Digital Six Sigma® Concepts in Expert Systems
Development of Web-Based User Configurable Numerical Data Acquisition Module for MOTOROLA Penang EMAS

by

Mohammad Ashraf Ahmat Amin

Project Dissertation submitted in partial fulfillment of the requirements for the
Bachelor of Technology (Hons)
(Information & Communication Technology)

June 2006

Universiti Teknologi PETRONAS
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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Mohammad Ashraf Ahmat Amin)

ABSTRACT

This Final Report on Final Year Project of Digital Six Sigma Concepts in Expert Systems describes from backgrounds, problem statements, objectives, methodologies, results until the conclusions of the Final Year Project which covers both part I and part II. The scopes of research in this project focus exclusively on Six Sigma® initiatives and how it could be realized efficiently and with enhancement using Information Technology tools and capabilities. In this project there were two developments been identified as the main objectives. They were the development of a Numerical Data Acquisition Module and a model of Motorola Penang Electronic Measurements & Action tracking System (EMAS). The Numerical Data Acquisition Module was meant to be integrated with current MOTOROLA Penang implemented system. The developed Numerical Data Acquisition module and also the model of Motorola Penang EMAS were tested, analysis were done to produce results for discussion. Some analysis of the results was based on surveys during visits to plants adopting Six Sigma® and literature reviews conducted throughout the project. The research methodologies in this report explained in detail the procedures and tools used along the progress of the project. In the last chapter, future recommendations were suggested for future enhancements and expansions of the project.

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بسم الله الرحمن الرحيم

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CHAPTER 1
INTRODUCTION & BACKGROUND OF STUDY

1. INTRODUCTION & BACKGROUND

This project involved with an improvement methodology called Digital Six Sigma applied with the technology and features of an expert system. While other expert systems were based on requirements and its intended process, this project showed the integration between initiative concepts and information technology tools. This project had developed an expert system which had the capability of achieving results and objectives of Six Sigma initiative.

In collaboration with engineers and staffs from Motorola Penang, this project used latest manufacturing processes requirements. This was especially in terms of measurable data and variables which were needed to be stored in a digitalized manner for later observation.

1.1 Digital Six Sigma® – An Evolution of the Original Six Sigma®

Created by some of America's most gifted CEOs, people like Motorola's Bob Galvin, AlliedSignal's Larry Bossidy and GE's Jack Welch, Six Sigma® got its start in manufacturing at Motorola in the 1980s (Ref. from *Motorola internal DSS corporate portal*).

Six Sigma® is a defect reduction methodology that transforms organizations by forcing them to focus on the quality of the customer experience. The term *sigma* refers to deviations from an ideal level of operation, where each level of sigma, starting from one, allows for fewer defects. Sigma six, the operational equivalent of nirvana, allows a mere 3.4 defects per million outputs as shown in Table 1.1. If you're in manufacturing, that means 999,996.6 flaw-free widgets (Chowdry, 2001)[1].

Table 1.1 Comparison of Sigma Levels Three through Six			
Sigma Level	Percent Correct	Number of Defects per Million Opportunities	Lost Time per Century
3	93.3193	66807	3 ½ months
4	99.3790	6219	2 ½ days
5	99.9767	233	30 minutes
6	99.99966	3.4	6 seconds

*Truscott (2003), **Six Sigma® – Continual Improvement for Businesses***

With the executions of Six Sigma®, companies adapted the concept save hundreds per second, thousands per minute and millions of dollars every year. The uniqueness of Six Sigma® is the adaptation of practical values from various process improvement tools available such as Total Quality Management, Statistical Process Control, Lean Manufacturing and others. The difference between Six Sigma® and these current programs or concepts is Six Sigma® does not emphasize on forcing people to be enthusiastic towards changing their current processes to others but as simple as doing normal processes but in a more arranged and as perfect as possible so that in the end a highest quality result can be achieved. Further theories of Six Sigma® are explained in chapter 4.2.1.

Digital Six Sigma® is a re-tooled version of the original Six Sigma®, it leverages the leanings, both good and bad, of the companies that adopted the original Six Sigma® process (Ref. from *Motorola internal DSS corporate portal*).

This is because in Digital Six Sigma® the use of information technologies and automation was greatly exercised to improve the "classic" Six Sigma® effectiveness. The digitization had included the use knowledge based expert system in the whole Motorola especially in manufacturing processes. Through the digitization, upper management decision support system had been enhanced through accessible digital dashboards showing the data in statistical concepts to help in their daily monitoring or decisions making.

1.2 Motorola Penang Knowledge-Based Expert System - EMAS

Motorola around the world adopted widely the implementation of Digital Six Sigma® but through different system architectures but still data centralized in certain indices such as the database. At Motorola Penang Digital Six Sigma® implementation is executed widely through the digitization of basic and advanced Six Sigma® tools such as Failure Mode Effect Analysis (FMEA), statistical dashboards, analysis charts and automated processes. The main framework designed specifically for Motorola Penang Digital Six Sigma® implementation was the Generic Knowledge-Based Expert system called Generic EMAS (Electronic Measurement Action tracking System).

This system consists of three main modules (refer Figure 1.1), which are the corrective modules for short term immediate action, improvement module for long term recommended action and planned activities (entitlement) module for defect prevention and lesson learnt.

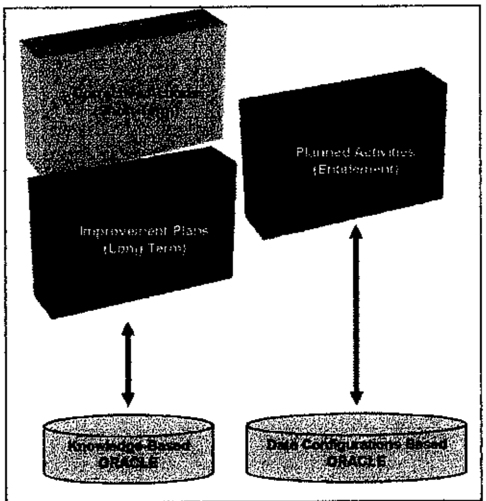

Figure 1.1 Generic EMAS modules

Generic EMAS is a web based system to track immediate and long termed action items with embedded knowledge as the mechanism in assisting problem solving, making improvements and performing analysis in manufacturing processes.

The system contains reusable modules generic for all types of processes. The major purposes of the system are to capture knowledge, share knowledge and track action items (Short term/corrective action, Long term/Improvement).

Short termed action items will be triggered upon daily operations, line stopper items or certain dashboard indices. Based upon the data entered, users can perform analysis through charts, user request or other reporting formats. To prevent the same problems/issues from occurring, improvements action needs to be taken by performing root causal analysis and provide recommended actions, which will be verified by area champions for knowledge enhancement. The improvement action entries should collect the current, actual and forecasted business indices to show the organizational business impact.

1.3 User Configurable Numerical Data Acquisition Module

The User Configurable Numerical Data Acquisition Module is actually one of the two major sub modules in EMAS module for planned activities or also known as the entitlement module (refer Figure 1.2).

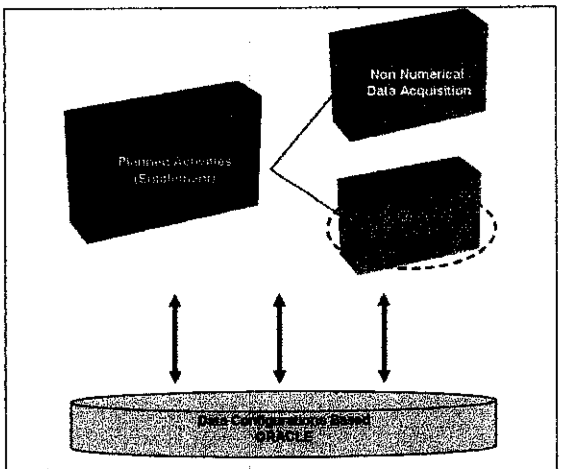

Figure 1.2 Numerical Data Acquisition modules

Currently inside the entitlement module used in Motorola Penang, there is only a non numerical data acquisition module which actually collects compliances of planned activities. These compliances collected currently are just in the form of mere yes and no. The compliances were measured according to specifications set in the configuration for each activity planned. In the end these compliances can be calculated statistically to perform engineering deviation or total compliances. Nevertheless the non numerical data acquisition model had actually a user configurable feature that was built in the generic framework for the module.

The numerical data acquisition model was expected to perform similar functions but with the advantage of having numerical data acquisition module for processes that takes readings and measurements. These data and measurements are to be varied in types but should be accessible by processes which need them. The results will actually be connected directly to the database where manipulation towards the data and measurements collected can be done to execute statistical analysis.

As all modules inside EMAS is featured with reusable module which actually make each module a generic platform for any processes, the numerical data acquisition module was designed to have similar features and could be integrated with any connections of database configurations available.

CHAPTER 2

RESEARCHED PROBLEM STATEMENTS

2. PROBLEM STATEMENTS

In this Preliminary Report researched problem statements were based on real problems or concerns aroused in Motorola Penang manufacturing IT based systems.

2.1 Managing Various Types of Complex Processes and Inputs

In the manufacturing line itself various processes using various types of inputs took place. In order to capture the data and measurements for each process a digitalized method was identified. The problem exists when there was a large variation between each process. Developing unique method for each process would incur cost and it is making the system decentralized.

That is why a system which is configurable and generic enough to cater each processes requirement is needed. This is also why such module development (1.3) could probably benefit Motorola Penang manufacturing and even non manufacturing areas or processes.

2.2 Manipulating a Large Collection of Numerical Data

In Motorola Penang manufacturing areas a lot of processes involve numerical data gatherings. To name a few are torque screw readings, electricity usage, water usage and maintenance measurements. These readings are important as sometimes they involve costs, quality and safety.

Gathering of numerical data is a significant aspect especially when it involves micro readings where the boundary between goals and specifications are determined by a mere μm (micrometer). Besides that the collections of these data digitally could later be manipulated for the process of decision making after statistical calculations. These manipulations require a disciplined collection of data. Furthermore a real time automated analysis and manipulation of data is undeniably needed in making quick decisions.

This is also why a module which could collect numerical data and generic enough to be configured for different types of processes is needed.

2.3 Achieving Standardization and Integrating Independent Systems

Currently the module for numerical data acquisition was developed independently and not being integrated into the main system desired which is EMAS, to be specific in the entitlement module. Numerical data acquisition was made custom with fixed inputs web forms which had been designed uniquely for designated processes.

It is actually the desired objective in Motorola Penang to have a generic, centralized and standardized application which can cater the needs of different processes configurations and data acquisitions. With the development of such module integrated into EMAS, it is expected that this objective of standardization can be achieved. The definition of standardization can be explained in terms of users' login and accessibility as well as the database configuration. Besides that having all application or system standardized into one framework helps in identifying processes structure as the information can be configured in a single destination.

2.4 A Generic Framework to Support Centralizing

The problems with unique and custom forms arise when there are updates, change of format, new requirements or anything that will force the current interface to change. New fields need to be created, types of inputs need to handle and a few other things to consider. When these happen the current forms need to be changed hardcodedly (computer programming). Besides the forms interface, the database configurations for these forms might also need to be change and all these might lead to disorder and sometimes lost of valuable information. The problem could be worst when the cycle time taken to attend these changes is out of specifications which will result in long downtime of the processes associated with the use of these forms. In terms of costs, it is high to maintain such forms.

That is why a generic configurable module is needed in order to address such issue. Through a generic architecture which framework been designed to cater the need or requirement possibilities for various processes there wouldn't be any problem when a change occur. The characteristics of a generic framework inside this project module will actually involve overall database configurations and interface controls which will simplify the process of updating without even the need to do thorough computer programming.

Even though the engineers have not started to address such module development. The level of complexity in this project is expected to be in the range of moderate to high. This is especially in terms of having the generic framework which can cater user configurable interface for data acquisition that will actually suit their processes. This will solely involve lots possibility of algorithms.

Nevertheless the significant impact of the project in the sense of the configurable algorithms findings that will build the generic framework architecture of the module will actually help the initiation of such module for numerical data acquisition. The activity of numerical data acquisition was held broadly in manufacturing areas especially in preventive maintenance processes where numerical data acquisition is in practice to take readings from machines, manual measurements or other types of inputs.

CHAPTER 3

OBJECTIVES & SCOPES OF STUDY

3. PROJECT OBJECTIVES & SCOPES OF STUDY

Digital Six Sigma® had been appointed as the initial scope of this project (refer Figure 3.1). Therefore, the areas of research and literature review were mostly focused on Digital Six Sigma® concept. The objective to have Digital Six Sigma® as the main area of research/study was to research for the effectiveness in having expert systems been integrated with Six Sigma concepts. Meanwhile, this project tangible objectives were focused on two developments (web based user configurable numerical data acquisition module & model of EMAS).

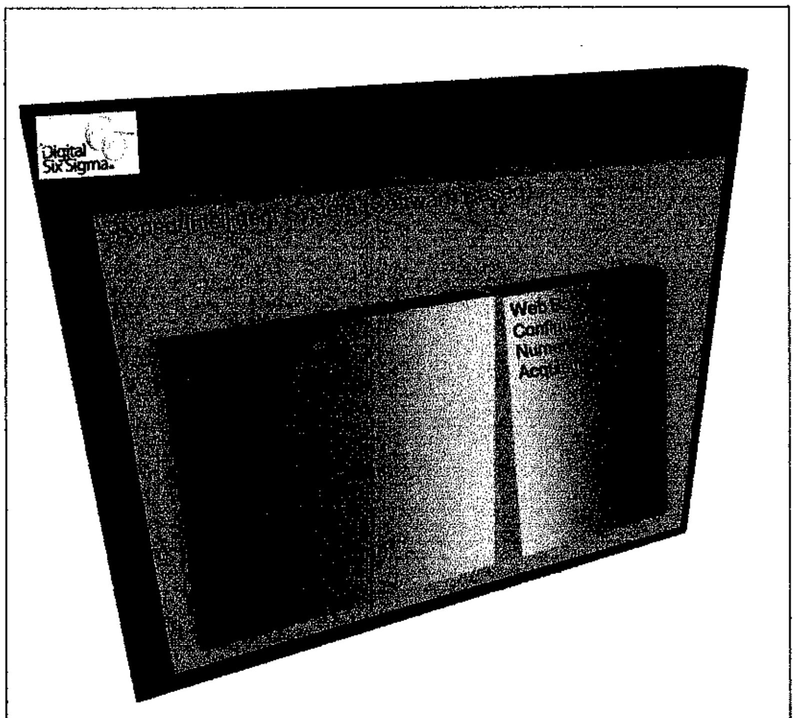

Figure 3.1 Total Project Scopes

3.1 Digital Six Sigma® Study Objectives

Rather than specifically focusing on the two developments only, studies were also conducted on Digital Six Sigma® theories as its underlying component. As refer to Figure 3, the scope will be narrowed from the Digital Six Sigma® concept to the software based tool which is the expert system and later towards the two developments. As for the study on Digital Six Sigma® concept, a few objectives were preset.

Table 2 presents the planned objectives for Digital Six Sigma® study which will change continuously as the project progresses.

Table 1.2 Digital Six Sigma® Study Objectives

Main Objective(s)	Objective Components	TimeFrame
Literature Review	Definitions History Comparisons	Whole Project
Analysis	Company Adaptation Surveys Method of Implementation Survey Efficiency Survey Tools & Components Survey	3 weeks 3 weeks 3 weeks 3 weeks

The overall purpose of conducting such study is to proof the relevance of digitizing existing improvement methodology such as Digital Six Sigma®. The study will also search for known stories of triumph and failures of this implementation and it is hopefully with that, contributing factors could be identified and formulized for this project success.

The main objective of developing a user configurable numerical data acquisition module in Motorola Penang knowledge-based expert system is to benefit such capability in any processes that involve numerical data acquisition. This is inevitable especially in manufacturing environment where data and measurements take place in most of the processes. This showed that the outcomes of the project will broadly benefit processes associated with the system. In the end the manipulation of these numerical data through statistical analysis will eventually facilitate decisions making and daily observation on designated processes.

There were actually two high level objectives identified in the project which were tangible and observable. These high level objectives were relevant to the FYP requirements as both combinations will actually result in a framework of an expert system.

It is also relevant to have these two objectives as their development will give a clearer demonstration on how the module developed will work in the real whole system environment. Thus the second high level objective is a model of EMAS (Motorola Penang knowledge-based expert system).

In each high level objective laid a number of main objectives to be achieved. These main objectives are followed by objective components in order to realize the particular main objective. These objectives however are arranged in a time sequence.

The feasibility of the project within the scope and time frame had actually been planned so that the total time taken to complete the project would be no more than 47 weeks which the amount of weeks for the whole FYP period. Factors affecting the time frame would most probably be the traveling factor (distance) and overall system complexity.

Table 3.1 and 3.2 will show the main objectives, the components for each main objectives and their timeframe.

3.2 High Level Objective 1: Development of a Web-Based User Configurable Numerical Data Acquisition Module for EMAS

This module is planned to be developed 5 to 6 months time inclusive of the time taken to define the requirements and testing.

Table 3.1 High Level Objective 1

Main Objective(s)	Objective Components	TimeFrame
Documenting Requirements Clarification	Define task/role Scope Documenting processes flow diagrams Documenting required data/ measurements type Documenting required system functionalities Identify tools, platform, database Requirements Documentation Acceptance	1 week 2 weeks 2 weeks 2 weeks 1 week 1 week
Designing System Interface Prototype	Research on Interface Requirements Analysis of current interface Draft/Design Interface Present Interface Prototype Designs Interface Design Acceptance Test	2 weeks 1 week 2 weeks 1 week 1 week
System Functionalities Development	Research & Document Configurable Algorithm Program/Develop functionalities Present Configurable function developed Documenting Acceptance Test Plan Configurable function Acceptance Test	1 week 4 weeks 1 week 1 week 1 week
System Integration	Configure system integration with database Documenting Blackbox Test Plan System Blackbox Test	2 weeks 1 week 1 week
Launch System	Clarification on system launch	1 week
Total No of Weeks		29 weeks

3.3 High Level Objective 2: A model of MOTOROLA Penang knowledge based electronic measurements & tracking system - EMAS

This model will actually be the main system which will consists the previous module (3.1). The objective of constructing the model in 18 weeks is seemed relevant and logical even though it is a huge system. This is because certain functionalities will only be developed partially and some maybe omitted. The important aspect of having the model is just to present the integration of the developed module (3.1) with the main system.

Table 3.2 High Level Objective 2

Main Objective(s)	Objective Components	TimeFrame
Documenting System Requirements	Prepare system process flow diagrams Identified system functionalities Identify tools, platform, database	1 week 1 week 1 week
Designing Main System Interface Prototype	Develop login page Develop main menu interface	1 week 1 week
System Functionalities Development	Develop Short Term(corrective action) module Develop Long Term(recommend) module Develop Entitlement module Integrate Numerical Data Acquisition module into entitlement module	3 weeks 3 weeks 3 weeks 2 week
System Test	Documenting Blackbox Test Plan System Blackbox Test	1 week 1 week
Total No of Weeks		18 weeks

CHAPTER 4
LITERATURE REVIEW

4. LITERATURE REVIEW PROCESS

Throughout the process of familiarization with the area of study, certain references were made through books and journals. These books and journals provided necessary explanations and even comparisons. In this part of the report, those relations will be revealed by the arrangement of the literature review from large area of study to the central topic of study.

4.1 Topic Definitions

The title **Digital Six Sigma Concepts in Expert Systems – Development of Web-Based User Configurable Numerical Data Acquisition Module for MOTOROLA Penang EMAS** could be separated into two major portions area of studies. The large areas of study will be on initiatives or methodologies (4.2) which are currently known and the study on expert systems (4.3) from history till present. Correlations will be specific study on the concepts of Six Sigma® (4.2.1) as one of the initiatives and the philosophy in an expert system (4.3.1). Lastly at each of these major portions, consequences after the specific area of study are the central more specific areas; Digital Six Sigma® (4.2.1.1) and the configurable module (4.3.1.1).

4.2 Improvement Initiatives: Overview

Nowadays, companies are in the midst of executing programs, schemes and others. Towards advantageous desired objectives. Anyhow most of these initiatives actually sponsor for quality improvement, process efficiency, cost savings and productivity optimization.

William Truscott(2003)[2] listed and explained several of these initiatives which are ISO 9000 :2000, Total Quality Management, Juran, Deming, Crosby, Feigenbum, Ishikawa, Kaizen, Taguchi and Lean Organization. Each of these initiatives, even though focus improvements as the end result had actually different types of approaches.

ISO 9000:2000 provide quality management systems standard at least in terms of information load through eight principles which are customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making and mutually beneficial supplier relationships. Total Quality Management is a management approach of an organization centered on quality, based on the participation of all its members and aiming at long term success through customer satisfaction, and benefits to all members of the organization and to society. Juran directed management activity at two events which are control and improvement. Deming approach uses a top-down and bottom-up towards quality management. The Crosby way emphasis on Zero Defects in which through this initiative quality at the first time is a company performance standard. Feigenbaum had three management commitments to the concept of quality control which are excellence driven not failure driven, make quality improvement a basic habit that is relentlessly pursued within the organization and promote quality and cost as complementary not conflicting objectives. The Ishikawa way is best known through its diagram which is now known as the 'fishbone' diagram and also the creation of 'Quality Circle' as a quality problem solving session. Imia's kaizen process promotes continual improvement as a matter of daily habit thus success can be achieved when this becomes standard practice throughout an organization. The Taguchi way approach quality improvement through various stages of product/process/service development with eight concepts to make up the key elements of Taguchi's design quality strategy. The lean organization which is based on the production system evolved at Toyota aims to achieve highest quality, lowest cost and shortest lead time through lean based techniques which are continuous flow, pull system and waste elimination. Six Sigma®, which uses the strength of statistical analysis and having quality improvement as its goals is also known as one of improvement initiative which will be describe in detail in 4.2.1.

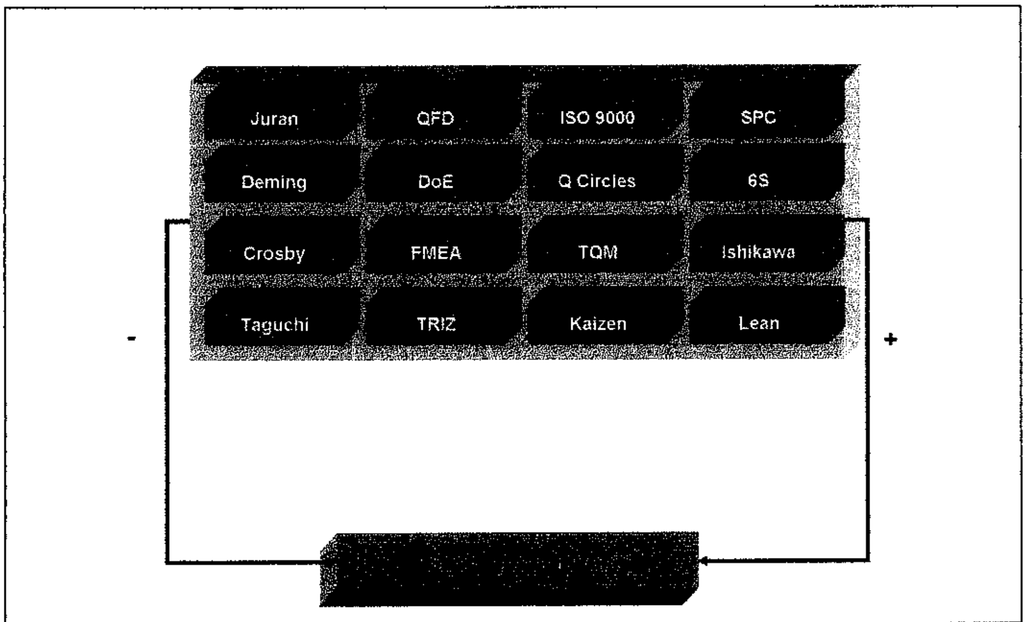

Figure 4.1 Six Sigma® as Orientating Mechanism for selected elements of various approach

Figure 4 shows that Six Sigma driver actually comprises of other existing initiatives in the use of tools. Through the study of these various initiatives, Six Sigma® is noted to adopt, and builds upon, many of the best-practice methods and practices applied on those initiatives as described by William Truscott (2003).

4.2.1 Six Sigma®

As one of existing initiative in its era, Six Sigma® encompasses certain commonalities and differences with other initiatives. While other initiatives are being deployed in a fragmented manner throughout the organization, Six Sigma® provides an orientating and integrating mechanism which actually embodies four focuses; system, process, project and Guru.

Compared with Ishikawa's there is actually much similarities between Six Sigma® and quality circles, the significant differences are the choice of project, extent of training and outcome expectations as detailed by Wiliam Truscott(2003)[3].

The seed of Six Sigma® was sowed around 1979, when Motorola CEO Bob Galvin set up a task force to counter arising competitions in the industry with a ten fold quality improvement target within five years. This effort was exclusively focuses on manufacturing as it was the source of a majority of the problems besides helding greatest promise for improvement. The manufacturers' competition in wireless communications products and semiconductors were actually very fierce during the time especially with the intervention of top Japan manufacturers in the industry as described by Ed Bales (2003)[4].

The technique or methodology used during these times was still vague. The establishment of Motorola Manufacturing Institute (MMI) in 1984 produces great impact. The institute conducts two weeks program for senior manufacturing managers focused on developing and sharing quality improvement goals. This gave useful insights to them and made them realized that the tenfold quality improvement goal would fail if focus was only given on manufacturing alone. Therefore improvement and refocus of MMI moved from just manufacturing to all aspects of management based on the remarks received from the first program participants. Still there is a need to align these different aspects of management in order to allow a common metric for sharing and comparing improvement initiatives.

Then in late 1985, quality engineer Bill Smith as a result of a meeting with Bob Galvin, created a program entitled "Design for Manufacturability"(DFM). DFM defined the "Six Steps to Six Sigma®" and became huge with technical personnel worldwide were required to take the training. Another Motorola engineer, Craig Fullerton developed and thought

"Six Sigma® Design Methodology" which is today called as Design for Six Sigma®.

Chronologically Six Sigma® had been able to align all quality efforts around a common measurement process, and Six Sigma® goals actually drive every team worldwide. Ed Bales (2003)[5]

Based on these early studies of Six Sigma® development and concept it is obvious that compared to other initiatives Six Sigma® had been able to demonstrate its commonality to be used in any aspect of the management, from manufacturing to business. As mentioned by Doug Sutton, president of Fidelity Wide Processing, Six Sigma® is not only in manufacturing but it can also be applied effectively to the financial services industry.

4.2.1.1 Digital Six Sigma®

Motorola recently improved traditional Six Sigma® techniques and successfully applied them in many different types of organizations around the world. As Six Sigma®'s inventor, Motorola is uniquely qualified to provide insight into past failures and future opportunities.

The latest result is the initiation of digitizing the version of the original Six Sigma® with the capability of automation and IT. Martin Swarbrick (2004) quoted that Digital Six Sigma® (DSS) activity which started on 2003, could be highlighted with a few of recent accomplishments, demonstrating the diverse areas where the DSS approach has been used to increase Motorola effectiveness: increased share of indirect market, component cost savings, and net meeting based training.

The use of IT in Digital Six Sigma® can possibly be viewed thorough the development of expert systems, digital dashboards, web based applications, centralized database and computer aided or automated system.

4.3 Expert Systems: Description

The wealth of a nation was once depends on physical labors. These physical labors were at no doubt are limited in size and stamina. Then came the era of machines fueled by steam and oil. These machines were created exclusively to assist labor intensive tasks thus eliminating previous issues of limited size and stamina. As time passes by, initial value in machines powered by steam and oil was challenge by an asset which can be considered as much more valuable.

Today, surpassing the value of machine power was the intellectual capital. Intellectual capital possesses by skillful people that were actually producing innovations, improving inefficient processes, and even breakthrough new findings at no doubt bring benefits and ease others.

This ongoing evolution placed us in search for new machines which can capture the expertise, preserve experience and still maintains skills for desired results. Such machines are called machines powered by knowledge.

4.3.1 Philosophy of Expert Systems

John Durkin (2002)[5] described that the foundation of AI (which was expert system main framework) was first laid through the work of Socrates, Plato and Aristotle. This complies with the logical thinking which Socrates is so intrigue with, Plato searches for nature of forms and Aristotle logics.

The architecture and algorithm which lies within an expert system is complicated, logical and infested with thousands of possibilities. In order to develop such system, the nature of the process should be understand and analyze for possibilities. These possibilities should actually refer to the logical algorithms which construct the process. All possibilities should also being addressed within the scope or process.

In designing an expert system constructing decision trees as shown by Hussein, Shigeo and Yasuhiro (2003) from examples could actually be implemented through observing the processes. Hussein, Shigeo and Yasuhiro (2003) mentioned that a decision tree is used as a classifier for determining appropriate action for a given case.

Designing a decision trees prior to expert systems algorithm draft will assist the process of understanding and listing possibilities. Through that also the range of the system complexity could actually be estimated. This is important as time would not be wasted on unworthy case extensions.

4.3.1.1 User Configurable Module

But as time changes, people around are getting much more independent of themselves. They would prefer something that can be controlled and changed based on their requirements.

Motorola Penang is concern on the concept of achieving standardization and commonalities but without the cost of leaving any unique requirements. That is why such configurable module should be developed to be generic enough to suit all process requirements regardless complexity and unique processes.

The configurable module should actually get the process became better and improved as time passes by as mentioned by John Durkin (2003)[6] that being forgers of our own tools, provides capability of shaping according to our own purpose but at the same time the tools also shape us. As we use them, they tend to shape our conception of our world, processes and show ways that might improve it. This interaction is an essential aspect of the evolution of human knowledge.

CHAPTER 5
RESEARCH METHODOLOGIES

5. RESEARCH METHODOLOGIES APPLIED

In this project the research methodologies could be divided into four major methods. Figure 5.1 visually explained this. The four major methods were:

a) **Continuous Literature Review**
b) **Research Visit**
c) **Real Case Study**
d) **System Development Techniques**

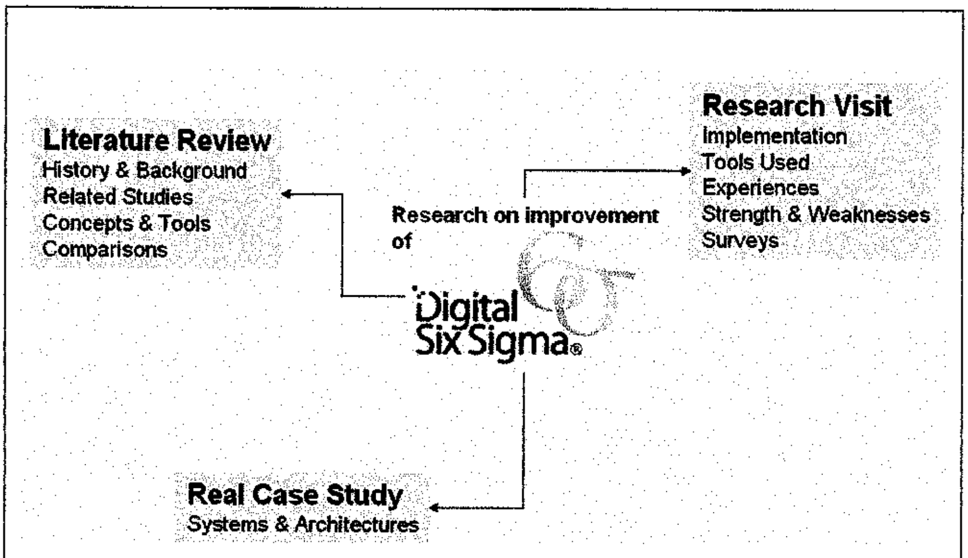

Figure 5.1 Project Work: Methodologies I

5.1 Continuous Literature Review

Literature review, a common method in any research had been crucially important in pursuing these aspects:

- **History & Background**

- **Related Studies**
- **Concepts & Tools**
- **Comparisons**

In order to collect information regarding these, primary and secondary sources are collected from library and websites. This information are later digested and converted into summarization for analysis purposes.

The literature review will actually strengthens the fundamentals of Six Sigma concepts. The understanding in fundamentals is definitely needed in order to ensure successfulness of this project.

5,2 Research Visits

For this project research visits had been exercised in order to get the real feeling of processes Implementation, Tools Used, sharing Experiences, identifying Strength & Weaknesses and also gathering Surveys statistics.

5.3 Real Case Study

Real case studies are derived from the research visits. Trough this, the overall system and architecture could be analyze.

5.4 System Development Techniques

Other defined methodologies for this project are based on the development of the software system. The techniques listed below are actually proposed techniques that will be applied into the project. Nevertheless these techniques might be replaced or even additional techniques will probably be introduced along the period of this project's development.

5.4.1 Digital Six Sigma® Methods – DMADV

Digital Six Sigma® method of DMADV is actually used for developing new products or processes. DMADV is the cycle that will be used in software system development process which stands for Define, Measure, Analyze, Design and Verify. Processes for the data acquisition module and the expert system model will be done and keep track according to DMADV cycle. As it lies under Digital Six Sigma® methods, using DMADV cycle the status will be track digitally in terms of information storage and static digital dashboards.

This technique will be used to achieve both **High Level Objective 1 and 2** (refer section 3.1 and 3.2) which are the **Development of a Web-Based User Configurable Numerical Data Acquisition Module for EMAS** and **model of MOTOROLA Penang knowledge based electronic measurements & tracking system – EMAS.**

5.4.1.1 Static Digital Dashboard

As mention in 5.1, Static Digital Dashboard will be the monitoring technique to be apply in the software system development. Digital Dashboard could be described as a method of tracking current status of software system development through arranged data in a digital tables called as dashboards. These dashboards can be developed through computer programming (HTML, ASP, VBScripts, JavaScripts) with the data connected to database service or just using Microsoft Excel. For the purpose of the project, as the dashboards will be static (means that it will not automatically update the data itself), Microsoft Excel will be used.

The dashboard will have requirements or components for the software system in the y axis and timeline on the x axis. The term static is used for these dashboards as they are not dynamically alive, which means they are not automated. For the sole purpose of tracking these dashboards will be simple but carries descriptive functionality for within specifications tracking during the software system development. The advantage would be the early control for the software system as early as during development.

The objective of this methodology of monitoring is to achieve partially both objectives mentioned in 5.1 as the monitoring tool – dashboard; will be used in both systems development.

5.4.2 Generic Algorithm Testing

Generic Algorithm Testing was an own defined term for the structure of computer programming to be used during the development of user configurable module. It is in the mode of testing as a generic algorithm which will be able to cater any process requirement will include lots of possibilities and configurations. So testing is the most appropriate as in the sense of testing the algorithm will be developed to engage users' expectations.

The objective for this method is to achieve a generic algorithm in computer programming code that will suit the requirement for variations of configurability. This methodology will help in producing the web based user configurable module.

5.4.3 Requirements Analysis & Identifications through Process Flow Diagrams

Through drawings in diagrams, processes flow could be visualized. These diagrams will each represent the system or process as a whole and also if needed highlights certain critical portions as with this method requirements should be clearer. These process flow diagrams will be draw based on current working processes which are approved by responsible personnel to ensure their validity.

The Process Flow Diagrams will assists effectively in the process of understanding multiple and various processes flows. Therefore the requirements for the system in terms of knowing functionalities to be constructed will be much easier to identify. Figure 5.2 shows the relations between methodologies and tools with the two major objectives.

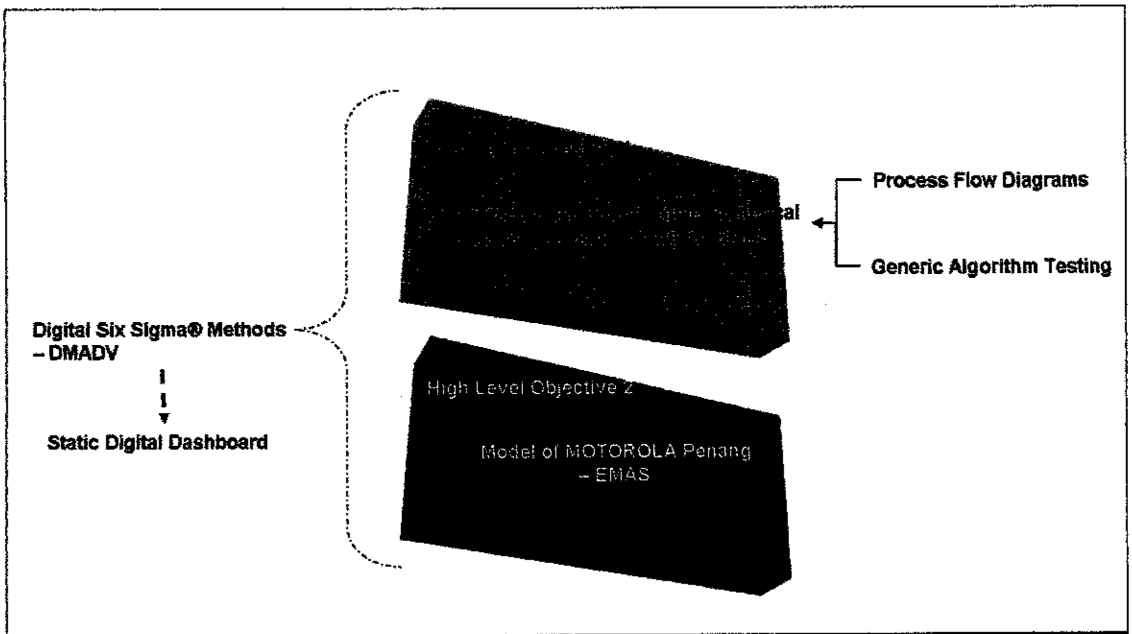

Figure 5.2 Project Work Methodologies II – System Development Techniques

CHAPTER 6
RESULTS & DISCUSSIONS

6. ANALYZED RESULTS

The results were analyzed from information gathered through visits, observation on methods used for this project and comparable advantages produced from the project.

6.1 Research Visits Results

Below are listed facts gathered from the visit to PETRONAS Penapisan Melaka and PETRONAS Fertilizer Kedah.

Source : PETRONAS Penapisan Melaka

Date : 1 Dis 2005

Six Sigma presence : Yes

Condition : Six Sigma projects observed and executed by Six Sigma department.

Man power : 8- 10 engineers in the department itself, consists of Black Belts and Master Black Belts, total BB & MBB : 17 - 20.

History : Six Sigma initiated by Konoko Philips, rooted from GE. Started in PPM about 2-3 years

Tools : SigmaNet,SigmaFlow,MiniTab

Based on interviews and observation, the used of Six Sigma at PPM could be consider as quite new compared to MOTOROLA, TOYOTA and a few other companies.

But still, in this visit, through the discussion and sharing session a few points with regards to this project are taken:

a) a digitalized system for Six Sigma had already been used

b) current digitalized Six Sigma system didn't have tracking module

c) Six Sigma projects were aimed mainly to reduce costs

6.2 Surveyed Statistics

Figure 6 described the impact of Six Sigma projects to Petronas Penapisan Melaka. Based on Research Visit gathered information we could derive the ratio of total costs saved for the past two years completed Six Sigma projects, total number of projects closed per year (latest) and the total cost saved.

Ratio : 2004 (RM 530 000) 2005 (RM 1 960 000)

Latest Total Six Sigma projects closed : 40

Total cost saved : 60 000 000

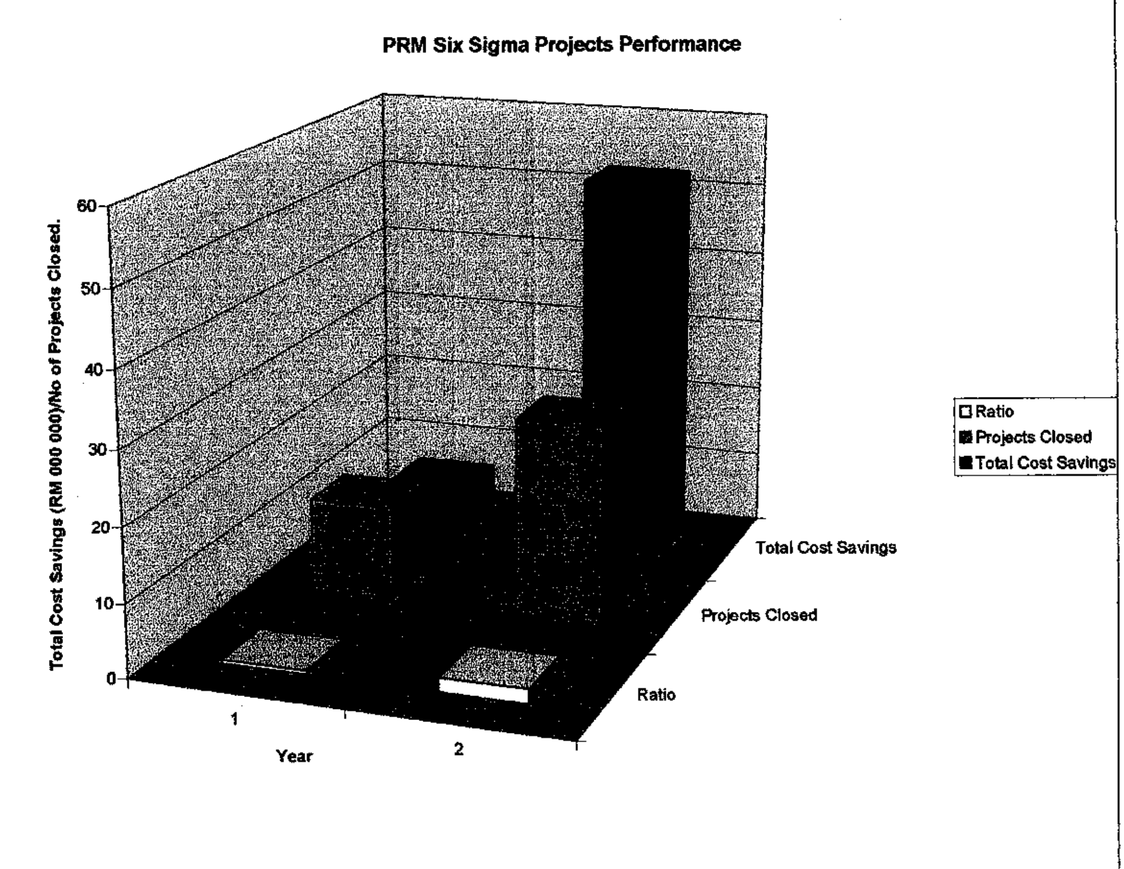

Figure 6.1 PETRONAS Penapisan Melaka Six Sigma Projects Performance (2004-2005)

6.2.1 Statistics/Graph Interpretation

From the graph (figure 7) we could see almost 50% increase both in ratio of total costs saved and number of projects closed. Meanwhile, even though the total cost savings may seem to be improved greatly in the second year, anyhow this condition may be influenced by the scale of Six Sigma projects conducted where bigger projects may involve larger amount of costs.

Based on the graph also it is observable that the interests towards Six Sigma projects had grow over the period. Referring back to the total costs saved in the second year, we could assume that the trust to Six Sigma projects had increased greatly with involvement of larger scale projects which eventually increases the total costs savings.

6.3 Data or Information Gathered for Project Improvements

Based on research visits and surveys, additional information for project improvement were gathered. These information will assist in the process of completing and enhancing the project developed.

6.3.1 High usability and reliability at minimum costs

From the visits, one of the concerns being taken into consideration is to have a reliable and usable system at a low cost. Nowadays most Six Sigma management system can be considered as having high costs just to get it deployed. In addition to that, the consumers need to attend Six Sigma courses, certified as Green Belts or Black Belts just to get a grasp of Six Sigma concepts. In the end a total lump of these figures might results in an expensive package.

Based from that, the requirement for a low cost system but packed with features and function emerged.

6.3.2 The need for tracking module

The tracking module is one of the features in this project that actually catches interest of personnel at PPM. The tracking module is meant to exercise the capability in monitoring Six Sigma projects as well as being a major contributor towards statistical analysis.

6.3.3 A detailed approach

The detailed approach showed from SigmaNet used by PPM, indicate the requirements for a comprehensive system.

6.3.4 Guaranteed results

Based on the visit also, measured results should be known and broadcasted to the users of Six Sigma system. Besides as the means of motivation, such method is also useful in tracking successful projects. This is also as well as making sure completion or closed of a Six Sigma project.

6.4 Analysis on Related Systems

SigmaNet

6.4.1 Introduction

SigmaNet is one of the systems used in PETRONAS Penapisan Melaka (PPM) in managing their Six Sigma projects.

6.4.2 Purpose

The SigmaNet application will be used by Six Sigma Blackbelts (BBs), Greenbelts (GBs), Project Champions (PCs), Master Blackbelts (MBBs), Finance Analysts (FAs) and Executive Champion to track Six Sigma Blackbelt and Greenbelt project progress and financials. This document is the User Guide for SigmaNet application.

6.4.3 How doest it works?

Basically it can be described as having four main modules which are:

- Ideas
- Projects
- Financials
- System Administration

6.4.3.1 Ideas

All employees and contractor that have access to the Company network and email will be able to enter ideas into Sigma Net.

In the Ideas module, users can do Sorting & Filtering, Scoping Ideas, Assigning Ideas, Rejecting Idea and manage On- Hold Ideas.

6.4.3.2 Projects

When any Six Sigma user enters the system, they will begin on the Welcome Page. Depending on the role of the users, the screen may display the user's current projects, as well as any BB projects they are mentoring, and GB projects they are mentoring. This is where users could perform various tasks such as Updating Projects, Moving to Measure Phase, review Project Summary and Audits.

6.4.3.3 Financials

This is the module where *Validating / Un-Validating Financials* as well as *Amended Financials* are being conducted.

6.4.3.4 System Administration

In this module, *User Roles & Rights* could be configured. Besides that there is also the function of *Sorting & Filtering Users, Adding Users* and *Updating Users.*

6.4.4 Systems Comparisons

In this section the specifications of SigmaNet versus EMAS was studied and been displayed in table 6.1.

Based on these comparisons, we could conclude that SigmaNet is a more specific software used by professional Six Sigma users compared to EMAS which was used by anyone granted access.

Despite the less in one module for EMAS compared to SigmaNet, EMAS modules seem to have larger capability in terms of satisfying users need and requirements. This statement is based on the scopes which were covered by both systems. EMAS scope is proven to be larger at scale compared to the scope provided by SigmaNet. This is because EMAS was actively used in the manufacturing processes where different types of processes exist. Meanwhile SigmaNet catered the need of Six Sigma group of professionals.

Table 6.1 SigmaNet vs EMAS Comparisons

SigmaNet	**EMAS**
Main purpose of this system is to track Six Sigma Blackbelt and Greenbelt project progress and financials.	Main objective is to track immediate and long termed action items with embedded FMEA knowledge as the mechanism in assisting problem solving, making improvements and performing analysis.
Contains 4 main modules : ▪ Ideas ▪ Projects ▪ Financials ▪ System Administration	Contains 3 main modules : ▪ Short Term – Corrective Action ▪ Long Term – Improvement Plans ▪ Planned Activities – Entitlements
Users : ▪ Six Sigma Blackbelts (BBs)	Users :

▪ Greenbelts (GBs) ▪ Project Champions (PCs) ▪ Master Blackbelts (MBBs) ▪ Finance Analysts (FAs) ▪ Executive Champion	Anyone with access
Tracking & Observation through : ▪ Audit Summary Page ▪ Project Financials Page	Tracking & Observation through : ▪ Digital Dashboards ▪ Online Analysis Processing

6.4.5 System Relevancy with Project

SigmaNet can be considered as a detailed approach in managing and constructing Six Sigma projects. Meanwhile the project (EMAS) emphasized in an overall coverage of Six Sigma project which includes managing, constructing and also monitoring the execution. The SigmaNet can be among the best reference in terms of additional features and functions.

6.5 Project Findings

The project findings were based on overall observation to the outcome produced since the project development initiated. In this section two areas were specified; the advantages (6.5.1) and observation on the proposed method (6.5.2).

6.5.1 Numerical Data Acquisition Module Advantages

The numerical data acquisition module developed through this project would benefit most of the manufacturing processes and preventive maintenance activities in Motorola Penang plant.

6.5.1.1 Replace Current Numerical Data Acquisition Module

This module replaces the current web forms used in the area where numerical data is acquired from the manufacturing processes. Furthermore it support towards the vision of having a single generic platform which means these processes would have a standardized framework and accessibility. Regardless the location or types of user processes the developed module could be easily access and would guaranteed synchronization to the whole system and database.

6.5.1.2 Assist & Ease New Processes

As a conjunction from the previous advantage, the Numerical Data Acquisition module helped new processes involve in collecting numerical data through easy and user friendliness configuration capability. In addition to that the configuration itself could be done based on the process requirements.

6.5.1.3 Centralized Data Storage versus Configurable Capability = Time

The Numerical Data Acquisition module embedded and integrated into the EMAS architecture provides centralized data storage as this module would share the same database. Besides that aspect, there is also the configurable capability which let users configured the module based on their processes need and requirement. Both features actually contributed towards a better cycle time this is important especially in getting crucial processes on the run as soon as possible. For example, lesser time will be taken to prepare data acquisition interface for a desired process as the configuration capability had been made available.

6.5.2 Observation on method proposed

Generic Algorithm Testing

This procedure was crucial in developing the configuration form for Numerical Data Acquisition module.

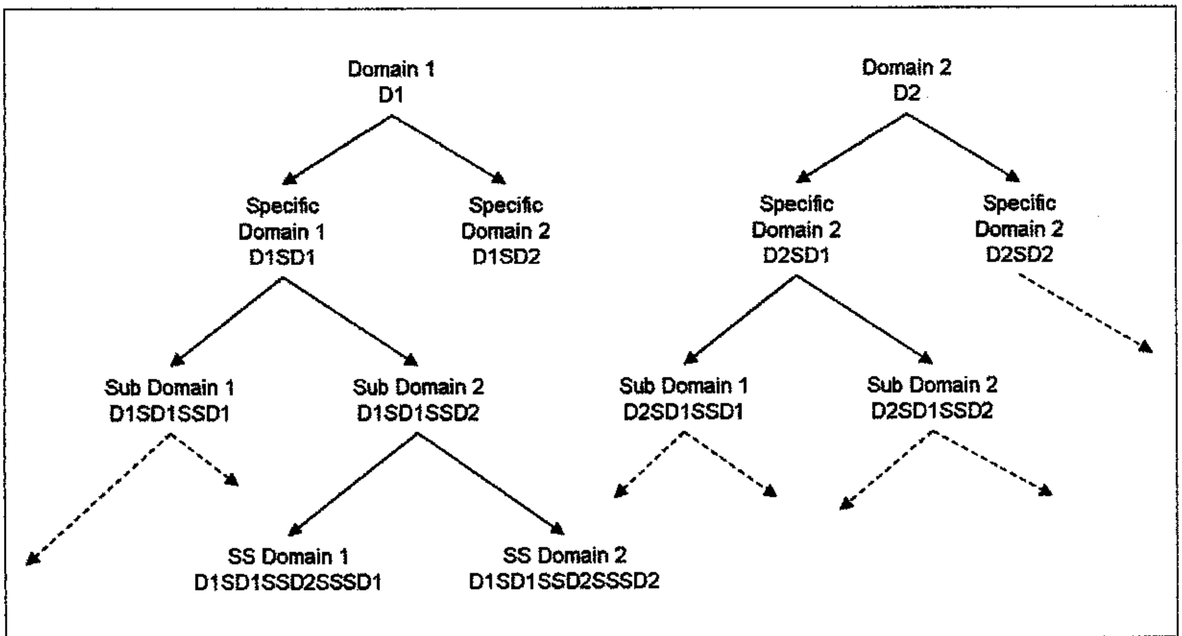

Figure 6.2 Generic Algorithm Hierarchical Tree

This method had proved itself usable for the development of the completed module. The algorithm which consists of conditional statements produce the capability needed for this module which is the configurable capability. Below is the portion of the coding with regards to the explanation:

```
<SELECT NAME="domain" id=domain STYLE="FONT SIZE=9">
<OPTION <%If request("pass") = 1 then%> VALUE=""<%Else%>VALUE="<%=request("domain")%>"<%End If%> selected><%=request("domain")%>

<%ctrArr = 1%>
<%x = 1%>

<%If cntRec1=1 then%>
<OPTION VALUE="<%=arrDom(1)%>"><%=arrDom(1)%>
<%Else%>

<%Do until ctrArr = cntRec1%>

<%Do while cstr(arrDom(ctrArr)) = cstr(arrDom(x))%>
```

```
<%If x = cntRec1 then%>
<%Exit Do%>
<%Else%>
<%x = x+1%>
<%End If%>
<%Loop%>


<%If x = cntRec1 and cntRec1 = 2 and arrDom(cntRec1)
<> arrDom(cntRec1-1) then%>
<OPTION VALUE="<%=arrDom(x-
1)%>"><%=arrDom(x-1)%>
<OPTION
VALUE="<%=arrDom(x)%>"><%=arrDom(x)%>

<%Else%>
<OPTION VALUE="<%=arrDom(x-
1)%>"><%=arrDom(x-1)%>

<%End If%>
<%ctrArr = x - 1%>
<%ctrArr = ctrArr + 1%>
<%Loop%>

<%If arrDom(cntRec1) <> arrDom(cntRec1-1) then%>
<OPTION
VALUE="<%=arrDom(cntRec1)%>"><%=arrDom(cntRec1)%>

<%End If%>

<%End If%>

</select>
```

Note that in this coding if and else statements had been used quite extensively to create the sequential effect of a selection. The selections and its post effect is what considered as the configurable capability. Besides just mere conditional statements of selections and their effects, take note that for each selections and their effects are dynamic. This means that these selections and effects could be changed and it is not hard coded. This is through database configuration which again complies with the project requirements for a generic configurable module.

Table 6.2 Examples of Processes Requirements

Processes/Product	Scheduled Intervals	No of Major Class	No of Subcomponents	Types of Inputs
Proscan	Daily	3	4 2 3	Numeric
model assembly	Weekly	4	2 3 2 3	Numeric + Compliances
tune test	Monthly	4	3 3 3 3	Numeric
air check	Daily	2	4 4	Numeric
compro	Quarterly	3	6 6 7	Numeric
packing	Event	5	2 1 3 2 1	Numeric + Compliances

Table 6.2 actually showed examples of processes and their requirements. As observed, there are variations of requirements between one process and another. Using the Generic Algorithm Hierarchical Tree each processes requirement could be satisfied where each branch in the tree will consists of information for it correspondent source. Figure 6.3 illustrates the explanation using Proscan process as the example.

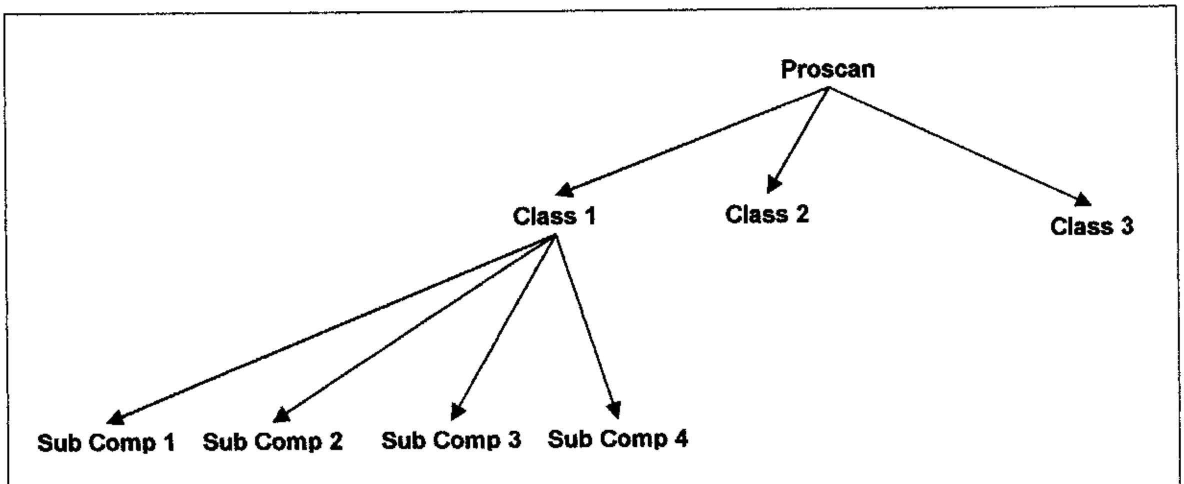

Figure 6.3 Generic Algorithm Hierarchical Tree on Proscan

CHAPTER 7
CONCLUSIONS & RECOMMENDATIONS

7. CONCLUSIONS & RECOMMENDATIONS

Both developments of the user configurable module (3.2) and Motorola Penang expert system model (3.3) required a lot of effort, time and efficient planning. Furthermore the study on Digital Six Sigma implementation using expert system was considered to be another important element other than the developments. Besides due to the tele – working environment of Ipoh and Penang, the complexity of the project is defined at moderate to high level of difficulties as such project has not been implemented yet at Motorola Penang.

It was also concluded that IT capabilities boost the implementation of Six Sigma original concept making Digital Six Sigma a powerful initiative. Anyhow the digitalization and automation process should be in a generic form to suit different requirements, processes or inputs. In addition to using the IT tools and capabilities, the implementation of IT systems should not necessarily be expensive in order to strive for improvement in turnaround time, cost, quality and productivity. This argument was proven with the use of open source language which was ASP in this project.

7.1 Relevancy to the Objectives

Even though this project is collaborated with professionals from Motorola Penang, much process of development and definitions need to be acquire with own defined methodologies or ways. Top processes (process prior to the development) in this project needed to be clarified especially in the definitions of requirements and knowledge on manufacturing or even non manufacturing processes involved. That was what initiated the concept of software development using Digital Six Sigma method – to overcome variations in requirements.

The project had been conducted within the expected time frame which actually proved the relevancy of the objectives. The biggest challenge was the development of MOTOROLA Penang EMAS module. This is because in order to model such expert system and integrates the modules to a scale which is presentable for the standard of Final Year Project, a lot of configurations and commitments were needed.

However, conclusively it is hoped that the concept of Digital Six Sigma®, could be digested especially in the area where Information Technology applies and the applications of statistical analysis. In addition, cooperating with a group of professionals in the area from managers, principal engineer, system engineers and technicians provide handful experience of the real working environment.

7.2 Suggested Future Work for Expansion & Continuation

As for future recommendations for this project mobile applications and machine automated data entry would most likely be suggested.

In fact the initiative towards both suggestions had already been triggered.

In order to execute the implementation of this expert system through mobile applications, a thorough study of the current wireless network infrastructure had to be considered. This is due to the hardware and infrastructure cost that will incur especially in purchasing mobile devices, taking care of them and setting up the wireless network environment. In addition, security of the network should also be taken into consideration.

Meanwhile machine automated data entry would means that the data entered into this system would be automatically configured based on the process executed by the machine. The configurations to suit the process execute by the machine would not be done manually, in fact automatically as soon as the machine is attached to the communication interface of the system. Through this automation, a lot of advantages will be gained. One of the advantages should be in eliminating the use of manual human configuration or data entry, which will actually diminish room for human errors whether directly or indirectly.

8 REFERENCES

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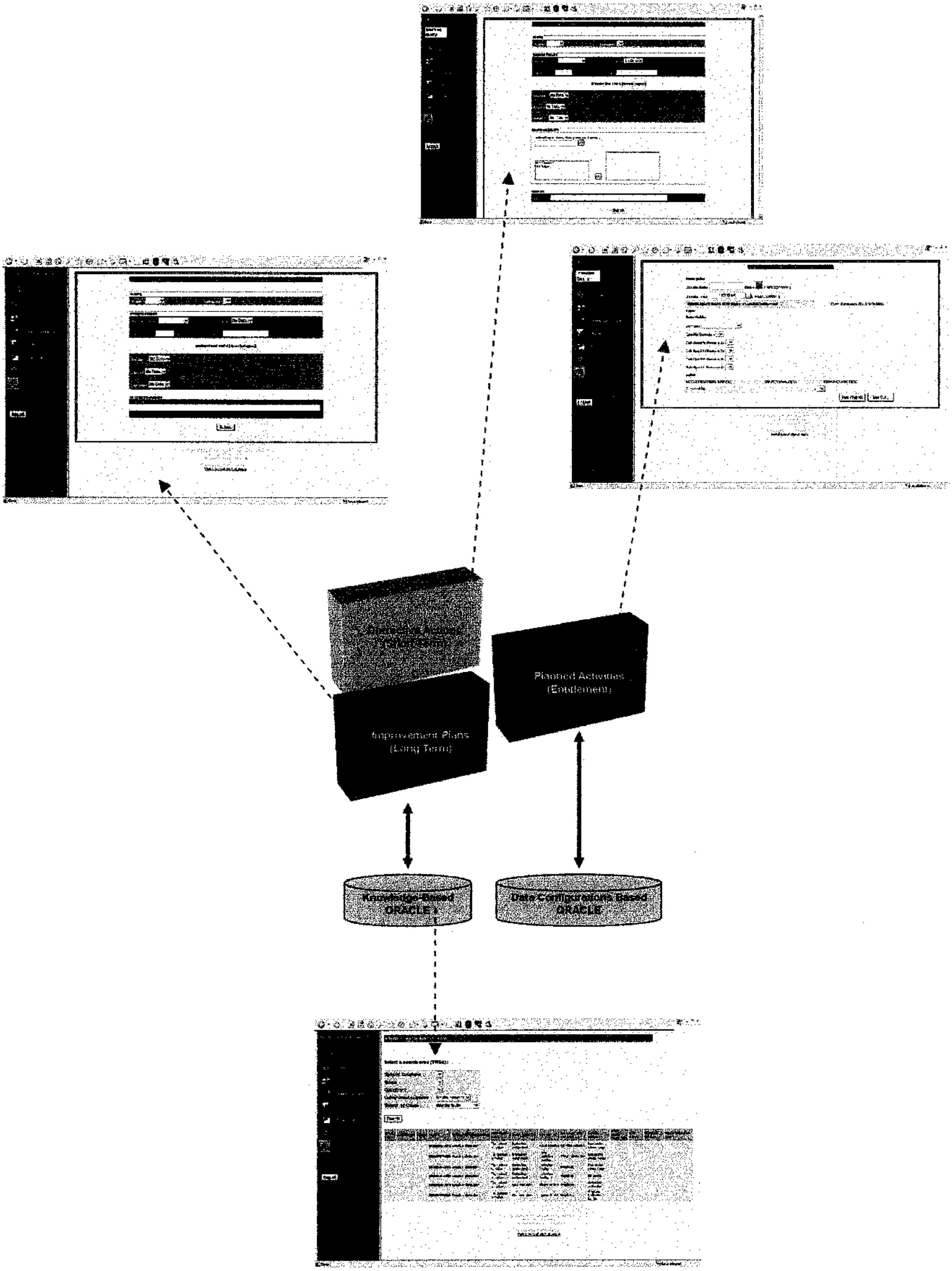
9 APPENDICES

- **Screenshots** –
  - Overall EMAS Architecture
  - Main Login & Main Page
  - Entitlement Module Interfaces (Web Based User Configurable Numerical Data Acquisition Module)
  - Analysis Module

- **Paper** - Revolution of Software Testing through Digital Six Sigma (Abstract Part only)

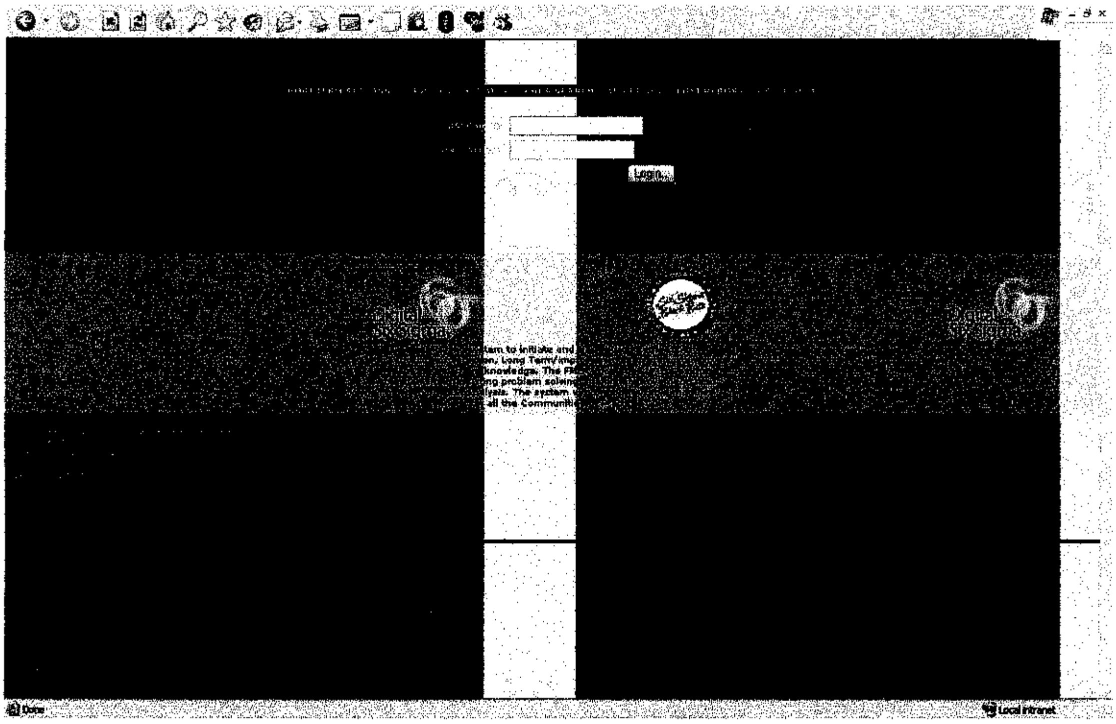
Screenshots

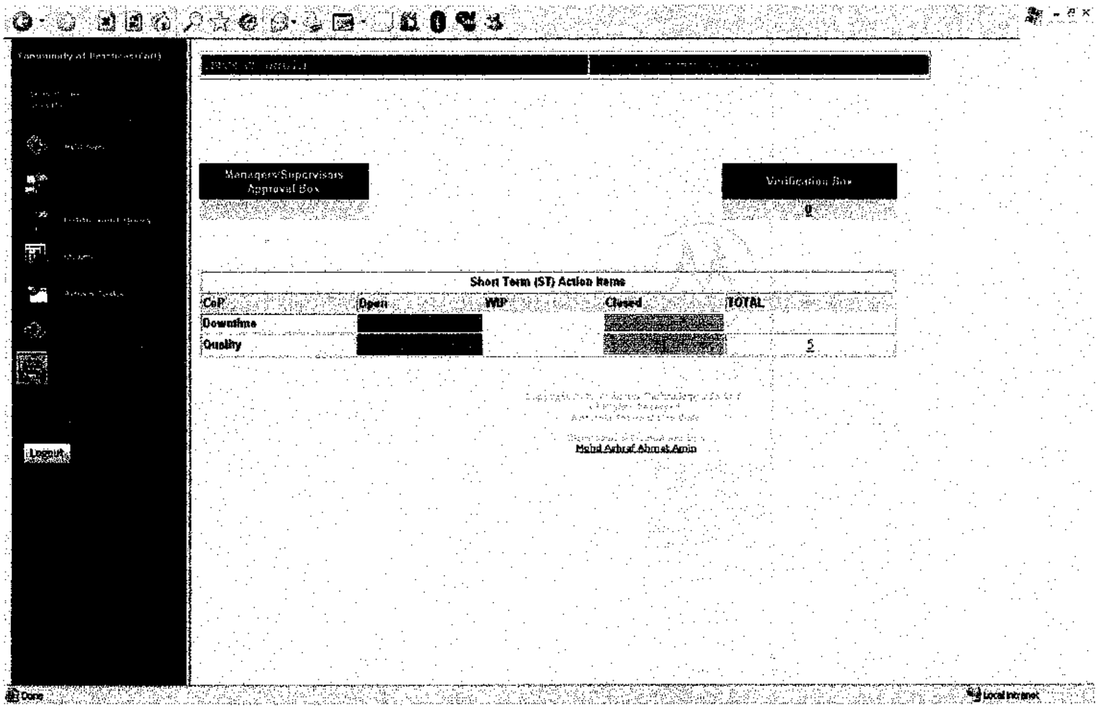
- Overall EMAS Architecture



Screenshots

- Main Login & Main Page

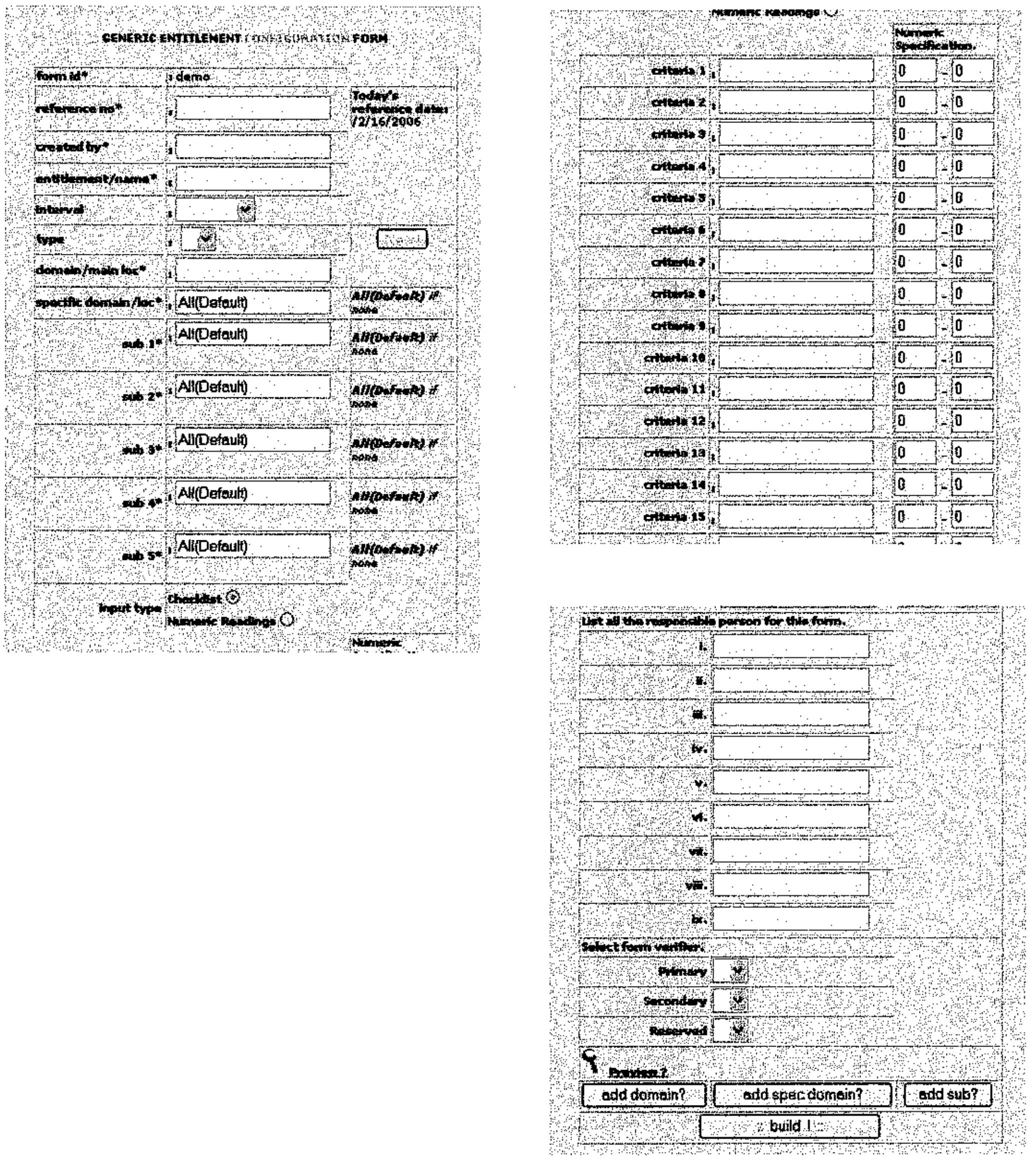




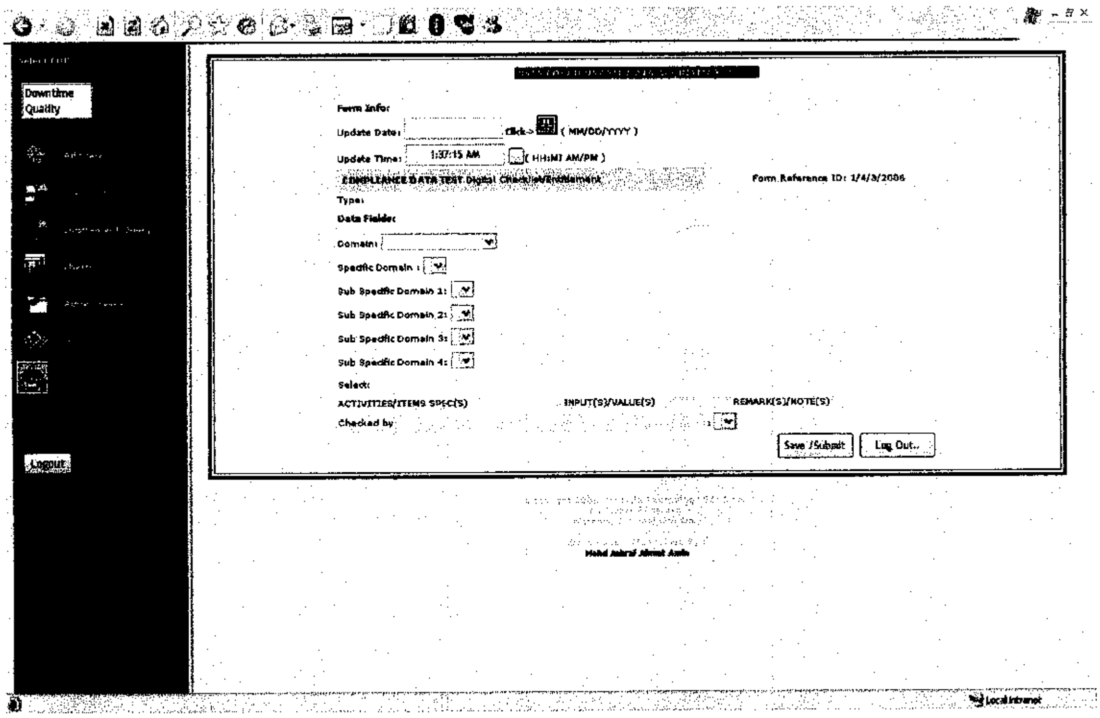
Screenshots

- Entitlement Module Interfaces (Web Based User Configurable Numerical Data Acquisition Module)

<u>Generic Entitlement Configuration Form</u>



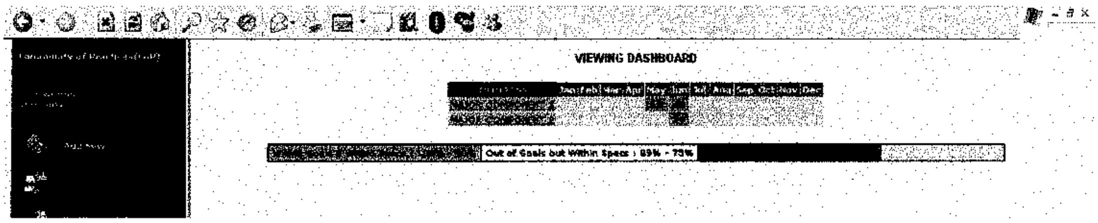
User Configured Data Acquisition Form



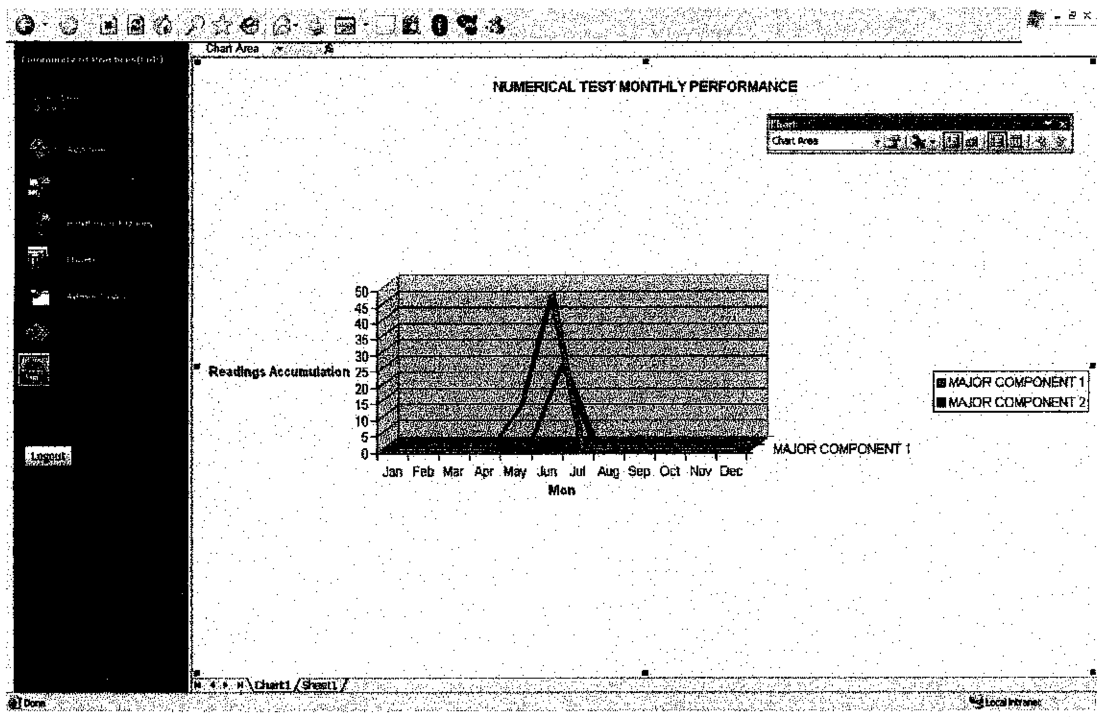
Screenshots

- Analysis Module

Digital Dashboard



Online Analysis Processing (OLAP)



Revolution of Software Testing through Digital Six Sigma

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Abstract

Software testing is any activity aimed at evaluating an attribute or capability of a program or system and determining that it meets its required results of software testing. There are many methods of software testing such as code-based testing, black box testing, module testing and many others. Although crucial to software quality and widely deployed by programmers and testers, software testing still remains an art, due to limited understanding of the principles of software. The difficulty in software testing stems from the complexity of software: we can not completely test a program with moderate complexity. Testing is more than just debugging. The purpose of testing can be quality assurance, verification and validation, or reliability estimation. Testing can be used as a generic metric as well. Correctness testing and reliability testing are two major areas of testing. Software testing is a trade-off between budget, time and quality. Hence using Digital Six Sigma for software testing from the beginning of the project till the complication of the project will be a useful method to have control on budget, time and quality of the software development project. The project development of the software will be visualized as product development in the process of software testing using Digital Six Sigma. We are deploying Digital Six Sigma tools and concepts in order to monitor and control the software development to be within the specification.