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SUMMARY OF THE PhD Thesis

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"Integrating Knowledge Management Concepts with Six Sigma Framework to Apply for Textile Manufacturing Processes"

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Content of the Thesis

Abstract

In the intensity and pace of today's cutthroat competitive business environment around the world, many companies have implemented Six Sigma like other continuous improvement methodologies to enhance the organizational performance by reducing variations from the process. In Six Sigma applications, both the success and failure experiences have been documented by the practitioners. As per their observations, it is very much important to access and use critical knowledge for a successful deployment of Six Sigma projects, which is often lost or inaccessible due to lack of proper knowledge management (KM) activities. The main aim of this research is to investigate the interactive phenomena of KM concepts with the Six Sigma deployment process, and how KM concepts including updated elements could be integrated in a structured, systematic and effective way with Six Sigma framework for project deployment. It was also an aim to unveil the advantages of the KM application within the Six Sigma projects deployment to the textile manufacturing process.

In this research, at first different existing approaches related to Six Sigma and KM integration are analyzed in order to indentify the leveraging effects. Then a structured integrated conceptual model; namely DMAIC- KM model has been proposed. An IT platform has also been developed for an effective KM procedure engaging different updated KM tools for six KM elements. Afterward, several Six Sigma projects have been executed through applying newly developed methodology aiming to enhance the projects performance. Additionally, the application impact of DMAIC-KM methodology has also been investigated through carrying out quantitative and qualitative survey within projects participants'.

The results from this study reveal that the Six Sigma projects performance has been significantly improved after using new methodology. During evaluating the application impact of new methodology, it is unveil that the quantitative and qualitative findings for the selected factors such as participants understanding, organizational benefits and the effectiveness of the applied DMAIC-KM methodology compared with other continuous improvement methodology, has also demonstrated positive impact on the Six Sigma project execution procedure.

From the above results, it can be concluded that the proposed DMAIC-KM methodology is an effective methodology, which integrates Six Sigma and KM concepts in a disciplined and structured manner. In respect to validation of the proposed methodology both from practical application and from participant's opinion, a positive impact on Six Sigma project has been achieved. So, this model would be used for further application in other organization for continuous process improvement. Moreover this study may offer some guidance to other organizations looking into utilizing the KM concepts for executing the effective Six Sigma projects in their own field.

Many organizations are trying to introduce KM concepts to enhance the Six Sigma projects performance. But all are not significantly successful due to lack of updated and structured model. The newly developed DMAIC-KM model has bridge those gaps through integrating updated KM tools within IT platform in order to use the created knowledge in every phase of DMAIC. On the other hand, existing Six Sigma and KM integrated approaches were applied in healthcare, aerospace engineering or automotive engineering process. But no application was found within textile manufacturing process. Therefore this study is a unique example, which demonstrates the application of KM within Six Sigma projects to the textile manufacturing process.

Keywords: *Six Sigma, DMAIC, Knowledge Management, Integrated Model, Project Performance, Textile Manufacturing, Application Impact.*

Chapter 1: Introduction of the Research

The Introductory chapter of this thesis starts with a brief Introduction of the present research followed by Problem Statement, Purpose of the Research, Theoretical Basis, Significance of the Study, Research Methodology, Assumptions of the present research, Limitations, Delimitations and ended with the Thesis Structure A brief description is given below:

- Six Sigma is a continuous quality improvement strategy for an organization that is being used in many industries during this time. In general, the Six Sigma is a process improvement methodology that reduces the defects of products, minimizes variations and improves capability in the manufacturing process. The objectives of Six Sigma are to increase the profit margin and improve financial gain through minimizing the defects rate of products. It also increases customer satisfaction and retention through production of the best class product from the best process performance (Pyzdek, 2003).
- Various researchers have documented the successful application of Six Sigma methodology in different areas such as automotive industry (Chen et al., 2005), small scale enterprises (Desai, 2006), manufacturing operations (Kumar et al., 2007; Tong et al., 2004) and services (Dreachslin and Lee, 2007; Kumar et al., 2008a). Along with success examples, there are some examples of failures in Six Sigma application, to assist in delivering improvements in organizations. The Whirlpool is one of the examples. Researchers opined that one of the possible factors for abovementioned failure is the lack of proper management and utilization of expertise knowledge, irrespective of its nature.
- On the other hand, for textile manufacturing, the product quality is essential and the variation in product is also a critical concern (Pande, Neuman, and Cavanagh, 2000a, p. 24). Unacceptable variation in textile products contributes a lot of defects which leads to higher production cost, less profit and customer dissatisfaction. The level of commitment to quality required to manufacture textile products is enriching day by day. In the intensity and pace of today's cutthroat competitive business world, many large textile manufacturing organizations have sought strategies such as TQM, balance scorecard, ISO certification and Six-Sigma to improve process and product quality (Taner, 2012). Some researchers have documented a number of initiatives regarding implementation of Six Sigma in textile manufacturing (Das et al, 2007; Mukhopadhyay and Ray, 2006; Karthi et al., 2013) using basic DMAIC or lean procedure. Moreover, Kumar and Sundaresan (2010) stressed that the textile industry is a field with a lot of variations and defects in it's processes. So, it is the ideal place for Six- Sigma application. But it is necessary to choose the right and innovative methods in order for Six Sigma application to be successful in achieving a significant process improvement. In that respect, KM is an important ingredient for application. The application of Six Sigma and KM integrated approach might be the right and innovative method to achieve the significant advantages from Six Sigma application.

➢ Research Objectives

The purpose of this research was to investigate the interactive phenomena of knowledge management concepts with the Six Sigma deployment process, and how knowledge management concepts including updated elements could be integrated with Six Sigma framework for project deployment. It was also an aim to unveil the advantages of the KM application within the Six Sigma project deployment. So the specific objectives were as follows:

- To develop an innovative conceptual approach integrating updated knowledge management elements with Six Sigma methodology after analyzing the existing approaches.
- To develop an IT based KM platform to leverage the newly developed methodology.

- To validate the new methodology through practical application within textile manufacturing processes.

➢ Research Methodology

Like all other researches, the results of the research presented in this thesis rely on the appropriate usage of a research methodology. Along with traditional academic research methodologies, i.e. quantitative and qualitative, an action research approach (Lewin, 1946, 1947) has also been used, which was very much essential for the practical research project. All the methodologies applied in different parts of the present research according to requirements. For instance,

The Quantitative method used;

- for calculating different statistical measures of process performance during Six Sigma project executions.
- for calculating the percentage of gain achieved from the deployment of new methodology.
- for interpreting data from questionnaire gathered from project participants feedback.

The Qualitative method used;

- for analyzing wide range of literature review in order to proposed a new model which integrates Six Sigma and KM concepts.
- for analyzing different types of KM tools in order to integrate within the IT platform.
- for analyzing the perceptions collected from participant's of the Six Sigma projects.

Finally, the Action research methodology used;

- for executing the Six Sigma projects within the textile manufacturing process. Where an "action research" start from an innovative idea generation followed by plan preparation for practical application and finally, unveil the truth through step by step action execution (Lewin, 1947)

➢ Structure of the Thesis

This Thesis is comprised of a total seven main chapters, spanning 231 Pages, with 81 Figures, 50 Tables, 4 Annexes and 201 Bibliographic references

The main heading of Chapter 1 is "Introduction to the Research", which is divided into ten sub headings. This chapter starts with a brief Introduction of the present research followed by Problem Statement, Purpose of the Research, Theoretical Basis, Significance of the Study, Research Methodology, Assumptions of the present research, Limitations, Delimitations and ended with the Summary of the Thesis.

Chapter 2 explained in detail the "Literature Review" related to the present research. The context of "Literature Review" explored into three main parts. In the first part, the Six Sigma deployment and its significant background has been provided. The second part includes a detailed discussion about the knowledge management that is most relevant to a study of Six Sigma. Last part of this Chapter contains the State of the Art review related to the integration of Six Sigma and KM.

Chapter 3 is concerned with the proposed new methodology, namely DMAIC-KM methodology. A detail background and motivation to develop new methodology has been described at the beginning of this Chapter. An extensive analysis has been done for existing Six Sigma and KM integrated model presented in the literature, which is justified the necessity of the newly proposed methodology. Afterward, the Architecture of the proposed methodology is presented. The tasks and tools for this methodology to be used are also outlined at the last section of this Chapter.

Chapter 4 provides a detailed description of an IT platform, which has been developed as a part of the present research for effective execution of newly developed DMAIC-KM methodology. In this Chapter, the selection procedure of updated elements for KM cycle has been described and then the Architectural base of the IT platform has been presented. In the last portion of this chapter, the selection of different KM tools for the IT platform has been evaluated by means of detail literature evident.

The Validation of newly developed methodology through a practical application has been presented in Chapter 5. This Chapter includes: application methodology, context of application and details description of Six Sigma project execution steps by using DMAIC-KM methodology. Most importantly, the KM procedure and its application in every phase of DMAIC have been explained clearly. The improvement of the project performance due to the application of KM has been calculated statistically. This Chapter ends with a brief conclusion regarding the outcomes of the executed projects, which supports the validation of DMAIC-KM methodology.

Chapter 6 provides the assessment of application impact of DMAIC-KM methodology on Six Sigma projects execution. The assessment has been carried out through quantitative survey, discussion with focused groups and Semi- structured interviews. The detailed execution procedure and findings from every approach has been depicted through either quantitative or qualitative presentation. All findings are critically analyzed to find the leveraging effects of DMAIC-KM methodology on executing Six Sigma projects.

Chapter 7 presents the Overall conclusions of the research, which comprises three parts. In the first part, a general conclusion of the study has been drawn. The personal contributions of the researcher within this research are outlined. Finally, the future research scopes/opportunities related to this study are also discussed.

Chapter 2: Literature Review

This Chapter reviews a wide range of literature related to the Origin and Back ground of Six Sigma quality management, different perspectives of Six Sigma quality management, Tools and techniques usually used for deploying Six Sigma projects and the main breakthrough strategy used for deploying Six Sigma projects. The Critical success factors and knowledge creation opportunities have also been identified from the literature. This Chapter also describes the concept of Knowledge, Knowledge Management (KM), Knowledge conversion techniques, different elements of KM, Tools and techniques used for KM based on the wide range of literature evident. Finally, the State of the Art literature has also been analysed, which integrates Six Sigma framework with KM concepts that existed in the available literature. The outcomes from the literature review are summarized as bellows:

- Six Sigma is a quality management program for enhancing process performance through reducing variations, which focuses on continuous and breakthrough improvements. Six-Sigma is used to improve the organizations products, services and processes across various disciplines including manufacturing, new product development, marketing, sales, finance, information systems and administration.
- Six Sigma has two major perspectives. One is statistical perspective and another is business perspective. From the statistical point of view, the term Six-sigma is defined as having less than 3.4 defects per million opportunities or a success rate of 99.9997% where sigma is a term used to represent the variation about the process average. From business point of view, Six Sigma is defined as a *“Business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customers’ needs and expectations”*.
- Six Sigma is a data-driven systematic approach. It uses the define, measure, analysis, improve, and control (DMAIC) methodology in order to improve the existing process and utilize design for six sigma method (DFSS) for developing new product (GE, 2004). There are many important statistical tools and techniques that are used systematically in every phase of DMAIC and DFSS in order to find the root cause of the problem and eliminate the problem through applying effective improvement solutions. Out of many, some important tools are: Voice of Customer,

SIPOC, Statistical process control, Process capability analysis, Measurement system analysis, Design of experiments, Quality function deployment, Failure mode and effects analysis, Regression analysis, Analysis of means and variances, Root cause analysis, Process mapping and so on.

- The organization builds a Six Sigma role structure for quality improvement through assigning different levels of roles and responsibilities to the experts for leading the continuous improvement efforts. The experts are designated as Champion, Master Black belt, Green Belt as a top down hierarchy.
- Different researchers have identified various critical success factors for Six Sigma deployments. But most common and important factors are: Management commitment and involvement, Understanding about the tools and techniques of Six Sigma methodology, Linking Six Sigma to business strategy, Linking Six Sigma to customers, Project selection, reviews and tracking, Organizational infrastructure, Cultural change, Project management skills, Liking Six Sigma to suppliers and human resources and Continuing Education and training of managers and participants. According to the different researchers and also ISO guide line on Six Sigma (ISO 13053-1, 2011) it was unveiled that the Knowledge Management is another key element of successful six sigma applications.
- In the literature, it was evident that all most every researcher opined that the DMAIC is the most important place where most of the new knowledge is created during gate review, during identifications of root cause and during problem solving activities. All those created knowledge can be shared and disseminated within the participants of the Six Sigma project teams.
- Knowledge is a difficult concept to define. Nonaka and Takeuchi (1995) define knowledge as the *justified true beliefs*. According to Pillania (2009) "Knowledge" is defined as a whole set of intuition, reasoning, insights, experiences related to technology, products, processes, customers, markets, competition and so on that enables effective action.
- Today, knowledge is known as a key property and a valuable asset that is the base of constant development and the key of permanent competitive advantage of an organization. In the current climate of increasing global competition, there is no doubt about the value of knowledge and learning in improving organization competence (Preto and Revilla, 2004). Organizations need to consider adaptive and intelligent strategies of knowledge management processes to succeed in today's competitive environments (Kangas, 2005).
- Researchers identified two main types of knowledge: tacit knowledge and explicit knowledge. Tacit knowledge is that stored in the brain of a person. Explicit knowledge is that contained in documents or other forms of storage other than the human brain. Explicit knowledge may therefore be stored or imbedded in facilities, products, processes, services and systems. Both types of knowledge can be produced as a result of interactions or innovations (Skyrme, 2002). Nonaka (1997) mentioned the four modes for conversion of knowledge from one form to another such as i) socialization (from individual tacit knowledge to group tacit knowledge), ii) externalization (from tacit knowledge to explicit knowledge),iii) combination (from separate explicit knowledge to systemic explicit knowledge), and iv) internalization (from explicit knowledge to tacit knowledge).
- Knowledge management (KM) may simply be defined as doing what is needed to get the most out of knowledge resources.KM is viewed as an increasingly important discipline that promotes the creation, sharing, and leveraging of the corporation's knowledge. Knowledge management enabler's factors are essential infrastructure for increasing the efficiency of knowledge management activities. The most important knowledge management enabling factors are technology, structure and organizational culture (Gold et al, 2001).Different scholars have

identified different elements for knowledge management. But researcher have indentified six important updated elements, such as: i.) Knowledge creation, ii) Knowledge capture, iii) Knowledge organization, iv) Knowledge storage, v) Knowledge dissemination and vi) Knowledge application., which is important for effective KM procedure

- Literature review also identified some important tools that are used for managing organizational knowledge properly. Those tools are: Document Management, Knowledge Map and Skills Management, Information Database and Enterprise information portals and Communities of Practice. Recently, researchers discovered the great advantages of communities of practices. World renowned companies like Raytheon, Compaq (now HP), Ford, Halliburton also established communities of practices with Six Sigma initiatives and gained a lot of success.
- During analysis state of the art literature related to the KM and Six Sigma integration, it was found that some models are all ready available, such as: Raytheon Six Sigma model, TEKIP Model, Process-based Knowledge Creation and Opportunities Model, Knowledge flow model in Chinese Six Sigma Teams, SECI/SIPOC Continuous Loop Model, Six Sigma, KM and Balanced Scorecard integration model
- The literature also identified numerous ways in which knowledge management can be integrated with Six Sigma approaches. But in the existing available initiatives, the KM concepts are integrated either partially or scattered way with basic or modified Six Sigma approach. The integration with DMAIC, which is main problem solving methodology of Six Sigma, is not evident.

Chapter 3: Developing new model through integrating DMAIC and KM

In this Chapter, the existing models have been critically analyzed considering their leveraging effects and identified the gaps and scopes which lead the necessity of developing a new model. Then a newly proposed conceptual model has been described which integrates DMAIC and KM concepts. The methodology, tools and techniques to be used for the proposed model have also been discussed.

➢ The Proposed conceptual model

The main objectives of the proposed model are i) to integrate KM concepts with Six Sigma quality management methodology, ii) to execute Six Sigma projects by using DMAIC breakthrough and recommended tools in order to improve the organizational performance, and iii) to enhance the Six Sigma project performance by using KM methodology.

➢ Architecture of DMAIC-KM model

The proposed DMAIC-KM model (figure 1) is an integrated conceptual model, which is developed as a part of Six Sigma quality management system that consists of tasks, tools, activities, knowledge managing IT platform and project performance evaluation methodology. All those items are networked in a horizontal platform towards connecting the knowledge management procedure with quality management methodology. This model will be based on the DMAIC problem solving steps and required three key factors to successfully carry out the management procedure.

These factors are:

Factor 1: DMAIC breakthrough should be performed for enhancing the product quality.

Factor 2: The created knowledge should be identified in every step of DMAIC and stored while the breakthrough is performed.

Factor 3: The identified knowledge should be managed properly for each step and will be used for the immediate next step in order to achieve a better performance. The DMAIC-KM integrated model has been developed with these three factors in mind. The proposed model is shown in Figure 1.

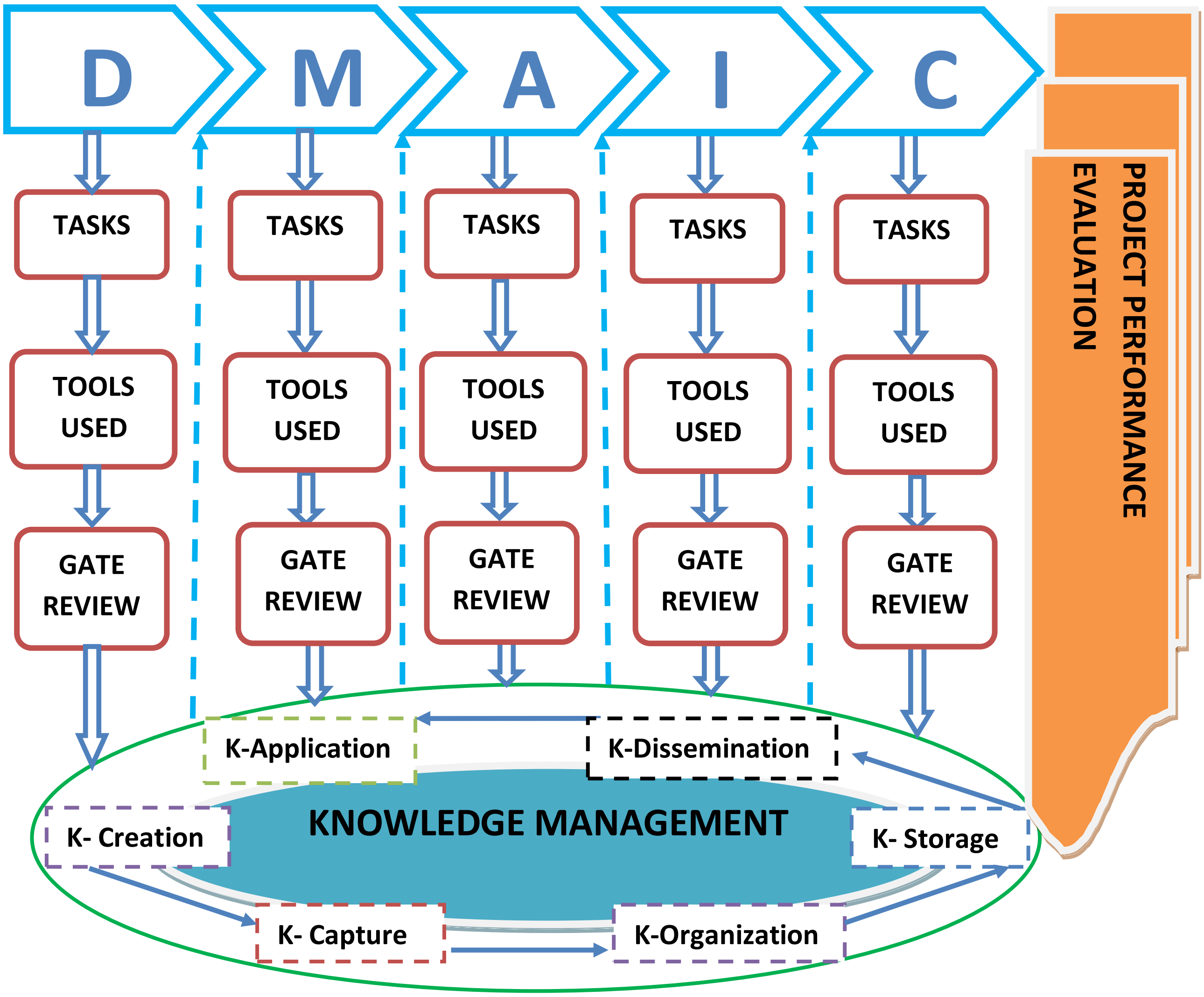


Figure 1: Proposed DMAIC-KM model (Baral and Kifor, 2013)

As shown in Table 1, the proposed model is composed of seven stages. All those stages are explained in detail in the following section.

Stage 1: The purpose of the first stage of proposed methodology is to execute the DMAIC breakthrough step by step according to the recommended Six Sigma guideline (ISO 13053-1&2, 2011). In this stage, Six Sigma project should be defined according to the voice of the customer and its execution will be performed through Measure, Analyse, Improve and Control phases.

Stage 2: In this stage, all the specific tasks of different steps of DMAIC phases should be identified according to the recommended guideline from ISO.

Stage 3: The aim of this stage is to use the tools according to the tasks for every step of DMAIC phases, as Six Sigma management system recommended for every task. With the help of those tools, the knowledge materials should organize what has already been developed by the tasks completed within the DMAIC phases.

Stage 4: The main activities of this stage are to review the gate when a project is deemed to have finished one phase and about to move onto the next. A review panel comprising the Six Sigma project team and any other interested manager, as an observer, should be convened to conduct the review. A copy of all the relevant data and analysis and reports should be circulated to the panel in advance of the meeting. The project team leader who is running the project should give a short presentation of the work to date and respond to all questions from the other members of the panel. The Project Sponsor shall initiate the gate review when the panel are agreed that the work has been done properly through intensive analyses and the conclusions are correct. Then the project may proceed to the next phase

Table 1: Stage wise activities and methodology for DMAIC-KM model

Stages	Activities	Methodology
Stage 1	Outline for DMAIC breakthrough execution.	Six-Sigma guideline
Stage 2	Identification of Tasks for every phase of DMAIC	ISO Checklist for Six Sigma
Stage 3	Using Tools based on Tasks	Recommended Six Sigma tools for every step
Stage 4	Gate review to overlap the created knowledge among participants	Workshop, Brainstorming, Discussion and Socialization
Stage 5	Knowledge management	Six- Steps of KM methodology (Through knowledge managing IT platform)
Stage 6	Knowledge reuse for next phases	Using Total Recall Data Base
Stage 7	Final evaluation of project performance	Process capability calculation Survey in order to gather participants' perception

Stage 5: This stage is a common stage, which should spread within all phases of DMAIC methodology. In this stage, the hidden knowledge from every phase should be unveiled through knowledge management procedure containing six steps like: i) K-creation ii) K-capture, iii) K-organization, iv) K-storage, v) K-dissemination and vi) K-application. Here first step (K-creation) should be functionalized after stage 4 and the final step (K-application) should be the input of the immediate next phase of DMAIC. During this procedure, all created knowledge will be identified according to its characteristics (Tacit/Explicit) with the help of an IT platform and convert the knowledge from tacit to explicit or vice versa by using Nonaka's four modes of knowledge conversion. All those activities should be done in order to properly organize and store the created knowledge.

Stage 6: The Goal of this stage is to reuse the created explicit knowledge from every phase to immediate next phase of DMAIC from a Knowledge storage data base called Total Recall database. For instance, the created knowledge from Define phase should be identified, organized, converted, stored, and managed properly through KM procedure and then available required knowledge should be used for Measure phase for better execution. In this way every phases will be executed to complete the entire project.

Stage 7: Upon completion of the above stages, finally, the project performance evaluation will be done through calculating the process capability and gathering the participants' perceptions.

➢ Tasks and Tools to be used for DMAIC breakthrough of new methodology

The most important and formalized improvement methodology for Six Sigma management is DMAIC methodology. This methodology can enable real improvements and real results by working equally well on variation, cycle time, yield, design and others through some guided activities (Park, 2003). The international standard organization for Six Sigma (ISO13053-1, 2011) has mentioned the specific tasks for every step of DMAIC, which should be maintained properly. The Systematic organization of those tasks will enable to complete the Six Sigma project effectively. So, the ISO recommended tools should be used during performing DMAIC breakthrough of DMAIC-KM methodology.

Chapter 4: Proposed IT platform for DMAIC-KM methodology

This Chapter describes an IT platform which is developed for newly proposed DMAIC-KM methodology. The Architectural base, KM elements, KM cycle and KM Tools to be used for effective KM activities have also been discussed. The summary of this Chapter is presented below:

- According to the researcher's opinion, Information and communication technology plays a vital role in knowledge management. It is an essential part of the codification strategy because of its utilization of knowledge storage data bases and also of the personalization strategy for facilitating communication between individuals. The main aspect is establishing the correct amount of ICT (Hasen, Nohria and Tierney, 1999) required based on industry levels and knowledge strategy so that the investment to return balance is a favourable one. Thus, the researchers have given emphasize to develop an IT platform for DMAIC-KM methodology, which is describe in the following section in brief.

➢ KM Elements and KM Cycle

Different researchers have proposed different KM elements according to their end uses. From wide range of literature review, we have selected six updated elements for the KM cycle of newly proposed DMAIC-KM methodology. Those elements are: i.) Knowledge creation, (ii) Knowledge capture, (iii) Knowledge organization, (iv) Knowledge storage, (v) Knowledge dissemination and (vi) Knowledge application. The Cycle is organised in a sequential order step by step. All the selected elements/ processes have their own activities as presented in the table 2.

➢ Architectural base of the IT platform

In order to design the IT platform for the DMAIC-KM methodology, the Moodle (Modular Object-Oriented Dynamic Learning Environment) has been taken as a base platform. The Moodle is a well-known and widely used free software e-learning basic platform, which can be modified and prepare a new platform according to the end uses. Through modifying the basic Moodle platform, new KM platform has been developed by introducing the required KM elements (figure 2).

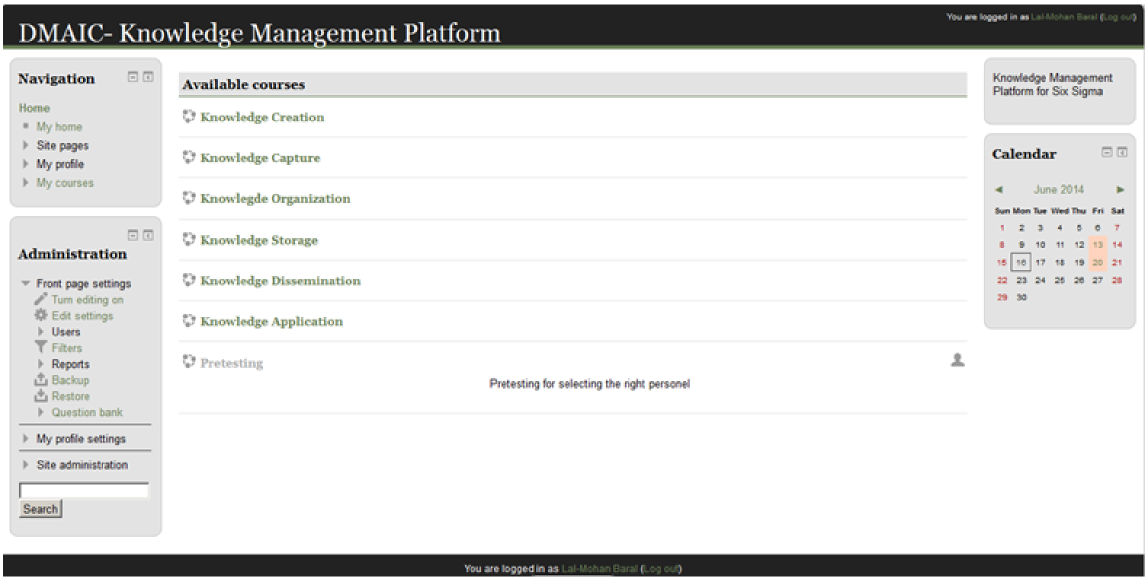


Figure 2: Included main courses of DMAIC-KM platform

➢ Tasks and Tools for DMAIC-KM IT platform

During designing the IT platform, a numerous number of soft tools have been integrated with every step of knowledge cycle to perform the KM activities properly. The Step wise activities of KM elements and integrated tools within the cycle are presented in the table 2.

Table 1: Step wise activities of KM elements and integrated tools within the cycle

Order of Elements	Name of the Process	Activities	Tools and Techniques
First	Knowledge Creation	Knowledge should be created based on the activities and tools used within the DMAIC phases of Six Sigma project.	Social forum, Chat room, News forum, Platform for creative dialogue, Communication Network, Data base, Document Reading and Rating, Experience sharing
Second	Knowledge Capture	All created knowledge should be captured from various available sources.	Story writing, Mailing network with experts and partners, Concepts Maps, Context based reasoning
Third	Knowledge Organization	All knowledge should be organized, which has been already captured.	Document management (with rating system), Data base (according to source and communities), Rating sheet
Fourth	Knowledge Storage	After organizing, the knowledge should be stored in a data base.	Organizational memory (with limited access through password technology)
Fifth	Knowledge Dissemination	Knowledge should be disseminated/ shared within the participants.	Knowledge exchange forum, Reports/ Publications, Best practice database, Lessons learned systems, Expertise locator systems, Training course/ workshop, Communities of practice
Sixth	Knowledge Application	Finally, the explicit knowledge should be extracted from an Organizational memory for reuse in the immediate next phase.	Total Recall Database

Chapter 5: Practical application of proposed DMAIC-KM methodology

This Chapter describes the detail practical application of proposed DMAIC-KM methodology within the textile manufacturing process and it’s evaluations through process performance calculation. The application methodology, context, procedure and process improvements calculation are described below:

➢ Application method of the DMAIC-KM integrated model

In this research, at first the DMAIC-KM integrated methodology has been applied while Six Sigma projects were executed in an airbag manufacturing process in order to enhance the organizational performance. Afterwards, the improvements of project performance and application impacts of DMAIC-KM methodology have been investigated through quantitative and qualitative analysis. The Step wise research methodologies are described below:

- ***Six Sigma projects execution***

The Six Sigma projects has been executed using DMAIC-KM methodology under a pilot project entitled "**Six Sigma projects execution in textile manufacturing by using DMAIC-Knowledge Management model"** within the case company TAKATA Sibiu SRL by applying the "collaborative action inquiry" (Lewin, 1946; Westlander, 1999; Cronemyr, 2007) methodology, where collaborative partners were University and case company.

Five Six Sigma projects have been selected for practical execution under the umbrella of the proposed pilot project. All five projects were selected by identifying five real life problems faced by the case company during the production process. A prioritization matrix was then applied to rate the potentiality of all those projects. Afterwards, first, third, fourth and fifth ranking potential projects were selected for the application of DMAIC-KM methodology and second ranking potential project was selected only for the application of the DMAIC methodology. All those Six Sigma projects were involved in the improvement of an airbag manufacturing process. The project coordinator has conducted the research with the help of five technically expert mentors from case company and another five team members for each group from University. The researchers have followed the DMAIC break through and KM cycle step by step (presented in the chapter 3) and executed the projects towards a logical solution of the problems.

- ***Project performance evaluation***

After completing both of those selected projects, the performances have been evaluated quantitatively and qualitatively by using the following techniques.

i) By comparing the initial and final capability of the process of the executed projects.

ii) By assessing the impact of DMAIC-KM application through the following approaches:

   a) A survey questionnaire

   b) Discussion with the focused group and,

   c) Semi-structured interviews with the project team members.

➢ Context of application

The case company is a technical textile manufacturing unit, which is producing different types of safety components for automobiles, specially airbags, seatbelts, and steering wheels and so on. This company was established in 2002 and located in Sibiu, Romania as one of the sister concern of TAKATA Corporation, which has started its journey since 1933 in Japan. The case company employs approximately 1500 people belongs to the TAKATA Corporation, which has more than 36000 employees distributed on the 56 plants in 20 countries around the world. The main product of the case company is airbag for cars that exported to different world's leading automakers in Europe, the USA and Asia. The company has earned a good reputation and developed long-term relationship with the branded customers for using continuous improvement initiatives like Six Sigma, 5S, Kaizen, Kanban, Lean management, PDCA, Just in Time, Fi-Fo (First in and First out), Andon etc., which have been applied for international standards of quality to products, process and to the management system. The company has started to implement basic Six Sigma project since 2008 in order to solve the manufacturing problems. They have also Six Sigma experts like, Champion, Black belt and Green belt holders. Though the case company is data driven and well structured, it has been facing some real life problems in the manufacturing area due to lack of knowledgeable worker and experts. So, in order to solve the real life manufacturing problems as well as to become a knowledge based organization, the company was interested in implementing DMAIC- KM methodology within the Six Sigma project.

- **Case study on most potential project (Project no. IV)**

The Define phase

In this phase, the project related real life problems have been clarified, which deals with the variations occurred during the production of perimeter seam in airbag cushion manufacturing process. More specifically, the perimeter seam of airbag cushion should be produced maintaining same seam width (the same distance from the edge of pattern) all around the perimeter. But, a wide range of variations have been observed in the perimeter seam width (Sewing reserve), which also led to variations of stitch density (stitch/cm) along the seam stitch line. The perimeter seam of airbag cushion has been produced in the sewing section through sewing operation. In our case, Automatic Lock Stitch (ALS)/Manual Lock Stitch (MLS) machines were used for this sewing operation. In order to sew the perimeter seam, both parts of airbag cushion patterns were set properly inside the template and started the sewing operation following a guided slot, which controls the path of perimeter seam. After completing this process, some airbags were rejected due to the variations of sewing reserve of perimeter seam. The main objective of our Six Sigma project was to reduce these sewing reserve variations of perimeter seam and enhance the process performance. Upon executing the Define phase of our Six Sigma project, some ISO recommended selective tools have been used to complete the specific tasks step by step. The used tools for this phase are VOC, Project Charter, Gantt chart, Risk analysis, SIPOC, Process flow diagram and Define gate review.

- **Application of the KM cycle for the define phase**

According to the proposed DMAIC-KM model, the Six steps (Creation, Capture, Organization, Storage, Dissemination and Application) of KM methodology had been applied after completing the gate review session in order to indentify, convert (if required) and disseminate the created knowledge from the define phase aiming to reuse the extracted explicit knowledge to the next phase (Measure phase) of DMAIC application.

The Measure phase

The main objective of measure phase is to identify the actual reasons of the project related problems that show the current process reality (Orbak, 2012). The activities involved in this phase are to measure and highlight the critical variables or influential factors that are closely related to the problems and by which the process improvement is affected. The measurements of those criteria should be assumed through practical data and logical argument in this phase. Through applying this phase, first-hand data were obtained from the related process along with samples for proper analysis meant to achieve a better outcome. In our project, some important tasks and tools have been used for the measure phase. The Tools used for measure phase are: Brainstorming, Prioritization matrix, Data collection plan, Determination of Sample size, MSA, Data collection template, Capability Indicators calculations and Measure gate review.

Samples selection

In order to collect the data, a total of 50 samples (50 airbags) have been selected on a random basis. To confirm an un-biased selection, five airbags have been selected from each sewing line randomly.

Identifying critical points

Prior to collecting data, three critical points (figure 8) have been selected on the sewing line of the perimeter seam to measure the sewing reserve for all 50 Airbag samples. In order to establish critical points with the highest defect frequency, a QA 010 check sheet was used. The identified critical points are shown in figure 3, where all the measurements have been done, in order to gather the data.

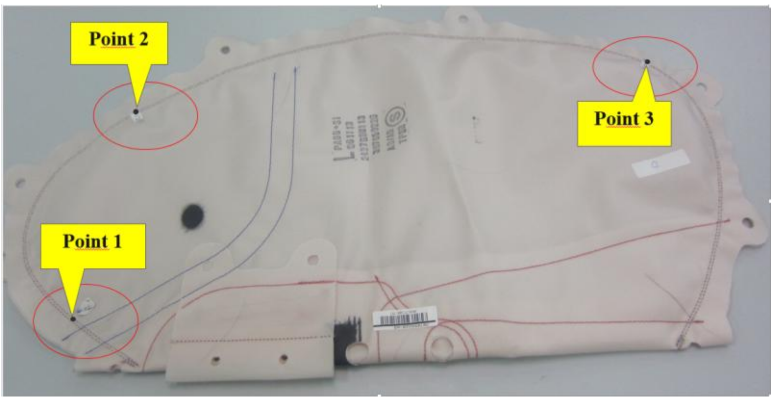
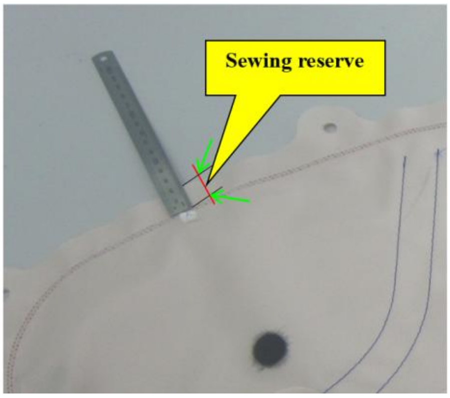


Figure 3: Selected critical points on the sample for data collecting

After selecting the samples data has been collected by using MSA tested methods and instruments such as ruler and stitch gage template as shown in the figure 4 and 5. After collecting Data, all data has been computed in order to identify the process performance for both sewing reserve and stitch density**.**



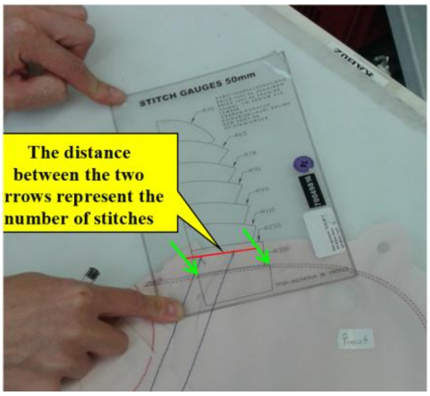


Figure 4: Sewing reserve measurement

Figure 1: Stitch density measurement

➢ Calculating the Process Performance for Sewing Reserve (SR) and Stitch Density Measurements

In order to calculate the process performance, the important statistical measures have been computed through the data obtained from all selected 50 samples (Airbag). All the statistical measures are presented in the table 3.

All the required statistical measures have been calculated for all three (3) critical points as shown in table 3. According to the calculated measures it can be found that the sewing reserve process capability (Cpk) values are 0.672, 0.344 and 0.403931 for critical points 1, 2 and 3 respectively. Additionally the Cp values of those 3 consecutive points are 1.2075, 1.0697 and 0.721305. But the indices of process capabilities, Cp and Cpk are desired to be above 1.33 in general for process precision and adjustment (Montgomery, 2005). So, this process is not under control and process capability is insufficient. In order to control this process, variation must be decreased and process capabilities should be compared after implementing the improvement solutions.

Like Sewing reserve capability, the data collected from Stitch density has been computed and different statistical measures have been calculated in order to identify the process capability. All the calculated data are depicted in table 3.

Table 3: Statistical Data of Sewing Reserve (SR) and Stitch Density (SD) Measurements (before improvements)

Statistical Measures	**Critical Points**					
	01		**02**		**03**	
	SR	**SD**	**SR**	**SD**	**SR**	**SD**
X min	19	14	20	14	16	15
X max	23	17	24	17	22	17
R	4	3	4	3	6	2
Mode	21	15.5	22	15.5	19	16
Mean	21.2	15.6	21.9	15.6	18.6	16
Standard deviation (σ)	0.82814	0.5979	0.93481	0.5771	1.386377	0.6060
X-3σ	18.74558	13.8461	19.1355	13.8286	14.42087	14.1817
X+3σ	23.71442	17.4339	24.7444	17.2913	22.73913	17.8182
UCL	22.6	19.75	22.6	19.75	22.6	19.75
LCL	17.2	15.25	17.2	15.25	17.2	15.25
LSL	16.9	15	16.9	15	16.9	15
USL	22.9	20	22.9	20	22.9	20
k	0.44	0.74	0.68	0.77	0.44	0.60
Cp	1.2075	1.3936	1.0697	1.4439	0.721305	1.3749
Cpk	0.672	0.3568	0.344	0.3234	0.403931	0.5499
kεl	5.23	1.07	5.39	0.97	1.21	1.65
kεu	2.02	7.29	1.03	7.69	3.12	6.60
εl (%)	0.00	14.23	0.00	16.60	11.31	4.95
εu (%)	2.17	0.00	15.15	0.00	0.00	0.00
Precision	**NOK**	**OK**	**NOK**	**OK**	**NOK**	**OK**
Adjustment	**NOK**	**NOK**	**NOK**	**NOK**	**NOK**	**NOK**

The calculated data presented in the table has revealed that the process capability values Cpk for the stitch density of our selected critical points 1, 2 and 3 are 0.3568, 0.3234 and 0.5499 respectively, which is very low. And the chart shows that the adjustment of the process is not ok for all three points. But the calculated values for Cp are 1.3936, 1.4439 and 1.3749 for point 1, 2 and 3 respectively. According to the requirements, Cp is ok for all three points. Like sewing reserve measurements, the control charts and capability charts have also been prepared for stitch density measurements to get the clear idea about the present process condition.

- **Application of the KM cycle for the measure phase**

In this step, Like define phase, the Six steps (Creation, Capture, Organization, Storage, Dissemination and Application) of KM methodology had been applied after completing the gate review session in order to indentify, convert (if required) and disseminate the created knowledge from the measure phase and after all to reuse the extracted explicit knowledge to the next phase (Analyze phase) of DMAIC application.

The Analyze phase

After completing the measure phase of DMAIC breakthrough, the analyze phase has been started intending to analyze the data and to investigate the basic reason of our targeted problem (Chang et al., 2012). In order to examine the potential variables and to find the most important cause or root of the defects, the logical or statistical analysis has been done in this phase. To achieve that goal, some important tasks and tools has been used such as: Cause and Effect diagram and Five (5) Why? Analysis and Analyze gate review.

Through the Cause and effect analysis, the project team indentified various parameters as the cause of sewing reserve variations. The project teams had prioritized the main causes for our selected problems as presented below:

- The Sewing reserves presented a lot of variations and potential problems can occur due to uneven geometry of the sewing shape in the sewing template design.
- Inexperienced workers can cause in-correct placement of the template during the sewing of the perimeter seam.
- Incorrect panel assembly may happen and the templates were not placed into all adjusting pins.
- The differences between part sizes originated from cutting operations and will increase until the sewing process is started.
- In sufficient pressure on template made by Operator during sewing, that may cause the movements of the upper layer due to higher thickness on the layers inside the cushion.

After getting ideas about the above important causes, the project team decided to get deeper knowledge regarding the origin of the causes. To achieve that goal, another effective tool called 5WHY has been used by the team members.

Finding the root causes of identified problems

In the process of root cause identification for sewing reserve variations, the “5 Why?” analysis has been done. The techniques of using this tool includes, the team members should ask “Why” five times and try to find the answer regarding the reason behind the identified problem (sewing reserve variations in our case).

After completing all the selected steps of the Analyze phase, several root causes for sewing reserve variations have been found. All the root causes are presented below:

I) Lack of flexibility in Sewing template design
II) User-unfriendly template adjusting mechanism during perimeter sewing
III) Defective pattern cutting of airbag cushion.

➢ Application of the KM cycle for the analyze phase

Like Define and Measure phase, the Six steps (Creation, Capture, Organization, Storage, Dissemination and Application) of KM methodology has been also applied in this phase after completing the gate review session in order to indentify, convert (if required) and disseminate the created knowledge from the Analyze phase and to reuse the extracted explicit knowledge to the next phase (Improve phase) of DMAIC application.

The Improve phase

The purpose of the improvement phase is to generate a set of probable solutions in order to eliminate the root cause/ causes that are identified in the analyze phase. The main goal of this phase should be to improve the process performance after applying those solutions. Some systematic tasks and important tools that have been applied in order to deploy this phase are: Brainstorming, Prioritization matrix and other decision-making methods, Project planning tools (Gantt chart/ Project schedule), Implementation tools, Cp and Cpk calculation, Process capability diagram and Improve gate review.

Generating solutions ideas/ redesign

Based on the identified root causes of the selected problem, the project team has proposed some solutions through active brainstorming activities that had been performed by the team members. The proposed solutions are listed below:

- Modifying the seam geometry according to the deviation found in the sewing reserve.
- Modifying the sewing template fixation.

- Mounting hinges on the sewing template.
- Increasing the distance from the hinges to the shape.
- Training the Operators to grip the template during lower bobbin winding while sewing
- Solving the pattern deviation during cutting.

Implementation of solutions

According to the plan for implementing first improvement action, the pattern design department has modified the seam geometry based on the identified deviation of the seam width. The sewing line of the perimeter seam has been newly defined through a red line as presented in the figure 6.

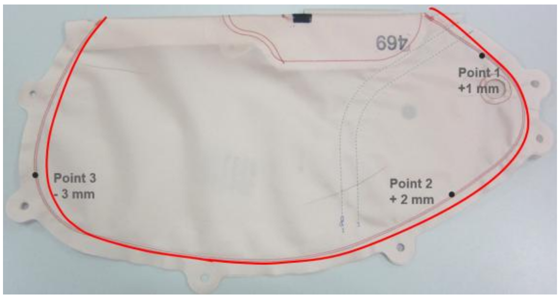


Figure 6: Modifying the seam geometry according to the deviation

As showed in the figure 6, point 1 and point 2 on the sewing line have been moved 1 and 2 mm outside from the previous line respectively. On the other hand, point 3 on the sewing line has been moved inside 3mm from the previous line and a new line has been drawn for the modified pattern. In line with the development an improvement plans, the project team has prepared an As-Is and To-Be arrangements for the pattern design of Air bag cushions. The immediate next improvement action has been performed by the Tooling department. The responsible has mounted two hinges to the sewing template as shown in figure 7.

Figure 7: Mounting hinges on the template

The newly introduced hinges made the sewing template user friendly and flexible to adjust with the pins. Then the Human resource department has provided Training to the Operators with the help of project team members regarding the modified technology, and also taught the technique to grip the template during lower bobbin winding at the time of sewing. As a next action, the Tooling department has shown the procedure of how to adjust / fix the template during sewing. In this case, the alignment of the upper and lower part of the template can be carefully handled and fix the adjusting pins. Next action has been performed by the pattern cutting department. All the safety measures have been taken carefully and tried to maintain the precision of the shape for both parts of the airbag cushions during pattern cutting.

Calculating new process capability

After implementing all improvement solutions, the production has continued for two days and then data has been collected from fifty samples, same as the measure phase in order to calculate the new process capability and also to observe the effectiveness of the implemented solutions. The statistical measures for new process are depicted in table 4. The Data presented in the table 4 revealed that the sewing reserve variations had been dramatically reduced and process capability indices of Cp and Cpk had been improved for all three critical points, which is numerically more than 1.33 for every point. The precision and adjustment of the process has shown OK for all three critical points. From data it can be seen that the numeric value of stitch density process capability indices Cp and Cpk are also higher than 1.33, which confirms that the process is under control. The precision and adjustment are also ok for all three critical points.

Table 2: Statistical Data of Sewing Reserve (SR) and Stitch Density (SD) Measurements (after improvement)

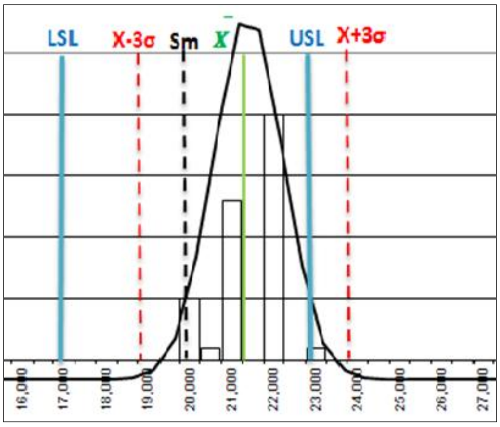
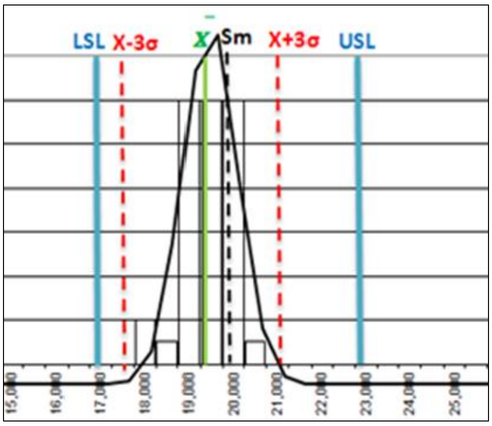
Statistical Measures	**Critical Points**					
	01		**02**		**03**	
	SR	**SD**	**SR**	**SD**	**SR**	**SD**
X min	18.0	17	19.0	16	18.0	17
X max	20.5	19	22.0	19	21.0	19
R	2.5	2	3	3	3	2
Mode	19.25	18	20.5	17.5	19.5	18
Mean	19.3	17.6	20.1	17.5	19.5	17.5
Standard deviation(σ)	0.6028	0.5746	0.6878	0.6141	0.6267	0.6144
X-3σ	17.5216	15.8561	18.0166	15.67764	17.6299	15.6566
X+3σ	21.1384	19.3039	22.1434	19.36236	21.3901	19.3434
UCL	22.6	19.75	22.6	19.75	22.6	19.75
LCL	17.2	15.25	17.2	15.25	17.2	15.25
LSL	16.9	15	16.9	15	16.9	15
USL	22.9	20	22.9	20	22.9	20
k	0.19	0.032	0.06	0.008	0.13	0.00
Cp	1.6589	1.4502	1.4539	1.3569	1.5957	1.35622
Cpk	1.344	1.4000	1.3667	1.3461	1.3882	1.35622
kεl	4.03	4.49	4.62	4.10	4.16	4.07
kεu	5.92	4.21	4.10	4.04	5.41	4.07
ε**l** (%)	0.00	0.00	0.00	0.00	0.00	0.00
ε**u** (%)	0.00	0.00	0.00	0.00	0.00	0.00
Precision	**OK**	**OK**	**OK**	**OK**	**OK**	**OK**
Adjustment	**OK**	**OK**	**OK**	**OK**	**OK**	**OK**

Application of the KM cycle for the improve phase

After application of proposed KM methodology, some important explicit knowledge is also identified during this step in order to be reused for the next phase (control phase) of DMAIC.

Comparing the process capability chart

For better understanding of the process improvements, the control charts has been prepared for all those three critical points individually both for Sewing Reserve and Stitch Density. The control charts has been compared between before and after improvement as presented in the figure 8 and 9.

<table>
<tr><th>Critical Point 1 (Before improvement)</th><th>Critical Point 1 (After improvement)</th></tr>
<tr><td>
</td><td>
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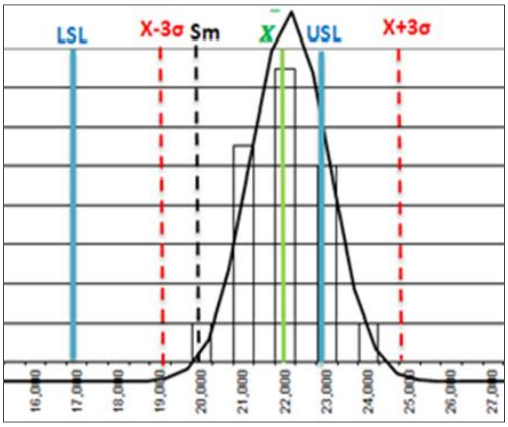
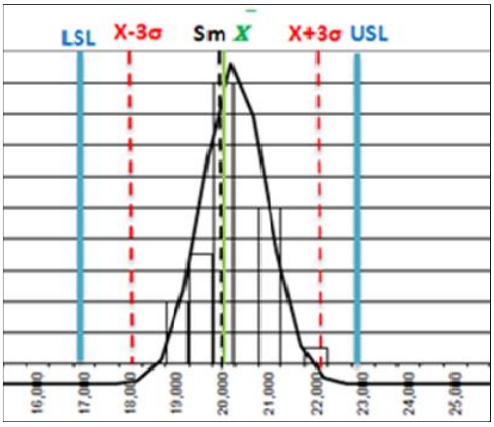
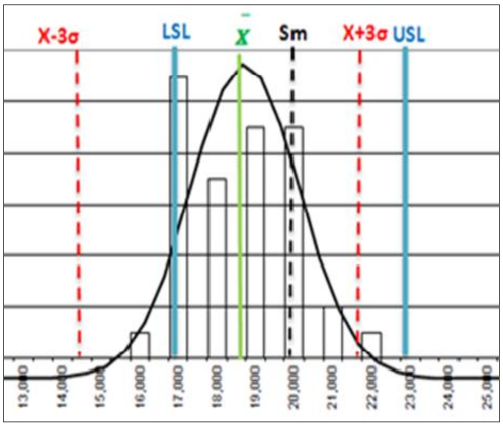
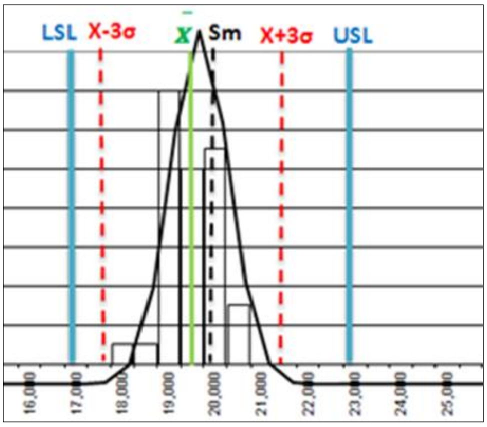
<tr><th>Critical Point 2 (Before improvement)</th><th>Critical Point 2 (After improvement)</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Critical Point 3 (Before improvement)</th><th>Critical Point 3 (After improvement)</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Figure 8: Comparison for Sewing Reserve process capability

<table>
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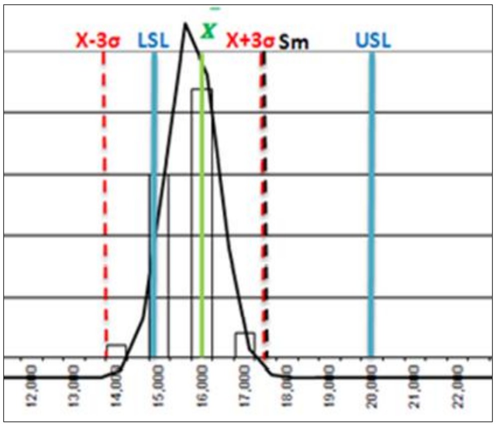
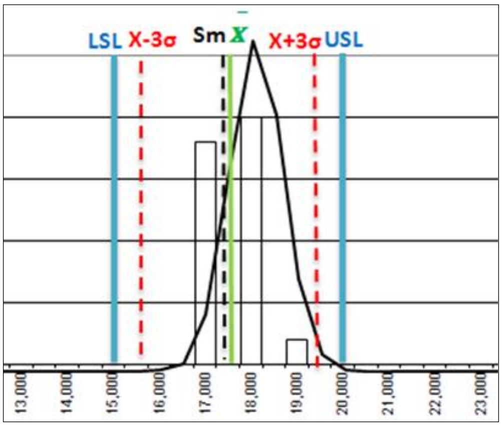
<tr><td>
</td><td>
</td></tr>
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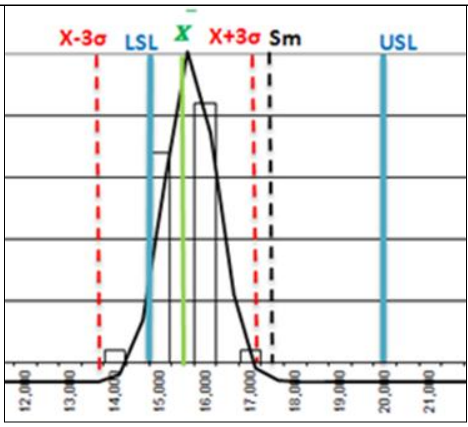
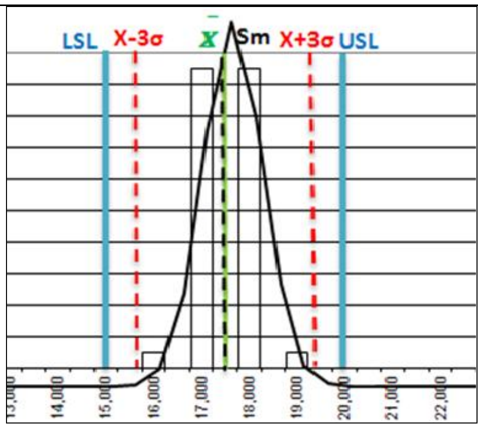
<tr><td>
</td><td>
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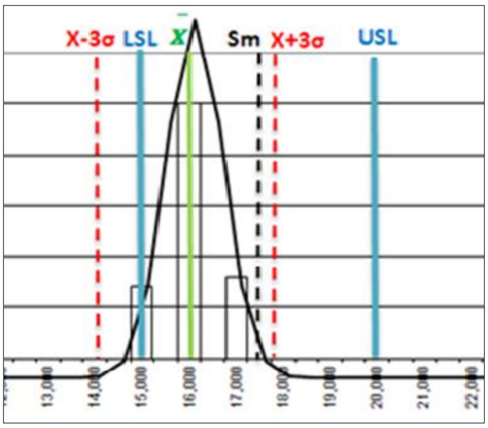
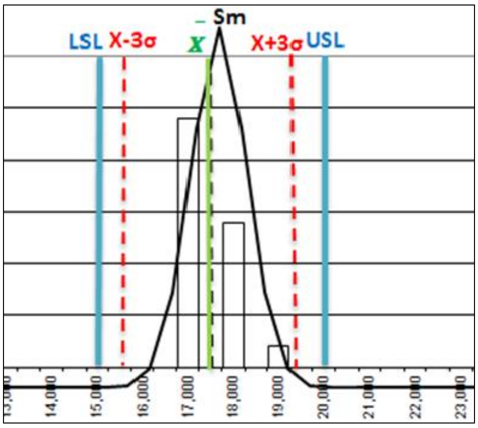
<tr><td>
</td><td>
</td></tr>
</table>

Figure 9: Comparison for Stitch Density process capability

The Control phase

The control phase is the last phase of our implemented DMAIC methodology. In this phase the project team has ensured that the improvement achieved from our implemented solutions are maintained and controlled consistently. In order to keep a consistent evaluation, this phase is carefully performed. After implementing the improvement solutions and system integration, the overall process performance had enhanced. So, if a close supervision can be maintained then the performance of the production process will constantly be enhanced and the company will enjoy the benefit achieved by the Six Sigma projects and will achieve customer satisfaction. To ensure those activities the project team has performed some tasks and used some selective tools, those are: Control plan, Drafting process procedure, Training, Calculation of gains achieved through Process capability calculation and Control gate review.

➢ **Application of the KM cycle for the control phase**

After completing the gate review of Control phase, the KM methodology has also been applied like other phases and explicit knowledge has been extracted for dissemination and re-use in the project performance evaluation and also for organizational learning.

Calculating the process improvements

In order to evaluate the process improvement of our project, which has been executed by using the DMAIC-KM methodology, the Cp and Cpk values are compared in between, before and after implementing the improvement solutions. And finally, the Percentage of gain has been calculated for documenting the achievement. The achievements are presented in the table 5 and 6.

Table 3: Assessment of the production process efficiency through improvement

Process factors	Critical points	Process measures	Before improvement	After improvement	% of gain
Sewing Reserve	01	Cp	1.2075	1.6589	37.38
		Cpk	0.672	1.3440	100
	02	Cp	1.0697	1.4539	35.91
		Cpk	0.3440	1.3667	297.29
	03	Cp	0.7213	1.5957	121.22
		Cpk	0.4039	1.3882	243.69
Stitch Density	01	Cp	1.3936	1.4502	4.06
		Cpk	0.3568	1.4000	292.37
	02	Cp	1.4439	1.3569	-6.02
		Cpk	0.3234	1.3461	316.23
	03	Cp	1.3749	1.3562	-1.36
		Cpk	0.5499	1.3562	146.62

Table 4: Average improvement of process performance

Process Factors	Average improvement (in %)	
	Cp	Cpk
Sewing Reserve	64.84	213.66
Stitch Density	-1.11	251.74

Project closure and celebrate completion

Upon completing the project, a celebration party has been arranged in the University premises with all participants to the project. Within the celebration party, at first the project outcomes have been presented by the project team leader in front of the university and Company representative (Top management). Then the result was disseminated through a Question and Answer session.

Chapter 6: Assessing the application impact of the DMAIC-KM methodology

➢ Impact assessment methodology

After experiencing the positive performances of the DMAIC-KM methodology on practical Six Sigma projects, researchers have further assessed the application's impact of DMAIC-KM methodology on Six Sigma projects gathering the participant's perception. Like Cronemyr (2007) and Orbak (2012), the researchers have applied three major approaches for this study such as: i) questionnaire survey (ii) discussion with focused groups and (iii) semi- structured interviews. All three approaches were carried out in parallel over the survey period. The quantitative data was collected from questionnaire survey while the qualitative data was collected from the discussion with the focused groups and semi- structured interviews. This research was conducted only within the case company (TAKATA Sibiu SRL), where DMAIC-KM approach was applied in executing Six Sigma projects in an airbag manufacturing process.

i) Questionnaire survey

In order to collect the written feedback, some sets of Likert scaled type questionnaires were supplied among the participants immediately after the project has completed. The questionnaires were formulated focusing on the issues of the participants' experiences, awareness, influential factors and benefits achieved from the application of the DMAIC-KM methodology in executing Six Sigma projects.

ii) Discussion with focused groups

A total of 4 focused groups have been selected for discussions, only those who were involved as a team for four Six Sigma projects. All the participants to the discussion groups gathered experience and had responsibility for deploying Six Sigma projects using DMAIC-KM model. Each discussion group consisted of six participants and the discussions were held arranging a workshop session after completing the Six Sigma projects. The main goal of the discussion was to obtain detailed information on participants' experience about the application of the DMAIC-KM model.

iii) Semi-structured interviews

Semi-structured individual interviews were conducted via face to face meeting with senior executives of the company (Project sponsor and Quality manager) and factory experts (four mentors) fifteen days after completion of the project in order to get valuable opinions and criticism about the application, effects, contribution and future scopes of the DMAIC-KM methodology. Each interview lasted for 15 minutes. The Answers or opinions of the participants were documented in handwritten notes by the researcher. Finally, all the data was gathered and analyzed in order to assess the project application performance and find the feasibility of DMAIC-KM model application in the manufacturing area.

➢ Results discussions and implications.

a) Awareness and understanding of DMAIC breakthrough and KM approach

The results from the conducted survey have shown that the respondent's awareness and levels of understanding on DMAIC breakthrough application and KM application has gradually improved after completing the Six Sigma projects. The majority percentage (45.84%) of respondents achieved good level and 29.16 % achieved average level of understanding form basic and from little understanding level. A key implication of this is the frequent discussion with the team members regarding the application procedure and its advantages before starting the projects and also the discussion during Gate review session of the DMAIC phases. The midterm workshop might be another opportunity to achieve the knowledge on these issues.

b) Factors that influence the DMAIC-KM application

In respect of the study regarding influential factors, it was shown that the management commitment and continuous support is to be mentioned as the most crucial factor for the application of the DMAIC-KM approach in executing Six Sigma project which is also considered as the most influential factor for basic Six Sigma project deployment. The DMAIC-KM model is an integration of Six Sigma and KM approach applied in executing Six Sigma projects. Understanding of tools and techniques used for application of DMAIC-KM approach are considered second crucial factors according to respondents .The reason behind of this rating may be the integration of new knowledge management tools for the DMAIC-KM approach. Two factors like Cultural change and Training& education are given more or less same importance, because of adopting the mindset and learning technical aspects of new methods. Organizational infrastructure and Project management skills are also given importance by the respondents for DMAIC-KM application because these methods are applied as a continuous quality improvement management tools.

C) Benefits in adopting the DMAIC-KM methodology

i) Organizational changes

With respect to the benefits achieved by the organization through the application of the DMAIC-KM model it is illustrated that all the measures indicated the improved state after having introduced the DMAIC-KM methodology during the execution of Six Sigma project in comparison to the previous state. From the figure it is clear that the average score for all measures lie in between "good" to "very good" at present condition, whereas previous score were in between "average" to "good". According to the respondents rating, the performances of some important measures like "Application of KM on process management, Development of knowledge based staff, Improvement of process performance and Increasing the data collection efficiency had significantly improved. The implication is that, the application of Knowledge management tools with DMAIC breakthrough made it more effective towards improvements of organizational measures.

ii) Improvement of the participants' level of maturity after applying the DMAIC-KM model.

The study also indicated that after the application of the DMAIC-KM methodology the Organization has benefited by improving the knowledge and maturity level of participants. About fifty five percent (55%) of participants have achieved their competence level in the method of DMAIC-KM application and could demonstrate it while executing a Six Sigma project in their manufacturing unit and thirty percent (30%) have progressed their knowledge level. It should be mentioned that participating to the workshop, Gate review session and brainstorming with team members regarding the application procedure was the main driving force for this progression of knowledge.

iii) Effectiveness of DMAIC-KM approach in comparison to other improvement tools

The study regarding the effectiveness of the DMAIC-KM approach comparing to other applied continuous improvement tools/ approaches revealed that according to the participants' experience DMAIC- KM method is highly effective for their manufacturing process among all other methods such as Six Sigma, PDCA, Just in Time, 5S, Kanban, Kaizen, Fi-Fo (First in and First out) and Andon (flags) that they have applied for their manufacturing process. The main implication of this result may be the effect of huge advantages of KM methodology that was applied with DMAIC breakthrough.

➢ Results from the Discussion Groups

Though the comments from the discussion groups focused on some specific themes, it unveiled the overall phenomena of DMAIC-KM application methodology. According to the group's comments on the understanding of the DMAIC-KM application, it is clear that the majority of the groups faced little problem to understand the new method at the beginning of the application. But continuous briefing, discussion, monitoring made it easy and understandable during the application. The implication is that a new method is always difficult to understand at first when applying it in any organization. So it is important to make it easy through effective activities carried out by the coordinator.

During discussion, the groups' opinion on the DMAIC-KM model architecture has disclosed that new model architecture was not difficult for them to understand but for the KM cycle. It can be easily explained that all the group members were familiar with Six Sigma application, where DMAIC is well known for them as a problem solving methodology of Six Sigma project. On the other hand Knowledge Management is a new emerging concept with few applications in different area all over the world. So it is normal to be unfamiliar for them.

All the groups have given positive comments about the effectiveness of the DMAIC-KM application. Some groups have highly appreciated the applied methodology as an effective continuous improvement tool among the others they have already applied. The reason for this appreciation is that all groups could be able to increase the process capability and knowledge gains more than when applying other methods then the DMAIC-KM methodology.

As comments revealed, most of the groups believed that the DMAIC-KM model can be used not only in the manufacturing area but also in other domains, where Six Sigma can be applied. All the groups which experienced good results in their application of the DMAIC-KM model wish to have new experiments in other domain.

If we summarize the last comments of all groups, it can be concluded that the DMAIC-KM model can be helpful for organizations to cope with challenges they are facing during their activities. It can be possible by using the strong impact of the KM methodology at the Organizational level.

➢ Results from the Interviews

During interview sessions, the higher management (Director and Quality manager) and domain experts of the case company have expressed that they have recognized the application advantages of the DMAIC-KM method within their Organization. Some of them have appreciated the methodology and some of them also criticized it in a positive way. All participants are expert in the application of Six Sigma and other continuous improvements tools. So their opinion is more acceptable than other group members', the criticism they brought is also important for upgrading the DMAIC-KM methodology for a wider application. Finally, it is most important that top management of case company liked the DMAIC-KM methodology as their opinions revealed.

Chapter 7: Overall Conclusions of the Research

The individual conclusions that were presented in the different parts of the research are summarised in this section. The overall conclusions of this research will be drawn spanning three major segments, which are very important, for researchers and companies, for a successful deployment of the Six Sigma and KM integrated approach within textile manufacturing processes.

➢ ***Development of a new methodology***

The proposed DMAIC-KM model is an integrated conceptual model, which is developed as a part of Six Sigma quality management system that consists of tasks, tools, activities, knowledge managing IT platform and project performance evaluation methodology. All those items are networked in a horizontal platform with the goal of connecting the knowledge management procedure with quality management methodology. The DMAIC problem solving steps were taken as the main foundation for the new methodology, because most of the new knowledge is created within those steps in a Six Sigma project deployment (George, 2002; Stevens, 2007; Zou and Lee, 2010). Every phase of DMAIC was manifested explicitly with tasks, tools and gate review activities, which enables better access of created knowledge within the DMAIC phases.

In order to integrate KM concepts with DMAIC phases, six updated KM elements (Knowledge creation, Knowledge capture, Knowledge organization, Knowledge storage, Knowledge dissemination, Knowledge application) were identified from the literature (Lawson, 2003). All though those elements are very much important for an effective knowledge management procedure, all of those elements were not present in existing Six Sigma and KM integrated models.

All those KM elements were sequentially integrated step by step and made functional through a newly designed IT platform that comprises numerous soft tools. The development of a new IT platform was necessary for the new methodology due to its unique model architecture. So, the new IT platform was designed and named DMAIC-Knowledge Management Platform. This platform is designed including some holistic tools that are required for DMAIC- KM model to perform effectively. The tools that were included within the IT platform were selected from the KM literature, and are already proven tools for KM activities. All the introduced tools were simplified to be active and easy to operative for the targeted users. The DMAIC-Knowledge Management Platform presented in this thesis is designed with the goal of facilitating the conversion of expert's tacit knowledge to explicit knowledge to be used for enhancing organizational performance.

In the architecture of the new model, the KM elements were integrated in such a way that the newly created knowledge from every step can be used for the immediate next step through an effective KM procedure aiming to enhance the performance of every step of DMAIC breakthrough, which results in the overall performance of the Six Sigma project. This approach was lacking within the existing models. Finally, the new model explained the seven important and necessary stages of the execution procedure including its methodologies (Baral, Kifor and Bondrea, 2014).

In order to evaluate the Six Sigma project performance after executing the new methodology, another two approaches were integrated within this model. One is a quantitative statistical method for process capability calculation and another is a qualitative survey method for gathering opinions and perceptions from the project participants.

In summary, the newly proposed DMAIC-KM methodology is the culminating product of a disciplined and structured approach to KM and scientifically proven activities for Six Sigma project deployment. This methodology makes the Six Sigma deployment more effective and successful.

- ***Application of the new methodology***

To achieve the targeted goal for which the new methodology was developed, the DMAIC-KM methodology was applied during Six Sigma projects execution in a technical textile manufacturing process. The main product of the selected process was an Airbag for different car manufacturing companies. Though four Six Sigma projects were executed using DMAIC-KM methodology, only one project is documented in detail within this thesis; which was identified as the most suitable project in respect to different prioritization criteria's for Six Sigma project selection (Six Sigma participant's material'2002). The project was selected based on a real life problem, which deals with the variations which occurred during the sewing of a perimeter seam in the airbag cushion manufacturing process. As a problem, a wide range of variations have been observed in the perimeter seam width (sewing reserve), which also led to the variations of stitch density (stitch/cm) along the seam stitch line. The DMAIC-KM methodology was applied in order to enhance the process performance by reducing the aforementioned variations. After a systematic application of DMAIC-KM methodology on this process, the improvement of process performance has been calculated statistically for both factors (sewing reserve and stitch density). The process performance was measured through process capability indices such as Cp and Cpk values. For process factor sewing reserve, the average improvement of Cp and Cpk values were calculated as 64.84 % and 213.66 % respectively. Concurrently, the improvements of Cp and Cpk values for process factor stitch density were computed as -1.11 % and 251.74% respectively. The above mentioned results revealed that the Cpk values have improved a lot after applying DMAIC-KM methodology for both factors .This improvement is significant in comparison with basic Six Sigma projects applied in the textile manufacturing process (Das et al, 2007; Mukhopadhyay and Ray, 2006; Karthi et al., 2013). For a basic Six Sigma project, the highest improvement of Cpk values documented at about 100-120%, as cited in the above literature. So, the results of this research have revealed that the newly developed DMAIC-KM methodology has shown great impact on enhancement of Six Sigma project performance. The key of such great improvement is the application of the integrated KM procedure, which has also a great impact on the enhancement of organizational performance (Becerra-Fernandez and Sabherwal, 2008).

- ***Assessment of the application impact of the new methodology***

The last part of the present research has documented the results from the study conducted to assess the application impact of DMAIC-KM methodology on Six Sigma projects execution within an airbag manufacturing process. In this study, the application impact of DMAIC-KM methodology was assessed by analysing the opinions and perceptions collected from projects participants. The opinions and perceptions were collected by using three well known scientific and logical common approaches such as: i) questionnaire survey ii) discussion with focused groups and iii) semi- structured interviews. These are widely used methods by researchers from different domains. In total 24 participants from four Six Sigma project teams have participated in the questionnaire survey and discussions. On the other hand, the interviews were conducted with two senior executives of the company (project sponsor and quality manager) and four mentors from four project teams. The quantitative findings from the selected factors such as participants understanding, organizational benefits and the effectiveness of the applied DMAIC-KM methodology compared with other continuous improvement methodologies has demonstrated positive impact on the Six Sigma project execution procedure. The discussion groups have disclosed both positive and negative opinions about DMAIC-KM methodology. But most of the groups have given positive feedback about the application of the new methodology. The results from the interviews that were conducted with experienced top management officials (factory director and quality manager) and experts (project team leader/mentor) expressed the advantages of DMAIC-KM methodology in executing Six Sigma projects.

From the above conclusions, it can be summarised that the proposed DMAIC-KM methodology is an effective methodology, which integrates Six Sigma and KM concepts in a disciplined and structured manner. In respect to validation of the proposed methodology both from practical application and from participant's opinion, a positive impact on Six Sigma project has been achieved. This model will be used for further application.

➢ Personal Contributions

The overall research outcomes have contributed both theoretically and practically to the Six Sigma and KM integrated research domain. Both types of contributions from the present research are outlined in the following sections:

❖ *Theoretical Contributions*

- analysis of a wide range of literature related to Six Sigma and KM integration based on their leveraging effect on Six Sigma project execution.
- identification of the weak points of existing models, which tend to integrate Six Sigma and KM concepts.
- identification of updated KM elements, which are essential for an effective KM activities.
- identification of the scope and necessity for integrating DMAIC and KM concepts with updated elements.
- selecting the important IT tools from literature analysis in order to functionalise the KM elements effectively.
- identification of the effective methods for project performance evaluation.
- developing a new conceptual model integrating DMAIC and KM concepts for Six Sigma project deployment and specified as DMAIC-KM model.

❖ *Practical Contributions*

- creation of an IT platform for KM activities performed within DMAIC-KM model.
- outlining the stage wise sequences for practical application of DMAIC-KM methodology.
- Developing the practical application procedure of DMAIC-KM methodology with the goal of improving of process performance by reducing variations.
- creation of an example regarding improvement of process performance by using DMAIC-KM methodology in the technical textile manufacturing area.
- achieving a significant amount of improvement of process performance from DMAIC-KM application.
- systemizing the assessment techniques for DMAIC-KM application by using opinion and perception of project participants.

❖ ***Scientific Contributions***

As scientific contributions from this research, a number of papers were produced: four (4) Journal papers (two already published and two under review process) and eleven (11) international conference papers (all are published in indexed proceedings). The extended list of the publications can be found as an annex at the end of this thesis.

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W_5- "E- learning features" from web: http://www.cpce-polyu.edu.hk/itu/new/

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W_7- "About Moodle". *Moodle.org Documentation*

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Annex. Recognition Letter from Case Company

TAKATA

S.C. TAKATA SIBIU S.R.L.
Str. Florian Rieger nr. 3
550018 Sibiu, Romania
TEL: + 40 269 203-700

S.C. TAKATA SIBIU S.R.L. – Str Florian Rieger 3, 550018 Sibiu, Romania

October 9, 2014

We hereby confirm that Mister Lal Mohan Baral, a PhD student, has performed research activities in our company during the period of 01.10.2013-18.01.2014 as a part of his doctoral studies. He has coordinated a research project entitled **"Six Sigma projects execution in textile manufacturing by using DMAIC-KM model"** within our airbag manufacturing process aiming to enhance the process performance. The research activities were supervised by Prof. Dr. Eng. Claudiu Vasile KIFOR, the scientific coordinator from "Lucian Blaga" University of Sibiu and sponsored by Mister Alan STAMEY, Director General of S.C. TAKATA Sibiu S.R.L., Romania (TKSR).

In this research activity, five Six Sigma projects have been executed under aforementioned research project indentifying five real life problems from the airbag manufacturing process. The Six Sigma experts from S.C. TAKATA Sibiu SRL, Faculty members and Students from "Lucian Blaga" University of Sibiu were involved as member of the project teams.

After a successful execution of all projects, the results that have been presented in front of evaluation commission, formed with experts both from University and Factory, has found very much impressive. The structure of Six Sigma/DMAIC & KM provided an effective framework for communicating the project results. These methods have advanced the cooperation between the university and TKSR and provided a fundamental basis for future collaboration.

We wish every success for his further professional life.

Sincerely,

SOCIETATEA COMERCIALA TAKATA SIBIU S.R.L. RO 16866758 J32/1181/04 2 SIBIU-ROMÂNIA

Alan Stamey
Director Manufacturing Plant Sibiu
Airbag Operations
Takata Sibiu S.R.L.

S.C. TAKATA – PETRI SIBIU S.R.L. – Str. Florian Rieger 3, 550018 Sibiu, România, TEL. +40 269 203-700; e-mail: sibiu.office@eu.takata.com
Administratori: Alan Stamey si Shimizu Hiroshi, Nr. înregistrare O.R.C. Sibiu J32/1181/09.08.2004, Capital social: 9.000.500 Euro, RBS BANK (Romania) SA, Cont IBAN: RO54ABNA3300264100124059

Annex. List of the Scientific Publications

List of the Publications

Author: Lal Mohan Baral

➢ Prior to Doctoral Research

In Peer Reviewed Journals:

i. **Baral, L.M.** (2011).**Feasibility Study of CAD and CAM Technology in Garments Industries of Bangladesh.** *The Journal of Advanced Material Research,* Volume: 264-265, (Page.1563-1567), Trans Tech Publication, Switzerland.

ii. **Baral, L.M.** (2010).**Comparative Study of Complaint & Non-Compliant RMG Factories in Bangladesh**. *International Journal of Engineering & Technology (IJET),* Volume: 10, Issue No.2, (Page.119-131), Pakistan.

iii. Rahman, F. M., **Baral, L.M**., Khan, A. N, & Mannan, A.(2009).**Quality Management in Garments Industry of Bangladesh.** *The Journal of Management of Sustainable Development (MSD),* Volume: 01, Issue No.2, (Page.29-35), LBUS, ROMANIA.

In Indexed Conferences:

i. Islam, I., & **Baral, L.M.** (2011).**Study on range of fabric cost percentage against FOB price of knit garments**. Published in the proceedings of *the International Conference on "Innovative solutions for sustainable development of textiles industries",* (Page.109-114), which is held on May 29th -30th '2011 at University of ORADEA, ROMANIA.

ii. **Baral, L.M.**, & Islam, I. (2010).**Study on Value Addition in Knit Garments of Bangladesh and Price Analysis between Basic Style & Value Added Style**". Published in the proceedings of *"13th Annual paper meet of ME Division*, which is held on 25th September 2010 at IEB, Dhaka, Bangladesh.

iii. **Baral, L.M.** (2009).**Determination of the Clothing Comfort of Spacer Fabrics by Chimney Effect Model.** Published in the proceedings of *the International Conference on "Innovative solutions for sustainable development of textiles industries",* (Page.35-39), which is held on May 29th -30th '2009 at University of ORADEA, ROMANIA.

➢ During Doctoral Research

In Peer Reviewed Journals:

i. Kifor, C.V., Tudor, N., & **Baral, L.M**. (2013).**Quality System for Production Software (QSPS): An innovative approach to improve the quality of production software**". *International Journal of Software Engineering and Knowledge Engineering (IJSEKE),* Vol.23, Issue No. 8, (Page.1061-1083), World Scientific Publishing Co. Singapore.

ii. **Baral, L.M.**, Kifor, C.V., Bondrea, I., & Oprean, C. (2012).**Introducing Problem Based Learning (PBL) in Textile Engineering Education and Assessing its Influence on Six Sigma Project Implementation.** *International Journal of Quality Assurance in Engineering and Technology Education,* Vol.2, Issue No. 4, (Page. 38-48), IGI Global publication, USA.

iii. **Baral, L.M.**, Kifor, C.V. (2014).**Application of Six Sigma and Knowledge Management Integrated Conceptual Model to the Technical Textile (Airbag) Manufacturing Process.** (Under review process).

iv. **Baral, L.M.**, Kifor, C.V., & Vlad, D. (2014).**Applying Six Sigma Quality Management to the Technical Textile (Airbag) Manufacturing Process in order to Enhance the Process Performance.** (Under review process).

In Indexed Conferences:

i. **Baral, L.M.**, Kifor, C.V., & Bondrea, I. (2014).**Assessing the Impact of DMAIC- Knowledge Management Methodology on Six Sigma Projects: An Evaluation through Participant's Perception**. Published in the proceedings (published by Springer Lecture Notes in Artificial Intelligence, 8793) of *" The 7th International Conference on Knowledge Science, Engineering and Management, KSEM 2014,*(Page.349-356), which is held on 16-18 October, 2014 at "Lucian Blaga" University of Sibiu, Romania.

ii. Bogdan, C., **Baral, L.M.**, & Kifor, C.V. (2014).**Review of Knowledge Management Models for Implementation within Advanced Product Quality Planning**. Published in the proceedings (published by Springer Lecture Notes in Artificial Intelligence, 8793) of *" The 7th International Conference on Knowledge Science, Engineering and Management, KSEM 2014,*(Page.338-348), which is held on 16-18 October, 2014 at "Lucian Blaga" University of Sibiu, Romania.

iii. **Baral, L.M.**, & Kifor, C.V. (2013).**A Study on different approaches of six-sigma and knowledge management integrated models to identify the leveraging effects**. Published in the proceedings of the *"1st International Conference for Doctoral Students IPC- 2013",* (Page.192-197), which is held on 22-23 November, 2013 at "Lucian Blaga" University of Sibiu, Romania.

iv. Bogdan, C., **Baral, L.M.**, & Kifor, C.V. (2013).**Knowledge Management Platform in Advanced Product Quality Planning**. Published in the proceedings of the *"1st International Conference for Doctoral Students IPC- 2013"*, (Page.227-232), which is held on 22-23 November, 2013 at "Lucian Blaga" University of Sibiu, Romania.

v. **Baral, L.M.,** Kifor, C.V., Bondrea, I., Oprean, C., & Oprean, L. (2013**).Assessing Impact of Problem Based Learning (PBL) On Six Sigma Projects Associated with Textile Engineering Education.** Published in the proceedings of the *"International Engineering and Technology Education Conference (IETEC) 2013",* which is held on 3-6 November 2013 at The University of Technical Education, Ho Chi Minh City, Vietnam.

vi. Kifor, C.V., & **Baral, L.M**. (2013).**An integrated DMAIC-Knowledge Management conceptual model for Six Sigma quality management.** Published in the proceedings of the "*6th International Conference on Manufacturing Science and Education-MSE 2013"*, (Page.7-14), which is held on 12-15 June, 2013 at "Lucian Blaga" University of Sibiu, Romania.

vii. **Baral, L.M.**, & Kifor, C.V. (2013).**Knowledge creation scope within Six Sigma project implemented in Textile Manufacturing**. Published in the proceedings of the *"6th International Conference on Manufacturing Science and Education-MSE 2013"*, (Page.15-20), which is held on 12-15 June, 2013 at "Lucian Blaga" University of Sibiu, Romania.

viii. **Baral, L.M**. & Kifor, S. (2013).**A case study on the acceptance quality level (AQL) for woven garments quality inspection**. Published in the proceedings of *the International Conference on "Innovative solutions for sustainable development of textiles and leather industry",* (Page. 66-71), which is held on May 24 -25'2013 at University of ORADEA, ROMANIA.

ix. **Baral, L. M.**, Muhammad, R., Kifor, C.V., & Bondrea, I. (2012).**Evaluating the effectiveness of Problem-Based Learning (PBL) implemented in the textile engineering course- A case study on Ahsanullah University of Science and Technology, Bangladesh**. Published in the proceedings of *the "International Conference on Engineering and Business Education, Innovation and Entrepreneurship"*, (Page. 123-126), which is held on 18-21 October, 2012 at "Lucian Blaga" University of Sibiu, Romania.

x. Kifor, C.V., Crîngaşu, M., Lungu, A., & **Baral, L. M**. (2012).**Research evaluation in engineering schools**. Published in the proceedings of *the "International Conference on Engineering and Business Education, Innovation and Entrepreneurship"*, (Page. 407-412), which is held on 18-21 October, 2012 at "Lucian Blaga" University of Sibiu, Romania.

xi. Rizwan, M., Fakharun, N., Muhammad A., Muhammad, R., & **Baral, L. M.** (2012). **Impact of Instructional Technology inclusions in course delivery for Engineering and Business Education.** Published in the proceedings of *the "International Conference on Engineering and Business Education, Innovation and Entrepreneurship"*, (Page. 633-638), which is held on 18-21 October, 2012 at "Lucian Blaga" University of Sibiu, Romania