cited are:

- Delay in receiving raw materials on the job location and sometimes raw materials are mistakenly delivered from the store.
- Lack of skilled and experienced manpower to conduct changeover practice.

In practice of changeover data documentation, the company made a study for calculating changeover and set-up time for a ten-year decade and recorded it in ORACLE system. This study was only undertaken to estimate the production cost and even to help the Production Planning Department to fill in the Daily Production Report easily (The copy of the Daily Production Report of Company G is given in Appendix 6-C). In fact, the company has not recorded the actual changeover time or

specifically set-up time and instead is totally reliant on old data that are recorded in the system. The Production Manager stated:

"When we have a job order for a specific product; we know how much it takes for setup time but actually it takes more time than what it supposed to be in the study. It is an old study; but we need it just to fill the Production Daily Report. It might be in the future we update this study".

The contradiction appeared between two respondents' answers relating to the scrapped products after changeover; while the Quality Inspector affirmed there were no scrapped products after changeover, and the Production Manager claimed that there should be between one and five scrap items. Based on the researcher's observation the firm had scrap items after set-up for at least one to three pieces. Also, there was no actual recorded data of the first outcomes of the rejected items after conducting the changeover. The company was not creating a sense of urgency for recording scrapped items after the changeover since it considered these data unimportant and time consuming.

People

Top management provides suggestions in a weekly follow-up meeting for improving the production and changeover process. However, top management were spending a lot of time in order to provide solutions to some problems that appear in the production or changeover process. This was because the process and procedure involved in informing and receiving the feedback was consumed time. The Quality Inspector claims top management commitment to the changeover as:

"Top management defined the scope of changeover to fulfill changeover requirements by documented changeover data in the ORACLE system".

Recently, lean deployment training was delivered in the site to the company's foreman and engineers in order to become a lean company which is a strategic objective for the company. In addition, top management attended this training session. On the other hand, new operators have short general training for the plant facility only. The operator was involved in the changeover process feedback by informing the foreman in regard to the past problems experienced during changeover. The suggestions of changeover improvement regularly took place every week as an improvement meeting between the Production Manager, the Foreman and the Operator. For example, the company suggested doing machine set-up by end of the shift for tomorrow's job order production in order to save time.

Process

The operator performs the changeover process under less time pressure. Based on the respondents' answers, this due to the fact that the company is operating on two shifts and that helps to complete job orders in the next night shift. The Production Manager argued that the night shift production was always better than the morning shift in terms of productivity and production time, this because there was a variability of manufacturing process and time between crews' shift. The company was not implementing and using the procedure for changeover process, this was because the Production Department was relying on supervisor guidance and experience to deliver the changeover process. The company is generating a production plan on weekly basis and forming the order based on the raw materials' availability. On the subject of materials' availability from the previous production process during changeover, Company G faced a delay in materials that comes from the previous process, particularly from the bending process which is a bottleneck of the production. This is because the communication channel between production and planning departments is weak and the production plan needs to be evolved with manufacturing activities. In terms of interruption to changeover tasks, the company rarely interrupted the operator to undertake another job. The Production Manager claims the following about changeover interruption:

"Actually it is important to not interrupt the operator. Because when he interrupted to undertake another job and returns to complete the set-up he will not remember where he stopped. The interruption impacts on repeating the sequence of the set-up and the probability of error occurs".

The company did not have a tooling department for changeover preparation as it relied on the foreman to prepare the dies and tools for the upcoming changeover. Figure 7.12 shows that the dies and tools cabinets were organised and easy to identify, which are located near the machines in the shop floor. The company was aware of the colour-coding technique as it was implemented on the shop floor for quickest changeover process. The colour-coding technique is implemented for quickest alignment of machine die and tool during the set-up time. In terms of new product changeover, the company affirmed that time and motion study during the changeover process can be helpful for identifying the operator's movement and allocation of materials and tools.

Figure 7.12 Dies and tools cabinet (Source: author).

Quality

Regarding the changeover preparation in term of checklist, the company was not using checklist for confirming changeover process. The company was totally relying on the operator's experience to prepare for the changeover. The company was not disseminating the knowledge of QM and changeover between operators. It depended on the foreman and engineers to provide the knowledge verbally, as the Production Manager claims that:

"I think we do not give high attention to the company's operator. We are relying on the foreman and engineers to provide proper feedback to the operator by verbal communication".

The improvement of the changeover process was take place within the company. Firstly, the company is prepared for the next changeover during manufacturing the previous product in order to eliminate the waste of preparation time. Also, changeover can be conducted one day in advance by the end of the shift for the next job order and to start the production for the following day. Secondly, the company compared between an estimated and recorded set-up time in the ORACLE system for recognising the improvement. Finally, the company was using the colour-coding technique for the easy and quickest set-up time. The colour-coding technique is implemented on the machine that has a plate with small holes identified by numbers. Due to the difficulties of alignment of the holes and

reading the numbers for fixing the tool, the Production Manager suggested using the colour-coding technique for each hole in order to identify them easily for each set-up. The colour-coding categorised each hole for enhancing changing the tool of the machine. Recently, the Production Department proposed changing the manufacturing layout in order to improve the flow of the production process (The copy of the proposed manufacturing layout of Company G is given in Appendix 6-D). This suggested change will impact on improved changeover process and the flow of materials.

In terms of safety on the shop floor during changeover, the company was conducting the process with safety requirements. Also, the shop floor was clean and the safety sign was clearly observed in the plant.

Infrastructure

The top management was involved in decisions on the machine features while purchasing it. Respondents affirmed that the company was aware of purchasing new machines that would be better than old current machines in terms of productivity and set-up time. The Production Manager discussed this:

"I think the company is aware of buying new machines that enhance production and changeover time. So we are level 4. I do not think that the company will purchase new machines with no differences from the old ones in terms of production and set-up improvement. They are considering this point while purchasing a new machine".

Changeover effectiveness levels of Company G are shown in Figure 7.13. Based on the respondents' answers and the researcher's observations the score was 3; this indicates that the company is working on level 3 of initiative changeover process. It can be seen that the lowest practice of changeover process was on quality factors which was overall 2.25 which can be considered as a managed and controlled process level. There were contradictory answers particularly in relation to the People factors which are top management commitment (Factor 1), Training and multiskilling (Factor 2) and Personnel involvement (Factor 3). The interview was conducted with the Quality Inspector as the company does not have a Quality Manager position. The difference in the education level and job position should be noted between the two respondents. Also, a quality inspector has a limited involvement in and accessibility to the top management compared to the production manager.

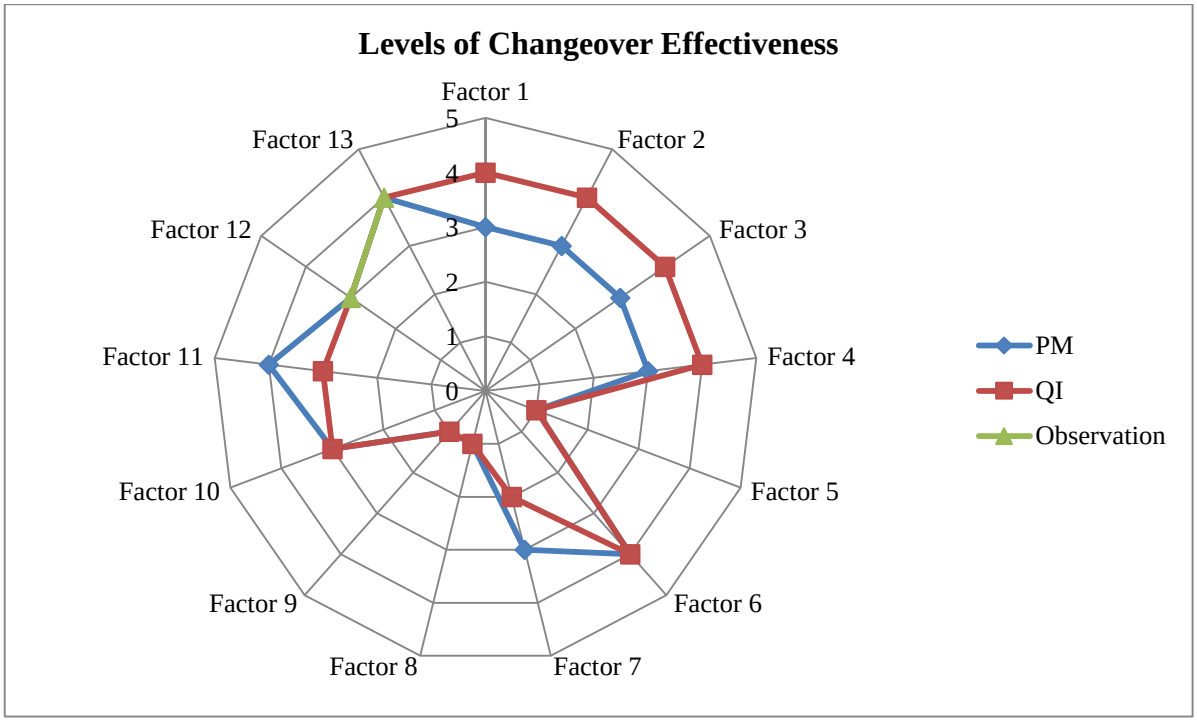

Figure 7.13 Levels of changeover effectiveness, Company G (Source: author).

Company H

Company Background

Company H was established in 1977 and is considered a small-sized (SME) company with 50 employees. The production capacity is around 200,000 lighting units per a year. The company has a range of different lighting products, such as industrial, commercial and residential. It mainly focuses on providing indoor lighting units for domestic projects. The plant operates on one shift per day. The Quality Control (QC) department has been operating for the last five years, and has recently been certified for ISO 9001: 2000 for Quality Management System.

The first impression of the shop floor was that it was disorganised in terms of the signs of the machine section and dies cabinet. The company has two sections – the steel section and the assembly line section. The steel section contains cutting, punching, bending and painting machines. The quality department has a manager and an inspector. With only a small number of workers in the QC department, much of the work has been empowered and designated to the production operators for inspecting the product after the changeover.

Challenges in changeover practice

The research participants of the company explained the problems that they faced relating to shop-floor activities during changeover. The challenges can be described as follows:

- Availability of raw materials from supplier. Sometimes there is delay from the supplier or from Saudi Arabia's customs.
- Retaining workers. It is expensive to retain skilled manpower as they are reaching the threshold limit of workers' salaries. The average retention of workers is four years maximum.

In practice of changeover data documentation, both respondents agreed that the firm was not attempting to record the changeover time and its activities. The company is only considering labour manufacturing hours in order to calculate the estimated production cost. The interviewees discussed the first outcomes after the set-up due to ensuring the measurement which should be that at least three to five pieces are scrapped. Both respondents were just fine about this result as well as the fact that there was no emphasis on recording the data of acceptance or rejection items of the first outcomes.

People

Occasionally top management were involved in providing some suggestions for improving the changeover process. The company provided general training for new workers only; the Production Department divides new workers between the steel and assembly sections. The training is served by manufacturing sections assembly and steel in order to keep the operator more focused on the process as well as to learn faster. Top management were considering the operator's feedback through the communication channel of supervisor and engineers in regard to the manufacturing changeover process and production process. The Production Manager makes the following claim about the changeover process within the company:

"Our company does not consider or improve the changeover process".

Process

Company H affirmed that the changeover process performs under less pressure. The company did not confirm that the time taken for the changeover was consistent - and it might be not. This is because of the low level at which the changeover process is monitored and lack of recording changeover time. The company does not have a standardised changeover procedure; instead it relies on experienced workers to conduct it. However, the company was using a notice board on the shop floor in order to inform the operators of the planning schedule. Clearly, it maintains the communication channel between all levels of workers for the upcoming orders and set-up. Company H normally interrupted the operator during the changeover process to undertake another job, in order to meet the delivery time of another an urgent job.

Due to the small scale of the plant there was no delay in materials transportation to the location of the upcoming changeover. The transportation of materials was usually undertaken during the internal time while the previous job order was completed and the machine stopped. The Production Manager discussed the process of requesting raw material for the next job during the internal time:

"Once the previous job is finished, the raw material is shipped from this section to this section, they will give the raw material for the next process, they will issue the request. Then the request goes to the store and the store will give the raw material".

The company was experiencing some delays in the supplying of raw materials due to the unavailability of raw materials from the supplier. In terms of changeover preparation there was no tooling department to prepare tools for the upcoming changeover. Also, the dies and tools cabinet was located on the shop floor, it was not organised, and the dies were not identified by part number.

Quality

Regarding the preparation level of changeover in terms of using a checklist, the company was not using one but instead relied on the operator's experience and recall of the changeover task. The QM and changeover knowledge and awareness was not disseminated across the shop-floor level. This is due to financial difficulties for developing and providing the knowledge facilities, such as leaflets, books and notice board. There was no seeking of changeover improvement within the manufacturing processes. The Production Manager describes the situation of changeover improvement:

"No improvement for set-up. The improvement we do not need it here. Here is simple manufacturing. We are not doing any critical machining".

In terms of safety on the shop floor, it was an untidy workplace for conducting safe changeover practice. Indeed, the unorganised tools and unsecure shop floor has a negative impact on the operator while conducting changeover activities.

Infrastructure

The firm was not considering the reducing of changeover time while purchasing new machines, as smooth production and high quality rate were significantly more important for the company than reducing changeover time. The Quality Manager makes the following claim about this:

"The importance here of buying a new machine is about the production and quality only, not for improving changeover".

The levels of changeover effectiveness are shown in Figure 7.14. Based on the respondents' answers and the researcher's observations, the score was 2.2; this indicates that the company is working on level 2 of a managed and controlled changeover process. The lowest practice of changeover process was on the quality factors which was the overall 1.3 and that can be considered as preliminary process level.

It should be noted that the Production Manager was not able to answer the question of time pressure to deliver changeover process (Factor 4). This is due to the unavailability of the information regarding the impact of time pressure on the operator during changeover as well as a lack of involvement on the shop floor during the changeover process. In addition, there were contradictory answers between the respondents particularly relating to the availability of raw materials on job resources (Factor 6) and interruption to the sequence of changeover tasks (Factor 7). This is because of a lack of communication between the departments' managers as well as a lack of their involvement in shop-floor manufacturing changeover activities.

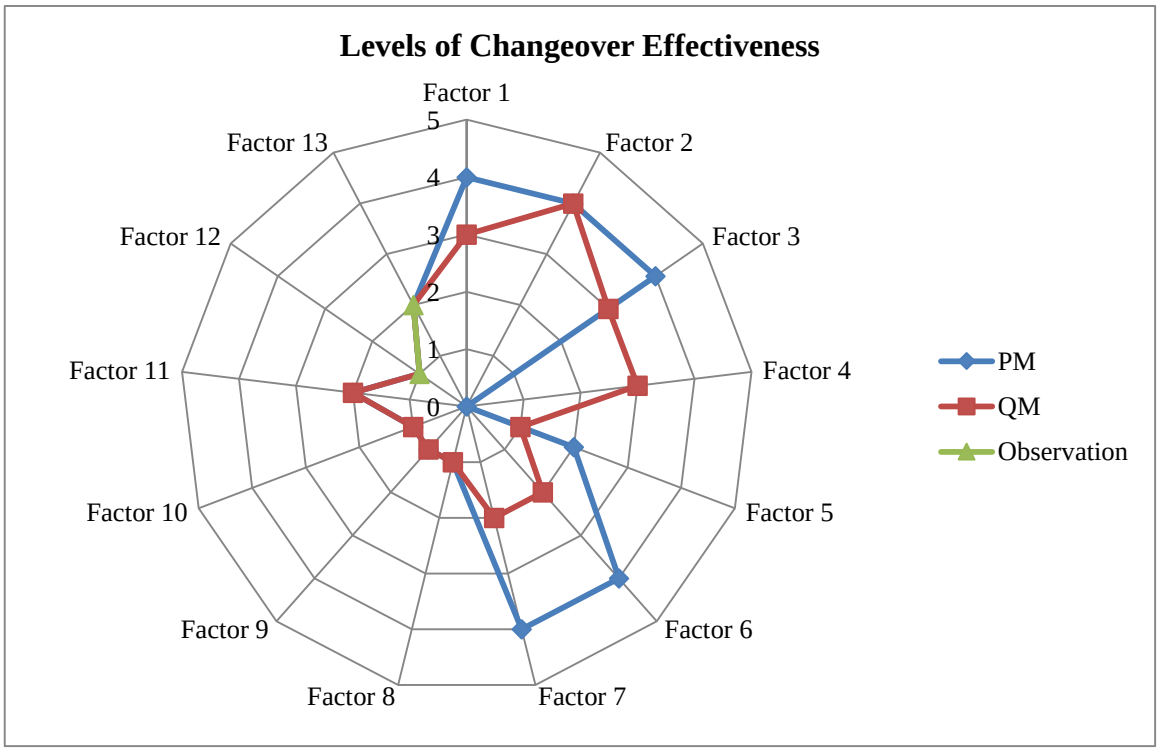

Figure 7.14 Levels of changeover effectiveness, Company H (Source: author).

Combined results of lighting companies

The preceding companies were studied to assess their position in the implementation of manufacturing changeover practice. Figure 7.15 concludes the assessment results of changeover effectiveness within the Lighting Sector Companies. The assessment of the companies was measured through four criteria: People, Process, Quality and Infrastructure. Clearly, it can be indicated that the lowest main factor was Quality; the reason for that was lack of initiative to improve the quality process of changeover practice. Also, the Process factor of lighting companies was limited between levels 2 and 3. This was because their processes during the changeover were already identified and there had been no improvement since. However, there was a significant variation in relation to People and Infrastructure factors.

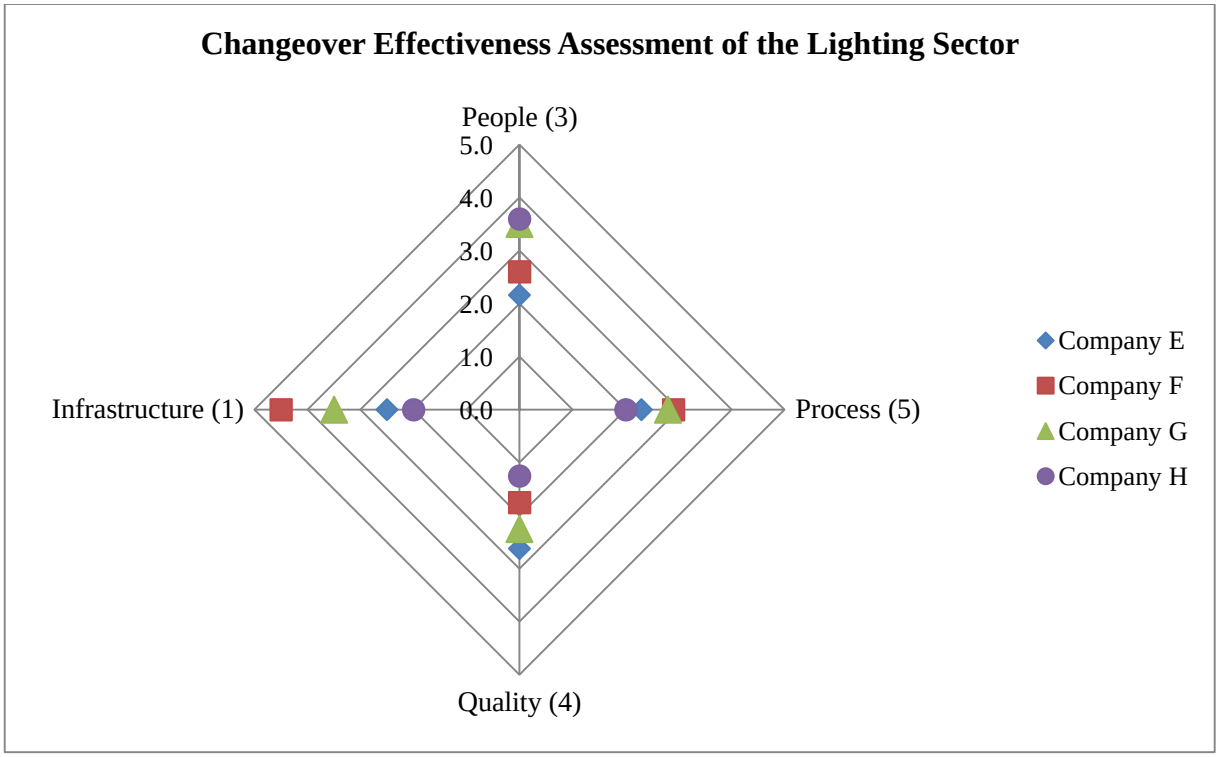

Figure 7.15 Combined results of lighting companies (Source: author).

* Note: the number indicated in the parenthesis tends for the number of sub-factors.

7.2.2 Medical Products Sector

The medical products sector in Saudi Arabia was valued at US$1.1 billion in 2013 which is around £670 million based on the exchange rate with annual growth of around 9% forecast for the next five years (Arab News, 2013). Saudi Arabia is the largest market for healthcare, medical products and equipment within Gulf region countries. Significant progress has been made by the Saudi Arabian government in terms of expanding the range of potential foreign customers of healthcare and medical products. There are Fifty two per cent of the medical product equipment manufacturers are located in the capital city, Riyadh while the rest of the plants are divided between Jeddah, Dammam and other cities. Therefore, the market is very attractive to foreign investors as well as joint venture and partnering businesses that can access to the country.

The selection of case companies from the medical products sector was based on the recognition that each was implementing batch production in its manufacturing process as well as satisfying research sampling strategy. The sampling strategy was based on the companies' implementation of QM programs, their location in one geographical industrial area, and exporting their products. The studied manufacturing processes within the medical products companies were based on the high occurrence of the changeover in their processes. The changeover process for each selected case company is described below:

- Company I: the researcher selected the attaching, winding and packaging processes, because the changeover occurs hourly between the attaching and winding parts of the process. The attaching process involves connecting the thread to the surgical needle and the winding process is winding up the thread.
- Company K: the researcher selected the cutting process of non-woven fabric materials. This is because the process requires hourly changeover.
- Companies J and L: the researcher selected the moulding plastic injection process as it is considered the main manufacturing process of both companies.

Companies' profiles

The profiles of the case-study medical companies are described in Table 7.5. The table shows the participating firms in terms of company size, company established, quality program and for how long the quality program has been implemented. It can be noted that the small-sized (SME) Company L had QC which had been in place for the last 15 years. Company I was a medium-sized company and had QC and QA for the last 15 years. However, the large-sized Company K had been implementing both QC and QA for more than 15 years. Also, Company J which is considered as a large-sized firm had been implementing TQM for the last three years and QA for the last 15 years.

Table 7.5 The main characterises of the medical products companies (Source: author).

Companies	**Company Size**	**Company established**	**Quality program**	**Years of implementing quality program**
Company I	50-200 > Medium size	More than 15 years	Quality Control (QC) and Assurance (QA)	10-15 years
Company J	More than 200 > Large size	More than 15 years	TQM	10-15 years
Company K	More than 200 > Large size	More than 15 years	Quality Control (QC) and Assurance (QA)	More than 15 years
Company L	Less than 50 > small size	10-15 years	Quality Control (QC)	10-15 years

The interviews and observation matrix of the medical firms can be seen in Table 7.6. The sub-factors were studied from F1 to F13, described below; these sub-factors indicated the level of changeover effectiveness and are grouped into four categories: People, Process, Quality and Infrastructure. The sub-factors from F1 to F11 were based on the research instrument, CEAT, and selected by the respondents as suitable level during the interviews, while the sub-factors F12 and F13 were related to the direct observation of changeover practice and preparation. The CEAT tool was implemented in order to measure their practice in terms providing a high quality and reliable changeover process (The copy of CEAT is given in Appendix 3). The respondents' answers are represented as L1 to L5, where "L" refers to their implementation level towards changeover practice. The levels that indicated respondents' answers from L1 to L5 were explicated in Chapter 5 in the research instrument section 5.5. The Production Manager (PM in the table) and the Quality Manager (QM in the table) were involved in semi-structured interviews for approximately 45 minutes each. It should be noted that the semi-structured interview in Company L was conducted with the Production Manager only who also represents the position of Quality Manager as it is considered a small-sized firm. The last column of the table shows the researcher's attendance at the changeover practice within the participant firms.

Table 7.6 The interviews and observations matrix of medical products firms (Source: author).

Interview & Observation Matrix		**Interview**											**Observation**		
		People			**Process**				**Quality**			**Infra.**	**Process**	**Quality**	**Overall**
Firm		**F 1**	**F 2**	**F 3**	**F 4**	**F 5**	**F 6**	**F 7**	**F 8**	**F 9**	**F 10**	**F 11**	**F 12**	**F 13**	**Attending changeover**
I	PM	L3	L3	L5	L4	L1	L5	L5	L1	L2	L3	L4	L3	L5	Fully
	QM	L5	L3	L4	L4	L1	L4	L5	L3	L3	L2	L4			
J	PM	L4	L2	L3	L4	L1	L3	L4	L1	L1	L1	L3	L3	L4	Partially
	QM	L4	L2	L2	L3	L1	L3	L5	L1	L1	L1	L4			
K	PM	L4	L2	L2	L4	L1	L3	L4	L1	L1	L1	L4	L3	L4	Partially
	QM	L4	L2	L4	L4	L1	L3	L4	L1	L2	L1	L4			
L	PM	L4	L4	L5	L3	L1	L5	L3	L1	L1	L2	L2	L1	L3	Fully

F1 (Factor 1) Top management support the changeover process
F2 (Factor 2) Training for changeover practice
F3 (Factor 3) Personnel involvement during changeover
F4 (Factor 4) Time cause an undue pressure
F5 (Factor 5) Speed up the set-up process (standardisation)
F6 (Factor 6) Availability of the materials and tools
F7 (Factor 7) Interruption the sequence of changeover tasks
F8 (Factor 8) Using checklist (Preparation)
F9 (Factor 9) Awareness of changeover and QM
F10 (Factor 10) Initiative for changeover improvement
F11 (Factor 11) Using new machines and equipment
F12 (Factor 12) Changeover preparation
F13 (Factor 13) Safety and facilities on shop floor (clean and lighting)

Companies' respondents

The respondents of the research interviews are shown in Table 7.7. The table describes the interviewees in terms of job position, education level and experience in the manufacturing industry.

Table 7.7 Respondents profile of medical products companies.

Companies	Respondent position	Education level	Experience
Company I	Production Manager	Bachelor degree	More than 15 years
	Quality Manager	Bachelor degree	More than 15 years
Company J	Production Manager	Bachelor degree	10 - 15 years
	Quality Manager	Bachelor degree	More than 15 years
Company K	Production Manager	Bachelor degree	5 - 10 years
	Quality Manager	Master degree and chartered quality professional	More than 15 years
Company L	Production Manager	Bachelor degree	More than 15 years

Objectives for and Obstacles to improving changeover process

Both respondents from the Quality and Production Departments identified the reasoning behind the main goals, and the constraints to improving the changeover process. The objectives and obstacles for improving the changeover process within the medical products sector is shown in Table 7.8. Noticeably, most of the respondents stated that the main objective for improving the changeover process was to impact on increasing the productivity. Also, they stated that better quality outcomes, reduce waste and reduction on production cost would be influenced by improving the changeover process. On the other hand, the respondents identified the obstacles that prevented the improving of the changeover process. Lack of a particular type of worker, as well as limited skilled personnel were considered as obstacles within Company J because of the most of the workers had little or no education. The respondents also raised the difficulties of obtaining new personnel. In addition, respondents stated that lacking of financial resources impacted on purchasing lower-quality dies and tools which affect the changeover process in terms of time and product quality. Also, an obstacle cited was a lack of employing the changeover procedure on the shop floor.

Table 7.8 The objectives and obstacles of improving the changeover process of medical products companies.

Companies	Respondents	Objectives of improving changeover process	Obstacles of improving changeover process
Company I	Production Manager	Reduce changeover time and wastage	No, nothing like that kind of any obstacle here
	Quality Manager	Increase the capacity of the productivity	There is no obstacle - we are free to improve
Company J	Production Manager	To increase the output and productivity	Lack of personnel numbers
	Quality Manager	To increase the efficiency and productivity and reduce the cost	Lack of a particular type of skilled personnel, and low personnel numbers
Company K	Production Manager	Better productivity and efficiency of outcomes	There is no obstacle or major need to improve it
	Quality Manager	It is to avoid mix up, to reduce waste, to reduce interference time and to improve productivity	1) Employees need to be aware of the importance of the decisions taken during changeover 2) Implementing changeover procedure
Company L	Production and Quality Manager	Better quality production and then we will reach our productivity	Lack of financial resources impacts on purchasing cheap mould quality

Company I

Company Background

Company I is considered a medium-sized firm; with a workforce of between 50 to 200 employees. The company claims itself as one of the most experienced firms in the Saudi healthcare industry for more than 15 years and is responsible in producing a wide range of sutures, ligatures and ophthalmic instruments. These products include absorbable and non-absorbable sutures, latex surgical and examination gloves, and other specialist products that mainly used in the operating theatre and other medical facilities. These products are disposable and mainly designed with specific style and structure to satisfy the surgical requirements of surgeons. The plant operates two shifts every 12 hours. The company was running on small batch production that took an hour, or half an hour. The company followed the British Pharmacopoeia, European Pharmacopoeia and United States Pharmacopoeia specifications for its surgical products.

In addition, to respond to the changing demand in healthcare and modern surgery, Company I invested in enhancing performance and providing high quality products with specific criteria. The company obtained ISO 9001: 2008 for Quality Management System requirements as well as ISO 13485: 2003 Medical devices for Quality Management System and it was certified with the Directive 93/42/EEC for manufacturing medical devices products for European market requirements. The company was awarded the Saudi Food and Drug Authority (SFDA) certificate in order to fulfil their requirements. The SFDA is an organisation body for monitoring the fulfilment of the regulations and procedures of quality and safety that are required.

Challenges in changeover practice

The interviewees were asked to identify the changeover process problems that occurred on a regular basis; they highlighted the challenges as follow:

- Packaging machine breakdown was lasting for four hours to rectify the machine failure. This is due to the frequent changing of the packaging material colour based on the product package. Recently, the company solved this issue by scheduling the same packaging material colour to be printed together in order to reduce the frequent changeover and eliminate losing time.

- Availability of raw materials particularly for new items. Because the products depend on customer requirements, if a new item was ordered, it will take time to obtain the raw materials from abroad.

During the interviews, both respondents affirmed that the company was recording changeover time. Based on observation, the researcher found that the company was recording the starting time of the batch size and the die that was used (The copy of the Batch Record Sheet of Company I is given in Appendix 6-E). As a result of that, production starting and finishing time of each batch was recorded. The company can calculate the changeover time from starting production time between each batch. However, the company claims that the changeover time consumes between 20 and 30 minutes in normal conditions. After the set-up process, the company followed the QA procedure in the Process Check Quality (IPC) by inspection for the first and last 10 pieces in the quality inspection lab. The Quality Lab has three types of test - tension, destructive, and non-destructive - for ensuring that products meet the quality requirements. During the inspection of the first 10 pieces the operator had to wait for 15 minutes to receive the acceptance from the Quality Laboratory to proceed with the production again. During the quality test, if the product does not pass, the supervisor would be informed and complete the changeover with the operator in order to learn the process. The Production Manager affirmed that product quality would be affected by the changeover process:

"Quality would be affected. If it's changing the die or they missed something, and it's interrupted. Changeover has an impact on the acceptance outcomes of a product".

The company has not attempted to link changeover data with output data of the production and quality for changeover improvement. The reason for not linking the data was because each operator often had to meet the acceptable time of the changeover. In terms of new product changeover, the company emphasised the initiative of the changeover procedure for a more consistent process.

People

Top management were committed to improving the production and changeover process as well as the quality issue by implementing weekly meetings that all department heads and the general manager participated in; however, top management were not involving directly in the changeover process and time on the shop floor. The general manufacturing training was provided internally for operators in

order to meet ISO requirements. Since then training has become a continuous cycle that is delivered to employees and operators. The training program did not encompass the SMED technique for reducing changeover and set-up time. One of the respondents discussed the training process as follows:

"Suppose we have ten categories of workers - attachers, winders, packagers. So each one will be given his training. The internal training from the expert staff is based upon seniority. Who is senior? Who learns more? He will be the training expert. It is formal and documented training".

The personnel involved during changeover were engaged in providing feedback on past problem experiences to the Foreman or department heads. However, the company was not taking feedback on the documented process as this was usually discussed during the meeting or verbally on the shop floor. The company was not holding a brainstorming session with shop floor workers on how to improve the changeover process, as it held a discussion meeting for changeover issues between senior operators, the Foreman and the Production Manager. Foremen were involved in meeting with the Production Manager in order to clarify issues that emerge during production and changeover on the shop floor. Also, the Production Manager affirmed that the company considered the operator's decision-making as follows:

"We do consider the operator on decision making because he's the main person who's standing on the machine. He knows much more than anyone, what the machine is doing. So anything changes, he knows".

Process

The company was not imposing time pressure on the operator to finish the changeover process. However, it was well known that each operator has to finish the changeover within a certain acceptance time. There was a low degree of variability of changeover process between the morning and night shifts. The reason for that was because of the monitoring production and changeover process of each shift by the supervisors. The company has understood that each product has different raw materials size, such as micro or macro, and that creates some difficulties during changeover based on the raw materials. The changeover time and quality of output for each individual operator are measured and monitored to confirm if operators meet the company requirements. In the situation where operators fail to meet the requirements, proper training will be provided.

The company has a common Standardised Operating Procedure (SOP) for all operations and products. The SOP was attached on the machine itself in order to ensure that operators were following the instructions for operating procedures. The QM discussed not having a changeover procedure for each product as follows:

"We have a one common SOP for all products. It is general but not for each specific product. Because all have the same kind of needle and one thread".

In terms of raw materials availability, there was no delay in receiving items from local and overseas supplier. The production plan usually delivered between the firm's departments in the form of a monthly plan. The Planning Department has maintained the stock level of raw materials for at least six months stock. Also, in case of a shortage in raw materials, the company has a contract with suppliers in order to preserve the stock level. However, there were products based on customer requirement which require ordering raw materials two months before delivery. Overall, it seems that communication between the firm's departments is well maintained through the processing order procedure from the sales department until the products are shipped. The company was only using Excel software for materials production planning which is uploaded in the firm's server. In respect to raw materials transportation, before finishing the job, raw materials will be delivered during the external time in order to be ready for the next job.

The company has disallowed anyone from interrupting the operator while they are conducting the changeover process unless someone has permission from management. Also, each operator has a single responsibility on the shop floor due to the fact that the changeover time has standardised variation. The Production Manager discussed that how the quality of the outcome can be affected based interrupting the operator, as follows:

"No one has permission to interrupt the operator during changeover because quality would be affected. No one is permitted to do that unless given permission by me or top management."

A dies cabinet was located on the shop floor and dies were easy to identify by part number. On the other hand, there was no preparation of tools and drawings before changeover commenced. Also, there was no use of the set-up cart during changeover.

Quality

The company used the Line Clearness Sheet; before starting up the machine of each manufacturing process, the operator has to check and inspect some points of concern noted in the sheet, such as raw material type, length and checking the winding and labels (The Line Clearness sheet is given in Appendix 6-F). This form was made for quality inspection purposes and it is usually assigned with a job order. It is used within the production process, such as attaching, winding and packing sections, in order to measure the quality of each section. In terms of QM and changeover knowledge, the company indicated that short weekly sessions were conducted by the Production and Quality Managers which related to their manufacturing practice as well as suggestions for manufacturing improvement. The sessions targeted the supervisor, senior operators and a few operators. Also, the company was relying on the supervisor to monitor and disseminate knowledge and awareness to operators.

In respect to initiatives for changeover improvement, the company was totally satisfied with the current changeover process and time. Also, it was not implementing improvement tools such as SMED or recording changeover activities by video tape. The reason for that was because the production hours were achieving the target of the delivery time, and major delays in changeover time were not happening. The Production Manager discussed the improvement of the changeover through planning the same colour product to be packaged at one time on the packaging machine, in order to minimise the occurrence of the changeover on the shop floor; as stated:

"We have to do that in the planning - that we bring all the products once. And packaging, we bring all the same job order at one time. This is the partial improvement we can do. No, the video, we're not doing anything with video."

The changeover was conducted with safety standards in terms of safety clothes, shoes and protective glasses on the shop floor. Also, there was a clean and tidy workplace that facilitates a smooth changeover process.

Infrastructure

The firm reviewed the impact of a new machine on changeover time; it also compared the new and old machines while purchasing the machine. The company was considering some features on the new machine, such as automatic feeding and collection, and less manpower requirement. The Production Manager discussed the aspects of the new machine that the company was looking for:

"Based on the product nature, changeover is the must in our business. We are trying to bring machines which will reduce manpower - number of workers working on that - like automatic feeding, automatic collection. When we purchase the machine, we look at these aspects. Changeover is the must in our business and different capabilities - we will check that the changing is easy, not very difficult on the machine. When we buy the new machine, we check and see that the changing for the machine is very easy, and we study it."

The levels of changeover effectiveness are shown in Figure 7.16. Based on the respondents' answers and the researcher's observations the score was 3.6; this indicates that the company is working on level 4 of standardised changeover process. It can be seen that the lowest practice of the changeover process was on quality factors, which was 3 overall; and the highest of changeover practice on infrastructure factors was an overall 4. There were contradictory answers particularly relating to top management commitment (Factor 1); this is due to the fact that the Quality Manager was not involved in changeover problems and issues that appeared on the shop floor. Moreover, there was a discrepancy on the procedure checklist (Factor 8); this is because of a lack of communication between the Production and Quality Departments. As a result, the Production Manager was not aware of the existing confirming set-up/quality tool, which is line clearness, while the Quality Manager was aware of it.

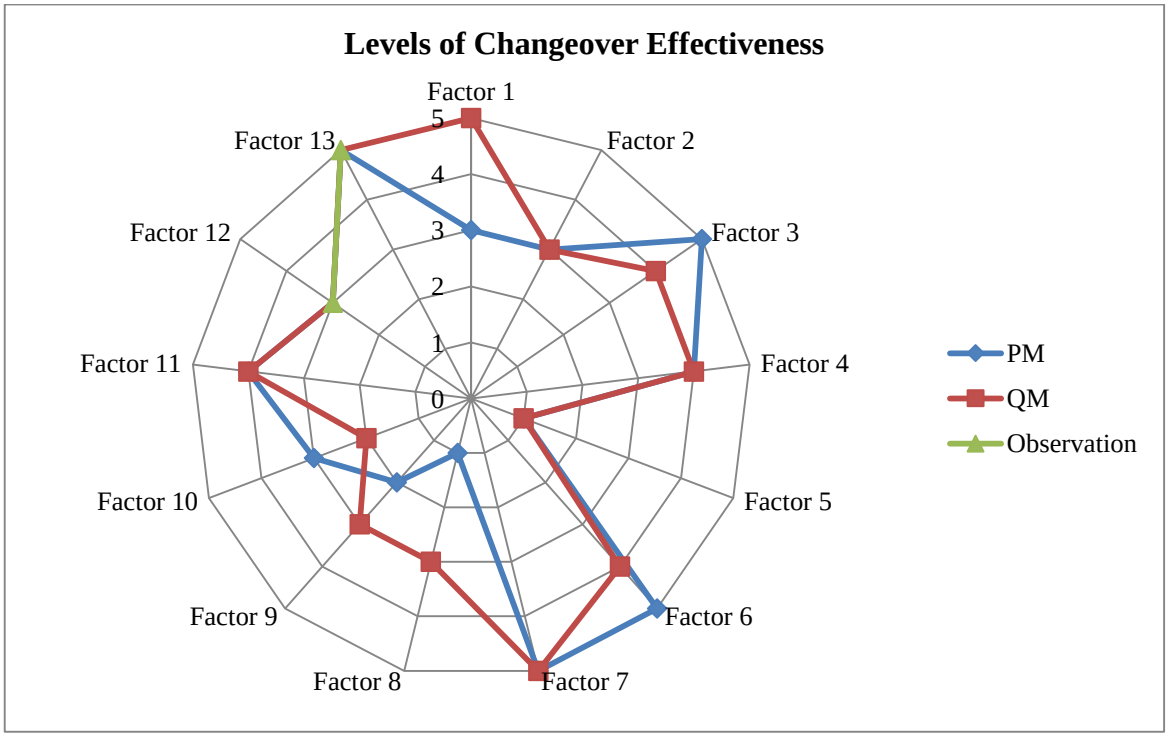

Figure 7.16 Levels of changeover effectiveness, Company I (Source: author).

Company J

Company Background

The company operates to manufacture and distribute a number of different products to satisfy the demand of the healthcare requirements in Saudi Arabia as well as the Middle East. The company has been operating since 1979 and has modern manufacturing facilities located in Riyadh. It is considered as a large-sized firm and the plant operates two shifts every 12 hours. The main products are surgical and disposal which includes crepe wrapper, paper wrapper, wound drainage system, foley's catheter latex and plast zinc oxide adhesive tape which are designed to meet the various demands of the healthcare field. Therefore, it implements a number of quality techniques and programs to ensure the quality of their products in different stages of their productions. This includes implementing a rigorous supplier certification program to ensure the quality of the raw materials. In addition, it is investing in human resources and modern technology, and adopted the ISO 9001: 2008 for Quality Management System, ISO 13485: 2003 Medical devices for Quality Management System. These ensure it achieves production to the highest standard of quality specifications. Recently, the company has implemented TQM in order to maintain the products quality.

Challenges in changeover practice

The research participants of Company J explained the problems that faced shop floor activities during changeover. These are challenges can be described as follows:

- Shortage of raw materials in the stock from supplier
- Shortage of skilled manpower
- Machines breakdown during conducting changeover

The company constantly conducts changeover in the daily process because of small batch size and the limited expiry date of the products (two years). In terms of changeover data documentation, the company was not recording changeover time and its activities. Also, the Quality Manager was uncertain whether there was any changeover data documentation on the shop floor, and described the changeover practice as:

"Changeover is taking out the mould and putting in another mould - that is all you will do. That is besides changing the raw material".

It should be noted that the changeover process is conducted by the maintenance team. After the set-up process is conducted, the company has followed the procedure of the first-sample approval process for ensuring the product's quality. The Quality Manager affirmed that the first outcome was usually not accepted, based on measurement requirements for ensuring the product's acceptance. Moreover, during the inspection of the first outcomes, the operator had to wait for 15 minutes to receive the acceptance from QC in order to proceed with the production again. The QC examined the product through visual inspection and in the QC laboratory. Company J consumes two hours and one day for the changeover time according to the Production Manager:

"I think the average would be two hours but some machines can take a whole day. We have a machine or two that take a day long, which are considered a production line. The two machines almost take a shift or a little bit less than that."

The company respondents believed that there was no impact of improving the changeover process on product quality but it would be impact on productivity. The reason for that is because the changeover process was seen within the company as a fixed process and fixed parameters.

People

Top management were involved in providing adequate tools and machines that helps with the changeover process; they also revised the machine capacity in terms of changeover and productivity per shift and hours. However, top management were not present on the shop floor for direct interaction with the production personnel. The former top management were involved in calculating the changeover and production times; as the Quality Manager said:

"The president himself was present in the work area with his stopwatch to calculate and figure out how to improve everything. That was done to almost all the processes. Everything was recorded - the set-up and the changeover time. But we lost these records with time because things changes as managers change".

The informal training was only provided for new operators as they have to observe and perform the changeover process with a senior operator and supervisor. New operators are considered as helpers for a period of time, and work under supervision. The period of training varied from two to three months until the supervisor informed maintenance that the operator was able to perform manufacturing practice in the firm. In fact, the company provided overseas training to the firm's supervisors how to

operate new machines or production lines in the location where the manufacturers are. However, there was no training for existing operators as they had received it previously. The company can measure the operator's performance in terms of changeover process by the QC In-Process Control. The acceptance of the product after the changeover and checking during production indicated the level of operator understanding after the training.

In terms of personnel involvement during changeover, sometimes the operator was engaged in providing feedback on a past problem to the supervisor or the Production Manager. However, operators were not involved in changeover process improvement within management meetings. The Production Manager discussed the operator's involvement in proposals for some ideas for improvement to permanent machine modification in order to improve the production or changeover process and time, as follows:

"During changeover and production, it differs from one person to the other. Some operators came up with some ideas, for example, instead of holding the roll, he would put it near by the machine in some way. Not all the operators can do that and it is rare. Sometimes we make some features on the machine. If the operator wants to carry up a roll in a very narrow place, we make something for him so he can hold the roll up and put it in. There are some modifications that can help to finish the changeover process as soon as possible. Those modifications come out as ideas that come out of experience."

Process

The changeover process was performed without time pressure on and repercussions for the operator if delays occurred. The reason for that was that the changeover time is variable between each operator. However, the supervisor would be reported to management if delays happened repeatedly. It should be noted that the changeover process was usually conducted by the maintenance department. There was a medium degree of the changeover process between night and morning since the full maintenance team were not available on the night shift, and also because the operators who performed the night shift were less experienced. Communication existed between the two shifts as the supervisors have to meet each other for 10 minutes; in addition, a daily report was produce with regard to any events that happened during the shift.

The company did not have a standardised changeover procedure - the respondents justified this because of the simplicity of the products and relying on experienced operators. The Production Manager discussed the opportunity of having the changeover procedure as follows:

"It is a necessity to make a procedure for the changeover but currently it is not urgent".

The company usually prepared the production plan as daily and weekly plans based on the market expectations and customer demand. In regard to the availability of raw materials on job resource, there was a delay on transportation especially in the night shift due to human error, such as mistakes in raw materials, size and counting. The reason for that was that the warehouse was located off the premises. Normally, the raw materials were requested and placed in advance in the Work-In-Process (WIP) area. Therefore, the raw materials were placed beside the machine once it had finished from producing previous product. The company purchased planning software; however the Quality Manager mentioned that this software was no longer being used due to technical reasons and difficulty of use. Currently, the company uses Microsoft Access that is designed internally for materials planning production, and uploaded it through the firm's server. In respect to the interruption during changeover, there was no interruption of the operator unless permission was given by a higher authority, such as the Production Manager as there was a production plan that needed to be followed in order to meet the delivery time; however the only reason that interrupted the operator was the breakdown of the machine.

There was no existence of in advance preparation of drawing and tools for the upcoming changeover. The firm was not using a checklist for changeover preparation. However, the tools and dies cabinet was located on the shop floor; it was organised and parts were easy to identify.

Quality

The company was not using a checklist or any confirming tool for the changeover process. The Production Manager explained that the training programme was enough to perform changeover process. Also, the Quality Manager justified that because it is a simple changeover process, it does not require a confirming tool. The Quality Manager defined the changeover as follows:

"Take out the mould and put another mould - that is all what we will do. That is besides changing the raw material."

The company was only relying on the supervisor to disseminate the QM and Changeover knowledge through verbal communication to the operator. The dependence on only the experienced supervisor and the long period of training provided to the operator was the reason behind that. In terms of changeover improvement, the company was not seeking to improve and record data of changeover time and process. The Production Manager discussed that the changeover and set-up time was satisfactory, but productivity needs to be improved:

"As time goes by, the set-up issue is not the problem. It is how to produce. What matters is what you add to increase productivity. For the set-up time we are satisfied with it."

The changeover was conducted smoothly in line with safety requirements, and there were no hazards on the shop floor. The impression of the shop floor was clean, and safety signs were visible.

Infrastructure

Top management were involved in reviewing the impact of a new machine on changeover time and productivity while purchasing it. The company purchased new machines that arrived on the company site at the end of 2013 and the beginning of 2014. The priority of the company was having a high productive machine rather than improving the changeover time. Top management take these aspects into consideration when reviewing features of the new machine, such as an automatic changeover and the possibility of implementing permanent tools modification in order to improve the changeover process and time. Six months after purchasing the machine, the company tried to improve the productivity of the machine. It improved the capacity of the machine in order to reduce the frequency of changeover per day on the machine; for example, the modification on holding the roll of the machine to hold a bigger diameter size of the roll and for liquid medical products can use bigger barrel to ensure that the production is continuous and to reduce the appearance of the changeover. These ideas were applied to both old and new machines. The Production Manager stated:

"Sometimes the supplier of the machine cannot meet what you expected especially when you buy a machine made from China. All we can do is that get the machine and then we modify it. These modifications either take place in the machine itself, the productivity, the safety, the press-button to stop or the product itself."

The changeover effectiveness levels of Company J are shown in Figure 7.17. Based on the respondents' answers and the researcher's observations the score was 2.8; this indicates that the company is working on level 3 of initiative changeover process. It can be seen that the lowest practice of changeover process was on quality factors which was overall 1.8, which can be considered as a managed and controlled process level. There were contradictory answers particularly relating to personal involvement (Factor 3); this is due to the fact that the Quality Manager was not involved in the shop floor production and feedback loop. However, the operator had an improvement idea of implementing a permanent machine modification that contributed to improve production and changeover process. This broken feedback loop between the Quality Manager and the supervisor has been identified as a primary cause of fragmented communication that lacks the involvement from the Quality Department.

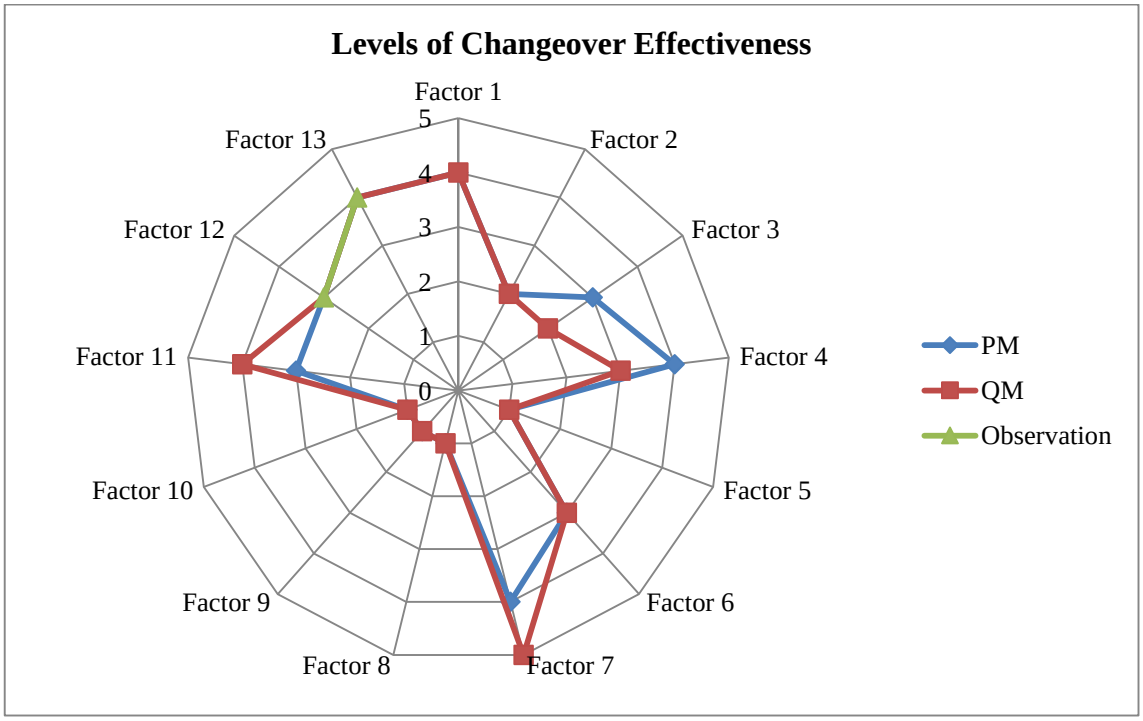

Figure 7.17 Levels of changeover effectiveness, Company J (Source: author).

Company K

Company Background

The company was established in 1991 and is currently operating as a joint venture that manufactures a wide range of healthcare disposal products. These products are hospital supply, such as surgical gowns, hospital coveralls and facial protective which are designed to fulfil the need of hospitals and other medical facilities. The manufacturer of the company is located in the 2nd Industrial Area in Riyadh, Saudi Arabia and it is responding to the demand in Saudi Arabia, the Gulf Countries, North African Countries and the Middle East.

These products are manufactured using the very latest technologies to produce a range of products with individual specifications. In addition to the healthcare single-use products, the company manufactures other Industrial Coveralls which are specifically developed to satisfy the need of the industrial and agriculture sectors. Furthermore, to respond to the various needs of customer demand, the company design customised products with different specifications which are different from the standard products. The company products carry the CE mark that conforms to the EU requirements health and safety. In terms of the quality of the company's outcome, there are specific standards implemented to ensure achieving the highest quality in operations. Therefore, the company obtained ISO 9001: 2008 for Quality Management System, ISO 13485: 2003 Medical devices for Quality Management System and European Medical Device Directive 93/42/EEC Annex V. Also, the company was registered and certified with the SFDA in order to fulfil the regulations and procedures of quality and safety that are required.

Challenges in changeover practice

The participants described how most problems occurred during changeover practice. The interviewees highlighted these issues as follows:

- The mix up of raw materials between previous and next batch during changeover. The company tries to avoid such mix up by cleaning the shop floor to manufacture the next product.

- Lack of monitoring during changeover in the night shift; consequently the operator performed the changeover and manufacture of an unrequested product.
- Delay of receiving raw materials from supplier.

Company K is operating their manufacturing process by MTO strategy through customers' requirements. However, there is a small percentage of products that are manufactured by MTS through the market forecasting. In terms of changeover data documentation, both respondents affirmed that the company was not recording changeover time. The Production Manager claims that changeover time is minimal and does not add value to the production as it achieves the required production capacity:

"The changeover time is minimal and we do not record it. Maybe we record it, if it showed that would be beneficial for us, then we will start it."

The contradiction appeared between the two respondents' answers relating to the time consumed during the changeover process. Based on the observation, the changeover time is consuming between 60 and 90 minutes because of transferring raw materials to the job location and cleaning the shop floor from the previous process. After conducting the set-up, the company was using First Piece Inspection (FPI) technique to measure the first piece quality requirement before starting production. As a result of that, the acceptance rate of the first piece was 95%. Both respondents discussed that the changeover time does not impact on product quality. The reason for that was because the changeover process was considered as a series of fixed parameters.

People

Top management were engaged in annual management review meeting to assess the effectiveness of their manufacturing practice and to take into consideration any new improvement to existing production and changeover processes. The Quality Manager identified the scope of top management as stated:

"The top management is always looking for continuous improvement by introducing new machinery, reducing time, reducing manufacturing defects and reducing the involvement of the human element, hence, improving productivity. We have two tasks to work on; meeting customers' requirement; and improving customers' satisfaction".

Also, the General Manager was involved in a monthly meeting that reviewed the firm's efficiency and performance. However, the Production Manager discussed that, during the meeting, not enough attention was given to the manufacturing changeover process:

"We can do changeover daily, we are producing more than 40 or 50 items. We can changeover like this. It's easy. We don't need to have a meeting about it."

The company was provided with Six Sigma Green Belt training two years ago specifically for the firm's engineers in order to improve the manufacturing layout and improve the output. The Six Sigma Green Belt training is known as a continuous improvement cycle applied by implementing Define-Measure-Analyse-Improve-Control (DMAIC). The new operators will have a short training session for plant facilities and how to preform changeover. The supervisor was involved in training the new operators by explaining and describing how to perform the changeover and manufacturing processes. However, the company is recruiting training personnel for monitoring and supervising new workers. In addition, the company implemented an annual evaluation for identifying training needs for existing operators and employees. Based on the annual plan, the training can be conducted either internally or externally. The company has to provide training for employees and workers if some changes are made to the procedure.

The personnel involvement towards the changeover improvement process did not directly involve top management. Also, the operator was not involved in the changeover process improvement. This is because of the lack of a feedback system and less encouragement from management to shop-floor workers to improve the changeover process, and also because the main focus for the company was to improve productivity and product quality. Therefore, on some occasions the operator was involving in providing suggestions for improving these two aspects only. The Quality Manager discussed that:

"We have a lot of very good suggestions coming from operators and workers to improve productivity and product quality only. On a lot of occasions, the suggestions came from the operators."

Process

The changeover was usually conducted without creating time pressure on the operator by consuming the standard time, based on the Quality Manager's response as follows:

"The company trusts the operator without performing pressure because it can create problems. He has to be questioned because, for example, if you are doing something within one hour, and suddenly, it takes three hours from him, he has to be questioned."

The company uses Excel software for production planning materials resource through uploading it into the company's server. Also, a notice board of job orders was observed on the shop floor to facilitate communication between the morning and night shifts. There was a low degree of variability of changeover process between shifts. The reason for that was because of a layover between the shifts in order for the team leaders to communicate and discuss issues, especially for the upcoming changeover and production. The company did not have a changeover procedure, and the respondents justified this as because of the simplicity of the products. The company was only used the Cutting Order Slip (COS) for indicating the specification of required products (The Cutting Order Slip (COS) is given in Appendix 6-G). The COS was initiated by supervisor to confirm the next changeover of the product.

The company has weekly and monthly production plan schedules. The monthly plan was for the mass and large-lot production, while the weekly plan was for batch and small-lot production. The availability of material from the previous process was always available to the next job. Delays occurred on the transportation of raw materials from the store because of the store was located off the premises. Also, there was a shortage of raw materials due to not receiving them from local or overseas suppliers. In this case, the company shifts the production to other products until the raw materials are received. In respect to the operator interruptions during changeover, both respondents affirmed that no one can interrupt the operator while he is conducting the changeover. Relating to this aspect, the Quality Manager stated:

"I think only the production manager or the production engineer can do that. If there is a specific task located and a specific number of products to be produced in a specific time, there is no way to take this operator from this area. There is no interruption, no."

The firm was not preparing the tools and drawing for the upcoming changeover. Also, a confirming tool was not used for ensuring the changeover process. The tools cabinet was organised and identified by part number and machine name.

Quality

The firm was not using a checklist or similar simple tool for confirming the changeover process because it was relying on the operator's experience for preparation. The Quality Manager discussed the importance of having a checklist before commencing changeover:

"It is necessary. For you to produce, you need to ensure that the sources are available. The resources include materials, manpower and machinery; all together. If one of them is available without the others it will be a main issue. It is very important."

In terms of changeover and QM knowledge, the company provided a notice board on the shop floor that contains leaflets and general background information regarding this subject. Also, it was relying on the supervisor to disseminate knowledge and changes to procedures among the shop-floor level staff. The improvement of changeover time was undertaken through changing the manufacturing layout of the plant. As a result the movement of materials and the personnel during changeover and production was improved. Moreover, the manufacturing layout improvement helped to improve the hygienic environment of the shop floor. The company reduced changeover time from three hours to approximate between 60 and 90 minutes. For example, the improvement was changing on machine tools of the spreading roll that helped to reduce changeover time. The company highlighted that a documented changeover process can be crucial in terms of improving the changeover process of a new product, as it helps to priorities the process. The changeover was conducted with safety requirements and smoothly, without any hazards on the shop floor.

Infrastructure

The company reviewed and studied the impact of changeover time and outcomes quality while purchasing a new machine. The main focus was on considering an automated changeover feature in a new machine without the need for the human element, which would impact on improving the outcome and product quality. In 2009, the company carried out a study on improving changeover time; subsequently it purchased new machines that have less changeover time. Also, in 2014, the company introduced a new production line that has a better set-up time than the previous one. Currently, the company is totally satisfied with its changeover time which is between 60 and 90 minutes. However, improving changeover performance contributes directly to increase productivity and product quality

(Singh and Khanduja, 2011). The PM claims that the company needed to enhance the production and product quality as follow:

"I think it's not the main concern, the set-up time. The main concern is always the product quality. Whatever gives us the best quality."

Figure 7.18 describes the levels of changeover effectiveness within the company. Based on the respondents' answers and the researcher observations the score was 3; this indicates that the company is working on level 3 of initiative changeover process. It can be seen that the lowest practice of changeover process was on quality factors, which overall was 2.1 which can be considered as a managed and controlled changeover process level. There were contradictory answers particularly relating to personnel involvement (Factor 3); this is due to a lack of defining the operator's job responsibility between the Production and Quality Managers. The discrepancy occurred on QM and changeover knowledge (Factor 9); based on the observation there was a notice board on the shop floor that providing QM and safety knowledge. However, the company was depending on the supervisor to disseminate the knowledge.

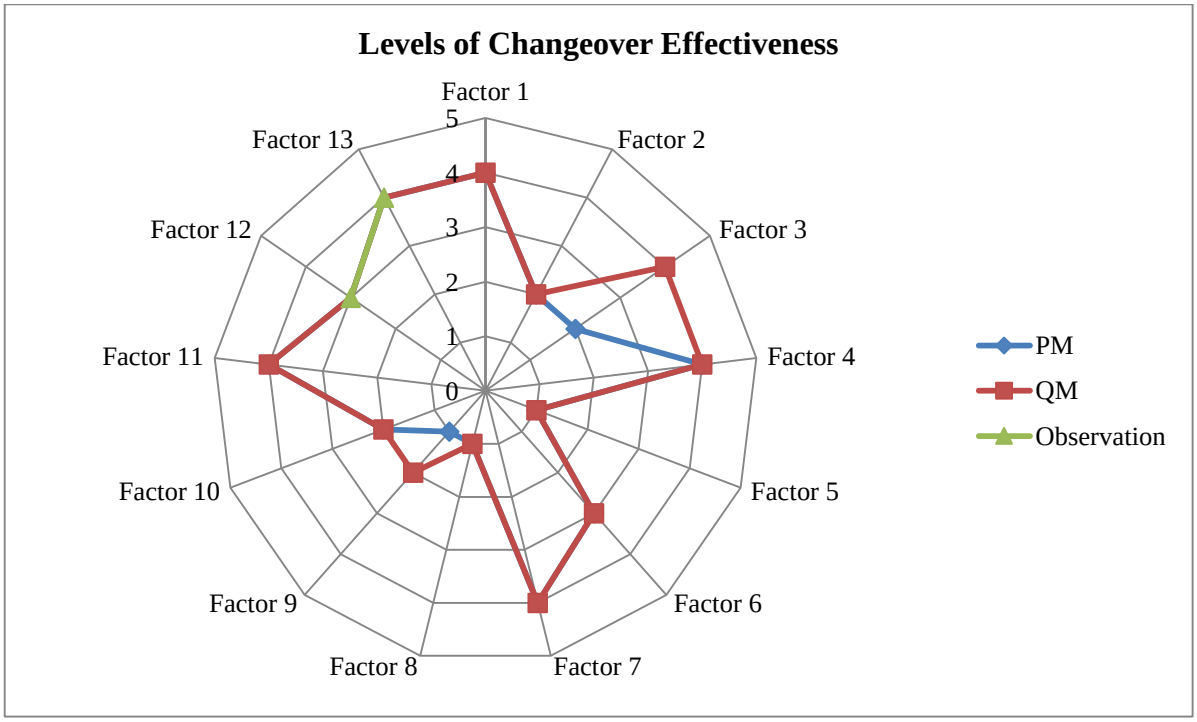

Figure 7.18 Levels of changeover effectiveness, Company K (Source: author).

Company L

Company Background

Company L is considers a small-sized company with 50 employees. The company was established in 1997 specialising in manufacturing single-use laboratory and medical products. The company operates with two additional lines to produce medical detergent and antiseptic disinfectant field. The products of the company include blood collection tube, test tube, Pasteur pipettes, Petri dishes and containers with medical disposables products and other bacteriology products which are provided to fulfil the needs of hospitals and other medical facilities in Saudi Arabia and the Middle East. The wide range of the products fulfils the requirements of the SFDA regulations to ensure that customers are provided with the highest quality of sterile and non-sterile products. In addition to the standard products, the company manufactures other products according to customers' requirements on equipment manufacturer basis.

The company's manufacturing facilities are located in Riyadh, Saudi Arabia and it has sales branches in Jeddah, Dammam and the United Arab Emirates (UAE) in Dubai. The factory is operating and controlling injection and blow-mould machinery which is designed to ensure high-quality products. The company also operates two shifts every 12 hours. In addition to production, the company offers an online service to provide better communications and to ensure that the daily customers' requirements are achieved. Furthermore, the company has implemented several techniques such as direct sales to ensure a better understanding of customer requirements and to provide excellent service that exceeds customer expectations. Quality Control approaches are used to provide a superior engineering laboratory for medical products. The raw materials used in productions have the SFDA certificates. Additionally, the company obtained ISO 9001: 2008 for Quality Management System requirements and it complies with the SASO standard. Based on the organisation chart in Figure 7.19, the changeover process is related to the maintenance department; however the QC department is considered part of the Production Department as it is empowered by the Production Manager.

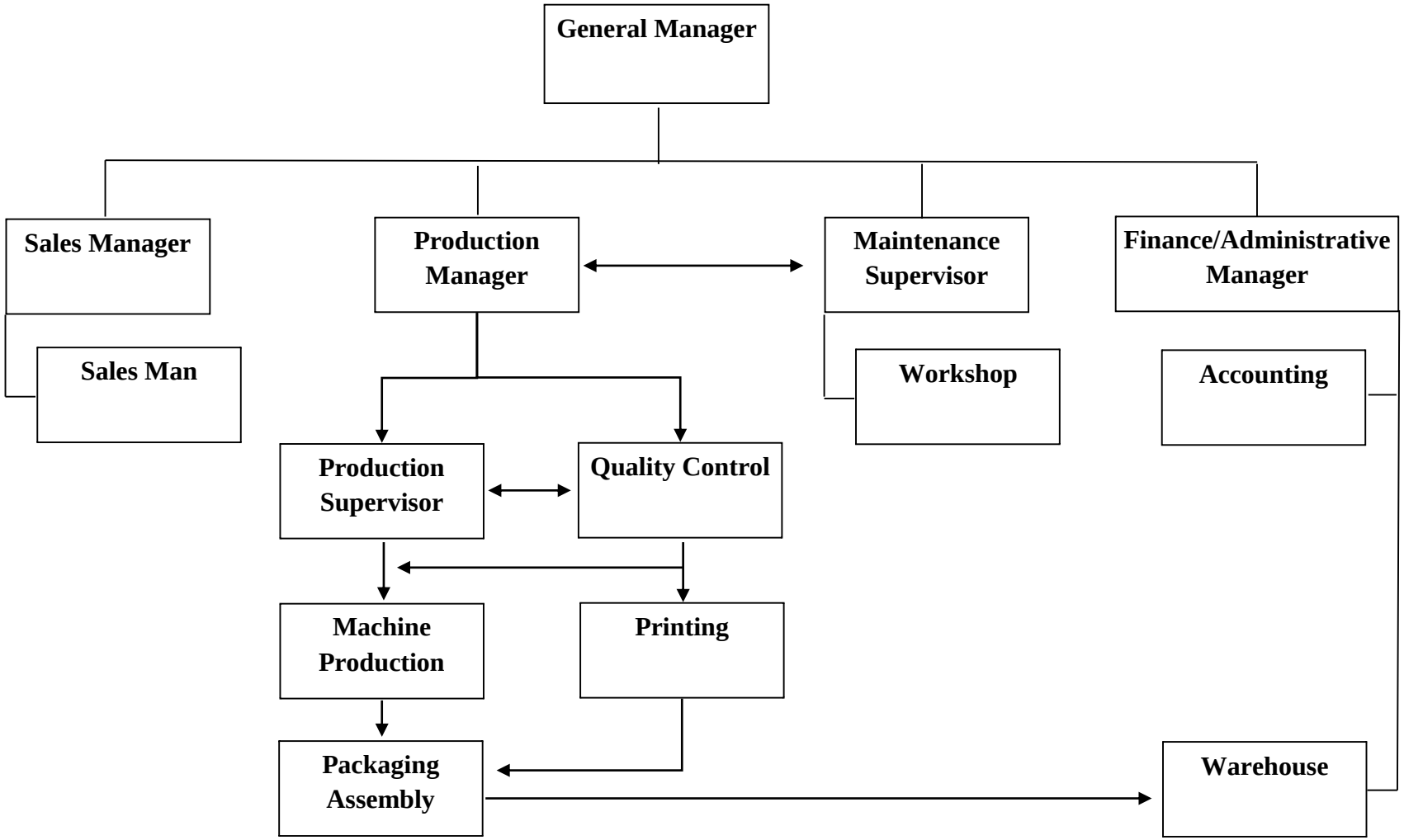

Figure 7.19 Organisation chart of Company L (Source: author).

Challenges in changeover practice

The interviewees of the company discussed the challenges that the changeover practice faced within the firm. Based on the respondents' answer the most common problem is as follows:

- Mould failure during changeover process, consequently that causes delays to the changeover and production time during the maintenance of the mould which normally consumes five hours approximately.

During the changeover process, the maintenance team is fully responsible for performing the process as the company considers that the changeover process is a maintenance breakdown. In terms of changeover data documentation, Company L was recording start and finish changeover time through filling in the Breakdown Maintenance Report (The Breakdown Maintenance Report is given in Appendix 6-H). The frequency of the changeover within the shop floor is weekly and monthly which is based on the production plan. Normally, the changeover time consumes between two and four hours. After conducting the set-up, 90% of the products were accepted with a rejection rate of 10%.The company used first sample approval from the QC department; however the operators were empowered to accept the products after the changeover. On this issue, the Production Manager said:

"We ask the operator to check also. If they find something abnormal in the products, some problems shows up, flashing, directly they will stop the machine. They will inform the supervisor, there's a problem, this one. Then after, our supervisor assumes his responsibilities. They will inform the mould technician. So, that's why we come in for breakdown, we will down the mould, we will look at mould".

The inspection process was taking place three times during the production; first after the changeover, then in the middle and at the end of the production. Also, hourly monitoring of the outcomes was undertaken to ensure the required quality specifications.

People

Top management were providing suggestions during visits to the shop floor and attending changeover of the machine. In addition, top management were contributing to improve the changeover process by giving feedback and suggestions on the shop floor before changeover proceeded, and also made suggestions through weekly meetings in order to implement a safe and reliable changeover process. Top management were committed to implement the best practice of changeover on the shop floor. The training is given to new operators only as they observe the experienced operators while working for a

short period of time. However, the changeover training was not conducted by the company's engineers or supervisors as new operators have to learn the manufacturing process by themselves.

The personnel involvement in changeover activities was by informing the management regarding any abnormal process. The Production Manager was monitoring and meeting up with operators towards improving the changeover process, and was also considering operators' feedback in decision making against changeover and production improvement. Operators were maintaining effective two-way communication with the Production Manager; however, operators were not engaged in implementation of changeover improvement ideas. The reason for that was the level of education and awareness of operators concerning improving changeover practice.

Process

Changeover is performed under less time pressure because there was no pressure to deliver it at the earliest time. The changeover time can vary from one product to another as long as the quality of the outcomes is high and accepted; the respondent indicated that as follow:

"We don't exert pressure. It is okay if he takes more than one hour but it must be a good quality output. As long as they are must produce good quality."

Also, there was a medium degree of variability of changeover time and process between the morning and night shifts. The reason for that was the lack of monitoring on the night shift as well as the absence of having a written standardised changeover procedure. Mould breakdown was the issue that most often impacted on changeover time. The company only has a QC and Processing Orders procedure to meet quality requirements and to identify the departments' responsibility towards achieving customer demand. The company justified its lack of a changeover procedure as that it has had the same products and process for14 years.

The availability of raw materials on job resource and the planning schedule has to be produced every week in order to prepare and transport the raw materials near by the machine for the next job. The company was only using Excel software for material resource planning. The company was not experiencing delays in raw materials transportation on job resource because the warehouse is located within the plant and they also have an on-site store for finished good. The planning department has set its policy for requesting raw materials five months in advance in order to receive and prepare them in the warehouse. Regarding the availability of machine tools, the company was not experiencing any

major problems in the changeover process as it can order tools from abroad or locally. The operation strategy of the company was to keep each operator on the same machine in order for them to gain experience and skill. Besides, the company strictly prohibited any interruption to the operator during the changeover process. Figure 7.20 shows that the machines moulds are stored without identifying names and part numbers. Also, there was no existence of drawing preparation for the next changeover.

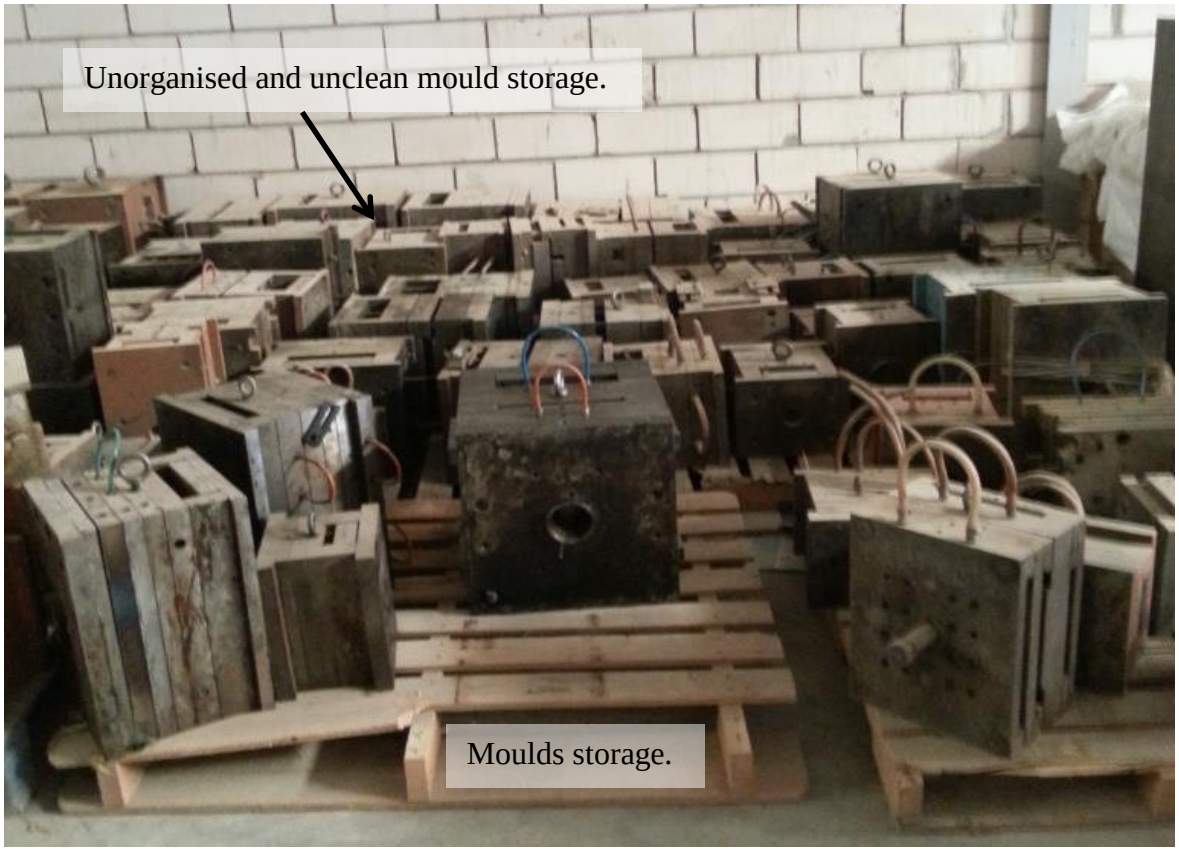

Figure 7.20 Mould/Die storage area (Source: author).

Quality

There was no evidence of the use of a checklist or confirming quality tools for the changeover process. The company instead relied on experienced operators to perform the changeover process, which the company believed the checklist is beneficial if that can be used. In terms of knowledge and awareness of QM and changeover, the company was relying on the supervisor or the Production Manager to disseminate it to the operators' level. The reason for that was because it was considered too expensive to provide an information book, CD, leaflet or notice board. There was no evidence of implementing improvements to reduce and improve changeover time or process. However, although the company

collected changeover data, did not using them for improvement purposes because collecting data was a routine work task without any clear purpose. In terms of safety on the shop floor during changeover, there was a safety sign and safety requirements were attended to while conducting the changeover process in order to maintain and increase the level of safety awareness among the shop floor workers. However, it was an unorganised workplace for conducting safe changeover practice.

Infrastructure

When purchasing new machines, the firm did not consider the reduction of the changeover time which can be achieved by a new machine. The key focus when installing a new machine was on high quality and productivity. Top management were involved in reviewing the process of the new machine. The Production Manager mentioned that the company was not reviewing the impact of the new machine on changeover time:

"They are not fully reviewing this one but sometimes they will see the effect after they buy it."

Figure 7.21 describes the levels of changeover effectiveness within the company. Based on the respondents' answers and the researcher's observations the score was 2.7; this indicates that the company is working toward to achieve level 3 of initiative changeover process. It can be seen that the lowest practice of changeover process was on quality factors which was overall at 1.8, which can consider as managed and controlled changeover process level. This is due to the low level of quality factors implementation in the firm.

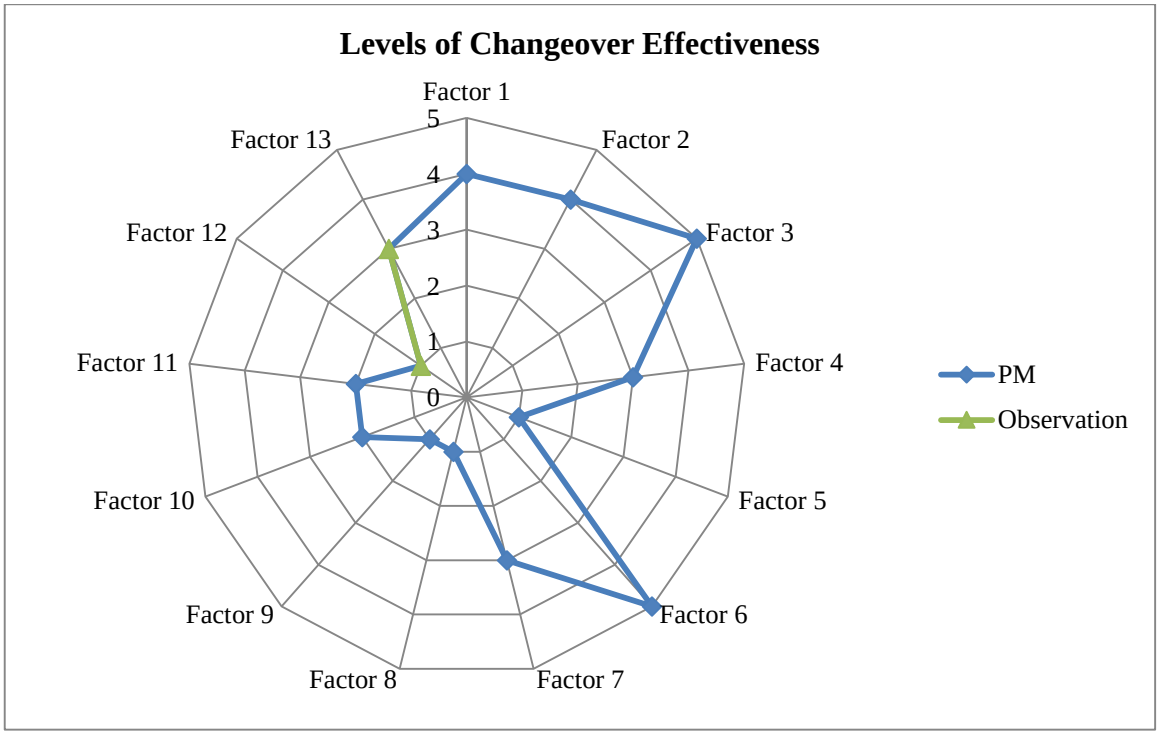

Figure 7.21 Levels of changeover effectiveness, Company L (Source: author).

Combined results of medical products companies

The preceding companies were studied regarding their implementation of manufacturing changeover practice. Figure 7.22 concludes the assessment results of changeover effectiveness within the Medical Products Sector Companies. The assessment of the companies was measured through four criteria: People, Process, Quality and Infrastructure. It can be seen that the People factor was given a high level of attention by case companies in its involvement in the changeover practice. However, the Quality factor was the lowest between the other main factors. The reason was because the quality process of confirming changeover needs to be enhanced towards improving changeover activities. The Process factor was grouped within one level range; this is due to the similarities of the changeover process between the participated companies. Different stages of Infrastructure improvement were highlighted among the case companies. However, three of the case companies achieved a high score of Infrastructure improvement, the remaining except company does not review the impact of a new machine on changeover time and process.

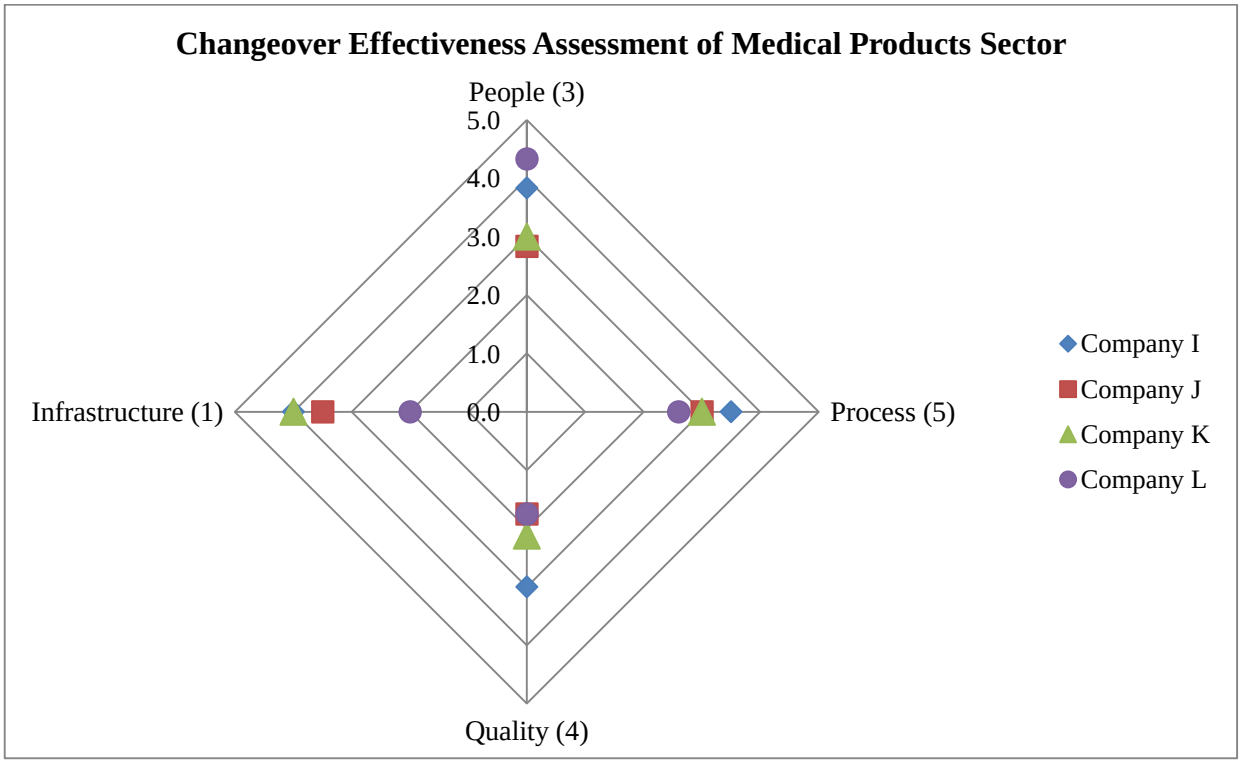

Figure 7.22 Combined results of medical case companies (Source: author).

* Note: the number indicated in the parenthesis tends for the number of sub-factors.

7.3 Cross-case studies comparison

In trying to determine the changeover process implementation that was undertaken by the case companies, this section provides an overview of the changeover practice in terms of documentation procedure, activities related to changeover practice and an overall trend of main factors - People, Process, Quality and Infrastructure - within the participating companies.

The researcher was unable to collect accurate recording data of changeover time and accurate data of first outcomes after the setup period from the respondents. This is due to a lack of practice of recording changeover data within the case companies; however the case companies provided an estimated changeover time and an estimated number of rejected items of the first outcomes as presented in Table 7.9 based on the respondents' answers and observations. The first aspect examines the changeover documentation procedure within the case studies. Table 7.9 describes the companies' implementation in respect to the changeover time, changeover recording system and whether or not this is recorded on the format sheet. Also, it discusses the status of the first outcomes after the changeover and whether it is recording the first output data or not. Clearly, it can be seen that Company I was achieving less changeover time compared with the other companies. However in some cases, Company J took a day to perform changeover on some machines. The variance of changeover time among the case studies companies was caused due to different level of understanding about the changeover practice in terms of improvement and monitoring. From the table below; it indicates that some companies were recording the changeover time, although all companies there were not having a specific format sheet for recording changeover time. Furthermore, the participating companies were ending up with scrap and rejected items after performing the changeover process. However, a few companies were attempting to record the rejects of first outcomes after the changeover.

Table 7.9 Changeover time and documentation procedure by case companies (Source: author).

Company	Lighting Sector				Medical Sector			
	E	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Changeover time	30 min	60 min	35 min	60 - 45 min	20 - 30 min	120 min or one day	60 - 90 min	120 - 240 min
Actual recording of changeover time	No	No	No	No	Yes, Indirect way	No	No	Yes
Where it recorded	Daily Production Report (App. 6-B)	No format sheet	Daily Production Report (App. 6-C)	No format sheet	Batch Record Sheet (App. 6-E)	No format sheet	No format sheet	Breakdown Maintenance Report (App. 6-H)
Status of rejected output after changeover	3 to 5 pieces per batch	1 to 3 pieces per batch	1 to 3 pieces per batch	3 to 5 pieces per batch	one piece per batch	1 to 4 pieces per batch	5% per batch	10% per batch
Recording the first outcome data	No	No	No	No	Yes	No	Yes	No

The second aspect determines the activities related to the changeover process within the case companies. The activities related to changeover process were discussed during research interviews and observations. Table 7.10 summarises these activities in order to understand the changeover practice within the participating Saudi companies. The comparison was made between two sectors in order to understand the differences and similarities. The changeover practice was found to vary between companies; therefore each company had its process and practice that it had learned and gained. SMED implementation was missing in their changeover practice on the shop floor within all participant companies, the reason being because of the low level of training provided to the shop floor workers. Also, the standardised changeover procedure was lacking except in Company I that had developed one common changeover procedure for all the products. Moreover, Company I was the only firm that had a confirming tool - called Line Clearness - for verifying the changeover process before it commenced and the ensuing manufacturing process (The Line Clearness sheet is given in Appendix 6-F). The Line Clearness form was designed for quality inspection purposes and it is usually assigned to a job order until the end product is produced.

Most of the companies, however, were not experiencing delay in transportation of materials from the previous process; this is because they have identified the bottlenecks in their manufacturing processes. In addition, the companies were relying on supervisors to disseminate knowledge and awareness to the shop floor level. This was because most of the case companies were not able to retain skilled practitioners and operators due to the fact that they had reached the threshold limit of workers' salaries. In terms of comparison between sectors, the medical products companies did not allow the changeover to be interrupted while some of the lighting companies accepted interruptions. A possible reason for this is the difference of the nature of the investigated manufacturing sectors as the medical products companies tend to be more rigorous in terms of shop floor access by management and supplier than the lighting companies. In terms of improvement, a few companies encouraged initiatives for improvement suggestions to the changeover process. The reason for this was because of less involvement and communication between the Production and Quality Managers for enabling the improvement.

Table 7.10 Activities related to the changeover practice within the case companies (Source: author).

Activities	Lighting Sector				Medical Sector			
	E	F	G	H	I	J	K	L
Top management involvement on changeover process (suggestion, follow up meeting, …)	Partially	No	Yes	Partially	Yes	No	No	Partially
SMED implementation	No	No	No	No	No	No	No	No
Personnel involvement on implement permanent tool modifications	Partially	No	Yes	No	No	Yes	No	No
The variability of changeover process between crew's shift	Medium	N/A	Medium	N/A	Low	Medium	Low	Medium
Written standardised changeover procedure	No	No	No	No	One common procedure	No	No	No
Delay on transportation of raw materials on job-resources	Yes	No	No	Yes	No	Yes	Yes	No
Delay on material transportation from previous process on job-resources	No	No	Yes	No	No	No	No	No
Material planning software	Oracle	Not mentioned	Oracle	Microsoft Excel	Microsoft Excel	Microsoft Access	Microsoft Excel	Microsoft Excel
Interruption of changeover process	Yes	No	Yes	Yes	No	No	No	No
Confirming method\tool before changeover commenced (checklist, check sheet, …)	No	No	No	No	Yes	No	No	No
Disseminating knowledge and awareness of QM and changeover in the shop floor	Relying on supervisor	Relying on supervisor	Relying on supervisor	Relying on supervisor	Weekly Session	Relying on supervisor	Notice board	Relying on supervisor
Initiative for improvement changeover process and time	Partially	No	Partially	No	No	No	Yes	No
Firm reviewing the impact of new machine on changeover time and process during purchasing	No	Yes	Yes	No	Yes	Yes	Yes	No
Dies cabinet organised and easy to identify	Yes	No	Yes	No	Yes	Yes	Yes	No

The final aspect discovers a trend of the case companies with respect to the main factors of the study as shown in Figure 7.23. The comparison was made between two sectors in order to comprehend the strengths and weaknesses towards the changeover process. Clearly, it can be seen that the Quality factor was the lowest within the case companies' implementation. This was because of the low level of its implementation, such as using checklist, transferring the changeover and QM knowledge as well as initiating set-up improvement. The Process factor was in third place before the Quality factor; the companies were grouped from level 2 to 3.55. The Process factor indicated a small and tight variation due to the changeover process was not standardised on a regular basis in some cases. However, the People and Infrastructure factors represented in the figure below show a high variation among the case companies - between levels 2 and 4. This result indicates that the People factor influenced the Infrastructure factor as the involvement of reviewing the impact of a new machine on changeover time and process can be studied by top management. However, the high variance of the Infrastructure factor between case companies is considered as different stages of reviewing the impact of a new machine on changeover time and process. Finally, these offer evidence to suggest that Saudi firms do not value the changeover process to the degree that perhaps they should.

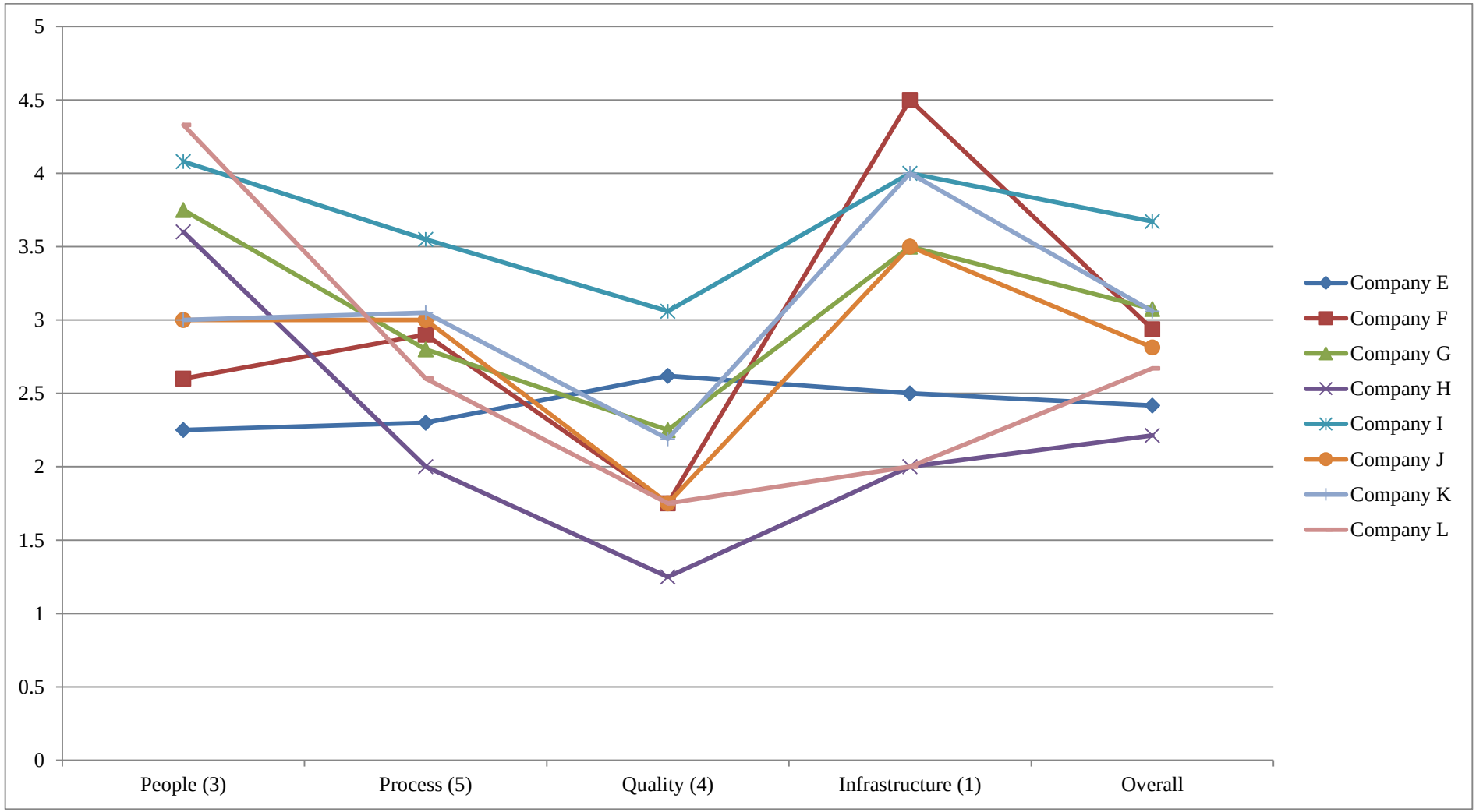

Figure 7.23 Overall case companies' implementation towards changeover practice (Source: author).

* Note: the number indicated in the parenthesis tends for the number of sub-factors.

Role of hierarchical structure on changeover

The study identified the role of the hierarchical structure which includes top management, managers or engineers, supervisors and operators on changeover practice within the case companies. In Figure 7.24 the research provides a holistic view of each role within the hierarchical structure towards changeover practice. However, each case company has different initiative levels of the role and contribution to changeover practice. Most of the case companies' top management were responsible for supporting and consulting over the best practice of changeover process. This can be done by providing suitable machines and skilled manpower. Secondly, the managers and engineers have a major role to play in overseeing and driving the changeover practice on the shop floor. The variance of the improvement towards changeover practice between case companies was recognised by the researcher and cannot be generalised. For example, managers and engineers of Company G proposed to modify the layout in order to improve the changeover process. Also, the managers of Company E improved the tools and dies rack by identifying their part numbers and locating the rack near to the machine in order to cut down on operator movement. The following level was the supervisory level; supervisors were also called foreman, move-man and lead-man in some case companies. Supervisors' role was monitoring changeover practice and guiding the operator. In a few cases the supervisor was conducting and leading the changeover process. Lastly, the operators' role was limited in helping the supervisor while performing the changeover process. The majority of the cases operators were responsible for conducting changeover.

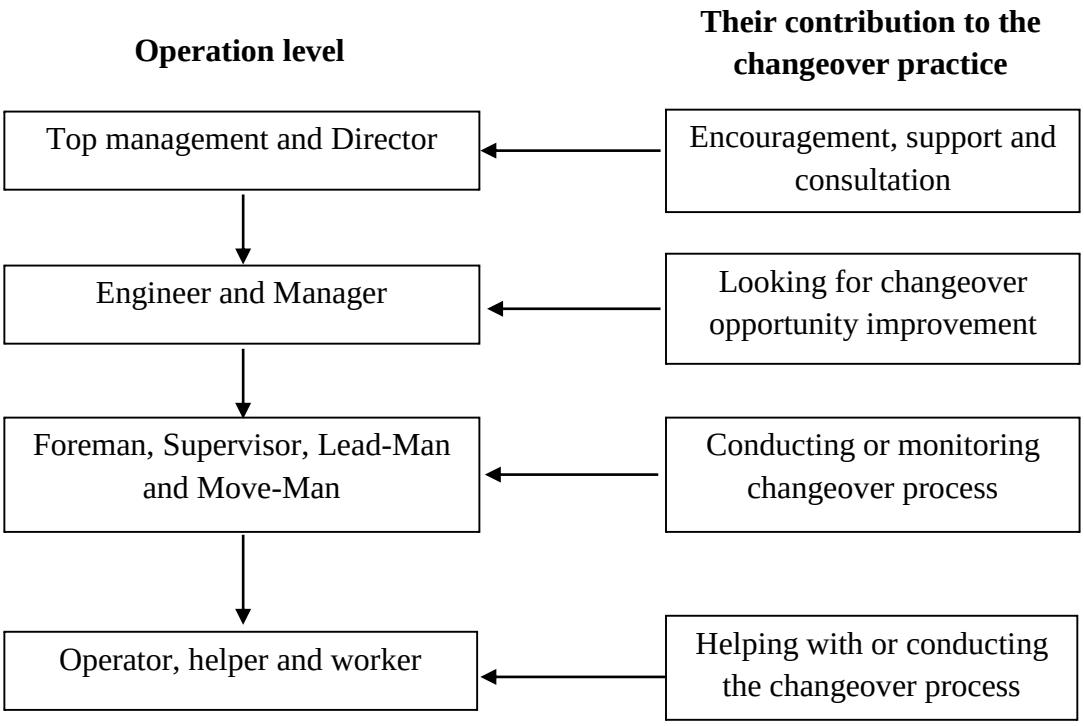

Figure 7.24 Holistic view of hierarchical structure role towards changeover practice from case study data (Source: author).

7.4 Summary

This chapter has described the case studies conducted in eight manufacturing companies; four lighting companies and four medical products companies. The qualitative research was employed and the researcher obtained information through semi-structured interviews and direct observations on the shop floor. The objective was to explore how the Saudi Arabian manufacturing case companies are practicing changeover process on a regular basis. The difficulties that occurred during performing the changeover were perceived from the case companies. The researcher aimed to explore the level of changeover data documentation and the status of the first outcomes in the case companies, and the researcher studied the main themes and sub-factors that impact on the changeover process in order to construct the conceptual model. The cross-case studies comparison was undertake in order to identify the similarities and differences that were observed between the case companies. The outcome of this chapter is used for the discussion of the findings and developing a conceptual model of a high quality and reliable changeover process; which is the subject of the next chapter.

CHAPTER 8 : DISCUSSION OF FINDINGS

8.1 Introduction

The preceding chapter discussed the implementation of changeover practice within the case companies. It examined the effectiveness of changeover practice in the lighting and medical products manufacturing sectors. The cross-case studies comparison was undertaken to achieve a further understanding of similarities and differences between the case companies. The research explored the activities which impact on the changeover practice with relation to the research themes.

This chapter interprets and discusses the main findings of the case companies in order to gain further understanding of changeover practice; it presents the differences in changeover practice between the case companies. The conceptual model of high-quality and reliable changeover process is also reviewed. The study identified different changeover processes in terms of originality (existing) and new of the products and processes which are discussed in this chapter.

8.2 Discussion of findings

It is vital to highlight and discuss the findings of this research in relation to the literature review undertaken. The study findings discussed the changeover practice in terms of effectiveness across the case companies. The outcomes of the research case studies are addressed further in the following sections: 1) Changeover concept, 2) Quality Management and its association with changeover practice, 3) SMED implementation, 4) Changeover time trade-off, 5) Manufacturing layout, 6) Material flow, 7) Training, and 8) Activities related to changeover practice.

8.2.1 Changeover concept

A significant lack of understanding was found regarding the changeover concept. Companies had varying levels of defining the changeover process in terms of starting and ending points. According to McIntosh et al. (2001a), changeover encompasses run-down, set-up and run-up periods. However, some of the case companies identified the starting point of the changeover from the set-up period; while other companies considered that the end of the set-up period is the end of changeover without taking into account achieving accepted output quality rate. For example, case companies F and J described the changeover as only changing the mould of the machine, as they defined and described the changeover process as:

"The changeover meaning for me is changing the dies only". (Production Manager, Case Company F).

"Changeover is taking out the mould and putting in another mould - that is all you will do. That is besides changing the raw material". (Production Manager, Case Company J).

These are a very limited description of the changeover concept which should cover further internal and external aspects of the firm's environment, indicating a lack of understanding of the meaning of the changeover concept. Prior studies have noted the importance of accuracy when documenting changeover data (McIntosh et al., 1996; Culley et al., 2003). In the research, inaccuracy of recording changeover data, such as time and tasks between case companies was found. Some companies, such as Company F, H, J and K were not recording changeover time at all; however the rest of the companies, such as E and G were recording it based on the previous documentation in their production system. In a few instances, such as the case of Company I, the company recorded the start and end times of each batch production; therefore the changeover time can be calculated based on the time of between each batch. It is crucial to record actual changeover data for companies in order that they can then initiative improvements based on these, as well as identify the progress made towards improving changeover activities (McIntosh et al., 1996).

In addition, there was a lack of recording data of the first outcomes, such as scrap, rework and defect within the case companies as shown in table 7.9 in the previous chapter. The study found that none of the lighting sector firms was recording the status of the first outcomes after conducting the set-up on the machine. Also, the availability of a representative from the quality department was lacking during

that time. However, some companies in the medical products sector were recording the status of the first outcomes after the set-up time; for example Companies I and K. This is inconsistent with the findings of Motwani et al. (1994), which affirmed that the Quality Department has to take part of the responsibility for recording and generating reports of defects and failures of the process and final inspection. Khanna et al. (2011) found that the main role of the Quality Department was recording and reducing defective and rework items. Motwani et al. (1994), Quazi et al. (1998) and Antony (2002) discussed the role of the Quality Department in recording and reporting the quality data and considered that as a critical success factor of QM implementation in the firm.

8.2.2 Quality Management and its association with changeover practice

The research discussed the implemented QM program within the participated companies as shown in tables 7.1 and 7.5 in the previous chapter. Several QM programs, such as QC, QA and TQM were indicated within the case companies. Chiarini (2011) examined the implementation of lean manufacturing in relation to certified ISO 9001 firms; his study found that 89% had a standardised changeover procedure and were aware of the implementation of a quick changeover process. However, in this study, a weak association was found between the QM program and an effective changeover practice in terms of data documentation, standardised procedure and quick process. For example, despite the implementation of TQM in Company J, this does not reflect on changeover practice. This is due to lack of involvement and communication from the Quality Department to the changeover activities on the shop floor. On the other hand, Company L has a QC program that emphasises the documenting of changeover time data. The variation in the impact of the QM program on changeover practice in the case companies is a result of implementing these programs differently. For instance, Company I implements the QA program which impacts on their changeover practice in terms of using a confirming checklist for verifying the process (Line Clearness sheet is given in Appendix 6-F) and standardised procedure. On the other hand, the rest of the case companies did not have a confirming tool or formal procedure despite implementing the same QA program.

In addition, it was observed that the Quality Department was not involved in the changeover process parameters during the set-up process; that appeared to be the responsibility of the Production

Department or the Maintenance Department for both sectors. A lack of communication between the Quality and Production Departments was identified between case companies; for example, Companies H, I and J. This caused fragmented communication that lacks the involvement from the Quality Department in the changeover process activities. Also, based on the observation of the participating companies from the lighting sector, a lack of attendance was found from the Quality Inspector to check the first outcomes after conducting the set-up process, and a lack of involvement was found from the quality representative during changeover activities. In most of the cases, the production personnel, such as operator and supervisor, inspect the product in terms of measurement and quality requirements; therefore the production personnel are empowered to proceed to the next process to speed up the production process as there are a limited number of quality inspectors to attend at each changeover activity. However, the medical products sector was more rigorous in inspecting the first outcomes by having a quality representative and examining the product through the quality lab. This is because medical product sector is subject to strict government regulation, such as the SFDA, which is the body that monitors the fulfilment of the regulations and procedures of quality and safety that are required. Henry (2013) has a different view; he contends that the Quality Department needs to be involved and inspected pre- and post- changeover settings. The cooperation of the Quality Department in the changeover practice leads to secure and better improvement of outcomes (Henry, 2013). However, Badri et al. (1995) found that the role of the Quality Department in UAE manufacturing firms was lacking in terms of assimilating their potential role and communication with other departments. Motwani et al. (1994) studied the critical factor of effective QM in Indian manufacturing organisations, the study identified the role of the Quality Department in the organisation, which was to formulate and improve quality improvement programs and work closely with other departments. Motwani et al. (1994) affirmed that the Quality Department has to initiate the procedure for quality control which covers marketing, purchasing, manufacturing and distribution.

8.2.3 SMED implementation

The research identified the implementation of lean manufacturing for minimising waste and improving production on the shop floor in the case companies. Companies E and G had just started to introduce lean manufacturing for managers, engineers and supervisors in order to become lean manufacturing

companies. Also, Company K provided lean Six Sigma courses to its managers, although the study revealed that both lean and non-lean companies were not implementing the SMED concept within the shop floor. Patel et al. (2001) found the same result that a little knowledge of using the SMED within precision component manufacturing companies and the reliance on traditional work. The importance of the SMED technique is recognised in the literature as it eliminates the changeover time and facilitates the improvement of the process.

Based on the analysis of the case companies, however, it can be found that some of the SMED practices were implemented to reduce changeover time. For instance, Companies I and F separate the external and internal activities in terms of transporting raw materials during the external time of the current process. Also, Company L locates the raw materials one day in advance beside the machine that will operate in the run. This allows reducing the changeover activities during the internal time of the upcoming changeover. Chiarini (2011) examined the application of the SMED concept within ISO 9001-certified European firms. The study found that 76% of the firms used SMED as the principal tool for quick changeover because it reduces the changeover time and helps to initiate changeover improvements.

In terms of time pressure on the operator and its impact on changeover time, neither sector (lighting and medical products) emphasised the need for the operator to accomplish the changeover process within the standard time set by the company. This indicates that each company has different acceptable times to exceed changeover which is based on the Production Department policies. For example, Company I has ± 5 minutes of acceptable time to exceed the standard changeover time. Based on the result of the changeover effectiveness, the case companies realise that pressure and stress will impact on the operator's performance in terms of changeover practice. However, companies were usually exerting pressure to accelerate the manufacturing process in order to meet delivery time. This finding of the current study is consistent with Henry (2013) who found that reducing changeover time will impact on reducing stress levels. Also, the stress and pressure upon the operator causes job dissatisfaction, therefore increasing turnover and reducing performance (Henry, 2013).

8.2.4 Changeover time trade-off

The study recognised the changeover time trade-off against achieving productivity and high product quality. It has been identified that some of the case companies prioritised achieving high quality output on account of changeover time. This means spending more than the average time on the changeover process. This finding is in agreement with that of McIntosh et al. (1996) which discussed that trade-off occurred against changeover time in order to improve production and quality outcomes. For example, Companies L and K (medical product sector) allowed more than the usual time for conducting the changeover process in order to ensure high quality rate outcomes. Also, Company H (lighting sector) focused on buying a new machine that enhanced the quality outcome of the product without reviewing and considering the new machine features of improving or reducing changeover time. This is because the importance of the changeover process is not valued by company management; these companies consider it has a minimal impact on the overall manufacturing process. The Production Manager of Company K stated:

"I think it's not the main concern, the set-up time. The main concern is always the quality. Whatever gives us the best quality."

On the other hand, some companies value the importance of the changeover process and its impact on product quality; therefore no trade-off occurs. For example, when Companies I and F purchased a new machine the focus was on changeover features in terms of simplicity of set-up process, speed, easy to maintain and productivity. Patel et al. (2001) discussed the impact of a new machine or technology on the changeover process; it was found that a new machine should facilitate the changeover process with fewer mistakes, higher speed, and reliability. The reason for that is that a new machine has the ability to reduce changeover time; for instance a new machine can remove and insert another tool within 1.5 seconds (Patel et al., 2001). The Quality Manager of Company I discussed the factors that are considered while purchasing a new machine:

"The technical matters of changeover time and process we are considering whenever we are going to purchase any new machines; also the productivity, quality and efficiency of the machine. We are checking all these factors."

8.2.5 Manufacturing layout

The research was conducting on the batch production companies in order to examine further the changeover practice. Greasley (2013) categorised the layout types based on the manufacturing type of industry. The association of batch production process type was with process or cell layout type. However, the process layout – also called functional layout - was in full use within the selected case companies. This means that all machines with the same technology and function type were grouped together into sections. The study found that there was some initiative of modification to the manufacturing process layout in order to improve changeover time and productivity in some of the case companies. For example, Company K changed the equipment layout under its supervision. The potential derived from modifying the process layout was to improve the movement of materials and personnel on the shop floor. The company was successfully reduced the changeover time from three hours to approximately to one or two hours. During that time, new machines and production lines were introduced on the shop floor. This result agrees with the findings of Taylor and Brunt's (2001) case study, undertaken in a press shop, implementing lean manufacturing in order to reduce changeover time by redesigning the layout to improve materials flow. The pieces flow of material during the production was smoothly improved according to pull production. Also, set-up time was reduced and set-up process was facilitated for easy accessing the specific equipment, such as the forklift on the shop floor (Taylor and Brunt, 2001). Redesigning the layout enhanced communication and facilitated a cooperative environment among operators on the shop floor. Several advantages were revealed in Taylor and Brunt's (2001) study through modifying the equipment layout. Lee-Mortimer (2006) found that redesigning the manufacturing layout reduces the material movement and wasted activity during the changeover process.

In addition, it was indicated that some effort was made by the Production Manager of case Company G to modify the equipment layout in order to facilitate the efficient flow of manufacturing process. Company G is suggesting a new modification to the manufacturing process layout in order to improve changeover process and time (The copy of the proposed manufacturing layout of Company G is given in Appendix 6-D). Also, the Production Manager of Company I noticed the significant effect of the improved manufacturing layout on personnel movement during the operations system, and the

company also recognised the equipment layout role for saving changeover time and movement of handling materials. Despite the company's awareness, however, no layout modification was implemented on the shop floor, and the company is satisfied with the current manufacturing layout.

8.2.6 Material flow

The research recognised the involvement of material transportation on the changeover process and time. According to Co (1992) material flow depends on the number of machine types on the shop floor because of the number of material passes that are required to be produced. In an early study, Co (1992) affirmed that streamlining the material flow simplifies production planning. Kannan and Tan (2005) identified the relationship between JIT practice and supply chain management within US manufacturing firms. It was found that sharing planning schedule information with supply chain partners and linking that to make a unified material flow system can be streamlined.

The study found that material flow has an association with changeover process and time. In some cases the relevance of material flow between manufacturing processes and setup time was recognised. For example, Company K implemented VSM in order to improve and streamline the material flow. Thus, it has an impact on reducing time of materials transportation between manufacturing processes and its availability on job location. Also, the Production Managers of Company I and Company G highlighted the importance of streamlining the material flow as it has an impact on changeover time and process. The Production Manager of Company G stated:

"I think the improvement of the material flow on the manufacturing process would have an impact on improving the changeover process, especially on operator movement and time of receiving material between manufacturing processes."

Besides, the flow has to be in a sequential process from the store until the product reaches the customer. These findings are in agreement with Kannan and Tan (2005) who found the implementation of JIT techniques, such as set-up time and lot size reduction, has an impact on improving material flow.

8.2.7 Training

According to Van Goubergen and Van Landeghem (2002), the training operator for performing set-up activities can use multimedia technologies, such as CDs or video clips. Mileham et al. (1999) discussed implementing an improved strategy through continuous improvement training in the shop floor. This study investigated the training level towards changeover practice within the case companies, and revealed that a low level of attention was given in terms of providing formal training to the operator. However, Companies E, G, H, I, J and L were relying on operators to perform changeover practice. Informal training is based on visual and practical methods given by the existing operator or supervisor; also, informal training is only given to new operators and the existing ones will not receive further training. The present finding seems to be consistent with Culley et al. (2003); that informal training and little emphasis on training was found in many cases. However, Company I holds weekly refresh sessions to keep the shop floor workers updated with new improvements. In relation to lean training, Companies E and G have introduced lean manufacturing training that includes quick changeover methods which is attended by top management, managers, engineers and supervisors. Also, Company E has suggested providing proper training for operators to identify and separate the internal and external activities, which is an early stage of the SMED method. This indicates that a few companies are realising the importance of holding formal training in the SMED technique that contributes to improve the changeover process and time.

There was a high reliance on supervisors' experience which was a result of the high rate of operators who resigned. This is as result of reaching the threshold limit of operators' salaries. This led the case companies to invest less in the operators; for instance, Companies F and K were mostly relying on supervisors to conduct the changeover practice and the operator would be in attendance to assist. Formal training was provided to the supervisor, who attended a manufacturer training course on one occasion after the company purchased a new machine. Culley et al. (2003) affirmed that stability and retention of skilled practitioner/operators was highlighted as important; they are key personnel involved in implementing and sustaining the best practice of the changeover process. It was found that Company E (MPF), Company H (main cases) and Company D (pilot study) suffered from a high rate of resignation of skilled manpower, which can impact on the stability of changeover practice. This was

because of a lack of incentive rewards and the fact that the threshold limit of operators' salaries had been reached. Moreover, an absence of formal training for the shop floor workers can be a reason for resigning.

8.2.8 Activities related to changeover practice

The research recognised some activities that make either minor or major contributions to the changeover process and time within the case companies. Different initiatives were taken on the shop floor for better daily routine practice. The researcher identified these activities for further better understanding; as follows:

Production planning schedule

Production schedule was recognised within manufacturing industries by Taylor and Brunt (2001) studies as an erratic production plan that is a major source of production instability. The disruption production for changeover is more likely to restart and that can affect the performance of the production outcomes (McIntosh et al., 2007). A proper production schedule means meeting customer delivery time with minimum inventory (Taylor and Brunt, 2001; Allahverdi and Soroush, 2008), as the main aim of lean manufacturing is minimising waste. Henry (2013) stated that scheduling the same product orders together can eliminate and reduce changeover occurrence. Implementing developed scheduling plan techniques can meet customers' needs through reducing changeover (Henry, 2013).

In the study, the researcher investigated the importance of a proper production plan to the changeover time. Different production plan cycles, such as monthly, weekly and daily was found between case companies as shown in Table 8.1. Smaros et al. (2003) described the weekly planning cycle to be a more flexible production system than the monthly planning cycle, which is less flexible. As the weekly planning production can be more responsive to customer demand because it is a short period, the periodic nature of the monthly planning production means that it cannot. A few companies were combining the same orders in order to eliminate the occurrence of changeover practice in the shop floor. This is because of a lack of a rigourous and consistent system of production planning that emphasises the reduction in changeover occurrence. For example, Company I facilitated the

production by introducing a monthly plan that combined the same orders in one continuous job. Although the monthly plan is less flexible in terms of responding to new orders, it does allow the company to have fewer changeovers. Singh and Khanduja (2010) affirmed that a lack of production planning and control can contribute seriously to disrupt the set-up time of the machine. This is due to a lack of awareness on the part of management of the importance of scheduling orders. Less emphasis on improving scheduling can directly contribute to a haphazard way of selecting the orders on the shop floor (Allahverdi and Soroush 2008; Singh and Khanduja, 2010).

Table 8.1 Production planning of case companies (Source: author).

Lighting sector			**Medical products sector**		
Company	**Production plan**	**Combining same orders**	**Company**	**Production plan**	**Combining same orders**
E	Weekly	No	**I**	Monthly	Yes
F	Daily	No	**J**	Weekly	Yes
G	Weekly	No	**K**	Monthly & Weekly	No
H	Weekly	No	**L**	Weekly	No

On the other hand, the study reveals the inaccuracies within the production schedule that occur within the case companies that did not consider changeover time. Therefore, during the generating of a production plan, the changeover will be based on a fixed time. This obviously will impact on planned changeover starting time which has an impact on the delivery time being met.

Operator involvement

According to Klopsic and Houser (1997), managerial motivation is considered important for crew involvement in manufacturing changeover practice. Involving the crew in the improvement process can reduce changeover time and provide a valuable suggestion as they are more familiar with the changeover activities. Patel et al. (2001) asserted that employee' suggestions and participation - whether individually or as a team are vital in order to facilitate set-up time reduction. For example, the Production Manager of Company E discussed some improvement to enhance operator involvement during the changeover process. The company is planning to launch an annual and a monthly reward to

the best operator in order to raise motivation and involvement during production and changeover activities. Also, the Production Manager of Company E suggests providing a documented system feedback among workers and managers to improve manufacturing practice in the firm. However, only little attention was paid by the case companies to the idea of introducing a documented system feedback for improving changeover practice.

Time and motion study

Van Goubergen and Van Landeghem (2002) identified the rules for designing an efficient work method during the conducting of changeover practice. The major emphasis was on optimising the activities that are perform to minimise movement and walking distances. The main desired outcome of studying the time and motion for operators during changeover activities is eliminating the waste. A few case companies put emphasis on studying the operator's movement during changeover activities performed. For example, Companies E and G (from the lighting sector) studied operator movement and transportation distance during conducting changeover and production process. However, none of the medical sector case companies was involved in studying operator movement by observing and recording via video tape. The reason for that was a lack of awareness as they assume that this technique does not add value to changeover process improvement.

8.3 Conceptual model

The conceptual model of a high quality and reliable changeover process has been provided in different cases in the research: the literature review conceptual model, exploratory field study, pilot study and main cases studies. The evolving of the conceptual model during the research was essential in order to identify a robust and unified conceptual model for Saudi Arabian manufacturing firms. To further understanding the conceptual model implementation and its integration with studied themes and sub-factors, the model is represented in Figure 8.1. It is important to point out that the conceptual model is for long-term implementation. This is because the studied sub-factors in the research have an influence on a firm's level, such as managerial level (Top Management), middle level (Engineers) and shop-floor level (Supervisor and Operators). The conceptual model has three pillars that support the changeover practice from the beginning until the end. The pillars contain the changeover between products and processes (input), changeover main constructed factors (processing) and performance measurement of quality outcomes as well as productivity (output).

The uniqueness of the conceptual model is embarking on the input of changing between existing and new products, as well as processes. Also, the conceptual model identified further sub-factors that impact on the changeover process and its effectiveness within Saudi manufacturing firms' environment. This enables us to identify the relationship between the reliable changeover process and quality performance of the first outcomes. The measuring quality of the first outcomes has to be evaluated by firms during the implementation of the model. Therefore, the conceptual model emphasised recording changeover data and quality data of the first outcomes in order to link these data in one manner for further progression towards improvement.

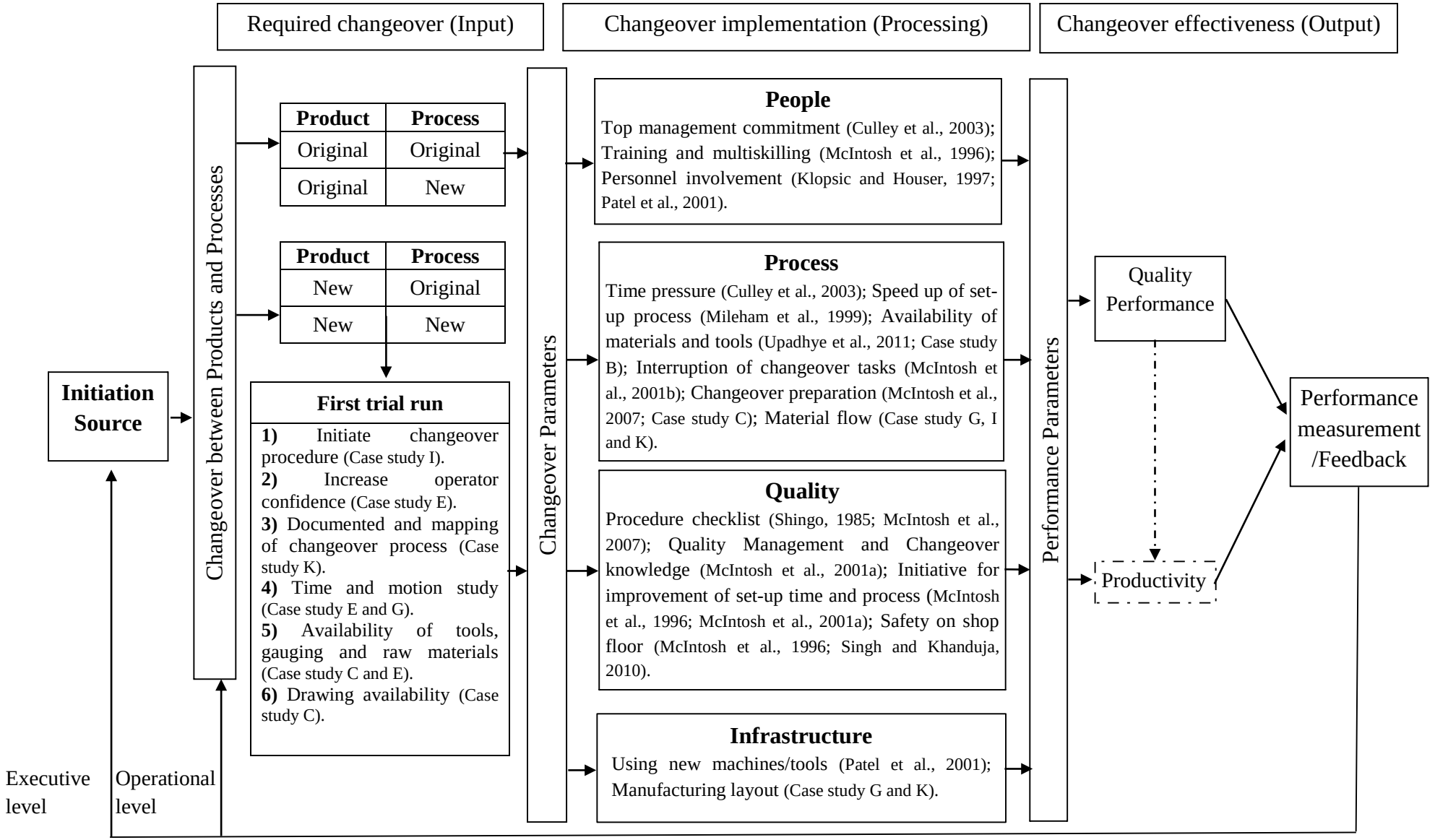

Figure 8.1 Conceptual model of high quality and reliable changeover process (Source: author).

The conceptual model shows different stages in the manufacturing changeover between products and processes within the case companies. The conceptual model discusses the difference between changeover of products and processes based on the research findings. The study affirmed that different types of changeover between products and processes have a direct impact and association with changeover process and the quality of first outcomes. The study examined the difference and occurrence of these changeovers, as discussed next:

- *Original product and process:*

  This is the most common changeover practice and the one that occurred most within the case companies. Normally that happened while conducting changeover of existing product and process. However, the case companies were facing issues and problems that related to this changing of changeover as presented in the previous chapter of case studies.

- *Original product and new process:*

  This type of changeover can happen while introducing new machine that combines two processes instead of keeping them two processes; for example, Companies F and K introduced new machines and production lines that helped to reduce several manufacturing processes, and changeover practice. In this type of changeover, the manufacturer usually provides training on new machine or production line for shop-floor workers. Therefore, workers gain more experience and become more confident during training. On the other hand, the occurrence of changeover will be minimised and firms have to initiate the changeover procedure while introducing new facilities on the shop floor.

- *New product and original or new process:*

  This type of changeover occurred less within the case companies. There were a few companies involved in launching new products and which had to meet the NPD process; for example, Company E as it had a NPD department. However, some of the case companies highlighted the importance of addressing the changeover process for new products as mentioned in the case studies chapter, while the rest of the case companies do not recognise the impact of new product changeover on quality outcomes since all products are homogeneous or have simple manufacturing process. It was suggested that, based on the conceptual model, the changeover of a

new product has to be addressed during the trial run production. In order to verify the changeover process of a new product, it needs to be linked to a trial production run. The trial production is described as a limited part of production in order to test the production facilities and quality of products. It is a small-scale testing manufacturing process and quality system of a large-scale production for further correction. Annacchino (2003) affirmed that pilot run allows reducing deviation of a new product in order to bring the processes into conformity. Therefore, the corrective action should be addressed immediately after the trial run to achieve continuous improvement by scheduling another run for further process improvement.

During the NPD process, the first production trial run will address the changeover process for the first time. For example, Company E produced between 100 and 200 pieces during the first trial run in order to ensure that products met their quality requirements and to overcome any obstacles during production. However, Company E was not addressing or establishing a changeover procedure for the new product during that time. The production trial run must be conducted within the company shop floor in order to examine the tooling, equipment, production personnel and facility. Based on the findings of the case companies, the challenges that need to be addressed during a production trial run were recognised. Several processes were identified in order to ensure the fulfilment of changeover of new product which has been described in the conceptual model in Figure 8.1. The processes of changeover new product are as follows:

1) The changeover procedure has to be established in order to standardise the process of a new product; for example Company I. This is because the changeover process needs to be more consistent and contribute to improving the product quality.
2) It was identified that the operator gained more experience and became more confident in the new product changeover during the trial run; for example Company E. The preparation of the operator and producing more pieces during the trial run for new product changeover process can reduce human mistakes.
3) During the trial run, there was recognition of the importance of changeover process documentation and a value process map for verifying how to conduct process, and identifying the activities that should be undertaken during transition; for example

Company K. The valued of process mapping is providing a breakdown of activities involved in the changeover process divided into sub-activities.

4) The time and motion study can be performed during a trial production run of the changeover in order to eliminate the non-adding value activities; for example Companies E and G. It can be helpful to understand the operator allocation and instrument that is being used during the changeover process. Moreover, it can be initiated by recording changeover time and its activities for further improvement and documentation record before it proceeds to the actual production.
5) The availability and preparation of machine tools and raw materials on the shop floor for new product changeover was highlighted in Companies C and E. A new product was identified that required availability of new raw material and tools in order to progress the changeover.
6) The drawing availability during tool preparation for upcoming changeover was recognised in the case of Company C. This creates a sense of urgency to prepare suitable tool, mould and die for the next changeover of a new product. Also, it helps Quality Inspector to confirm the new product's measurement after the set-up.

The conceptual model studied the research themes and factors that affect the high-quality and reliable changeover process. The pros and cons of the conceptual model can be highlighted for further understanding. The conceptual model provides a long-term perspective of clarity and focus to the changeover practice. Moreover, it contributes positively to enhance the flexibility of changing between products and improve communication channels between firm's departments. In addition, it prompts awareness and understanding of reliable and high-quality changeover process among shop floor workers. However, the long term implementation can be considered as a disadvantage because it requires full commitment from top management.

8.3.1 Validation of the conceptual model

The effective validation process of the conceptual model contributes significantly to ensure the quality of the outcomes after conducting the changeover practice. The study confirms that employing different types of changeover for new or existing product has an impact on changeover effectiveness

particularly on the status of the quality of the first outcomes. As a result of that firms have to identify the required changeover that would be implemented on the shop floor. During the validation process of the conceptual model, the observation is considers an appropriate method for attending and noticing the changeover process. Moreover, it is essential to identify the weaknesses and strengths of the current process during the implementation. Using observation sheet for identifying the time taken for each activity during changeover process. The sheet contains the task description, time of completed task, cumulative time and status of the quality of the first outcomes products. If a record of the observation sheet for every action is made during the implementation phase, this would be helpful to identify the weaknesses in the process and areas where most time is wasted. Moreover, firm has to support the documented feedback system for changeover process improvement between the shop floor worker, such as supervisor and operator, to engineers and production manager during and after model implementation. This feedback system can be used for identifying the problem and issues that most often occur during the changeover process. In addition, the result of the model implementation has to be announced and shared at all plant department levels. This is because the responsibility of implementation has to draw on the initiative of the firm's departments. The firm can announced the percentage of success of the model and the annual saving of raw materials or financial resources. At the end, the model needs to be implemented again after capturing the required improvement on the shop floor.

The guidelines for the conceptual model were provided in order to support and help firms in their implementation of the changeover process (The research guidelines for conceptual model implementation are given in Appendix 7). The guidelines discussed the implementation of the conceptual model in three phases which are: Before implementation (Phase 1), During implementation (Phase 2) and After implementation (Phase 3). It is necessary to implement the CEAT research tool after Phase 3 in order to evaluate the implementation of the changeover process. It should be noted that, in order for the conceptual model to achieve its expected results, all the constructed sub-factors require long-term use for full implementation.

8.4 Summary

This chapter has discussed the research findings of the case companies selected from the lighting and medical products industries. The study's aim was to develop the conceptual model of high quality and reliable changeover process that presented in this chapter. The research findings help to improve the conceptual model in terms of constructed factors and required changeover of new and existing products or processes.

To summarise, the conceptual model is a novel approach for optimising the quality and reliability processes of the changeover practice in the manufacturing sector. The following chapter concludes the thesis; it also discusses the limitations of the study and suggests future research directions.

CHAPTER 9 : RESEARCH CONCLUSIONS

9.1 Introduction

The preceding chapter discussed the main findings of the research. The conducted study adopted qualitative research that employed a case study approach. The conceptual model developed and presented in the previous chapter is based on the case companies' findings. It also proposed the guidelines to facilitate the use of the conceptual model within manufacturing firms (The research guidelines for model implementation are given in Appendix 7).

This chapter draws conclusions of this research. It summarises the contributions to knowledge in terms of research findings, research instrument (CEAT) and conceptual model. It discusses the research limitations and future research directions for the changeover practice in the manufacturing sector. Finally, the conclusions of the research are stated.

9.2 Addressing the research contributions

The first objective of this study was to understand the challenges of changeover practice within selected firms in the Saudi Arabian manufacturing industry. This research has addressed important issues that contribute to research knowledge. The main aim of the research was to develop the conceptual model of high quality and reliable changeover process particularly within Saudi manufacturing firms. To achieve this aim a comprehensive literature review was carried out, followed by exploratory research, methodology, pilot research and the main case studies with the selected companies.

In the early stage of the research, the research design suggested conducting exploratory research in order to enable the researcher to attain a broader and more in-depth understanding of the research dimensions. In the main study, qualitative research was used by conducting semi-structured interviews with production and quality managers in eight manufacturing firms. The research used data triangulation via semi-structured interviews, documentation and direct observation (attending changeover practice in the companies). The use of case studies was to investigate the various factors and sub-factors that influence a high quality and reliable changeover process.

The research assessed the level of changeover practice in the Saudi Arabian manufacturing sector. Also, it evaluated the effectiveness of manufacturing changeover practice by presenting the results using the Radar/Spider diagram, which helps to provide a rich representation of the research phenomenon for the case companies. Moreover, the study indicated the level of recording changeover time and its activities during changing between manufacturing processes. The study highlighted the different changeover activities between products and processes, whether the product is new or an older model.

The study makes several contributions to knowledge and towards the *theory of manufacturing changeover*. As the literature review of concept changeover and set-up time in Saudi Arabia is not well developed, this study can participate in building robust and rigorous theory. This work contributes to existing knowledge of changeover improvement by understanding the current changeover practice in the Saudi Arabian manufacturing industry. The main issues that contribute to body of knowledge are discussed in three parts: 1) Novelty of research findings, 2) Novelty of the research instrument - Changeover Effectiveness Assessment Tool (CEAT), and 3) Novelty of developing the conceptual model of high quality and reliable changeover process.

9.2.1 Novelty of research findings

In terms of data and results, and to the best of the author's knowledge, this is the first study to provide a comprehensive overview regarding how Saudi Arabian manufacturing firms practice the changeover process and its effect on production outcome. The research contributes to identify the key drivers - People, Process, Quality and Infrastructure - that impact on quality and reliability of the changeover practice. Further to that, the sub-factors related to Quality were considered the lowest levels compared to the other sub-factors. This was because of the low level of its implementation, such as using checklist, transferring the changeover and QM knowledge as well as establishing the initiative of the set-up process improvement. The research findings of the main case studies found additional sub-factors for Process and Infrastructure that affect changeover practice. Furthermore, the study found a low level of recording changeover time and its activities as well as the status of first outcomes.

A further contribution to the knowledge in terms of the research finding is identifying the level of implementing the activities that are related to the changeover practice within the case companies. This finding has significant implications for understanding how Saudi manufacturing firms practice the changeover process on a regular basis. Various activities and processes of manufacturing changeover were found to differ even within the same industry. The study focused on discovering and determining the implementation of changeover practice in the Saudi manufacturing sector. This was illustrated by providing a comparison chart line of the case companies in terms of their implementation towards changeover practice as presented at Figure 7.23 in Chapter 7.

9.2.2 Novelty of the research instrument (CEAT)

The study delivers a research instrument for evaluating the effectiveness of changeover practice within the manufacturing firm. A novel approach was taken in order to produce the research instrument, CEAT. It was constructed based on the factors that related to the changeover practice in the conceptual model. The extensive literature review of manufacturing changeover as well as the field work of the exploratory study was valuable to generate CEAT. These two sources were significantly important to construct the statements' levels of the research instrument, CEAT. Moreover, the pilot study was helpful in order to examine the rationality of the CEAT statements of each level in the manufacturing companies and capturing qualitative data clearly (The copy of CEAT is given in Appendix 3).

CEAT gives an insight into the practicing of manufacturing changeover which is based on 13 sub-factors; two sub-factors are mainly related to the direct observations on the shop floor and the rest of the sub-factors are related to the semi-structured interviews with the respondents. CEAT has focussed on evaluating the effectiveness of changeover practice in manufacturing companies, and it is considered a valuable instrument that contributes to the body of knowledge of the manufacturing changeover subject.

9.2.3 Novelty of developing the conceptual model

The study provides a theoretical ground for examining changeover practice in the manufacturing sector. The final version of the conceptual model is represented in Chapter 8; the conceptual model has been customised up to three times in the research since it was first established. It was constructed based on the theoretical literature review. Also, the conceptual model was modified as a result of the

exploratory research findings that were generated from Saudi cable companies, which guided the study for further field research. Similarly, the conceptual model was adjusted based on the findings of the pilot study of the precision component manufacturing industry in Saudi Arabia. Finally, the model of the high quality and reliable changeover process was customised based on the result of the main case companies in the lighting and medical products manufacturing sectors in Saudi Arabia.

A further contribution to knowledge in terms of the conceptual model is finding that different manufacturing changeover between products and processes occurred as discussed in Chapter 8. The conceptual model found different types of manufacturing changeover which are: (1) changeover for original product and process, (2) changeover for original product and new process, and (3) changeover for new product and original or new process. These changeovers have a direct impact on the reliability of the set-up process and the quality of the first outcomes.

The study identified 15 sub-factors for achieving high quality and reliability in the manufacturing changeover process: ***People*** (1) Top management commitment (2) Training and multiskilling (3) Personnel involvement; ***Process*** (4) Time pressure (5) Speed up of set-up process "changeover procedure" (6) Availability of materials and tools (7) Interruption changeover tasks (8) Changeover preparation (9) Material flow; ***Quality*** (10) Procedure checklist (11) QM and changeover knowledge (12) Initiative for setup improvement (13) Safety on shop floor; and ***Infrastructure*** (14) Using new machines/tools (15) Manufacturing layout.

As far as the empirical study of the manufacturing sector in Saudi Arabia, the conceptual model is a novel approach and can be considered as first model that contributes to improving manufacturing changeover in this country. The main implication of the research was identifying a conceptual model for implementing a reliable process of manufacturing changeover.

9.3 Research limitations

This study contributes to knowledge of improving quality and reliability of changeover practice in the manufacturing sector in Saudi Arabia. Similar to other case studies, the research has a number of limitations that need to be addressed in order to take into account future research. These research limitations are related to geographical area, time constraints, subjective nature and generalisation of the study. These are addressed below:

9.3.1 Geographical area

The research was focused on only one geographical area since it was essential for the consistency of the collected data. However, different geographical areas - locally and globally - should be examined in future research, as a comparison between different geographical areas is needed to identify the differences and similarities in the relationship between variables and factors studied.

9.3.2 Time constraints

The research is limited by its cross-sectional time frame. The use of a cross-sectional study was designed for the purpose of qualitative research which was collecting data through semi-structured interviews, observations and documentation at a point of time for the main case studies research. The study was not a longitudinal one as the researcher was not involved in following and tracking changes at the individual level at different points in time. Qualitative research was beneficial for identifying the relationship between variables and building the constructed factors of the research.

The nature of the research was measuring the impact factors of a high-quality and reliable manufacturing changeover process over a period of time. Thus, it may suggest a longitudinal case study for full cooperation by, and involvement in firms regarding their implementation and improvement of the changeover process over a long period of time.

9.3.3 Subjective nature

There is a limitation in the research in terms of subjective perceptions of the respondents during the semi-structured interviews. Although these interviewees were selected due to their job position in the participated firm, and because they had enough experience and knowledge of the changeover process implementation, the research design involved interviewing just two participants for each case

company, also direct observation and documentation were involved in the data collection in order to ensure the consistency of the reliability and validity of the research data.

9.3.4 Generalisation of the study

Another limitation of this research is the generalisation issue. The case studies showed that the firms were non-homogenous in terms of practicing the changeover process and its outcomes after set-up time. Therefore, any generalisation in the study is restricted by the research findings as the firms' approaches differ. However, the study provides a rich and contextualised understanding of the research phenomenon.

9.4 Future research directions

As the research covers an area in the subject of manufacturing changeover, there are many future research directions that need to be addressed. First, there is a need for implementing the conceptual model in the manufacturing sector. As the nature of constructed factors in the study cannot be measured over a short period of time, the result is that the conceptual model is needed to be implemented within the firm. If this is achieved, there is a chance of finding a rigorous result and a detailed study of manufacturing changeover improvement. The guidelines for using the conceptual model were provided to aid and facilitate implementation in the firm (The research guidelines for the conceptual model implementation are given in Appendix 7).

During the review of the literature, some different research areas were recognised and indicated for further research directions. Both the literature review and the research findings point to future research areas that call for further investigation; as follows:

9.4.1 Changeover process outsourcing

The study revealed a low level of practicing changeover process within case companies, particularly on quality and process factors. This is due to failure to use a checklist to confirm the changeover process, as well as the lack of a changeover procedure for a standardised process and the lack of a changeover sheet for recording set-up time. Therefore, it could be possible to outsource the changeover process; for example, to an expert or consultant foreign company with long experience in the manufacturing changeover field. This could help Saudi firms to improve the changeover process

and provide training to the shop floor employees. The research is needed for understanding and exploring the potential of outsourcing the process and to identify how willing Saudi manufacturing firms are to accept the outsourcing in their shop floor.

9.4.2 Changeover time trade-off

The concept of trade-off in the manufacturing sector has been discussed in the literature review in Chapter 3 as well as in the discussion of findings in Chapter 8. The study found that some of the case companies were prioritised achieving high quality output on account of changeover time. This finding is positively associated with the literature on the subject of changeover time trade-off (McIntosh et al., 1996). The study is required for identifying the reasoning and critical factors that impact the changeover process and time while trade-off has other advantages, such as productivity and quality outcomes. Also, research could study the combination of changeover time trade-off and the impact on production cost. This future research may indicate the cost of production in terms of tangible and intangible aspects due to changeover time trade-off.

9.4.3 VSM for changeover process

VSM is discussed in Chapter 3, as a diagnostic tool for strategic plan activity. VSM is not only widely used in industrial practice but it is also directly associated with lean manufacturing, reduced inventories and short lead time (Rother, 2003; Nash et al., 2011). However, there is a need for undertaking a qualitative approach in order to build a robust and rigourous process of manufacturing changeover through VSM. The outcome of this research helps to facilitate the improvement of the changeover process in manufacturing firms.

9.4.4 Weighting mechanism for the research factors

Normalising and identifying weighting mechanism for fine tuning to the research factors that studied in the conceptual model for different manufacturing industries. This idea proposed to measure and weight the studied research factors in terms of changeover practice in the shop floor. For instance, heavy manufacturing industry that required time during the changeover for preparing special equipment, such as crane or forklift, and weighting mechanism gives priority and more importance to the infrastructure factor than others factors which are People, Process and Quality.

If these research areas are conducted in the field, there is a chance of finding a rigorous result and a detailed study for the manufacturing changeover improvement subject.

9.5 Summary

This chapter concludes the thesis, as it addressed the research problem as well as the contribution to knowledge. The novelty of the research was addressed in terms of research findings, research instrument, and developing a conceptual model. The chapter pointed out the research limitations and future research directions. The thesis provides a holistic review of changeover implementation in the manufacturing industry through a comprehensive literature review, exploratory research, pilot study and main case studies. It has identified the reliability and quality factors of changeover practice as discussed in the conceptual model. It is necessary for the changeover practice to be successful from the very outset within the manufacturing sector. The key to this success lies in implementing lean manufacturing for an effective implementation of changeover practice.

This work has shown that Saudi Arabian manufacturing business must be aided in many aspects. The conceptual model of high quality and reliable changeover process which is the outcome of the research, along with CEAT the research instrument, have been developed for improving and assessing Saudi Arabian manufacturing firms, and will help to add value to their manufacturing changeover process.

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APPENDIX 1: DEVELOPMENT OF THE SAUDI ARABIAN MANUFACTURING INDUSTRY

Saudi Arabia is located in the continent of Asia which is the largest Arab state by landmass. It has borders with Jordan and Iraq on the north as well as from the northeast with Kuwait, the United Arab Emirates and Qatar, and Oman and Yemen to the south. On the west lies the Red Sea and on the east lies the Arabian Gulf. Saudi Arabia is divided into 13 regions as shown in Figure 1. In 1938 the discovery of oil was discovered in the eastern province of Saudi Arabia and that played a major change from different aspects, impacting on educational, cultural, economic and industry development. Saudi Arabia is considered the largest exporter of oil worldwide; so the government increased its focus on the quality management implementation within the oil and chemical sectors, which help to disseminate it to the rest of the manufacturing industries. The Saudi government plays a crucial role to deliver the quality awareness among the manufacturing, health and education sectors. Saudi Arabia is considered one of the largest producers in the Organisation of Petroleum Exporting Countries (OPEC) (Simmons, 2005).

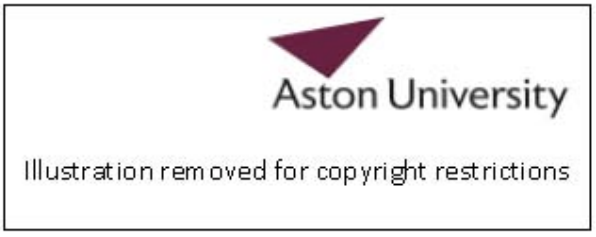

Figure 2 below shows the dramatic increase of the number of manufacturing factories within Saudi Arabia. In 2004, the number of manufacturing factories was 4223; this has been increased to around 6751 by 2014. Most of these factories were located in Riyadh, Jeddah and the Eastern province. The most common types of manufacturing are non-metallic mineral products, rubber and plastics products, fabricated metal products, chemical products and food products.

Figure 3 describes the location of Saudi manufacturing factories based on geographical area. Most of the factories (47%) are located in Central Region of Saudi Arabia, followed by the Eastern and Western Regions, at 23% and 22% respectively. However, a small percentage of factories are located in the Southern and Northern Regions - around 5% and 3% correspondingly.

The capital city of Saudi Arabia, Riyadh, leads the cities in having the highest number of manufacturing factories as shown in Figure 4 below. The reason for that is because Riyadh city has three industrial cities. Eastern Province and Makkah ranked second and third with 1571 and 1263 factories, respectively.

Table 1 below shows the number of factories according to the type of manufacturing. The manufacturing of non-metallic mineral products achieved the highest number with 1366 factories in Saudi Arabia. However, the lowest type of manufacturing was the repair and installation of machinery and equipment, was accounting for three factories.

The Saudi Arabian government paid great attention to the industrial exports. The percentage of non-oil products exported increased steadily from 1995 to 2011 as shown in Figure 5. Exported non-oil products contributed 16.4% to GDP, which indicates the importance of developing the export industry. The significant increase that occurred between 2003 and 2008 was due to the country's accession to the World Trade Organisation (WTO) and implementation of unified of Gulf Countries Council (GCC) customs.

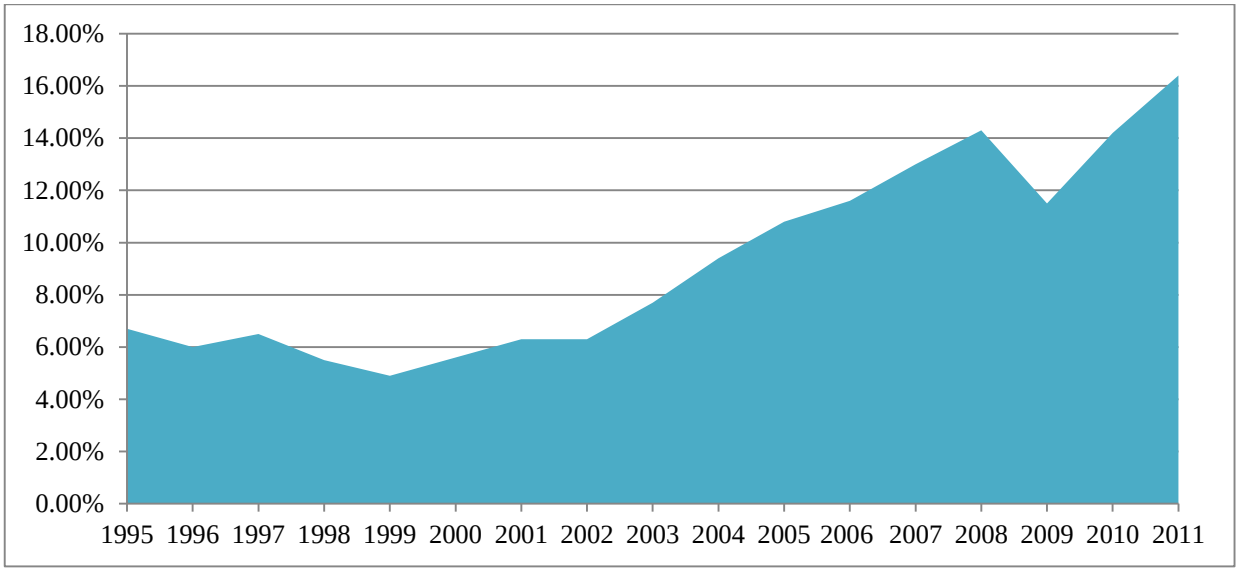

Figure 5. Percentage of exported non-oil product to GDP. (Saudi Industrial Development Fund, 2012).

The Saudi industrial exports achieved quick growth over the past years as shown in Table 2. It indicated the performance of Saudi industrial exported development between 1995 and 2011 for the major export sector. The exported annual growth rate reached around 15.7% during 1995 to 2011. The basic metals and fabricated industry achieved the highest annual growth by 19.7%. It was followed by chemical and plastic industry and food products which accounted for around 16.4% and 15%, respectively.

Table 2. Saudi Industrial Exports by Major Sectors (Saudi Industrial Development Fund, 2012).

Sector/Years	**Value of Exports (SR Million)**		**Annual Growth (%)**
	1995	**2011**	**1995 - 2011**
Food Products	1,589	12,605	15.00%
Chemical & Plastic Products	15,621	114,898	16.40%
Basic Metals & Fabricated Industries	2,631	8,395	19.70%
Machinery & Electrical Equipment	851	3,944	14.70%
Other Products	1,866	11,283	15.60%
Total	22,558	151,125	15.70%

APPENDIX 2: EXPLORATORY RESEARCH

2-A Letter for asking the firms to participate in the exploratory research

Dear Company A & B

I am a Saudi PhD student at Aston University in UK, I am doing my PhD in Engineering Management and I am studying the efficiency in implementation of Quality Management (QM) in manufacturing operations whenever product line or manufacturing operations change. Quick implementation of QM procedures to achieve the desired level of productivity helps the firm to reduce waste, downtime and be competitive.

Your esteemed organisation has a highly competitive position in Saudi industry. I would like to study the methodology of dissemination/ implementation of QM procedures on the shop floor in your firm. My work would primarily involve qualitative interviews (about half hours) with QM and Production manager. I am more interested in your production and quality division manufacturing operation. The study would act as a comparison, which other Saudi firms could emulate and compete, more professionally at local and international level.

I would be most obliged if I am referred to a suitable person with whom I can take up my case and provide him further details. I could come to Saudi between July-August 2012 if your esteemed organisation considers my request in a positive respect.

Thanking you in anticipation,

Majed Alnaeem,
Email: alnaemah@aston.ac.uk
UK Mobile: 00 (44) 7796866774
Saudi Mobile: 00 (966) 505232868

2-B Exploratory research interview questions

Research interview questions:

Section 1:

1. How many employees in the company?
2. What are the products that company offered?

Section 2:

3. What are the aims of the quality/production department? How do you manage them on shop floor especially?
4. How many times changeover implemented in production process? Could you please explain it? What is the key consideration of changeover?
5. What are the pressures at the time of changeover with respect to time/deadline:
    - For different product. What is the feedback to improve it?
    - New product. What is the feedback to improve it?
    - New process. What is the feedback to improve it?
6. What are the factors that affecting quality specification mentioned/desired during changeover in manufacturing operations?
7. Is the changeover has an impact on company's performance in terms of competitiveness and financial position?
8. How do you capture the learning from the changeover process?

Definition:

Changeover: is the complete process of changing between the manufacture of one product to the manufacture of alternative product to the point of meeting specified production and quality rates (McIntosh et al., 1996).

New process: is adding or creating new manufacturing process to facilitate production in shop floor.

Competitiveness: in terms of quality, cost, delivery, flexibility and time, generally refers to the ability of a business organization to survive in a competitive marketplace by offering products or services that attract and satisfy customers (Chi Phan et al., 2011).

Financial performance: based on increasing sales, market share and profits (York and Miree, 2004).

APPENDIX 3: CHANGEOVER EFFECTIVENESS ASSESSMENT TOOL (CEAT)

<u>Section one</u>: general background (Questionnaire before starting semi-structured interview)

The first part of the study collects general background information before starting the interview. I would be very grateful if you would complete the enclosed questionnaire. Your participation is highly appreciated and your response will be dealt with as strictly confidential.

Q1: What is the highest level of education that you have attained?

□ High School □ Diploma □ Bachelor's Degree □ Master's Degree

□ Other - please specify: _____

Q2: How many years of experience do you have in the manufacturing industry?

□ Less than 5 years □ 5 - 10 years □ 10 - 15 years □ More than 15 years

Q3: How many employees are there in the company?

□ Less than 50 □ 50 - 200 □ More than 200 - please specify: _____

Q4: How long has the company existed?

□ Less than 5 years □ 5 - 10 years □ 10 - 15 years □ More than 15 years

Q5: Which of the following quality management programs has your company implemented?

□ Quality Control (QC) □ Quality Assurance (QA) □ Total Quality Management (TQM)

□ Other - please specify: _____

Q6: How many years have QM programs been implemented for?

□ Less than 5 years □ 5 - 10 years □ 10 - 15 years □ More than 15 years

Thank you for your participation…

<u>Section two</u>: Understanding manufacturing changeover practice (semi-structured interview)

The second part understands the status of the manufacturing changeover process based on the semi-structured interview. It focused particularly on understanding the manufacturing changeover practice problems within the firm and documentation procedure.

1. Has the firm experienced any problems in the manufacturing changeover? If yes, please explain.

2. Does the firm document changeover data? If yes, what sorts of data are recorded? If not, why? (Please supply a copy of the changeover data sheet if available).

3. Has the company tried to link the changeover data with output data of the production and quality (McIntosh et al., 1996)? If yes, what was the result?

4. What was the condition of the first outcomes product after the changeover? (Scrap, rework, accepted).

Section three: Understanding the factors that influence the quality and reliability of changeover process (semi- structured interview)

The third part of the study indicates the level of changeover practice based on four categories: People, Process, Quality and Infrastructure. The following statements describe the sub-factors that impact on the changeover process. Please select the relevant statement that best describes your firm:

People:

1. Top management commitment:

What is the commitment level of the top management to support the changeover process?

☐ Level 1: Top management does not provide sufficient resources, such as skilled manpower, tools and equipment. No attention given by top management to improve the manufacturing changeover practice.

☐ Level 2: A little consideration of the top management is given to support the manufacturing changeover practice; unaware of the importance of the role of changeover to the firm.

☐ Level 3: Top management is encouraging changeover practice by providing adequate tools and equipment; provides suggestions for improving the changeover process.

☐ Level 4: Top management is encouraging and involved in changeover practice by providing adequate tools and equipment; top management defined changeover scope and identified the core of the changeover practice to the firm; provided suggestions and resources for improving the changeover process.

☐ Level 5: Top management is fully committed to improve changeover activities; regular meeting to follow up the improvement of changeover; direct participation and smooth cycle of feedback from top management to production personnel; top management defined the scope of changeover and undertake to fulfil changeover requirements.

2. Training and multiskilling:

What is the level of the training that is provided to the operators for performing changeover manufacturing practice?

☐ Level 1: No training provided for operators but firm relies on operator's experience.

☐ Level 2: New operators will have short introduction training for plant facilities.

☐ Level 3: General and basic manufacturing training, such as basic problem-solving or lean manufacturing technique provided on a regular basis by internal training staff.

☐ Level 4: General training on how to conduct manufacturing changeover and its importance for operators is provided by internal or external training staff.

☐ Level 5: An advanced and specific training program, such as Single Minute Exchange of Die (SMED) and 5S for improving the changeover process which is provided by external expertise. Operators will improve their skills by understanding and implementing these methods.

3. Personnel involvement:

What is the level of the operators' involvement during the changeover process?

☐ Level 1: Operators not involved in the feedback loop with management or engineers; operator not involved in the changeover improvement process.

☐ Level 2: Occasionally operators are involved in the feedback loop with management or engineers; occasionally the operator provides feedback on past problems experienced during the changeover process.

☐ Level 3: Operators involved in the feedback loop with management or engineers; the operator provides feedback on past problems experienced during the changeover process.

☐ Level 4: Operators involved in the feedback loop with management or engineers; operator provides feedback on past problems experienced during the changeover process or practice; occasionally the operator is involved in changeover improvement process; two-way communications exist.

☐ Level 5: Regular meetings between operators and management or engineers are provided for suggesting improvement to the changeover process; two-way communications; brainstorming session that involves who takes part in the changeover; considering operators' feedback in decision making; operators' feedback on past problems experienced during the changeover process or practice.

Process:

4. Time pressure:

What is the level of the impact of time pressure on operator and crews' shifts while performing the changeover process?

☐ Level 1: Often time imposes pressure on the operator during the changeover process and that impacted on the changeover process; high degree of variability of changeover processes between crews' shifts.

☐ Level 2: Partially time imposes pressure on the operator during the changeover process; high degree of variability of changeover processes between crews' shifts; the firm do not pay attention to reduce changeover time.

☐ Level 3: Changeover performed under less time pressure; medium degree of variability of changeover processes between crews' shifts.

☐ Level 4: Changeover performed under less time pressure; communication exists between crews' shifts to eliminate problem; low degree of variability of changeover processes between crews' shifts.

☐ Level 5: Consistently perform changeover time and process between crews' shifts; communication is exists between crews' shifts to eliminate problems; sustain the best practice of changeover process between crews' shifts.

5. Speed up the set-up process:

What is the level of the standardisation procedure of the changeover process?

☐ Level 1: Standardisation procedure of changeover process not yet established.

☐ Level 2: Standardisation procedure of changeover process is established; firm does not revise the changeover procedure frequently.

☐ Level 3: Standardisation procedure of changeover process is established; firm frequently revises the changeover procedure.

☐ Level 4: Standardised changeover procedure and the procedure booklet is easy to access; frequently the firm revises the changeover procedure; understanding of the impact of speeding up the set-up process on the run-up period.

☐ Level 5: Standardises changeover procedure and the procedure booklet is easy to access; frequently the firm revises the changeover procedure; understanding of the impact of speeding up the set-up process on the run-up and changeover performance; established the optimum changeover procedure in terms of time and process.

6. Availability of materials and tools -"on-job resources":

What is the level of the availability of the materials and tools during changeover?

☐ Level 1: Normally materials delayed from previous processes; delay on materials and tools handling during transportation from the store; difficulty occurs due to receiving item late into location for next changeover.

☐ Level 2: Occasionally materials delayed from previous processes to serve for next changeover; occasionally materials and tools delays due to handling during transportation from the store; a communication channel should be encouraged between production and planning departments.

☐ Level 3: Materials are available on time from previous processes to serve for the next changeover; occasionally delays occur due to transfer these materials and tools to the machine; a communication channel exists between production and planning departments.

☐ Level 4: Materials are always available on time from previous processes to serve as input for the next job; receiving tools and materials on time into location for the next changeover; a communication channel exists between production and planning departments.

☐ Level 5: Materials and tools are ready to use for the next job; materials are always available on time from previous processes to serve as input for the next job; better item receiving during external time of changeover; better communication channel between production and planning departments by using computer software; planning department disseminated the production plan in advance to the responsible departments.

7. Interruption of the sequence of changeover tasks:

What is the level of interruption to the operator while performing changeover tasks?

☐ Level 1: The sequence of changeover tasks is usually interrupted, for example waiting for item to be delivered or waiting for required skilled manpower; a high variation in changeover time.

☐ Level 2: Occasionally the sequence of changeover tasks interrupted; for example calling the operator to undertake another job; a medium variation in changeover time.

☐ Level 3: Changeover tasks performed in sequence without interruption; medium degree of variation in changeover time.

☐ Level 4: Changeover tasks performed in sequence without interruption; a minor variation in changeover time.

☐ Level 5: Changeover tasks perform in sequence without interruption or distraction; a standardised variation in changeover time; the firm understands that interruption will contribute to repeat changeover tasks again; better planning scheduling.

Quality:

8. Procedure checklist:

What is the preparation level of the changeover process?

☐ Level 1: Firm does not have a procedure checklist or simple check sheet for changeover preparation; operator relying on his experience and memory to prepare tools and materials for the changeover.

☐ Level 2: Sometimes the firm uses a check sheet for confirming the changeover process.

☐ Level 3: Firm uses checklist or check sheet for confirming the changeover process; reallocation and planning changeover task before commencing changeover in-advance.

☐ Level 4: Firm uses checklist or check sheet for ensuring the changeover process; the firm established a procedure checklist; reallocation and planning changeover task before commencing changeover.

☐ Level 5: Firm established a procedure checklist for ensuring the process; firm used tools and techniques such as mistake proofing and self-checking mechanism before commencing changeover; revised the changeover procedure checklist frequently; reallocation and planning changeover task before commencing in sufficient time.

9. Quality Management and Changeover knowledge:

What is the knowledge and awareness level of Quality Management (QM) and changeover process between operators?

☐ Level 1: No knowledge disseminated to Quality Management (QM) and changeover among shop-floor workers by firm but sometimes it relies on the supervisor to disseminate knowledge to the operator through verbal communication.

☐ Level 2: Firm provides a variety of QM and changeover information resources which is optional for operators to learn; knowledge-seeking by workers themselves as "self-learning".

☐ Level 3: Some efforts made by firm to increase awareness and importance of QM and changeover by providing information using notice board and conducting one-day sessions on a regular basis.

☐ Level 4: Firm helps to increase awareness and importance of QM and changeover among the shop-floor workers by different sources, such as leaflet, notice board, CD, book and one-day sessions; workers understanding the general concepts of QM and changeover.

☐ Level 5: Firm helps to increase awareness and importance of QM and changeover at all employees' levels by different sources, such as leaflet, notice board, CD, book and one-day sessions; workers understanding the general concepts of QM and changeover; operator has the ability to implement permanent tool modifications to improve the set-up process.

10. Initiative for improvement:

What is the initiative level of improving changeover time and process?

☐ Level 1: No improvement sought for improving changeover time and process; no documented changeover data, such as set-up time.

☐ Level 2: Partial initiative for improving changeover time and process; no documented changeover data, such as set-up time.

☐ Level 3: Partial initiative for improving changeover time and process; firm regularly documented changeover data.

☐ Level 4: Initiative for improving changeover time and process; documented changeover data; firm has standardised changeover data sheet; recording changeover process by video tape.

☐ Level 5: Continuous improvement for changeover time and process; fully documented changeover data; firm has standardised changeover data sheet; recording changeover process by video tape; implementing improvement methods, such as Value Stream Mapping (VSM) to prioritise areas of improvement.

Infrastructure:

11. Using new machines/tools "Technology":

What is the level of using new machines and tools that impact on changeover process and time?

☐ Level 1: Knowledge and understanding of using new machines/tools need to be improved to reduce set-up time; new machines were tested once installed and have not been updated; firm not reviewing the impact of new machines on changeover time and effectiveness while purchasing them.

☐ Level 2: Firm giving priority of buying new machines to the high quality rates output more than considering less changeover time; new machines were tested once installed; updated and latest machines/tools are provided.

☐ Level 3: Updated and latest machines/tools are provided; new machines were tested once installed; sometimes firm revises the impact of new machines on changeover time and effectiveness while purchasing them.

☐ Level 4: Updated and latest machines/tools are provided; firm understands that new machines need to match business capability in order to improve set-up time; firm understands that purchasing new machines will improve set-up time; new machines are always tested regularly.

☐ Level 5: Introduced specialised tools allowed the firm to perform more efficiently; sufficient knowledge of using new machines and tools successfully; updated and latest machines/tools are provided; new machines are always tested regularly; firm reviewed the impact of new machines on changeover time and effectiveness while purchasing them; firm understands the importance of machines' management such as development, installation and operation and how that directly impacts on changeover time, whether negative or positive.

Process: (Mainly related to the direct observation)

12. Changeover preparation: "Direct Observation"

☐ Level 1: No existence of tooling department for preparing tools for upcoming changeover; firm does not use simple checklist for changeover preparation; dies cabinet is not organised; firm does not prepare product's drawing before changeover commences.

☐ Level 2: No existence of tooling department for preparing tools for upcoming changeover; firm does not use simple checklist for changeover preparation; dies cabinet is organised; firm unaware of using the colour-coded technique and set-up tool cart for improving changeover practice.

☐ Level 3: No existence of tooling department for preparing tools for upcoming changeover; firm does not use simple checklist for changeover preparation; dies cabinet is organised and each die is clearly indicated by its name and die number; firm aware of the use of the colour-coded technique and set-up tool cart for improving changeover practice.

☐ Level 4: Firm has tooling department for preparing tools and drawing for upcoming changeover; firm aware of using the colour-coded technique, set-up tool cart and digital countdown timer for improving changeover practice; firm not used checklist for changeover preparation; no implementation of permanent tool modifications to simplified changeover; dies cabinet is organised and each die is clearly indicated by its name and die number.

☐ Level 5: Firm has tooling department for preparing tools and drawing for upcoming changeover; firm understands and is aware of the colour-coded technique, set-up tool cart and digital countdown timer for improving changeover practice; firm used checklist for changeover preparation; implements permanent tool modifications to simplified changeover; dies cabinet is organised and each die is clearly indicated by its name and die number.

Quality: (Mainly related to the direct observation)

13. Safety on shop floor: "Direct Observation"

☐ Level 1: Operator conducted changeover without attending to safety requirements; messy workplace and could not perform changeover process easily; unconscious of the safety requirements; unclean, and poor lighting and ventilation on the shop floor.

☐ Level 2: Occasionally changeover process is conducted without safety requirements; untidy workplace and poor lighting on the shop floor.

☐ Level 3: Usually changeover process is conducted with safety requirements; firm aware of the safety necessities and safety sign on the shop floor, but untidy workplace.

☐ Level 4: Usually changeover process is conducted with safety requirements; firm aware of the safety necessities; clean and safety signs on the shop floor area; no hindrance to the operator during practicing changeover.

☐ Level 5: Working area is clean and no remains of scrap or materials from previous job; neatly stored tools and equipment; safety addressed and no hindrance to the personnel during changeover process; safety working procedure is reachable and applicable for operators; marked area for safety equipment and safety sign on the shop floor.

APPENDIX 4: DATA COLLECTION & CODING

4-A Interviews and observations matrix sheet

Interview & Observation Matrix		**Interview**											**Observation**		
		People			**Process**				**Quality**			**Infra.**	**Process**	**Quality**	**Overall**
Firm		**F 1**	**F 2**	**F 3**	**F 4**	**F 5**	**F 6**	**F 7**	**F 8**	**F 9**	**F 10**	**F 11**	**F 12**	**F 13**	**Attending changeover**

F1 (Factor 1) Top management support changeover process.
F2 (Factor 2) Training for changeover practice
F3 (Factor 3) Personnel involvement during changeover.
F4 (Factor 4) Time makes an undue pressure.
F5 (Factor 5) Speed up the set-up process (standardisation).
F6 (Factor 6) Availability of the materials and tools.
F7 (Factor 7) Interruption the sequence of changeover tasks.
F8 (Factor 8) Using checklist (Preparation).
F9 (Factor 9) Awareness of changeover and QM.
F10 (Factor 10) Initiative for changeover improvement.
F11 (Factor 11) Using new machines and equipment.
F12 (Factor 12) Changeover preparation.
F13 (Factor 13) Safety and facilities on shop floor (clean and lighting).

4-B Observation check sheet

Observation	Shop floor safety	Changeover preparation	Changeover practice
Clean and tidy			
Good lighting condition			
Neatly tools and equipment			
Good ventilation condition			
Safety working procedure			
Colour coded for changing part			
Using setup tool cart			
Dies and tools cabinet is organised and identified easily			
Using checklist/check sheet			
Digital countdown timer			
Tooling department for preparation tools and drawing			
Visual Management for indicating upcoming changeover.			
Changeover documentation			
performing changeover based on standardised procedure			
Delivery of changeover practice (Machine stopped, delay in materials)			
operator movement			

Additional comments:


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APPENDIX 5: PILOT STUDY

5-A Pilot study documents

Figure 1. Products offered in Company D.

APPENDIX 6: MAIN CASE STUDIES

6-A Letter for asking the firms to participate in the research

Dear Company

I am a Saudi PhD student at Aston University in UK, I am doing my PhD in Engineering Management and I am studying the implementation of manufacturing changeover whenever product line or manufacturing operations change. Quick implementation of manufacturing changeover achieve the desired level of productivity helps the firm to reduce waste, downtime and be competitive.

Your esteemed organisation has a highly competitive position in Saudi industry. I would like to study the methodology of dissemination/ implementation of manufacturing changeover on the shop floor in your firm. My work would primarily involve qualitative interviews (about half hours) with QM and Production manager. I am more interested in your production and quality division manufacturing operation. The study would act as a comparison, which other Saudi firms could emulate and compete, more professionally at local and international level. I would be most obliged if I am referred to a suitable person with whom I can take up my case and provide him further details.

Thanking you in anticipation,

Majed Alnaeem,
Email: alnaemah@aston.ac.uk
UK Mobile: 00 (44) 7796866774
Saudi Mobile: 00 (966) 505232868

6-B Company E Daily Production Report

6-C Company G Daily Production Report

6-D Company G Proposed manufacturing layout


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6-F Company I Line Clearness Sheet

6-G Company K Cutting Order Slip


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6-H Company L Breakdown Maintenance Report

6-I Transcribed interviews of main case studies

This is one sample of the case companies' transcripts

Production Manager (I):

Interviewer: First of all, after we fill the background information sheet, we have to start Section 2, which is measuring and understanding the manufacturing changeover practice within your company. Has the firm had any problem in the manufacturing changeover recently or previously?
Interviewee: No. We don't have any major problem in changeover, because we have a small product. We are a surgical switches manufacturer, in which the product depends upon the customer request. So we are totally based on customer request. It's a normal process for us. We have to do it.
We have enough manpower, and planning is going for import of materials. Usually, the flow of materials is okay. And based on the history, we order the materials. So the items are-- and some new items which we don't have, it may take time to import the raw material.
Interviewer: Is the firm documented the changeover data or not?
Interviewee: Yeah, it is documented.
Interviewer: Which data do you documented?
Interviewee: Batch number of the material - what batch number we have changed, Because in changeover, usually we change the type of material. So each batch has written which material batch is used, which is-- this is documented on the batch record the product.
Interviewer: Do you document the time of the changeover - I mean setup time?
Interviewee: Yeah. Each machine has a time of the changeover.
Interviewer: Who is doing that?
Interviewee: The machine's operator will write on the machine log. The worker would write. The operator would write. We have a machine log. In the log, it is noted that this batch is changed for -- we know there is a changeover. Batch to batch. That is changeover.
Interviewer: What are you recording on the machine log?
Interviewee: Yeah. Type, the number, and the colour of the material. Sometimes, the color of the packaging material. Sometimes, it's the machine dies. Each product has different dies. And then, line clearance. Since it's a medical product, it's very important to have line clearance. So we have to do line clearance. That's a changeover. You have to remove all the existing product, and then put the new product on the line.
Interviewer: That's great. Has the company tried to link the changeover data with output data of the production and quality? What was the result?
Interviewee: No, we have not checked. Because usually, what we do for-- we have process for production - a little attaching process where we clean the needles. And that, it is individual - each operated one machine. It is normal, so we have to do it. We cannot await anything. Each product has to be changed through the machine set-up. Then we come to packaging machine. We have many different products that will have same packaging material. In that, we plan that one day we'll run white-colour. One day we'll run other colour. Because if-- suppose each batch we change, then they will be time loss and they will be wastage on the material also. So toward that, we'll plan to have one day, one colour.
Interviewer: What's the condition of the first outcomes of the product after the changeover?
Interviewee: In our medical process, we have-- each stage, we have IPC - In-Process Quality Check. So once we set up the machine, we test it. If packing machine is there and the packaging material is changed, we will send a sample to QC to test the strength of the pouch - acceptable or unacceptable. If it's acceptable, the machine will run. If not acceptable, then certain changes of parameters have to be done, and we're done. Unless it is acceptable. Usually, we have a validation of machines for each material, so it pass always.

Interviewer: Always pass? There's no percentage of error?
Interviewee: Yeah. 100%. It was 100%.
Interviewer: 1 We'll move to the next section of the research. I have here 11 factors. That needs to be indicating the suitable levels of each factor. So, the first factors here management commitment. What is the commitment level of the top management to support changeover process?
Interviewee: Actually, my process top management is not much involved in changeover process. It's total production process department. Mostly in changeover, we have to see the wastage. That we have certain-- acceptable is 2% or 1%. That is acceptable. More than this, then this it is a problem. So we always-- we are below the accepted range.
Interviewer: Did the top management provide enough tools and equipment, such as dies?
Interviewee: We do bring new dies, because dies always-- by using it, are worn out and break is there. So we order die is approved from management. We need manpower. We do request for manpower. The most important thing managing, that we should not have much wastage with the changeover. So we have to minimize the wastage, actually in the changeover.
Interviewer: Are they doing, daily meeting in regarding to the changeover?
Interviewee: No, because it is small batches.
Interviewer: Which level do you think here?
Interviewee: Level 3 would be okay, probably.
Interviewer: That's great. What did you missed at the level 4?
Interviewee: Top management in our changeover is not involved directly for our work. So, I don't think this is a problem.
Interviewer: We'll move, next one here - training and multiskilling. What's the level of the training that's provided to the operators for performing changeover manufacturing practice?
Interviewee: Since we have following ISO program, so each operator has to be trained. Whatever he is doing, he has to be trained for that. We have a complete training program, and each operator working to any place is given full training for their job. So training is completed. When we find that he's okay, then we assign him a job. So we do 100% training.
Interviewer: Do you provide training especially on the changeover as well?
Interviewee: Yeah. The operators, he knows that he has to do the changeover – on the machine or the line clearance especially. Then attaching crimping area. I told you, crimping area. The operator will sign it - all of the changeover - clear everything and he's changing the machine.
Interviewer: This means they have specific training for each. For how the production and especially for changeover as well.
Interviewee: Yeah. Suppose we have ten categories of workers - attachers, winders, packagers. So each one will be given his training. The attacher, 'You have to do this.' Winder, 'You have to this.'
Interviewer: This is provided as an internal training?
Interviewee: Yeah. Internal training. From the expert staff. Based upon seniority. Who is senior? Who learns more? He will be the training expert.
Interviewer: it is formal training or informal?
Interviewee: Yeah. Formal, it is. It is a documented training. We have a plan for training there. Actually, we need these things.
Interviewer: Do you do SMED techniques and 5S, especially when you do the changing?
Interviewee: No. I think we are at the level 3 because we did our training internally. Yeah, exactly. And general manufacturing training, such as basic problem solving. We implement this also.
Interviewer: We move to the next one. The personal involvement. What's the level of the operator involvement during changeover process?
Interviewee: Yeah, they are involved. The operators are involving on the changeover directly.
Interviewer: Are they giving feedback about the procedure of the changeover?
Interviewee: Yeah, sometimes they do come back and give feedback. We know by this, we've really improved.

Interviewer: So, they are communicating?
Interviewee: They are communicating.
Interviewer: To you directly or to their foremen?
Interviewee: No, we have foremen. It's forwarded to them, and then they come to me. I'm directly involved in this as well. Level 5, also we're doing it. We're meeting with operators and management. Management, I will present the management for improving the changeover process, two-way communication, then brainstorming session that involves during the meeting.
Interviewer: Do you do that brainstorming session with the operator?
Interviewee: We do this also. With the operator. We're doing on weekly basis this. Every Thursday, we have a meeting at 10:00.
Interviewer: How about operator decision making, do you consider it?
Interviewee: Yeah, because he's the main person who's standing on the machine. He knows much more than anyone, what the machine is doing. So anything changes he knows. And we do feedback from operator. So we are level 5.
Interviewer: We move here time. What is the level the impact of the time pressure on operator and between crew shifts while performing changeover process? Do you work as two or one shifts?
Interviewee: Yeah. We have two shifts. Yes, we have to make pressure. Suppose a real changeover time has to meet-- you need ten minutes. The operator has to change in ten minutes. He has a limited time. And same, even attaching crimping. If he need to change the die within five minutes, and then check samples within five minutes, two minutes, there is pressure always for them not to waste time on changeover. Because just to check the dies, he must know that what is-- what he will need the new die.
Interviewer: You make the pressure. How about the operator performing changeover process?
Interviewee: No, he knows the work we need. So he will make the-- just change, line clearance, and then bring the die, and fit it. In case-- if the product doesn't pass, then he will contact the supervisor that it is not passing, and he will go to another job. The supervisor will talk with the technician to complete this job, and then the machine is set, and then they will do that too.
Interviewer: That's great. You do here two shifts? Morning and night shift?
Interviewee: Yeah, but shift changeover is nothing because the process the same. I think that they should do this and this. The things continue, so everything is the same with the shifts.
Interviewer: Great. How about the degree of variability of changeover process between crew shifts? Especially in the changeover process?
Interviewee: Because each-- individual workers there, so there's much. Each individual will come in and join us. He will take his batch and he will do. There is one batch, one operator.
Interviewer: In the night, they will do the same of changeover process of the morning shift.
Interviewee: Operator will be the same. He will not give the job to another person. Then, he start that batch. Yeah, the changeover process is same. He will come and handover the-- that this is-- on the machine is this here, continue this here. If the product is finished and he need to change, then he changeover. But usually, there's no-- in our business, it's not like that. So the most important shift changing is for crimping, which each individual has his own work.
Interviewer: So this means each operator has different batch and even different performance, right?
Interviewee: Yeah.
Interviewer: how was the company deal with different performance between operators?
Interviewee: No, because-- since I showed you the needle sizes. It depends upon the needle size. Suppose the micro-operator that he is attaching, 6 mm needle. He will not be able to attach 1 per minute, or 1.5, or 2 per minute. But if it is 14 mm needle, it will be-- he may attach 4 per minute, because I will say "fast" and he will do it fast. So since the work is human-based, it's based on person to person. When we come to packaging machine work, the machine gives 14 per minute. You will get 14 per minute. That's it. There's no problem in the machine. It has to give 14, but people have to feed that machine for giving 14 per minute.

But when it comes to individual operator, each person is different than another. Then, depend on the product. You give him an easy product, big-- in our business, we have two types of material - multifilament and monofilament. Monofilament is very good to attach - easy, based on multifilament. So that also makes a difference between operator to operator.

Interviewer: The changeover here is hourly happened?

Interviewee: Yeah. Attaching, not hourly. The small batches will be hourly - half an hour. Only one batch can be half an hour. That will be there. Some batches will go whole day. One operator, if he-- supposes issue 500 in batch. He may complete in three days, this job.

Interviewer: the minimum time of changeover is 30 minutes?

Interviewee: Yeah, between 20 to 30 minutes. With all the setup, that gives you checking and everything. So we are level 4.

Interviewer: How about sustain? Do sustain the best of process of changeover process? How do you make sure operator is doing the best process of changeover?

Interviewee: By the time in the log and how much time he's taking to change that.

Interviewer: This means you compared with all operators together?

Interviewee: Yeah, if we found someone less than the others we have to improve his training maybe.

Interviewer: How about you? Are satisfied now from the shop floor especially in changeover practice?

Interviewee: management will not be happy at all, because we need to be standard, we will come back to eight minutes. If eight, we will come back to six minutes.

Interviewer: This is diplomatic answer. Now, give me the actual answer.

Interviewee: Leave it, because it is very difficult to say that we are satisfied with this changeover. Since it is going on, it's okay. But still, we think to handle to improve it. We need to improve it.

Interviewer: Do you have any tools for improving changeover that used in the shop floor?

Interviewee: We need some planning that we'll do this and move this way, so the time would be reduced.

Interviewer: Do you mean planning schedule?

Interviewee: Yeah. Suppose one machine, we have been attaching some wire sizes. The problem in that is die sizes. Each wire size will attach the same wire size, I say. So we'll try to have same wire size always, so the machine is not changed, the dies are not changed. Suppose for instance, we have 73. We put on this machine in the queue all the 73, so that he will not remove the die again - fix it. 73, they will just clear the line clearance in one minute, put them-- roll them out, bring the new one, start with the same setting. Check, pass, start.

So we do this planning. In packaging - when you come - we have one, collar. Whatever product goes in one collar will be in all of the machine so that we don't have changeover time, lose, and wastage of material. Say, it is whole-day product. Fine. The whole day, it will be whole. So we do-- and sometimes, the customer requirement is very urgent. Then we have to take care for the customer. That time, we do changes.

Interviewer: What's the main objective of improving the changeover process? Why do you want to improve it?

Interviewee: Reduce time and wastage. The manpower timing, which is costing more for us and wastage.

Interviewer: What's the major obstacle you faced of improving the changeover process?

Interviewee: No, the machine is not helpful. The product itself not helpful, because it is the type or the nature of the production that we have to do it. So it's something like this. Batch sizes are more, because some customers need one dozen urgently as sample - something like this, which cannot be unavoidable. Unavoidable circumstances. You can say, nature of the job.

Interviewer: Obstacles on the company for improving the changeover?

Interviewee: There is no obstacle we can improve. We are free to improve anything.

Interviewer: We move, next one. Here, speed up the setup the process. What's the level of the standardisation procedure of the changeover process? Do you have procedure?
Interviewee: Yeah, we have procedure.
Interviewer: For the changeover? I'm not talk about the quality procedure. I'm not talk about the production procedure. I'm talk about, especially for the changeover.
Interviewee: We have procedure for each machine - how it will work. In which, the changeover is there.
Interviewer: But do you have a changeover procedure between different products? For each one?
Interviewee: No, this type of procedure we don't have. Level 1.
Interviewer: Why? Why do you think you didn't have these procedures?
Interviewee: Because it's discovered in the machine changeover, so we don't have any procedure for changeover. Because the machine processes that changing of die. How to change the die is there, which is our changeover. It is in the machine procedures there, how to do the changeover.
Because the machine is-- especially, if it's the attacher. He knows when we give training or when we have procedure, he know that-- check the last dies of the product. Get the same die. Set the die. Check three. So he knows what he has to do. It may be-- by time, he will learn it. And then, you come to packaging machine, which has a-- how to change the reel. Check the material type and the reel. They will be on the back. If it goes on the batch, everything's there. The distribute, product meet-- while this product meet that reel. Check the batch card. Check the reel. If it is not there, change the reel. Changing of the reel. This is how to change the reel. All there is to it. Maybe it will have in the future.
Interviewer: The availability of materials and the tools - which is tools here, the die. What is the level of availability of materials and the tools on the job resource?
Interviewee: Actually, our procedure is based on plan. We have a planning section. Once raw material is ordered, which is most consumable. We order it regularly. We have it on hand - in stock. We will have stock in hand. And the other one is that based on customer, new product is there. Then we will order it. That will take time. But usually, when the customer order it-- request it, we will see the log that we have this particular available in the stock, and we will issue the order. Mostly, raw material is not a major problem, unless it is a new product.
Interviewer: What do you do for new product for the changeover?
Interviewee: The packaging method and the attaching method remains same. Only some needle types, they will say the size. That is the only new-- that's it.
Interviewer: Is the company manufactured the needle here?
Interviewee: No, we're getting it from outside. So, it depends on the needle only and material. Suppose a material's there which is not common material. We don't have in stock. We don't keep it. And then, we need it. So we'll order the material. Other processes are all same for everything. For all products, everything is same. It is all about time to get the needle from the supplier.
Interviewer: Is the supplier outside?
Interviewee: Outside supplier, yeah.
Interviewer: Do you have a problem of delaying the material from the supplier?
Interviewee: Yeah, sometime they're the needles maybe is run out. They're just not there, so we have to search new supplier. New supplier will not again have the-- all the needles.
Interviewer: How about the raw material availability?
Interviewee: Yeah, we received them on the time that we asked because we have a contract. Everything is good. The stock is less, so we just ask them to send the material. They send it. We have reorder level. So when the stock goes below the reorder level, we order it. And before it goes to zero, then new order comes in.
Interviewer: How many types of needles do you have?
Interviewee: Needle, maybe more than 2,000. Same thing but some little bit of difference. Some hole, a little difference. Some wire, a little different. Then profile it. Perhaps, After everything. That's the thing. Curve round body. Curve cutting. J-circle. Half circle. One by four circle. Five circle. Spray

needle. And then, the thickness of the needle. Each needle will have all the thickness, from fine to the thick one. Say, one size, it would be 100 different types. Size will be 14, but 100 different.
Interviewer: So here, which level?
Interviewee: level 5. Material receiving during external time of changeover or before starting the changeover.
Interviewer: We'll go to next one. Here, we talk about the interruption of the sequence of the changeover task. What's the level of operator interruption during performing changeover tasks?
Interviewee: Level 5.
Interviewer: So you're not interrupting operator at all?
Interviewee: No one has permission to interrupt the operator during changeover.
Interviewer: Maybe you are, just only.
Interviewee: If I required. For that, I will not interrupt.
Interviewer: Why do you protect operator from interruption?
Interviewee: Quality would be affected. If it's changing the die or something, they missed it, and it's interrupted, maybe he will pass it. So the company doesn't encourage interrupting the operator during changeover. And no one permitted to do that, unless me or top management.
Interviewer: So you believe that the high quality changeover or reliable changeover will impact on outcomes.
Interviewee: Impact on acceptance outcomes of product.
Interviewer: What is the preparation level of using checklist during changeover?
Interviewee: Yes, I told you. For operator and the batch operator, everything is written. The needle is suppose-- in attaching, and then there is the available wire 78. So he know that he has to wire 78 dies. And then, when we have attaching procedure, it will say, 'Wire 78, take this die.' Then, when he will come to packaging white colouring? Take white colouring. Winding card, they get it - winding cards - for all comprehensive listed.
Interviewer: You're right, but this is different process of checklist. Here, checklist for preparation before starting the changeover. So the operator, let's say, checking the availability of material, machine is ready, and tick the die is there.
Interviewee: We do record the die he uses, this die is used. This operator is there. Testing results is there. After is this test, what is that result-- is there? The batch number is there. Suppose-- what if he has written the batch number. But actually, we don't have any checklist for this.
Interviewer: Do you think it's a good idea to be implemented?
Interviewee: It may be important to-- again, it depends on, industry to industry. Look, for my industry, checklist would be no useful because we have everything-- procedures. So there is no requiring for checklist.
Interviewer: The procedure, do you have--?
Interviewee: the procedure is there for attaching-- that says bring this type in, that type. So it's clear procedure was written.
Interviewer: Now, you said, "procedure for attaching." Is it procedure for the same procedure for changeover or what?
Interviewee: Yeah, same thing for changeover.
Interviewer: But, for one product only, not for all products?
Interviewee: Standard product.
Interviewer: Quality Management and changeover knowledge, What is the knowledge and awareness level of Quality Management (QM) and changeover process between operators?
Interviewee: As I told you, every changeover, we will test three processes there. We'll test three, and if we pass, we'll continue. And then, we will document it also. Same thing in packaging. Changeover is there. We'll test the strength of the materials.
Interviewer: When you say three tests do you mean?
Interviewee: Tension, destructive, and non- destructive test.

Interviewer: Based on what your used these tests?
Interviewee: Based on our requirement of the product, which is a pharmacopoeia - U.S. pharmacopoeia or British pharmacopoeia.
Interviewer: How about the knowledge? Does the operator have the knowledge on QM and changeover?
Interviewee: Yes, they have the knowledge.
Interviewer: From where do they have it?
Interviewee: By training. This also we do sometimes - on a one day session on regular basis, we do. But not for all operators. For supervisors only.
Interviewer: So you are relying on the supervisor to disseminate the knowledge to the operator?
Interviewee: Yeah, All the knowledge not for the operator. So we are level 1.
Interviewer: Why you're not relying on the operator to disseminate the knowledge?
Interviewee: We have many operators. Not all-- we cannot call all the operators.
Interviewer: What's the initiative level of improving setup process?
Interviewee: No, we don't have videotape. We can say level 3.
Interviewer: What's the technique and method that used for partially improving setup process? What is it exactly?
Interviewee: As I saying that we have to do in the planning - that we bring all the product one time. And packaging, we bring all the same caliber at one time. This is the partial improvement we can do. Other than we cannot.
Interviewer: How about the improvement of changeover in the shop floor? Worker movement etc..
Interviewee: We cannot do anything because of the nature of the job.
Interviewer: Anything you want to add here?
Interviewee: No, the video, we're not doing anything video. We have, but we haven't had it in the past the videotaping and then the studying-- we haven't done that, actually.
Interviewer: Using the new machine and tools technology, what's the level of using the new machine and equipment that impact in the set up process and time? Do you do reviewing the impact of the new machine on changeover process and time?
Interviewee: Yeah, we do reviewing. Basically, we are looking - the changeover, as I call it - based on the product nature, changeover is the must in our business. We are trying to bring machines which will reduce manpower - number of workers working on that - like automatic feeding, automatic collection. When we purchase the machine, we look on these aspects. Changeover is the must in our business and different color that we have to put change reel that will be-- we will look that the changing is easy, not very difficult on the machine. When we buy the new machine, we check and see that the changing for the machine is very easy and we study it. So we are level 4.
Interviewer: So you're looking, for this point, for that machine that's helped you to reduce the time of the changeover?
Interviewee: Yes, and manpower. Less manpower should be there. And automatic machines.
Interviewer: Are there any new machine that you will bring in?
Interviewee: No. We have, but not yet.
Interviewer: So, you're not thinking about bringing new machine out yet. How long have you been using this machine?
Interviewee: We have one machine, very new - two years before we ordered - this machine, maybe ten years now. Every year, there's-- every two years, one year, there's a machine.
Interviewer: Do you have any factors that haven't been covered? We went through eleven factors. Do you have factors that haven't been covered through this interview?
Interviewee: The flow has to be in sequence. We have a sequence here. At the stores, we're attaching first stage. Attaching complete, go to winding. Winding complete, go to packaging. Packaging, then it will go to selection, packing, and to the customer. So we have a flow. Manufacture layout. This is

most important, because it will save time for moving here and there. And we do not to mix-up, so we don't want to go back. Once it is moving forward, it should move forward.
Interviewer: You're right. I think that's all. Thank you very much.
Interviewee: Welcome.

Quality Manager (I):

Interviewer: The research is regarding to manufacturing changeover process. The first section is background information we finished it, we start now section two. Section two here, I am going to ask you regarding to the understanding of the manufacturing changeover practice within the firm. Has the firm had any problem regard to the manufacturing changeover now or before?
Interviewee: No, no, no, we have never faced any kind of manufacturing changeover. Because all the changeovers are very small kind of changes only, all minor machines setting here, some things are only needed. So not a big changes happening. Kind of major problem never happened. Some kind of packaging machine breakdown once happened before. It is about one and a half year before. It was after four hours we have to correct it; it was take four hours' time to correct it.
Interviewer: And that had an impact on the changeover?
Interviewee: That impact yes, otherwise nothing, no major problem happened in between.
Interviewer: Is the firm documented changeover data or not?
Interviewee: maintenance has all these data. We have these KPI key process indicators; they are analysing all these data.
Interviewer: Okay what kind of data do you record? For the changeover.
Interviewee: Changeover, the maintenance, actually. It is maintained by the maintenance department itself; they are maintaining that what are the breakdown, weekly basis they are maintaining that. They have certain limit is there, this much is not allowed for per week, month, like that.
Interviewer: Okay. I'm asking for the changeover data especially on the shop floor.
Interviewee: Mention, mentioned it.
Interviewer: Not document it.
Interviewee: Documented it is. We have this Quality Management System; we are not doing anything without documenting. All the things are documented in our system.
Interviewer: Who does the recording of the data?
Interviewee: No, no, if the machine breaks down, if it happen then immediately the supervisor call the concerned department person, maintenance personnel.
Interviewer: No, I meant not machine failure. In normal process-- flow process on the operator while he conducted changeover.
Interviewee: Yes, definitely. Definitely he will mention it.
Interviewer: Do you have a changeover sheet?
Interviewee: We have a format. We have a control format. There is a control number on the format--
Interviewer: Can I see the format afterwards?
Interviewee: After we can show this but on the production department. It is called breakdown of the KPI.
Interviewer: Do you believe that if you provide high-quality and reliable of changeover process that would be impact of the outcomes, or not?
Interviewee: No. That's not what happened. I told you that all-- there is no heavy mechanical process here, not going on. Only semi-automatic manual operations are there. If you need, say in case of automatic-- fully-automatic cases, they may be a major failure in the process here, something happened. But it is manual, semi-automatic and fully manual that we are using. So any kind of occur at the same time we can correct it, though it will not affect any quality or output of the product.
Interviewer: What's the status of the first outcomes after the changeover? Accepted or rejected.

Interviewee: No, no, no, what you can see. It will directly go to the QC. They will review, check all the parameter of the material--Then they approve. They will give a report to the concerned section then only they will run machine for the check.
Interviewer: Okay. What's the percentage of getting accepted the products?
Interviewee: A 100%, suppose if one machine your die fitting attaching process. There is a needle and thread attaching process, one of the main processes we have. If there is any failure die changing is there. After that, they will produce few pieces, at least 10 pieces we have ready. Ten pieces produced will then go to QC. QC checks it and found that it is hundred percent okay then only they allow them to run the machine again.
Interviewer: You're right but I'm asking about the first outcomes of the changeover.
Interviewee: Destroy it and that our destructive test what we are doing on this. First to ten pieces. At least ten pieces. Ten products. We produce and the destructed that's to be tested and throw it. Then only the eleventh piece onwards we are taking it.
Interviewer: So this means if you have an order of 45 pieces. So this means you will do 55 pieces?
Interviewee: Yes. 55. More 55 some cases and yeah. This is the one section I am assuming the ten pieces. Many other section we are using more pieces. Means the total of 50 pieces. Maybe this up to 75 pieces we have to produce. This for quality requirements and all this. This can began for batch recorded. We can do exactly-- how many pieces exactly we use for testing. Suppose one batch is at least 20 to 25 pieces that we have to set for the test.
Interviewer: Why do you do 20 to 25 pieces exactly? I mean why this number it could be 30 or more?
Interviewee: Not only, actually attaching 10 pieces, the finished product is next 10. I saw two times.
Interviewer: Who decides to put these numbers?
Interviewee: The procedure we have, the quality paper of collecting the sample from this. Exactly we can give the number how many pieces for you. The finished product we are taking 10 pieces and the machine setting 10 pieces. 20 pieces in a single run production. A single batch.
Interviewer: How long it take to test the product?
Interviewee: It will take a-- maximum 15 minute. It is only we are doing the tensile strength, as well as the peeling as well.
Interviewer: Is this under your department?
Interviewee: Yes, in QC. The quality department.
Interviewer: Okay, that's good. We move now to the third section of the research. The third section's here. Actually, I have the 11 factors that have an impact on the changeover. So in order to measure the effectiveness of the changeover process in your company, we need to identify the level of the answers of these questions based on your practice within firm. What's the commitment level of the top management to support the changeover process?
Interviewee: Actually, we have fully supported by the top management, and here we are doing this class. We have a monthly meeting every first Tuesday. First Tuesday, monthly meeting, we are participating all the department heads. So we are level 5.
Interviewer: Are they discussing the changeover through that meeting?
Interviewee: Changeover, production, any problem, we are facing any kind of problem, or any kind of rejection happened, or difficulty to fulfill the order. That is manpower, anything like that. These things, we are discussing all these things.
Interviewer: Top management, are they defining the scope of the changeover here?
Interviewee: Yes, Top management, fully involvement is, I told you that there is no big changeover is going on, but top management involvement is coming in the monthly meeting, this kind of meeting we are conducting. In that time, we are discussing all these things.
Interviewer: We move to next one. The training and multiskilling. What's the level of a training that provided to the operator for performing changeover manufacturing process?

Interviewee: actually this is more a general manufacturing training, such as basic problem solving, or lean manufacturing technique, provide in regular basis by internal firm training staff. We have a training record also, and time to time we are refreshing all the employees, and any new changes come.
Interviewer: Do you provide training for the existing worker?
Interviewee: Yes, refresher training always. It's a continuous process. Any new changes, I immediately will hold the proper training to that subject, also. In addition to refresher training is going on this cycle process, continuous process.
Interviewer: How about the level four, do you do additional training on how to conduct manufacturing changeover and is important to operator?
Interviewee: Not externally, only internal training. We can say level 3.
Interviewer: We go next one. Personal involvement here. What's the level of operator's involvement during changeover process?
Interviewee: Provided feedback past problem. Then because very good experience at the staff we have-- what do you say? Operators we have, they have past experience also considered provided. If feedback on the past problem, experience of changeover process or practices. There are levels three and four we can consider.
Interviewer: So how about level five maybe?
Interviewee: The regular meeting also is that? The regular meeting between operator and management, I already told you that the regular meeting is monthly meeting.
Interviewer: Is operator attending monthly meeting?
Interviewee: Operator means senior operator. Supervisor, but not the a little bit or lower level class people. But who is a technical, technical person, all the technical persons are participating at the meeting. We don't do brainstorm session that involves who takes part in changeover.
Interviewer: Do you consider operator feedback and decision making?
Interviewee: We have not taken on the documented way; we have not taken the feedback, but other kind of means in the meeting discussion. Level 4.
Interviewer: We'll move onto the new one here. Here we'll move the new category of process of the time. What's the level of the impact of time pressure on operator and between the crew shifts while performing changeover process?
Interviewee: Already has time pressure because operator wants to finish changeover on less time. The changeover, there is no pressure come to anybody in any cases. No pressure. Because there is short time changeover so there is no pressure there.
Interviewer: But I have heard that changeover takes sometimes 30 minutes, right?
Interviewee: Maximum. In vary occasionally, anything happen like-- software problem and packing machine like that. Then only there's a big delay and it will happened.
Interviewer: So I can understand the most concerns here is the packaging machine?
Interviewee: Packaging machine. That is the software control, otherwise these mechanical machines only manually and only die fit-- dies are using only, and that is all using the semi-automatic, means manual and or little bit pneumatic fittings of that. That kind of-- that is nothing is-- but in software control, that is a problem because software we have time to; either we have to contact the machine supplier to how to correct these problems, all these kinds of anything to protect.
Interviewer: Do you have that the variability of changeover process between the morning and night shift is high or medium?
Interviewee: Same. The guy in the morning, they do the same changeover process in the night. Low degree of variability of changeover process between crew shifts.
Interviewer: How do you make sure that morning shift worker they do the same process in the night shift, for the changeover process. I mean let's assume guy called X, he does changeover in the morning, the guy called Y does the changeover in the night. How do you make sure that it's the same process of the changeover for morning the same and the night shift?

Interviewee: No, supervisors are in the night and the day shift, all that can concern. Responsible people are in each and every department we have. They have supervising and they are controlling it.
Interviewer: Did your supervisor before they were operator, right? Then they become like senior supervisor.
Interviewee: Yes.
Interviewer: What's the level of standardisation procedure of changeover process? Do you have procedure of the changeover process?
Interviewee: No, no, there is a design file, bill of material file. It is exactly showing that the design of product. Actually we are manufacturing the product according to the product code, suppose this code. This code means it's kind of this-- each code has a particular profile of needle, particular length of thread. Material of thread it's different according to these codes. And once the codes comes, not as SOP. Suppose this is the order for this code, DW8525 R. Then the operator goes to this-- we have a design file. It is controlled by conditions department. It is locked by password. Any other department can open and check whatever parameter record for the part of the product.
Then suppose this code come, then he will open this computer and check what other details of the specification of this particular product and needle is this kind of needle, is this kind of thread, is there this much length this needle required, and the packing is in this way or we have to pack. Such details are mentioned in that file. According to that, he set the machine whatever he's doing. Suppose one product finished, then our next product he will check the code and go to this--
Before he start. Once he's-- code will come. This code you have to make hundred dozens. This one. Then he immediately go, they see here. Here, this is the share for file we have then he immediately go to each department, whatever department. Now he is going to this file. Open and let's see. Then he goes here. This is a uniquely 40 emblem, half circle, reverse cut, and this is specification. Code, for other materials. Not only the code-- what the details-- the material is in, suppose this is the packing department, they would know that what to print on this product. Suppose the manufacturing department would know that what the needle need to attach. All the details are here. What the needle is.
Interviewer: Is this detail can be reached by the operator?
Interviewee: Everywhere. This is a shared folder but locked by QA, under control of QA.
Interviewer: That's a great idea to be understood the code and what is the exact specification for the product. My explanation here is the procedure for explaining instructions of how to conducting the changeover. For each product.
Interviewee: Yes, each product means our-- 16 products we have the same kind of process. Each process of SOP. We general procedure for that. We have a common SOP for all products. We have SOP control for SOP we have. General but not for each one. Because all have the same kind of packing, all have the same kind of process.
All we have the same kind of needle and one thread. So gentle SOP is needed overall, 16 item of what we are producing here. We have this control of SOP. We have distributed for each department for overall. So the job here is just cramping this part to this part. That's it.
Yes, but all 16 have the same process. Needle and thread this part. Now other material, maybe this material-- chemical composition of this material may be different. Suppose maybe this polypropylene. This material, but it is also a thread. Now in all cases there's a thread that's made of stainless steel, but profile maybe changed. Now it is a triangle shape, some needle is round shape, round shape, triangle shape.
Interviewer: So the material was brought from abroad?
Interviewee: Yes, all. Thread is from Korea, and needle is from Japan. Attaching and packing process then the main process, as far as the medical device is concerned, the sterilization is very important.
Interviewer: We'll move to the next one. The availability of the material, Do you have any delay of receiving this material from abroad?

Interviewee: No. Never, because the sales, the order from the customer comes to sales. Then sales inform the planning department. And always one or two months a time does the customer will give us two months' time at least or not two months' time to deliver it. Then the sales give the order to planning. Planning tell them within two months we need this material to the supplier. Then planning checks the material status in the store. If it is not available immediately, inform the purchase department. Then the purchase brings it immediately within that time. Delays never happen.
Interviewer: How did you maintain the stock of material?
Interviewee: Stock, we are maintaining well. Very good stocks we are maintaining, because we have a huge-- this is a bulk manufacturing company, bulk products, so we have maintained a good stock. We have at least a six month stock we have.
Interviewer: What is the level of the availability of the materials during changeover?
Interviewee: I think the level is 4.
Interviewer: What the software they are used?
Interviewee: No we are not-- no only we are using the Microsoft Excel, only.
Interviewer: Do you receive material during external time of changeover or once it finished?
Interviewee: You are talking about; here there will not be any delay. When the store actually pieces coming from the material and needles small individual pieces. Before finishing this, the production people inform the stores that this much needle and this much cut material we need. Though before ending this process it will be ready and come to this the next job. Just before finishing the previous one, the material will be ready for the next one--
Interviewer: Interruption the sequence of changeover tasks. What's the level of operator interruption while perform changeover task?
Interviewee: No one has permission to interrupt operator. If you are taking about half an hour then plus minus five minutes here, five minutes. It is minor.
Interviewer: How about level five?
Interviewee: Yes. But that kind of occurrence not happens. We are giving a single responsibility to each person. Each department is very physically integrated. No chance is there because one attaching, I do not give any other work; he is only doing this attaching. Packing guys never do attaching. No, there is a foreman who is there and each work there is a supervisor, also. There is no interruption. We can pick level 5.
Interviewer: Procedure checklist. Do you use here checklist for preparation of the changeover process or not?
Interviewee: We have in production only production procedures only. It is called line clearance. Before starting up we have to check all this points.
Interviewer: Who is checking that usually?
Interviewee: The individual that is concerned with their job only. That particular job. There is a sequence job is separately list as you can-- many sequences are, one attaching is there, packing is there, winding is there. That particular department will crosscheck how this format is there, you can get that.
Before starting or he still-- now he's closed previous order then checking correct material we have is here, the correct needle we have is here. Everything is safe? Checklist uses it before he starting.
Interviewer: Do you have a format of that? Can I have copy please?
Interviewee: Yes.
Interviewer: Who is doing that? Operator or foreman.
Interviewee: Supervisor.
Interviewer: Which level did you select?
Interviewee: We have the process procedure separately. The checklist all separately. This checklists are separated and the processes is very, very well defined in our SOPs, how to do it. So we are level 3.
Interviewer: We'll go next one. Quality manager within changeover knowledge. What's the knowledge and awareness level of quality management and changeover process between operators?

Interviewee: This is included in our training program. In the joining time, induction time we are providing each individual. Each employee has trained about our quality system, production plan, manufacturing process and everything. All are trained. All the employees are trained.
Foreman identifies the training requirements. He's the foreman always identify the training requirement of his subordinate who need what training. Who need the refresher training, who needs a new training, some new subject. That is a foreman decided. That foreman request to the HR department to give that training, then HR identify one person who the trainer among we have a lot of department heads and this. Then concerned person that HR for selecting one person for giving that training and decision within the training room. We will arrange a trainer to employ full-time training. We are doing, the training is there. The necessary instructions are stick on the walls also wherever they're doing this. And so this step by step instruction given, always verbal training we are giving, and necessary instructions, each--
Interviewer: What do you mean by verbal training?
Interviewee: Classroom training and each department you can see. Whenever you are going to sterilization department, the packing department. We have that step by step, what are the process, how to do it. What are the timing for this process? Everything as you see in the manufacturing area on the floor. Every Thursday we have a 15 minute session.
Interviewer: Every Thursday. What's it about, this session?
Interviewee: Manufacturing. Good manufacturing practice.
Interviewer: Who is providing it internally?
Interviewee: Internally we are the production manager and me also supervising this and during this and the current office. Weekly. All together we assemble the long hall here. We are assembled here all together and discussing many issues. Maybe some complaint comes and we will discuss all the employees. This is happened by this reason you have to take care on this, such way we are. So we are level 3.
Interviewer: Initiative for improvement. What is the initiative level of improving of the setup process? Do you record changeover time?
Interviewee: Yes.
Interviewer: So do you do improvement for the setup process or time?
Interviewee: Actually, improvement is not like that. Where the improvement is needed that we are taking the initiatives. In all cases there is like that.
Interviewer: So you're now satisfied with the changeover time and process of the operators?
Interviewee: Yes, Within time. We have a target that you know we are moving on. So we are level 2.
Interviewer: As you told me before, the changeover time takes half an hour, plus or minus 5 minutes could be that your target. That's fine. So maybe one day you record changeover process by videotape, and see if you can do some improvement, especially at the changeover process. Half an hour is such a huge time, and maybe it could be reduced by ten or seven minutes.
Interviewee: This kind of study we have never done, but you're talking about it-- that never we have done such a study that. We want timing in these matters. Actually, I'll say this, we are going to the target base of production hour target is getting. Because delays are not happening, so we are not meant that means its subject, if it is regularly over half an hour is happening, then it is okay. It is a small time it is taking. We never take care about it, like a daily production target this meeting. So we are not concerned to anything.
Interviewer: There is no improvement of setup process in the shop floor.
Interviewee: No. With our current system, we are satisfied.
Interviewer: That's fine. Now this is the last one. New machine and technology. What is the level of using new machine and equipment that impact on set-up process and time?
Interviewee: Yes, all these are all technical matters of changeover time and process we are considering whenever we are going to purchase any new machines or these. The productivity, quality and efficiency, suppose we are purchasing the sterilizer. We are checking all the factors.

Interviewer: Sterilizer, when will be happened? After the attaching or before?
Interviewee: one more per sealing is there, once we put the material inside and one side is open-- keep it to one side open and sterilizes it then to seal it. It's the sterilizer then the-- all the factors we are looking for this parameter and the speed of the machine. In all the machines may be the right changeover time maybe more. But our new machine is very less time it's taking, so we consider this when we purchase a new machine here also, we will consider all this matter and if it is faster than previous old machines.
Interviewer: So do you think here that updated and latest machine tools are provided?
Interviewee: Yes.
Interviewer: Firm understands that new machine needs to match the business capability in order to improve the setup time?
Interviewee: Yes.
Interviewer: Firm understands that new machine will improve the setup process?--
Interviewee: Yes.
Interviewer: A new machine is always tested regularly?
Interviewee: Yes. So level 4.
Interviewer: What are the objectives of improving changeover process?
Interviewee: The current changeover time is satisfactory, so we are not looking for reducing this time because it is impossible, because it is a standard timing.
Interviewer: If you have chance to reduce it, what's the benefit would contribute?
Interviewee: If we reduce the changeover time then we can increase the capacity-- the productivity we can improve. But we are using the minimum time, and the standard time we are using for changeover. So, reducing the standard is very difficult, and I don't hope so that even half hour time we can reduce more time in this changeover time because it's okay in one or two hour changeover time is that, then okay, we can think about that half an hour, one hour again. In half hour or five minutes, we can maximum we can reduce it overall, five minutes.
Interviewer: Have you tried before to reduce it or not?
Interviewee: No, we have never tried to because we are meeting the daily target for our work, so we are happy.
Interviewer: What are the major obstacles that face the company of improving the changeover process?
Interviewee: No, nothing that kind of any obstacle they are there. No, no. No technical problem, no electricity problem, no technical support problem, no. No problem.
Interviewer: So you are ready to improve it if you want to?
Interviewee: It will improve by time.
Interviewer: So you are ready. If you want to improve, there are no obstacles!!!
Interviewee: Nothing.
Interviewer: Do you want add more point that not covered here?
Interviewee: No, Everything covered.
Interviewer: Thank you very much. Thanks a lot for that.

APPENDIX 7: GUIDELINES FOR IMPLEMENTING THE CONCEPTUAL MODEL

Guidelines for implementing the conceptual model in a manufacturing firm

This part provides guidelines for facilitating the use of the conceptual model. Figure 1 represents the pyramid operation level of the investigated manufacturing firms in the study. There are three levels represented in the pyramid; these are managerial level, such as director and executive; middle level, such as production manager and engineer; and shop floor level, such as supervisor and operator. Prior to the implementation of the model, it is required to identify and select a Changeover Team (CT) for facilitating and following the model implementation in the firm. The suggested selection of a CT has to be one person from the middle level and two people from the shop floor level which is based on the pyramid level. A suitable selection of the CT can be a combination of engineer, supervisor and operator. The potential of having a person from the middle level is for providing guidance to the CT and to facilitate the communication with the managerial level on a regular basis. The main role of CT is enabling the implementation of the conceptual model in the firm.

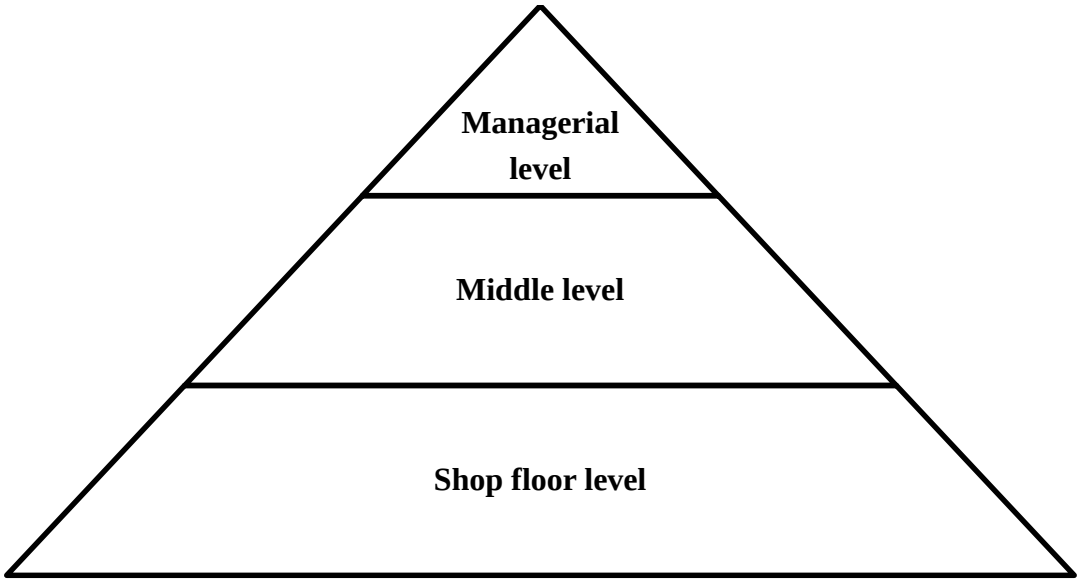

Figure 1. Pyramid of operation level in Saudi manufacturing firm.

Prior to implementing the model, the firm has to identify its current and desired level of changeover practice in order to indicate the aim of implementing the model. Several advantages can be indicated after implementing the model, such as improving changeover process, better quality outcomes and meeting delivery deadlines. These indications help to achieve the potential of implementing the

conceptual model. The guidelines identify the processes that need to be undertaken through model implementation which are before (Phase 1), during (Phase 2) and after (Phase 3) as shown in Figure 2. Also, enabling the feedback loop during the implementation can lead to optimal practice. These processes are discussed further in the following section.

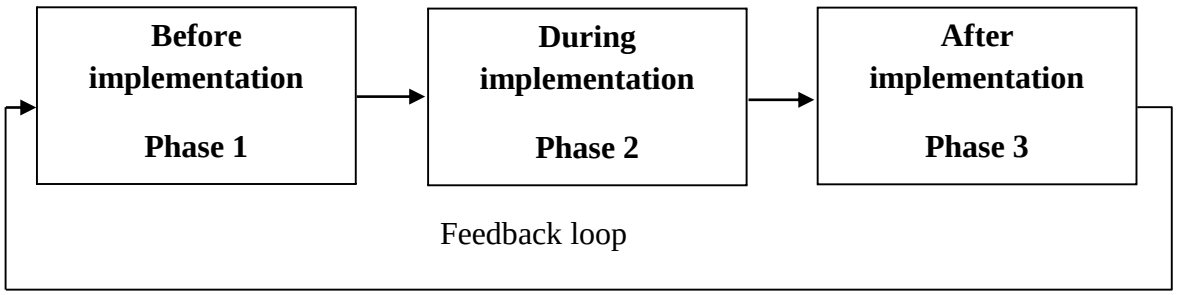

Figure 2. The processes that are undertaken through the conceptual model implementation.

The combination of the examined factors that are presented in Chapter 8 on the conceptual model Figure 8.1 has been grouped into People, Process, Quality and Infrastructure. Firms need to review these factors with middle- and shop floor-level personnel in order to enhance their practice. The implementation has to be initiated from top management as it is considered the vehicle of supporting and sourcing for better changeover practice within a firm. Table 1 indicates the relation between the operational levels in the plant with the constructed research factors. The table shows that the middle level of employees was the most responsible for encouraging the changeover performance. This indicates that middle level of management has a huge role in evolving the changeover reliability and quality practice. This is due to their position in enabling the implementation of the shop floor process as well as easy access to top management.

Table 1. The relation of constructed factors with operation levels.

Constructed factors		Managerial level	Middle level	Shop floor level
People	Top management commitment	✓		
	Training and multiskilling	✓		✓
	Personnel involvement		✓	✓
Process	Time pressure		✓	
	Speed up of setup process		✓	
	Availability of materials and tools	✓	✓	
	Interruption changeover tasks		✓	
	Changeover preparation		✓	✓
	Material flow		✓	
Quality	Procedure checklist		✓	
	QM and Changeover knowledge	✓	✓	
	Initiative for setup improvement		✓	
	Safety on shop floor	✓	✓	✓
Infrastructure	Using new machines/tools	✓	✓	
	Manufacturing layout	✓	✓	

Before the implementation (Phase 1)

Prior to the implementation of the model, the study suggests that firms need to identify the problem of changeover and recognise the level that is desired. In order to implement the model, there are steps that are required to be considered before undertaking model implementation. Table 2 indicates the factors related to Phase 1 which need to be revised by CT.

Table 2. The relation of constructed factors with Phase 1.

Constructed factors		Phase 1
People	Top management commitment	Review top management's commitment for supporting changeover process (resource, suggestion and guidance towards improving changeover practice).
	Training and multiskilling	Revise the level of training and its relation to deliver best practice for the changeover process.
Process	Speed up of setup process	Initiate changeover procedure for all manufacturing processes.
	Availability of materials and tools	• Establish communication between production and planning department for better planning schedule. • Establish communication between production planning and material store department for improving handling. • Improve production planning schedule.
	Changeover preparation	Identify the preparation stage for upcoming changeover, such as preparing drawing, allocating dies cabinet near the machine, and preparing tools.
	Material flow	Study the transport distances of items from the previous process.
Quality	Procedure checklist	Initiate checklist for confirming resource availability before changeover commences.
	QM and changeover knowledge	Provide knowledge through notice board, booklet, leaflets and one-day session on the shop floor.
	Safety on shop floor	Revise the safety requirements of cleaning and tidiness of shop floor.
Infrastructure	Using new machines/tools	Revise the impact of new machines on changeover time and process while purchasing them.
	Manufacturing layout	• Review the layout before conducting changeover process. • Review worker movement of receiving tools. • Review materials movement and Work-In-Progress (WIP).

Changeover data

The first element that is essential for successful adoption of the conceptual model is recording changeover data and their activities. The required documented changeover data are crucial for understanding the current state of the changeover practice (McIntosh et al., 1996; 2001a; Henry, 2013). The sequence of changeover tasks has to be recorded as it appeared on the shop floor.

The changeover documentation sheet has to be generated and formed in order to undertake the recording of the data. McIntosh et al. (2001a) proposed a changeover audit sheet for recording tasks, time of each task, name of personnel and the opportunity for reduction. Video tape recording can be used for recognising any noticeable process that consumed time during changeover. Besides, it is required to record the status of first outcomes after changeover practice and that can reflect on the effectiveness of the current manufacturing changeover. The role of CT is to propose the format sheet for changeover time documentation in order to implement the model on the shop floor. At the same time, CT can review and improve the documentation procedure of changeover and first-outcomes data. This documentation procedure can directly contribute to the recorded system history and that can be used for any further improvement.

Collaboration of firm's departments towards changeover

The conceptual model implementation needs to involve all firm departments before it is committed to be implemented on the shop floor. Most of the departments in the firm have either a major or a minor impact on changeover process (Henry, 2013). However, the department most responsible for delivering changeover practice is the production department as the practice is carried out on the shop floor. The production department has to understand that providing a high quality and reliable changeover process contributes to the quality of outcomes. The rest of the departments have to play their role in the changeover model implementation, as related to its activities. This is discussed as follows:

- The Production Planning Department is engaging in providing a rigorous and better planning schedule that has less transition occurrence as well as scheduling the same products together

which can eliminate changeover. Ultimately changeover is considered as a waste of productivity and time.

- The Quality Department has to be engaged in inspecting the parameters of machine set-up and neatness of the shop floor. The involvement of the Quality Inspector in the early stage of the set-up parameters can contribute to better practice and outcomes. The quality representative has to be involved in inspection of the first outcomes after conducting the changeover. It is essential that the Quality and the Production departments collaborate in order to enhance changeover practice and quality outcomes.
- The Purchasing Department has to be involved in providing raw materials on time as well as working accordingly towards a production plan in order to obtain items for upcoming changeover.
- The Human Resource Department has to provide training in order to improve production personnel skills. SMED training can be targeted as an important technique for reducing set-up time. Also, the human resource is responsible for disseminating knowledge of changeover and Quality Management in the shop floor. The knowledge can be distributed through notice board, leaflets and handbooks on the shop floor.

The CT has to enable the communication bridge for each responsible department in order to play a role in changeover implementation. Therefore, better changeover implementation has to be accomplished at firm level in the first place before commencing on the manufacturing shop-floor level.

Initiate changeover procedure and checklist tool

Changeover procedure (Factor 5) and checklist procedure (Factor 8) were identified in the conceptual model. The CT members have to establish the changeover process procedure in order to be standardised during transition in the shop floor. The team will be responsible for indicating the possible procedure for the manufacturing processes by confirming the final procedure with the Production and Quality Departments. The changeover procedure maintains the variance of the process between crews' shifts and keeps the transition running smoothly. It should be noted that the changeover procedure of a new product has to be addressed during the first trial production run.

In addition, the checklist needs to be identified by CT members for confirming the changeover process before it commences. The checklist procedure has to be generated until it reaches the final improved version. Also, the observation of the changeover procedure and checklist tools has to be evaluated in terms of its use on the shop floor.

Changeover preparation

The preparation for the upcoming changeover (Factor 12) is considered as crucial for the success of the process of set-up and run-up. Different initiatives were indicated within the case companies, such as preparing drawing, allocating the dies cabinet near the machine, preparing tools, and using a colour-coding technique for facilitating the changeover process. A suggestion is to initiate the preparation department for prompting the upcoming changeover.

During the implementation (Phase 2)

The sense of urgency was initiated in the previous process (Phase 1) in order to enhance the awareness of changeover. The firm has to understand the difference between manufacturing changeover of new or existing products and processes while changing as shown in figure below. The study confirms that employing different types of changeover has an impact on changeover effectiveness particularly on the first outcomes. Prior understanding of these changes helps to promote changeover practice particularly on process and time. As a result of that firms have to identify the required changeover that would be implemented on the shop floor.

Figure 3. The difference between manufacturing changeovers of new or existing product.

After identifying the required changeover, CT has to review the effectiveness of constructed factors on the shop floor and their impact on the changeover reliability process during the implementation. Table 3 reviews several studied factors in the research of Phase 2. However, the SMED tool is useful for converting the internal time to the external set-up time. It can be considered as an essential tool for the early-stage implementation of the conceptual model on the shop floor.

Table 3. The relation of constructed factors with Phase 2.

Constructed factors		**Phase 2**
People	Training and multiskilling	• Review the skill capability of workers on the shop floor. • Review the impact of SMED training on the shop floor.
Process	Time pressure	• Review the variability of changeover process and time between crews' shifts. • Review the communication between crews' shifts. • Review changeover time on production plan.
	Availability of materials and tools	Review the transportation of the raw materials and receiving materials from the previous process into job location.
	Interruption changeover task	Revise the interruptions to the operator while conducting changeover process.
	Material flow	Review material flow during changeover and identify any bottlenecks.
Quality	Safety on shop floor	Revise the safety requirements of cleaning and tidiness of shop floor.
Infra.	Manufacturing layout	• Review the layout during conducting the changeover process. • Review worker movement.

During the implementation of the conceptual model, firms have to consider changeover as a project for further improvement process. The role of CT during the implementation of this phase is to verify that the studied factors are implemented in the right place. Also, the middle level of management has a role to play in facilitating the success of the conceptual model implementation. This is because they are managing operations on a daily basis which are related to the shop floor activities.

Observation

The observation is considers an appropriate method for attending and noticing the changeover process. CT members can observe the current changeover process in order to implement the model in the right place. It is essential to identify the weaknesses and strengths of the current process during the implementation. Also, CT members can take visual pictures and participate in the process if that is required. During the model implementation, the researcher suggests using an observation sheet for identifying the time taken for each activity during changeover as shown in Table 4. It shows the task description, time of completed task, cumulative time and status of the first outcomes products. If a record of the observation sheet for every action is made during the implementation phase, this would be helpful to identify the weaknesses in the process and areas where most time is wasted.

Table 4. Observation sheet.

Observation Sheet				
Conducted by:	**Where:**		**Date and time:**	
Observer by:	**Changeover started:**		**Changeover finished:**	
Task No.	**Task description**	**Task completed**	**Cumulative time**	**Status of first output**

After the implementation (Phase 3)

This phase occurs after the implementation of the model in the firm. Any result that is achieved after implementation - whether positive or negative - has to be reviewed by the firm. Table 5 indicates the factors related to Phase 3, which need to be revised with middle management and CT for further improvement. The CT role is to improve and review the model implementation process with responsible departments.

Table 5. The relation of constructed factors with Phase 3.

Constructed factors		Phase 3
People	Personnel involvement	• Identify worker involvement in feedback loop and changeover improvement process with middle management. • Identify the level of worker in decision making for changeover process improvement.
Process	Speed up of set-up process	Revise and improve the changeover procedure frequently.
	Material flow	Review the material flow cycling of moving and queuing for set-up process.
Quality	Initiative for setup improvement	• Seek for improving set-up time and process by recording via video tape. • Implementing improvement methods, such as process mapping, 5S and Kaizen.
Infra.	Manufacturing layout	• Understand the manufacturing layout types and their impact on changeover improvement. • Review the die set-up layout/movement.

The following process needs to be undertaken after model implementation, as follows:

Documented feedback system

The firm has to support the documented feedback system for changeover process improvement between the shop floor worker, such as supervisor and operator, to engineers and production manager after model implementation. This feedback system can be used for identifying the problem and issues that most often occur during the changeover process.

Continuous improvement

After model implementation, the weakness of the current practice needs to be observed and discussed with the department responsible for further improvement. Moreover, CT has to arrange for a weekly

meeting in order to identify the current and next stage of improvement. The changeover process can be mapped for simplifying the identification of process improvement. It is necessary to implement the CEAT research tool after Phase 3 in order to evaluate the implementation of the current changeover process.

Sharing the result

The result of the model implementation has to be announced and shared at all plant department levels. This is because the responsibility of implementation has to draw on the initiative of the firm's departments. The firm can announced the percentage of success of the model and the annual saving of raw materials or financial resources. At the end, the model needs to be implemented again after capturing the required improvement on the shop floor. This improvement can be identified through CT observation and feedback system from the shop floor worker. Finally, the improvement of changeover after using the conceptual model can enhance the process in terms of changeover quality process, sustainability of best practice and reducing changeover time.