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I am submitting herewith a thesis written by Prashant M. Hulloli entitled "Development of Internet Based Lean Assessment Methodology and Tool: UTOPEX". I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Industrial Engineering.

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Development of Internet Based Lean Assessment Methodology and Tool: UTOPEX

A Thesis Presented for the

Master of Science Degree

The University of Tennessee, Knoxville

Prashant M. Hulloli

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Dedicated to my parents (Dr.M.S.Hulloli and Vasumati), my wife (Jyothi), my son (Arya) and my brother (Basavaraj)

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ABSTRACT

Lean implementation is a complex process and requires a comprehensive lean assessment methodology that collects information from all the areas of an organization, and helps to determine the current state of the organization. A lean assessment tool is a stepping-stone for successful lean implementation as it provides an accurate accounting of a company's current state and helps develop future strategies for business activities. It is quite essential to develop a lean assessment tool that focuses on manufacturing systems, support systems, operational excellence (integration of lean & six-sigma), and cultural sustainability of the organization. The assessment tool is developed focusing on an integrated approach, which is flexible, versatile and user-friendly. This assessment tool has been developed as an internet/intranet based software tool that adopts self-assessment surveys answered by employees from different parts of the organization as a methodology to determine the current state. The assessment tool has been tested at various companies and results are compared with conventional assessment methods.

Keywords: Lean manufacturing, Assessments and software based assessment tool.

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ABBREVIATIONS

LEI	:	Lean Enterprise Institute
TPM	:	Total Productive Maintenance
VMEP	:	Virginia's Manufacturing Extension Partnership
LESAT	:	Lean Enterprise Self Assessment Tool
MIT	:	Massachusetts Institute of Technology
UTOPEX	:	University of Tennessee Operational Excellence
ASP	:	Active Server Pages
IIS	:	Internet Information Services
SOP	:	Standard Operating Procedures

CHAPTER ONE: INTRODUCTION

The purpose of this study is to develop a lean assessment methodology that will help enterprises to develop the right strategy for lean implementation. This chapter provides an introduction to lean manufacturing, some background on the importance of lean assessment methodology, a problem statement to illustrate the necessity for the development of a new lean assessment methodology and a description of the organization of the research.

Introduction to Lean Manufacturing

U.S. manufacturing is currently undergoing a transformation of historical significance. In the late nineteenth and early twentieth centuries, manufacturing underwent a transformation from a craft to mass production (Ford, 1926; Piore, 1984; Taylor, 1967; Womack1960)[14]. Now as we enter the twenty first century, mass production is giving way to a new set of production paradigms: lean production (Womack, 1990), agile production (Preiss, 1997), knowledge-driven work (Cutcher-Gershenfeld, 1998), flexible manufacturing (Piore, 1984), innovative mediated production (Kenney, 1993) and sleek production (Handyside, 1997). The lean enterprise concept represents a new paradigm in the way businesses are managed in highly competitive market environments. This concept embodies a collective set of principles, tools and application methodologies that enables organizations to remove waste from their systems and achieve dramatic competitive advantages in speed-to-market, cost, quality, and delivery performance [14]. Re-conceptualization and redesign of the value delivery system are essential for a company to be economically competitive. Organizations that anticipate the need to change and adapt to change will survive in the long run. Lean is both a philosophy and a

set of guiding principles that provide the foundation for continuously improving organizations [13][14].

Background

Lean implementation is a complex, multi-dimensional process requiring strong leadership, a systematic strategy, a skill set, and a culture to carry out and sustain the implementation. Implementing such management practices requires simultaneous attention to several initiatives and their relationships within a lean implementation. Further literature reveals that lean implementation varies from one manufacturing environment to another (Sakikabara et al) [13][15]. With so many possible alternative approaches, choosing the "right" roadmap can be a daunting task. The ability to develop the right strategic roadmap from the outset will help alleviate uncertainty and reduce the chance of setbacks, failures, and disillusionments associated with failed attempts at implementing lean. This has been verified by a survey conducted by the Lean Enterprise Institute (LEI), which states that, "a lack of implementation know-how is one of the two biggest hurdles preventing successful lean implementation". The second biggest hurdle is "back-sliding" or lack of ability to sustain continuous improvement changes (LEI).

Problem Statement

Various industries have attempted to utilize various tools / methodologies to develop strategic roadmaps. Operational assessment is one such attempt, at developing a strategic roadmap based on the perceived strengths and weaknesses of operations. The very components that are essential to make the entire organization lean should form the basic foundation of a true operational assessment. These components include evaluation of the production system, the support system, operational excellence (integration of lean and six

sigma concepts to reduce variability) and cultural development. However, the majority of lean operational assessments focus only on production systems while neglecting the support systems and the operational excellence. Further, these assessments either ignore or provide superficial treatment of the topic of cultural awareness. A review of lean assessments, identified later in Chapter 2, has led to the conclusion that most assessments focus on tools such as total productive maintenance (TPM), visual controls, one-piece flow, cell layout, process mapping and standard work. Yet it is evident that a simple focus on tools and elements alone cannot provide the anticipated results. (Hayes *et al*., 1988)[1]. Less than one third of assessments focus on support systems, operational excellence and cultural awareness. The exclusion of these critical elements for developing a strategic roadmap can lead an organization to a false sense of comfort. Beyond these primary shortcomings in lean assessments, the following are other shortcomings of these assessments in general.

- The assessments lack detailed delineation of various functions of organizations and hence do not include comprehensive questionnaires on all the aspects of a lean organization.
- Assessment tools are not functionally diverse and lack flexibility to support data collection from multiple users from different functional areas of an organization.
- Assessments lack inclusion of complete metrics to measure the performance of the organizations against world-class standards.
- Online assessments lack the flexibility of functioning as an assessment tool, which can be used as a self-assessment tool or as an assessment tool for experts.

- The online assessments lack functionality features that are important for acceptance and continued use of the system/tool.

Organizations need a comprehensive assessment tool that can address the above-mentioned issues and enable users to understand and create awareness of lean practices deployed in their enterprise. These assessments must perform in a way that enables users to understand and create awareness of lean practices that are currently not applied.

Organization of the Research

This thesis is organized into four chapters. Chapter 1 presents an introduction to lean manufacturing and lean assessments along with the shortcomings in the present lean assessments. Chapter 2 presents the literature survey, which provides information on present lean assessment tools and provides a comparison of these present assessment tools against specified factors. It also provides information on the features/requirements of a new assessment tool. Chapter 3 provides an explanation of the research methodology utilized in developing the new assessment tool. It also provides information on the features introduced into the tool and how these features are achieved using internet programming and database management. A case study has been presented in Chapter 3 to compare a basic lean assessment tool with the newly developed assessment tool. Finally, Chapter 4 presents the results of the case study, analysis of the assessments and summarizes the contributions of the research, discusses the limitations of the study and suggests areas for extending this research. Appendix A includes the developed survey and appendix B provides instructions on the usage of the software assessment tool.

CHAPTER TWO: LITERATURE SEARCH

This chapter presents a literature review of the existing lean assessments and their associated methodologies. Representative lean assessments are presented and analyzed against specific criteria that define comprehensive and flexible assessments.

Analysis of Present Assessments

(a) LESAT (Lean Enterprise Self Assessment developed at MIT) [22]

Analysis: LESAT enables the leadership of an enterprise to assess the leanness of the enterprise as well as its readiness to transform itself in accordance with lean principles and practices. The LESAT tool is divided into three sections:

- Lean Transformation/Leadership
- Life Cycle Processes
- Enabling Infrastructure

It focuses specifically on the enterprise level and is designed to highlight the key integrative practices at the uppermost level of an enterprise, which may be a single entity or an aligned organization such as a partnership or a supply chain network.

Methodology: This assessment tool is a survey, which collects the rating of an organization for awareness of specific concepts and techniques in various areas. A set of lean practices is identified for each of the three sections with a total of 54 lean practices included in the LESAT maturity matrices. While not intended to be all-inclusive, these practices do represent some of the more important behaviors of lean organizations.

Method of scales: Each question has to be answered on the scale of 1-5, with 1 being least capable and 5 being the world-class standard.

(b) Corporate Diagnosis Assessment [9]

Analysis: Thomas L. Jackson with Constance E. Dyer in the book Corporate Diagnosis presents reference tables that combine generic diagnostic questions for the control points of the lean management system with progress tables that present the characteristics observed in companies at each level of organizational learning. This assessment focuses on the following nine areas:

- Customer Focus
- Leadership
- Lean Organization
- Partnering
- Information Architecture
- Culture of Improvement
- Lean Production
- Lean Equipment Management
- Lean Engineering

For each of these categories a set of questions is posed to assess the present status of the organization. The assessment team collects the information from the individuals of the concerned areas and evaluates the company depending upon the scores obtained. Finally, the work units and the organization as a whole are scored based on the efforts to improve each key area towards world-class levels.

Methods of Scale: Each question must be answered on an ordinal scale of 1-5.

- Level 5. Mass Production (not done at all)
- Level 4. System Initiation (newly started)

- Level 3. System Development (sound system)
- Level 2. System Maturity (advanced stage)
- Level 1. System Excellence (refined excellence stage)

Total scores in each category are added and the total is then divided by the total factors in that category to obtain a lean category score.

(c) Lean Operations Management Assessment [18]

Analysis: This site, maintained by "Lean Operations Management", has a facility of online assessment that can assist companies in determining their competitive performance in business excellence and lean manufacturing performance. This assessment focuses on the following areas of lean manufacturing:

- Demand and Customer Relationship Management
- Strategic and Business Standards
- Operating-Procedure Planning
- Operational and Customer Scheduling
- Knowledge and Skills Development
- Operating-Data Management and Accuracy
- Business-Systems Effectiveness
- Product and Process-Value Improvement
- Inventory and Capacity-Management

Methodology: The assessment collects data by surveying a single participant. It is an online assessment tool, which collects information of the performance for the above-mentioned factors.

Methods of scale: Each category has a set of 11 questions, which are answered on a scale of 1 to 10. The assessment score compares the organization against other organizations in the industry that are best in the class.

(d) Industrial solutions, Inc Assessment [19]

Analysis: This lean assessment tool contains 15 categories describing attributes of a lean manufacturing enterprise as follows:

- Communication within the Organization
- Operator Flexibility
- Visual Systems and Workplace Organization
- Continuous Improvement
- Mistake Proofing (Poke-Yoke)
- Quality
- Quick Changeover (SMED)
- Supply Chain
- Balanced Production
- Total Productive Maintenance (TPM)
- Pull Systems (Kanban)
- Standard Work
- Lean Accounting Systems
- Engineering
- Performance Measurement

Each worksheet must be completed with an objective effort to appraise the actual situation in an organization.

Methodology: This assessment is a survey, which collects the ratings of an organization for awareness of specific concepts and techniques in different areas. The tool is an online survey with automated results.

Method of scales: A ranking on a scale between 0 and 5 that best reflects the users' observations must be selected using the following definition of rank:

- 0 = The practice is not found anywhere
- 1 = The practice is only seen in a few areas, with inconsistencies
- 2 = The practice is commonly found but with inconsistencies
- 3 = The practice is found in majority of areas with no inconsistencies
- 4 = The practice is found everywhere with consistent execution
- 5 = The practice is everywhere, with improvement over last 12 month

The scores in each category are added and then calculation of the ratio of sum to the total possible score gives a "Lean Category Score". These scores are entered into a spreadsheet for automatic tabulation.

(e) VMEP Assessment [21]

Analysis: This assessment tool is developed by Virginia's A.L. Philpott Manufacturing Extension Partnership (VMEP), which focuses on fostering economic growth by enhancing the competitiveness of Virginia's small and medium-sized manufacturers. The VMEP assessment tool is comprised of 20 multiple-choice questions, with answers to these questions to be selected from a drop down box provided next to each question.

Methodology: The assessment uses an online survey form to collect data from one single participant. This assessment collects the rating performance for an organization on a scale of 1 to 5 with 1 being lowest and 5 being highest.

Method of Scale: The assessment tool offers an average of five options in a drop down menu. One of the options is "not measured", which indicates that the organization does not measure performance in this area. The assessment offers options on various scales, depending on the question: percentages, dollar values, greater than or less than, etc. The assessment sets a highest and lowest value for each of the factors.

Once the assessment is taken, a score is immediately displayed to establish where the organization stands. Depending on the score, an organization can assess its status, using the following scale:

- 91 to 100, outstanding! Your company ranks among the best!
- 81 to 90, your company is above average. Greatness is within your grasp!
- 71 to 80, your company is average. You can do much better.
- 70 or below, your company is below average. You need much improvement.

(f) Strategos Lean Assessment [20]

Analysis: Strategos lean manufacturing assessment has a questionnaire that explores each of nine different key areas. The key areas considered are

- Inventory
- Teams
- Processes
- Maintenance
- Layout and material handling
- Suppliers
- Setup
- Quality

- Production control and scheduling

Methodology: The assessment uses a survey form to collect data from one single participant. This format uses an excel template to record information and scores the results.

Method of scales: There are 3-6 questions for each key area with multiple-choice answers. A scoring worksheet totals the scores for each section and provides an overall lean index.

Shortcomings in Present Assessment Tools

The analysis of present assessments reveals the following shortcomings in general:

- Most of the lean assessments are not comprehensive, as they neglect various concepts of lean assessment, such as suppliers, maintenance, the culture of the organization, and metrics of comparison.
- Most of the lean assessments lack flexibility in terms of the number of people who can use them. Companies are evaluated on the basis of the opinion of only a single person, which may not provide an accurate representation of the organization's strengths and weaknesses.
- Assessments lack flexibility to support to incorporate changes in the assessments instantaneously and are not customized to be company-specific.
- The online assessments lack the flexibility to function as expert systems and/or people systems (allowing self assessment by people in an organization).
- The online assessments lack functionality features that are important for acceptance and continued use of the system/tool.

Criteria for Assessment Evaluation

The comparison of various available assessment tools is based on the factors developed, which are presented in Table 1. It also provides justification for selection of these factors for comparison. For example, the ability of an organization to reduce waste in its manufacturing processes is a key factor to determine effective lean implementation. Similarly an evaluation of the support systems, operational excellence and culture of the organization provide more robust assessment than is possible when these aspects are excluded from evaluation. In addition, functionality-based features such as the ability to support multiple-users, the ease of use of assessment and flexibility of the assessments are critical for evaluating performance. [8][10][11][12]

The assessments are rated in three different categories based on the extent to which a particular factor is incorporated into the assessment. Three different rating categories are defined as follows.

Full Consideration: The status of full consideration is given if a particular area of assessment or a functionality feature is broken down into different categories and sub-categories to obtain detailed information about its particular function. For example, the lean manufacturing section is classified into different categories such as value-stream mapping, visual systems, standard operating procedures and others. Subsequently, the categories are broken down into sub-categories to obtain more detailed information. For example, the category of standard operating procedures is subdivided into standard operating procedures for operations and standard operating procedures for set-ups, providing detailed information about implementation of standard operating procedures in the plant. A rating of full consideration is indicated using the symbol "*".

Table 1. Factors to Compare Lean Assessments

FACTORS TO COMPARE LEAN ASSESSMENTS		
Serial	**Features**	**Definition**
	Area of Focus	
1	Lean Manufacturing	Essential activities performed on the shop floor to eliminate waste in the production system Example: Value Stream Mapping, SOP, Visual System & others
2	Lean Support Systems	Existence of functional support systems to support efficient functioning of shop floor to reduce waste in the system. Examples: maintenance activities, suppliers, information systems, planning and engineering
3	Operational Excellence	Ability to integrate lean and six sigma principles to reduce process variation.
4	Cultural Sustainability	Culture of the organization to sustain the change and to focus on continous improvement
5	Metrices of Comparision	Measure the performance of company against defined parameters such as on time delivery, defect rate and others. These parameters should be compared with the world-class accepted standards.
	Functionality Features	
6	Multiple Participants	Capability to collect information from people working in different functional areas of the organization to better reflect their current state.
7	Company Specific	Flexibility to use assessments based on the type of company
8	Selective Assignment	Flexibility to assign only concerned people to evaluate the concerned functional areas. For example: The production floor people may not be capable of answering questions from area of suppliers
9	Automated Results	Flexibility to provide automated calculation of scores and base guidelines to build the strategy for implementation of lean systems.
10	Expert system	Flexibility to provide recommendationsfrom multiple experts to build the strategy for the implementation of lean systems.

Table 2. Comparison of Current Assessment Tools

Features / Assessment Tools	Assessments Factors									
	Area Of Focus				Functionality Factors					
	Lean Manufacturing	LeanEnterprise	Operational Excellence	Cultural Sustainability	Metrics Comparison	Multiple Participants	Company Specific	Selective Assignment	Automated Results	Expert Recommendations
Lean Enterprise Self-assessment Tool Developed By MIT	▲	▲	▲	▲	●	▲	●	▲	●	●
Corporate Diagnosis Assessment Tool	▲	★	▲	▲	●	▲	●	▲	●	●
Lean Operations Management Assessment Tool (www.leanops.com)	★	▲	▲	●	●	●	●	★	★	●
Industial Solutions, Inc Assessment Tool (www.isiworld.net)	★	●	●	●	●	●	●	★	▲	★
VPMEP Assessment Tool (www.vpmep.org)	▲	▲	▲	●	●	●	●	●	★	▲
Strategos Lean Assessment Tool (www.strategos.com)	▲	▲	▲	▲	●	●	●	●	★	●
UTOPEX Lean Assessment Tool	★	★	★	★	★	★	★	★	★	★

★ = Full Consideration: ▲ = Partial Consideration: ● = No Consideration

Partial Consideration: The status of partial consideration is given if a particular area of assessment or a functionality feature has been addressed but not broken down into different categories and sub-categories to obtain detailed information about the particular function. This suggests that assessments need to be worked on to obtain more detailed information. This rating is indicated using the symbol "Δ".

No Consideration: The status of no consideration is given if a particular area of assessment or a functionality feature has been totally ignored. This rating is indicated using the symbol "●".

Conclusion

Comparative evaluation of selected assessments, presented above in Table 2 shows only three stars, thirteen triangles and six circles out of possible twenty-four stars in areas of

focus that includes lean manufacturing system, lean support systems, operational excellence and cultural sustainability. This indicates that most of the assessments discussed above do not collect detailed information on all the functional areas. Issues related to lean support systems, operational excellence and cultural sustainability are either ignored or superficially treated in most of the assessments. This suggests the following essential requirements for the new assessments:

- They should focus not only on manufacturing aspects but also on support systems, operational excellence, and cultural sustainability.
- They should include a comprehensive questionnaire on all the delineated functions of an organization, resulting in an integrated approach for lean assessment, including the concepts of lean sigma.

Table 2 shows only six stars, six triangles and twenty-four circles out of a possible thirty-six stars in areas of functionality that includes metrics comparison, multiple participants, company specificity, selective assignment, automated result compilation and provision for expert recommendation. This suggests that issues related to the flexibility are not totally incorporated in present day assessments. It is quite essential to collect data from multiple employees as such a broad survey gives better representation of the current state of an organization. The features to support multiple participants, selective assignment, use of expert recommendation and ability to deploy customized assessments are ignored in most of the assessments discussed above. Support for data collection from the multiple users is necessary to achieve a broad vision of the organization. This need suggests the following as essential requirements for new assessments:

- They should be flexible enough to allow the collection of data from multiple users to obtain a broader perspective of the current state of an organization.
- They should have functional flexibility to deploy changes in the assessment to support the development of company-specific assessments
- They should be user friendly and easily accessible any time from anywhere to avoid time- and place-related complexities.
- They should be flexible enough to allow the collection of expert recommendations to develop a right strategic road map.

The literature study reveals that extensive amount of work has been done to develop assessments for manufacturing aspects, as revealed in study conducted by Bradley M.Green in dissertation titled "Taxonomy of the Adoption of Lean Production Tools and Techniques". The assessment developed in book titled "Corporate Diagnosis" and the assessment titled Lean Enterprise Self Assessment developed at MIT focus on corporate level but do not provide detailed approach for various lean concepts implemented on shop floor. The literature study reveals no evidence of studies conducted to compare various available assessments. The purpose of this study is to identify the requirements of new assessment based on comparison of present day assessments. The results of comparison are utilized to develop an assessment methodology that focuses on implementation of lean and six-sigma concepts on all the organizational levels. The results of the comparison are also utilized to develop an automated tool that is functionally diverse and flexible

CHAPTER THREE: UTOPEX ASSESSMENT MODEL

This chapter presents the methodology utilized to develop UTOPEX, an assessment methodology developed at University of Tennessee. UTOPEX has been developed on the assumption that it will address the weaknesses identified in the literature review.

The development of UTOPEX is based on a four-phase approach. The four phases of this approach are

- Development of the assessment including the survey and its rating system
- Development of the online UTOPEX architecture
- Addition of functional features
- Validation of the model.

Figure 1 illustrates the four-phase approach.

The UTOPEX methodology develops an enhanced assessment survey, which addresses the issue of comprehensiveness and focuses on the integrated evaluation of an organization. The UTOPEX methodology has a questionnaire with four different categories and respective subcategories, which can be used to gather delineated information about production systems, support systems, operational excellence and the culture of the organization. The UTOPEX methodology uses an internet/ intranet based software tool to add various functionality features such as multiple users, automated data collection and manipulation and selective assignment. UTOPEX is automated using web-based programming and relational database management tools making it highly flexible and user-friendly. The UTOPEX methodology has been validated at an actual organization and results are presented in the form of a case study.

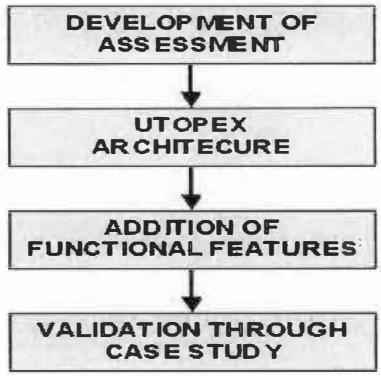


Figure 1. UTOPEX Methodology

Development of the Assessment

Surveys with large cross-sectional samples provide a certain level of external validity (Birnberg et al. 1990; Runkel and McGrath 1972). The UTOPEX assessment has been developed in the form of a survey tool that measures the degree to which the elements of lean have been implemented in the organization. The UTOPEX survey is an enhanced version of the basic lean manufacturing survey available to industry. Adding questionnaires to assess lean support systems, operational excellence and cultural sustainability has enhanced the UTOPEX survey. Different categories and subsequent sub-categories have been added to the survey to obtain more detailed information about particular functions in the organization. For example, the lean support system has been categorized into five categories that assist the operation of shop floor activities. The following are the five categories in lean support systems:

- Design development
- Manufacturing and production control
- Information systems and analysis
- Supplier assessment

- Maintenance program

The categories are further divided into sub-categories to obtain more detailed information; for example, supplier assessment is further divided into the following sub-categories.

- **System for suppliers**: To obtain information about the existence and functioning of system to select and monitor suppliers.
- **Procedures:** To obtain information about the existence and functioning of a system to handle transactions with suppliers.
- **Supplier's quality**: To measure the performance of supplier's quality.
- **Supplier's delivery**: To measure the maintenance of required delivery standards.
- **Supplier's costs**: To measure the cost of suppliers.

Wherever possible, the survey questionnaire has been arranged in a sequential manner to reflect sequential steps involved in lean implementation. To illustrate this, the lean manufacturing questionnaire flows from basic concepts such as value stream mapping, visual systems, etc to more complex concepts like cellular manufacturing, operational flexibility and continuous improvement. The details for categories and sub-categories for each main category are explained later in this chapter.

The UTOPEX assessment tool is designed in such a way that it is flexible to be used as a self-evaluation tool or as tool for lean experts to evaluate an organization's current state.

Self-Assessment Tool: An organization can select its employees to award points based on their perception of system excellence on an ordinal scale.

Expert Tool: A group of lean experts can award points accordingly from the information gathered during a facility tour or by interviewing employees.

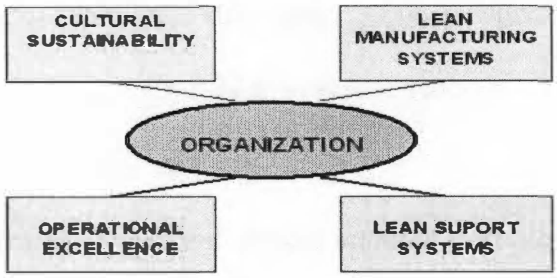


Figure 2. Assessment Model

The lean organizational assessment is presented in Figure 2. The organized questionnaire for lean manufacturing systems is available in Appendix A. The lean organizational assessment is divided into four main categories. The four main categories are lean manufacturing systems, lean support system, operational excellence and cultural sustainability. The assessment model is inherently intelligent, as it will flow from the basic to complex features of lean implementation in each particular category. A detailed breakdown of the four main categories is presented in further sections.

Lean Manufacturing [8] [10] [11] [12]: The basic assessment upon which UTOPEX is developed, focuses only on the activities performed on the shop floor. The enactment of value stream mapping and visual systems (6S) are considered initial steps in lean implementation in manufacturing environment, and the development of standard operating procedures, implementation of cells are considered subsequent steps in lean implementation. Hence the questionnaire categories in the lean manufacturing section flow from initial concepts to the more complex concepts of lean manufacturing to incorporate the sequential flow in the questionnaire. The complete list of categories and sub-categories for lean manufacturing systems is shown in Figure 3.

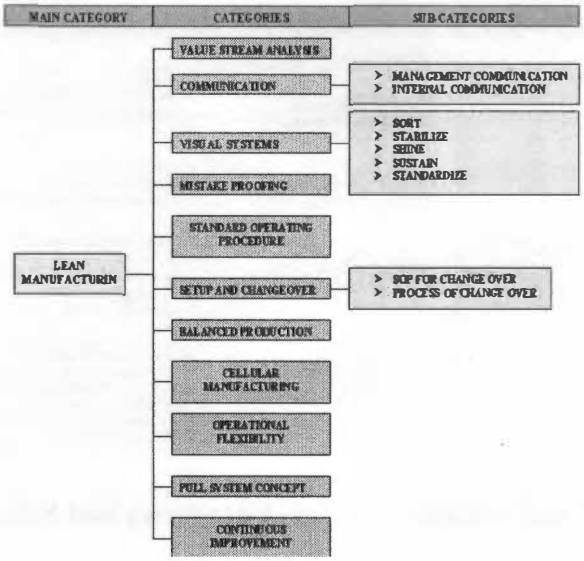


Figure 3. Lean Manufacturing Categories and Subcategories

The categories of lean manufacturing are sub-divided further into subcategories to obtain detailed information about the processes. For example, communication on the shop floor is broken down into two subcategories: i.e. management communication and workforce communication. Similarly, all the other categories in the manufacturing system are analyzed into sub-categories to gather more delineated information wherever possible.

Lean Support Systems [8] [10] [11] [12]: Activities on the production floor are not the only factors that affect the performance of an organization. For efficient production, support systems such as maintenance, suppliers, information systems, planning and engineering need to be quite functional. The basic lean assessment tool does not include any support systems (except maintenance) as essentials for seamless lean implementation. As in the lean manufacturing section, the categories in lean support systems section flow from simplest concept to the most complex concept. The complete list of categories and subcategories for lean support systems is shown in Figure 4.

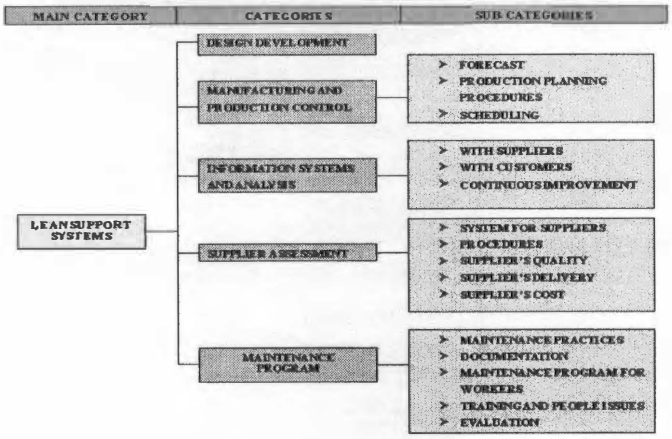


Figure 4. Lean Support Systems Categories and Subcategories

The categories in lean support systems are analyzed into subcategories to obtain detailed information about the support processes that impact manufacturing. For example, supplier assessment is divided into five subcategories. The subcategories for supplier assessment are system for suppliers (supplier selection and performance monitoring), procedures, supplier's quality, supplier's delivery, and supplier's cost.

Operational Excellence: The UTOPEX assessment facilitates evaluation of the organization's performance on concepts of lean manufacturing, six-sigma and their interaction through an operational excellence assessment. Lean is primarily concerned with eliminating waste and improving flow by following the lean principles, while Six-sigma will eliminate defects but does not address the question of how to optimize process flow. Lean in many cases explicitly excludes the advanced statistical tools often required to achieve essential process capabilities. Therefore, the methods of lean and six-sigma complement each other. The combined approach of integrating lean and six-sigma to reduce variability in the projects is called "operational excellence" [8] [10] [11] [12]. The list of categories and subcategories for operational excellence is shown in Figure 5.

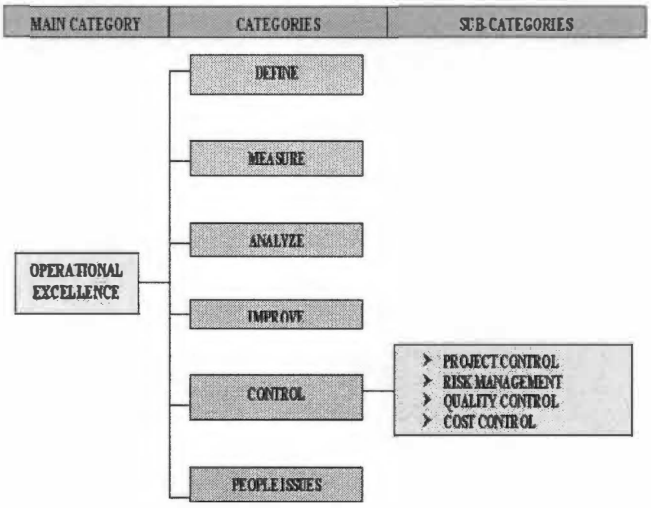


Figure 5. Operational Excellence Categories and Subcategories

The operational excellence assessment has been developed using DMAIC (Define, Measure, Analyze, Improve and Control) principles of six-sigma, which provide a basic framework under which six-sigma projects are implemented.

Cultural Sustainability [8] [10] [11] [12]: According to a survey by the Lean Enterprise Institute, one of the major reasons for failure of lean implementation has been the inability of organizations to sustain changes. Ability to sustain change in an organization depends on the culture of the organization. This aspect of lean enterprise, often neglected, needs to be incorporated into lean assessments. A cultural assessment is quite essential to identifying misunderstandings, communication issues, management style issues, and team behaviors that will allow an organization to identify the right direction. The company objectives and interaction between management levels, considered as main categories for cultural assessment, are shown in Figure 6.

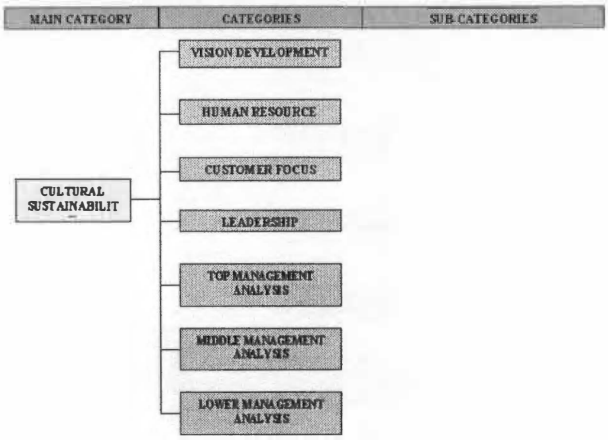


Figure 6. Cultural Assessment Categories and Subcategories

Ranking Methodology

The UTOPEX assessment uses an ordinal scale to measure satisfaction ranging from excellent to poor with some degree of gradation between the two. Point ratings for each question should reflect how well the organization performs in that particular area. The survey questionnaire has been worded in such a way that, higher score always represents a better performance on that particular question. If the organization has a moderate level of performance, one might rate it at 5. If an organization has excellent performance, one might rate it at 9 or 10. If the organization does not practice the activity or has poor performance, one might rate it at 1 or 2. The rating point scale is shown below in Table 3. According to a study conducted by Luigi Fabbris, ordinal scales with 1-7 and 1-10 points presented as sets of equally spaced within-square numbers are preferable for almost all considered indicators (stability of averages and gaps from maximum satisfaction levels, absence of no-choice category, independence from evaluative approaches)[4].

Table 3. Scale for Evaluating Rankings

Poor	1 or 2	Practice found in very few areas with inconsistencies(Not done or rarely done)
Bad	3 or 4	Practice commonly found in intial phase of implementation(Newly started)
Acceptable	5 or 6	Practice found with sound system (Sound system)
Good	7 or 8	Practice found with everywhere with consistent execution(Advanced stage)
Excellent	9 or 10	Practice found everywhere with continous improvement(Mature excellence stage)

A scale of 1-10 has been selected here as it provides a wider range of choices to answer the questions, and allows scoring by percentage perspective (That is, respondents can assess what percentage they would assign for a particular activity). Each question in each particular sub-category is given equal weight, as the questions are answered on the ordinal scale. The average score for each sub-category provides a good representation of the organizational performance for that particular concept. More than one question in a sub-category provides flexibility to breakdown the concept into all the requirements, whose complete fulfillment will lead to satisfaction of that particular concept. However, even if some of the requirements are satisfied the questionnaire helps to recognize the organization's partial fulfillment of that particular concept [24][25][26][27][28][29][30]. The complete organizational assessment with all the categories and sub categories for lean manufacturing, lean support systems, operational excellence and cultural sustainability is shown in Figure 7.

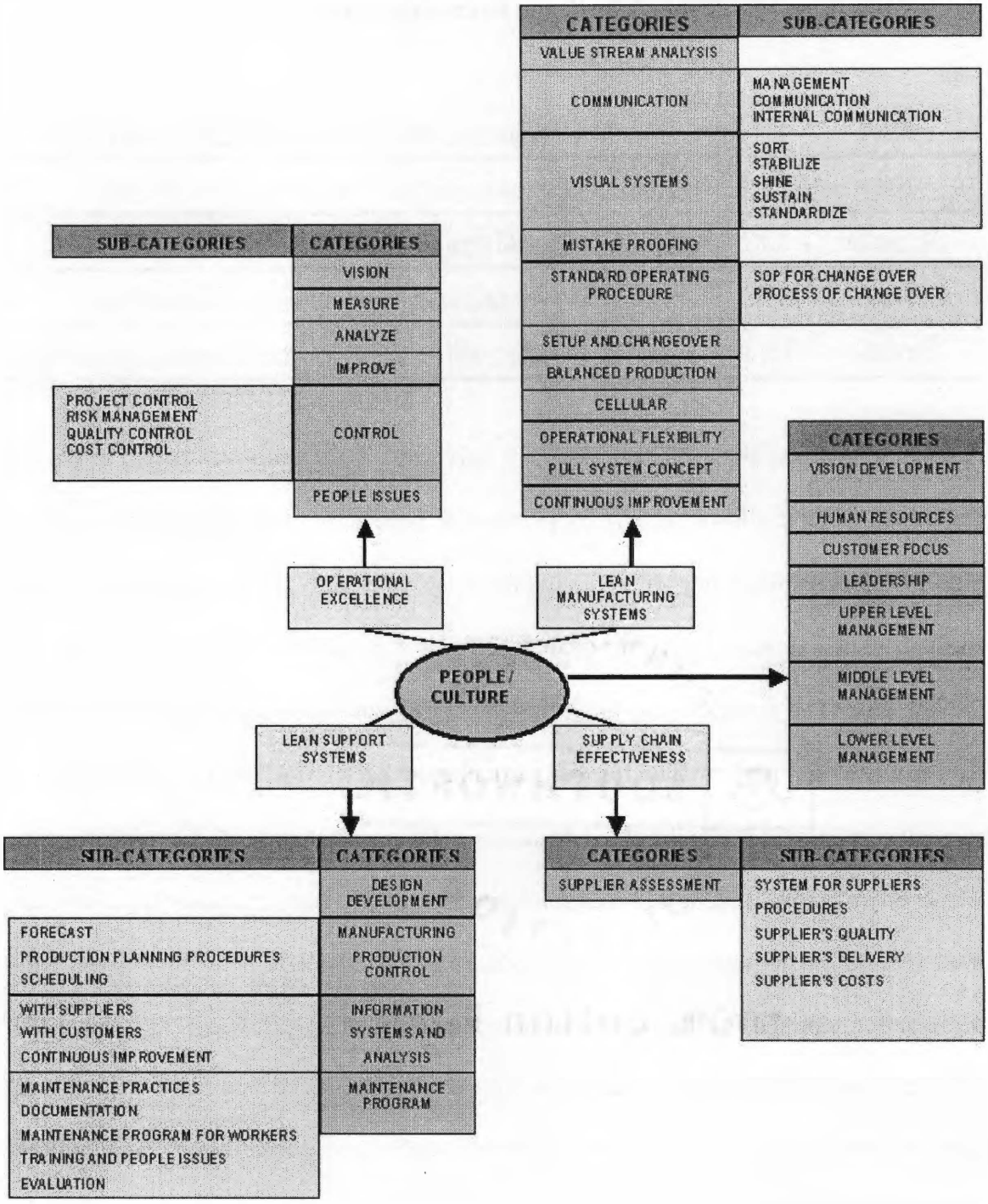


Figure 7. Lean Organizational Assessment

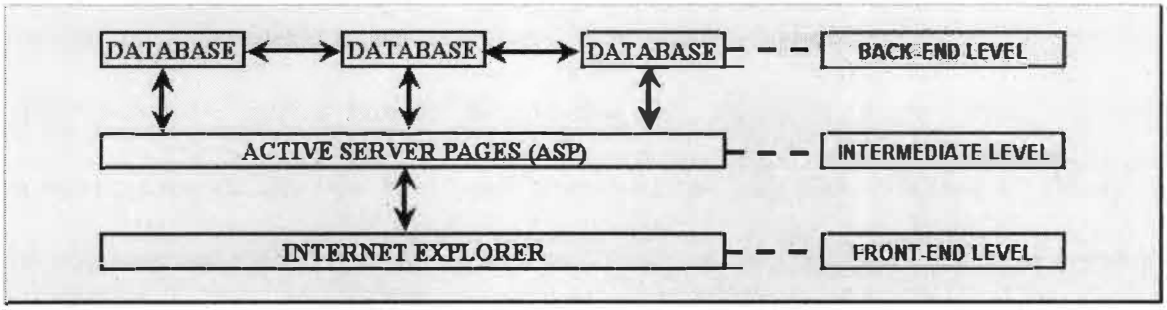


Figure 8. UTOPEX Architecture

UTOPEX Architecture

The architecture utilized to develop the UTOPEX software tool is shown in Figure 8. The assessment tool has been developed in the form of an internet/intranet based software tool to achieve the desired functionalities discussed latter sections. This architecture facilitates two-way data exchange among all three levels, which makes it possible to achieve the desired functional features. This architecture has been used to develop an interactive tool to store, retrieve and manipulate data to achieve desired results. Similar types of architecture have been implemented, in many other applications such as bank management systems and hospital management systems proven and established among others.

Back-End Level: Microsoft access is used as a back-end database tool. Microsoft access is the relational database used in the program to store data in one or more tables, which are joined in a variety of ways to provide efficient access to the information. Data is secured, revealing no secrets to the outside world and is manipulated by ASP to provide desired results.

Intermediate Level: Active Server Page (ASP), an intermediate programming tool, is a server-generated page, which interacts with Microsoft access (backend), and Internet explorer (front end) to exchange data and provide desired results. ASP calls other programs to perform tasks like accessing databases and serving different pages to different browsers. ASP runs inside the IIS (Internet Information Service) provided by the Microsoft operating system.

Front-end Level: Internet explorer used as the front-end tool collects data using various forms designed with ASP codes. This data is stored in appropriate relational tables as directed by ASP coding. There is interaction among all three levels to exchange and manipulate data.

Addition of Functional Features

The following functional features have been added to the lean organizational assessment to increase its value in terms of user friendliness and flexibility. Some of the features have been added to make the assessment capable of collecting more detailed information. The functional features, their benefits and the way these features can be achieved are explained as follows

- The lean assessment should be available at any time and at any location. Therefore, the assessment should be developed in a form such that it will eliminate geographical and time-related inconveniences. This is accomplished by developing assessment in the form of a software tool on an internet/intranet platform using web-based programming tools.
- Present day assessment tools are not flexible to collect data from multiple users. Data collection from multiple users is essential to involve employees and to

develop vision through a diversified perspective. This broad based perspective can be achieved by developing the software that will interact with the participants using a dynamic database as a back-end tool. (MS Access is the back-end tool)

- Operations vary in organizations depending on the type of production system. It is quite essential to develop assessments based on the operational specificity of the organization to provide true representation. Hence the assessment should be capable of incorporating changes in the questionnaire. This can be achieved by developing a software application capable of instantaneously incorporating changes and providing instantaneous results to the users.
- The amount of data collected from multiple users is huge and requires automated manipulation to provide scores and results. This goal is accomplished by software tool capable of providing automated result compilation, thus eliminating the tedious process of calculation.
- The lean organizational assessment focuses on all the functions of the organization; hence there is always a possibility that every individual may not be capable of answering each and every section of the assessment survey. For example an employee on the shop floor may not have knowledge of any supplier-related activities; hence it is not fair to collect information about suppliers from that particular individual. Hence the assessment should be capable of collecting data from only those members of an organization who are concerned with particular functional areas. The development of a web-based program capable of restricting the access of the questionnaire to only authorized individuals fulfills the requirement.

- The assessment tool should be capable of working both as an expert tool and a self-assessment tool. This need for dual functionality is again accomplished by developing the assessment as a web-based software tool.
- Lean experts can provide recommendations and possible strategies for lean implementation based on the scores and results of the assessment. It will be an added advantage to organizations to have recommendation available from multiple experts. The web-based software assessment tool helps to satisfy this requirement.

Case Study

An assessment has been conducted at a large multinational corporation facility to validate the usage of UTOPEX tool. The case study compares UTOPEX methodology with a conventional assessment method.

Conventional Assessment Method: The assessment conducted by a group of experts from the University of Tennessee (conventional method) focuses on only manufacturing aspects of lean assessment. It does not include survey questionnaire for lean support systems, operational excellence or cultural sustainability. The assessment requires manual calculation, which is time consuming. This method provides scores only for lean manufacturing areas that can be utilized to provide recommendations for improvement in aspects of only lean manufacturing.

UTOPEX Assessment Method: The assessment conducted using UTOPEX, developed at University of Tennessee (Method 2), involved a questionnaire on lean manufacturing aspects, lean support operational excellence and cultural sustainability. The employees responded to the questions on relevant work-areas, based on their expertise. The

assessment tool is an automated procedure, which gives instant results, and experts can utilize the scores to provide recommendations instantly. The new assessment tool is more comprehensive and flexible compared to the conventional method.

Software Tool Operation

The roles of four main users of UTOPEX software tool are explained as below.

- **Administrator:** This user is responsible for controlling and managing the assessment tool. Administrator logs into the tool using Internet Explorer (front - end) to sign organization for the assessment, to allot lean programs (time for the assessments), to add experts who will view scores, provide recommendations for improvement, to add questionnaires based on the type of organization and to deploy changes to the assessment. All the data are stored in relevant database tables (MS Access back-end) through ASP programming (intermediate).
- **Company:** This user is responsible for deploying the assessment in the organization. The organization logs into the tool using Internet Explorer (front-end) to validate and change organization profile, to assign the participants to take assessment and to view the recommendations for improvement provided by experts.
- **Participants:** These users are responsible for providing answers to the assigned questions on an ordinal scale. These users can access UTOPEX through internet explorer and are authorized only provide responses to the assigned questionnaire.
- **Experts**: These users are responsible for compiling the results of the assessment and for providing recommendations based on the obtained results.

The details for the usage of the UTOPEX tool are provided in Appendix B.

CHAPTER FOUR: RESULTS AND CONCLUSION

This chapter presents a discussion of the results compiled by the basic lean assessment method, which has a questionnaire for only lean manufacturing systems. And, results compiled by the UTOPEX method, the comprehensive survey questionnaire focusing on lean manufacturing systems, lean support systems, operational excellence and cultural sustain-ability. The results of a hypothesis test for the common part of the survey are presented along with other justifications to advocate the usage of the UTOPEX tool. Conclusions and scope for future studies are presented at the end of this chapter.

Results by Conventional Method (University of Tennessee Experts)

Members of the assessment team interviewed employees from different functional areas. These interviews, in conjunction with other sources of data including observations, value-stream mapping and metrics analysis were the basis for evaluating lean in the organization. During the interview portion of the assessment, each member of the assessment team filled out a survey. Ratings from 1 to 5 were given for the organization in each of the following 10 lean categories specified below:

- Communications and Cultural Awareness (CCA)
- Visual Systems (5S) and Workplace Organization (VS&WO)
- Standard Work (SW)
- Continuous Improvement (CI)
- Operational Flexibility (OF)
- Mistake-Proofing/Poke-Yoke (MP)
- SMED/Quick Changeover (QC)
- Total Productive Maintenance (TPM)

- Pull Systems (PS)
- Balanced Production (BP)

Table 4 summarizes the scores for each of the 10 categories of the lean delineation assessment. Figure 9 provides a visual representation of the assessment in the form of a radar chart. Analysis and details for the score are provided in the analysis section.

Analysis of Results

The results obtained from both methods were utilized to determine the action items essential to reduce the gap between the assessed organization and world-class organizations. Roadmaps to implement lean in the organization were developed using the scores from the lean assessment. The UTOPEX method yields scores for lean manufacturing systems along with lean support systems, operational excellence and cultural sustainability which help experts to develop action items to close gap between the assessed organization and world-class organizations for all the above mentioned main categories, whereas the conventional method helps experts to develop action items to close gap between the assessed organizations only and world-class organization for the lean manufacturing section.

Analysis Using Conventional Method

The lean assessment conducted by the group of experts from University of Tennessee used the lean delineation scores from Table 4 to develop the action items essential to close the gap between assessed organization and world-class organizations for lean manufacturing are presented in Table 5. A proposed plan for lean implementation in the organization using the scores from conventional method is presented in Figure 10.

Table 4. Lean Delineation Scores

SLNo.	Scores from assessment worksheets	Abv.	Lean Score	Score to plot	Target Score
1	Communication & Cultural Awareness	CCA	0.51	51	100
2	Visual Systems & Workplace Organization	VS&WO	0.57	57	100
3	Standard Work	SW	0.39	39	100
4	Continuous Improvement	CI	0.48	48	100
5	Operational Flexibility	OF	0.39	39	100
6	Mistake proofing/Poka Yoke	MP	0.54	54	100
7	SMED Quick Changeover	QC	0.32	32	100
8	TPM, Total Productive Maintenance	TPM	0.38	38	100
9	Pull Systems	PS	0.07	7	100
10	Balanced Production	BP	0.18	18	100
	TOTAL SCORE			384	1000

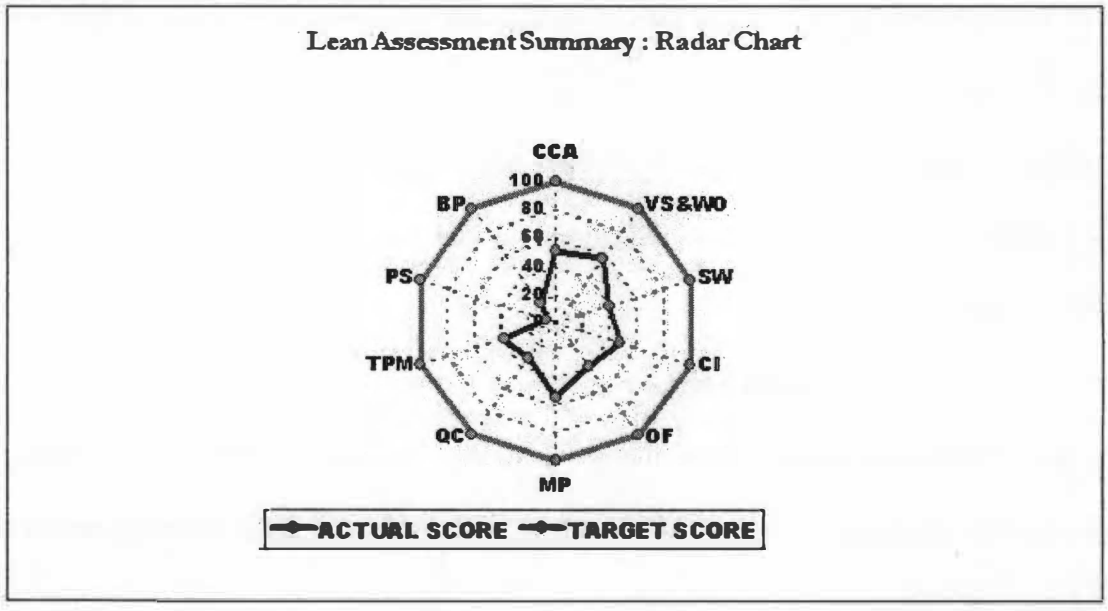


Figure 9. Radar Chart of Lean Delineation

Table 5. Action Item List for Closing the Gap

PARAMETERS OF ASSESSMENT	ACTION ITEMS TO CLOSE ASSESSMENT GAP
Communication & Cultural Awareness	A more transparent and efficent feedback system needs to be implemented so that production workers receive feedback concerning problems found in downstream processes or from customer correspondence.
	The management should encourage more production employees to work in groups in order to address performance, quality or safety issues.
	Employees at the shop floor level need to be given more training so that they can understand and use common performance metrics to monitor and improve the production processes.
Visual Systems & Workplace Organizatic	Check sheets describing and tracking the top quality defects are to be posted and updated on a daily basis at each work station.
	A more efficent system needs to be implemented to handle the communication between shifts.
Standard Work	The TAKT time for each product should be used as the basis for the production process time for each operation and the process manning requirements.
	The process of job design and standardization must involve both the operators as well as the support personnel.
	SOP'S are to be regularly audited, time dated and should indicate the improvements that have been made..
	Operators should individually perform their processes according to the process sheets or SOP'S and should be allowed to make few method or technique errors. Any errors during the operations are to be recorded and tracked.
Continuous Improvement	There should be a suggestion process to solicit ideas for improvements from all employees and to recognize their participation needs to be more transparent and efficent.
	All employees should know the eight wastes, and should be actively involved in identifying wastes in their processes/areas and are empowered to work to reduce and eliminate the waste.
	Product/process Value streams should undergo examination for continuous improvement on a regularly scheduled basis(6 months).
Operational Flexibility	Product/component travel distances should be accurately measured, analyzed and reduced by moving equipment and work stations closed together.
	Machines should be "right sized" for the operation/process. They should possess the ability to change speed to match the TAKT time. No "monuments" are present in the process.
Mistake proofing	Parts,products and components have to be analysed for design opportunities to eliminate waste and improve productivity
SMED Quick Changeover	Change over timeshould be visibly tracked and posted at each work station where changeovers are performed.
TPM, Total Productive Maintenance	Preventive maintenance activities are to be more focused on increasing process utilization and minimizing cycle time variation.
	Preventive maintenance responsibilities should be well defined for both maintenance and production workers.
	Sufficent time is to be allowed in the daily production schedule for workers to perform their preventive maintenance and cleaning duties.
Pull Systems	Each Manufacturing cell, line or process should display, visually, the target and actual hourly output as well as the shifts production requirements and timing.
	Production lines/cells should be capable of adapting to changes in customer demand by changing only one production schedule at the pacemaker process.
	Production supervisors should be motivated to produce more parts than the subsequent process require.
Balanced Production	Takt time should be known by all associates and should be the key factor which determines the pace of production in the plant.
	The TAKT time is used as the basis to determine process cycle times and allocate work throughout the production process.
	Processes on production lines or in cells should be balanced or leveled so the difference between cycle times of linked processes is negligible.
	When demand volume changes, production processes are to be re-balanced or redesigned to flex up or down the process cycle times to correspond to the new Takt time.

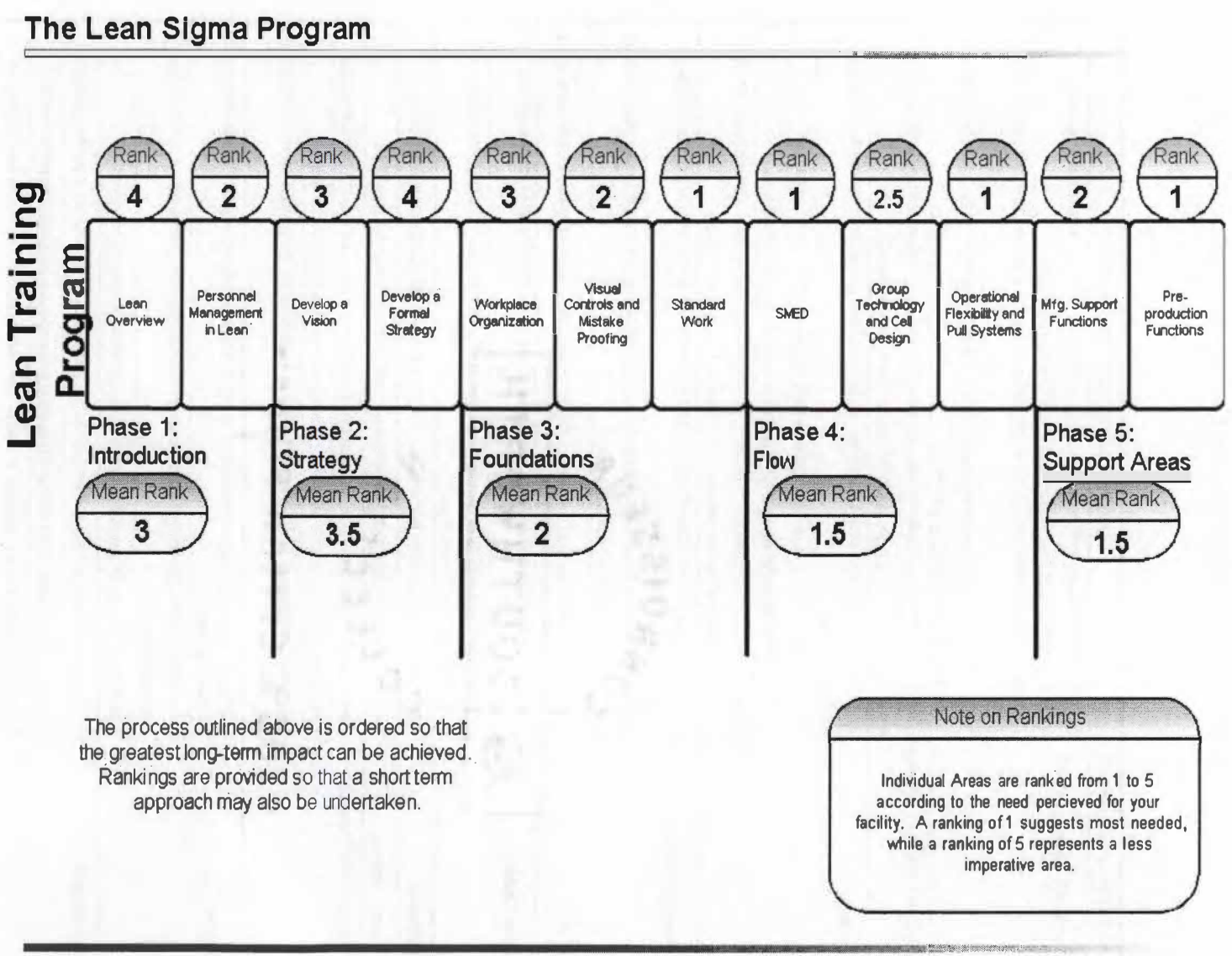


Figure 10. Lean Program

The above-mentioned action items are developed using the assessment results that was conducted at the organization by the group of experts from University of Tennessee. These experts utilized responses to the questionnaire (developed by VMEP) and their individual observations to identify the areas of improvement. The list of action items and the proposed plan are derived out of the report developed by Dr. Rapinder Sawhney [31], which was presented to the organization after the completion of the lean assessment.

Results by UTOPEX Method (Self Assessment)

The UTOPEX survey questionnaire was given to employees of the organization as a self-assessment tool. Employees from different functional areas answered questionnaires about their specific areas of expertise or work on a scale of 1-10. Since UTOPEX is an automated tool, an assigned expert can compile the results with click of button. The scores for each categories of the UTOPEX lean organizational assessment are presented in Table 6. UTOPEX graphically represent the scores for lean manufacturing assessment and lean support systems assessment in the form of bar charts, which are presented in Figure 11 and Figure 12 respectively. Figure 13 and Figure 14 graphically represent the scores for operational excellence assessment and cultural sustainability assessment respectively in the form of bar charts.

Table 6. Results of UTOPEX

Methodology		UTOPEX
Lean Manufacturing		
	Value Stream Analysis	53.80
	Communication on the Production Floor	53.71
	Visual Systems (6s) and Work Place Organization	61.08
	Mistake Proofing	56.11
	Standard Operating Procedures	40.88
	Setups and Changeovers	36.88
	Balanced Production	21.38
	Cellular Manufacturing	49.30
	Operational Flexibility	41.11
	Pull Production System/Kanban System	13.89
	Continuous improvement/Kaizen activities	48.13
Lean Enterprise		
	Design and Development	45.86
	Manufacturing and Production Control	48.71
	Supplier Assessment	40.71
	Information Systems and Analysis	46.29
	Maintenance Program Assessment Questionnaire	42.86
Operational Excellence		
	Define	47.14
	Measure	47.71
	Analyze	38.29
	Improve	37.57
	Control	44.14
	People Issues in Quality and Variation reduction	48.29
Cultural Sustainability		
	Vision Development	54.00
	Customer Focus	58.60
	Human Resource Development and Management	58.00
	Leadership	57.00
	Top Management Analysis	56.90
	Middle Management Analysis	49.40
	Lower Management Analysis	59.90

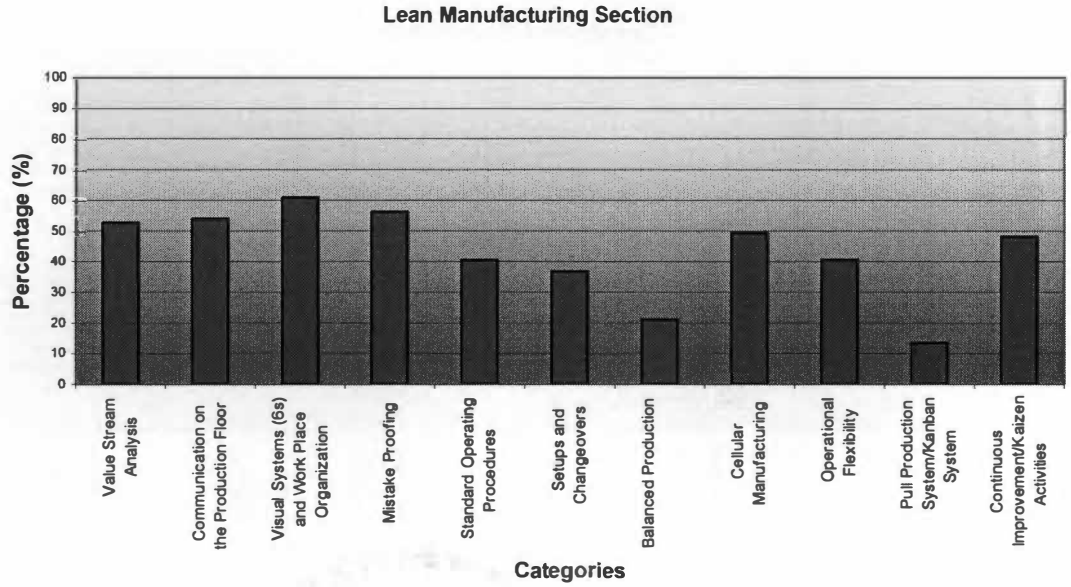


Figure 11. Lean Manufacturing

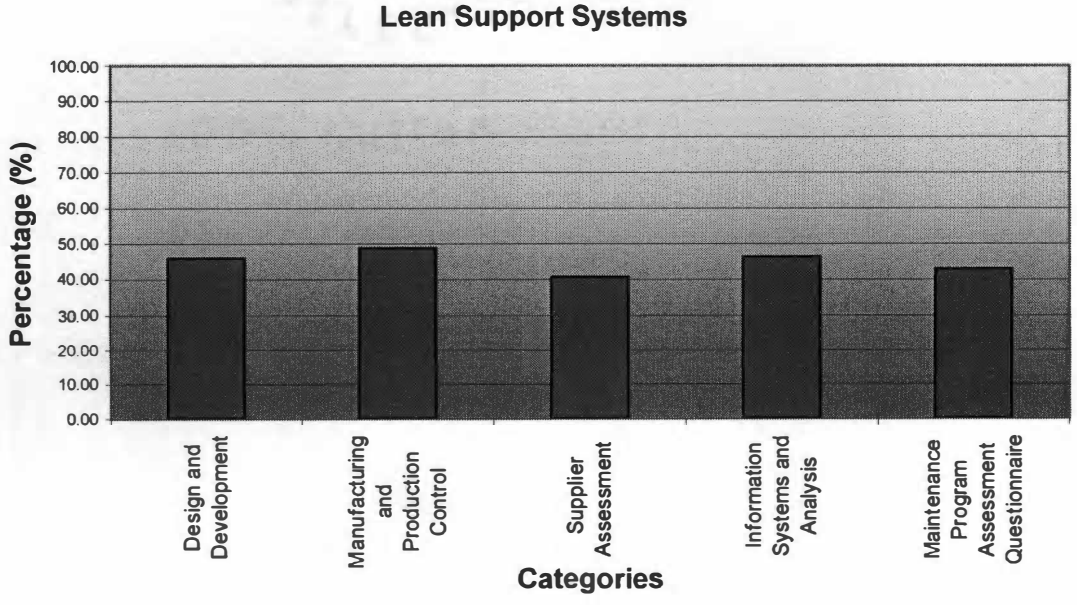


Figure 12. Lean Support Systems

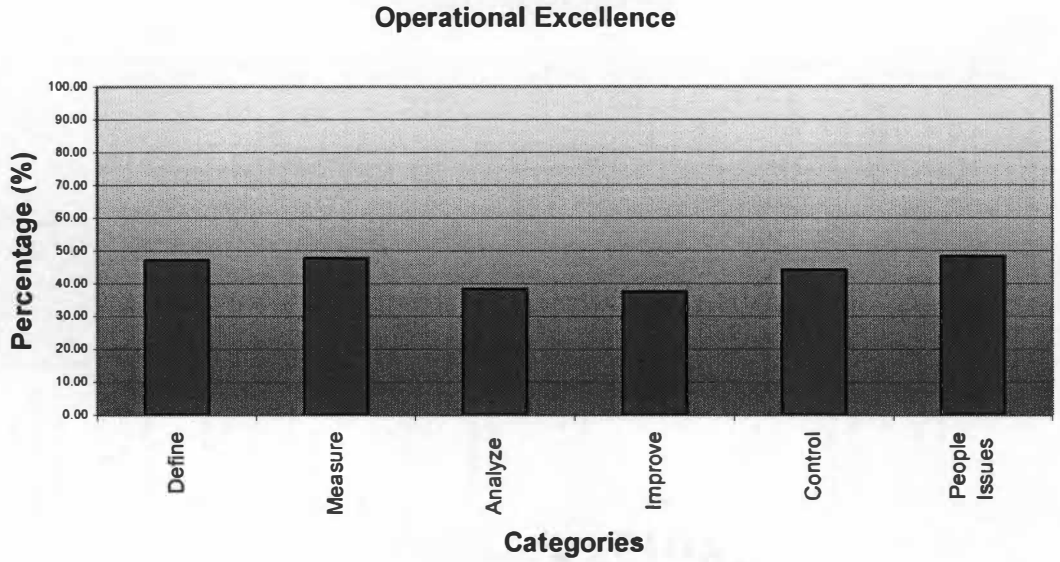


Figure 13. Operational Excellence

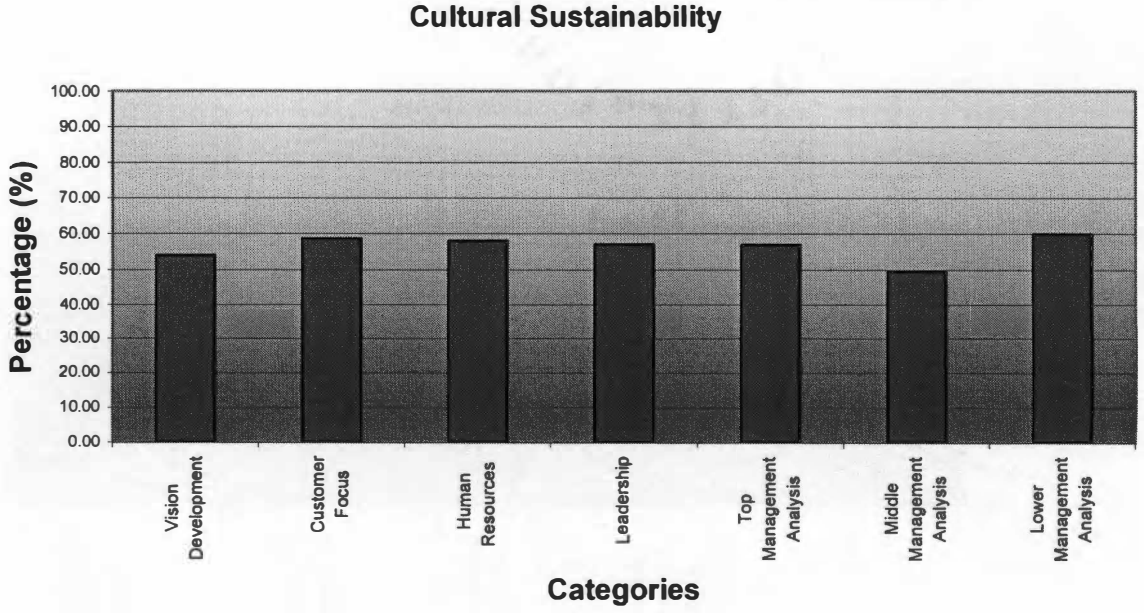


Figure 14. Cultural Sustainability

Analysis Using UTOPEX Assessment

The comprehensive lean assessment survey (UTOPEX) was given to employees of the organization as self-assessment tool to be answered on an ordinal scale. Employees from different functional areas answered the survey in their particular areas of expertise. A minimum of ten surveys for each section of the assessment was utilized to collect data and entered into the software tool. Upon completion of the assessment, the results were automatically compiled and scores for different categories and sub-categories were obtained as shown in the earlier sections. Due to the similarity between the two assessment methods for the lean manufacturing assessment section, the action items to close gap for this particular section are not presented here in the analysis using the UTOPEX method. A hypothesis test was conducted to prove that the results are compatible for lean manufacturing section for both methods. The developed action items to close gap between the assessed organization and world-class organizations for the lean support systems, are presented in Table 7. Similarly, the developed action items to close gap between assessed organization and world-class organizations for the cultural sustainability and for the operational excellence are presented in Table 8 and Table 9 respectively. A proposed plan for lean implementation in the organization using the scores from UTOPEX method is presented in Figure 15.

Table 7. Action Items (lean Support Systems)

Parameters of Assessment	Recommendations to Close Assessment Gap
Design and Development	1. The design and development is in the initial phase of lean implementation. 2. The organization needs to involve suppliers and other operational departments like production and marketing in the design and development process. 3. The organization needs to establish a strong system to implement usage of quality function deployment, design for manufacturability and voice of customers in the design and development process.
Manufacturing and Production Control	1. The Manufacturing and Production Control is in the initial phase of lean implementation. 2. The organization needs to establish an appropriate forecasting system to determine stable production schedule. 3. The organization needs to use the combination of the pull system and live customer orders to manage the flow of material into and through the factory. 4. The organization needs to develop standard operating procedures for all positions in manufacturing and production control. 5. The organization needs to develop a proper scheduling system to take care of variation in demand to meet customer requirement.
Supplier Assessment	1. The score of 40.71 % indicates that the supplier support is still in the initial stages of lean implementation. 2. The organization needs to develop a system to select and monitor the performance of suppliers. 3. Scores indicate requirement for improved delivery system to reduce WIP and implement just-in-time system. 4. The organization needs a proper system to establish standard operating procedures for transactions with suppliers. 5. Cost and quality of suppliers needs to be regularly monitored and improved upon to achieve better results.
Information Systems and Analysis	1. Score of 39.71% indicates a necessity for proper system to communicate with suppliers. 2. The organization requires a strong communication system with customers to collect feedback and ensure improvement in terms of cost, quality and delivery. 3. The organization requires a strong communication system to ensure availability of data and feedback to improve the processes.
Maintenance Program Assessment Questionnaire	1A low score of 42.86 % in maintenance program indicates that the organization requires a reliable system to ensure preventive maintenance program that maintains a schedule to carry out preventive maintenance. 2. The organization needs preventive maintenance activities that focus on increasing process utilization or minimizing cycle time variation. 3. The organization needs to provide additional training for machine operators, with emphasis on TPM and sharing of preventive maintenance duties between operators and maintenance personnel. 4. The organization needs a standardized preventive maintenance program that collects feedback and maintains performance measurement parameters.

Table 8. Action Items (Culture)

Parameters of Assessment	Action Items to close the assessment Gap
Vision development	Average Score of 56.26% in the area of cultural sustainability indicates following key features. 1. Score of 56.26% indicates that the organization is willing to move towards achieving great results in lean and six-sigma implementation. 2. Conducting the lean assessment to evaluate their current state itself is a significant step towards implementing lean and six-sigma. 3. Organization needs strong training program to help them understand the concepts of lean enterprise and help them implement lean in their organization. 4. Organization has leadership, which needs to be harnessed in proper direction to ensure that organization moves towards lean implementation and achieve great results. 5. Top management and lower management seem to be more than willing to see changes in their system. 6. Middle level managements needs to be convinced that lean implementation is correct way to achieve long term goals. 7. Requirement of cross-functional team to develop vision for future and carry the load of lean implementation.
Customer focus	
Human Resource Development and Management	
Leadership	
Top Management Analysis	
Middle Management Analysis	
Lower Management Analysis	

Table 9. Action Items (Operational Excellence)

Parameters of Assessment	Action Items to close the assessment Gap
Define	1. Low score of 47.8 % in defining the projects indicates that organization is still in initial phase of implementing six-sigma projects. 2. The organization needs to define its quality goals for internal processes and delivery performance. 3. The organization needs to develop detailed criteria to regularly conduct assessments of quality systems, processes, practices, products and services.
Measure	1. The score of 48.18 % in measuring the performance of the projects indicates that organization is requires improvement is auditing the six-sigma projects. 2. Requirement of system to develop key metrics to measure the performance of quality projects. 3. Requirement of system to measure and calibrate the devices to maintain quality reliability.
Analyze	1. The score of 39.0518 % in analyzing the data indicates that organization requires considerable improvement in interpretation of data for better quality systems 2. Requirement of system to ensure use of proper statistical tools to analyze the data and identify key problem areas in achieving the desired quality system. 3. Requirement of proper training system to educate employees in usage of statistical tools to analyze data.
Improve	1. Low score of 39.21 % in improving the system using the analyzed data indicates lack of continuous improvement and inability to sustain improvement. 2. Requirement of proper training system to educate employees in usage of PPAP, FMEA, QFD and others to design implementation plans. 3. Organization requires implementing kaizen activities to improve the process. 4. Organization requires usage of project management concepts to integrate various subprojects to optimize the use of resources and to maximize the shared results.
Control	1. Low score of 44.14 % in controlling the output of projects indicates requirement of proper planning system to implement six-sigma projects. 2. Requirement of proper system to conduct risk analysis to determine necessity of projects and their possibility of success. 3. Requirement of proper system to control the budget of projects.
People issues in quality and variation reduction	The score of 48.29% related to people issues in quality systems and variation reduction indicates following issues 1. Moderate level of performance in training people to meet higher quality standards. 2. Employees are willing to learn and need to be trained in lean and six sigma issues. 3. Requirement of strong training system to help employees to implement lean and six-sigma concepts. 4. Necessity to educate employees to understand that customer satisfaction is highest priority and to nourish information, resources and support to meet or exceed customer quality, cost and on-time delivery expectations.

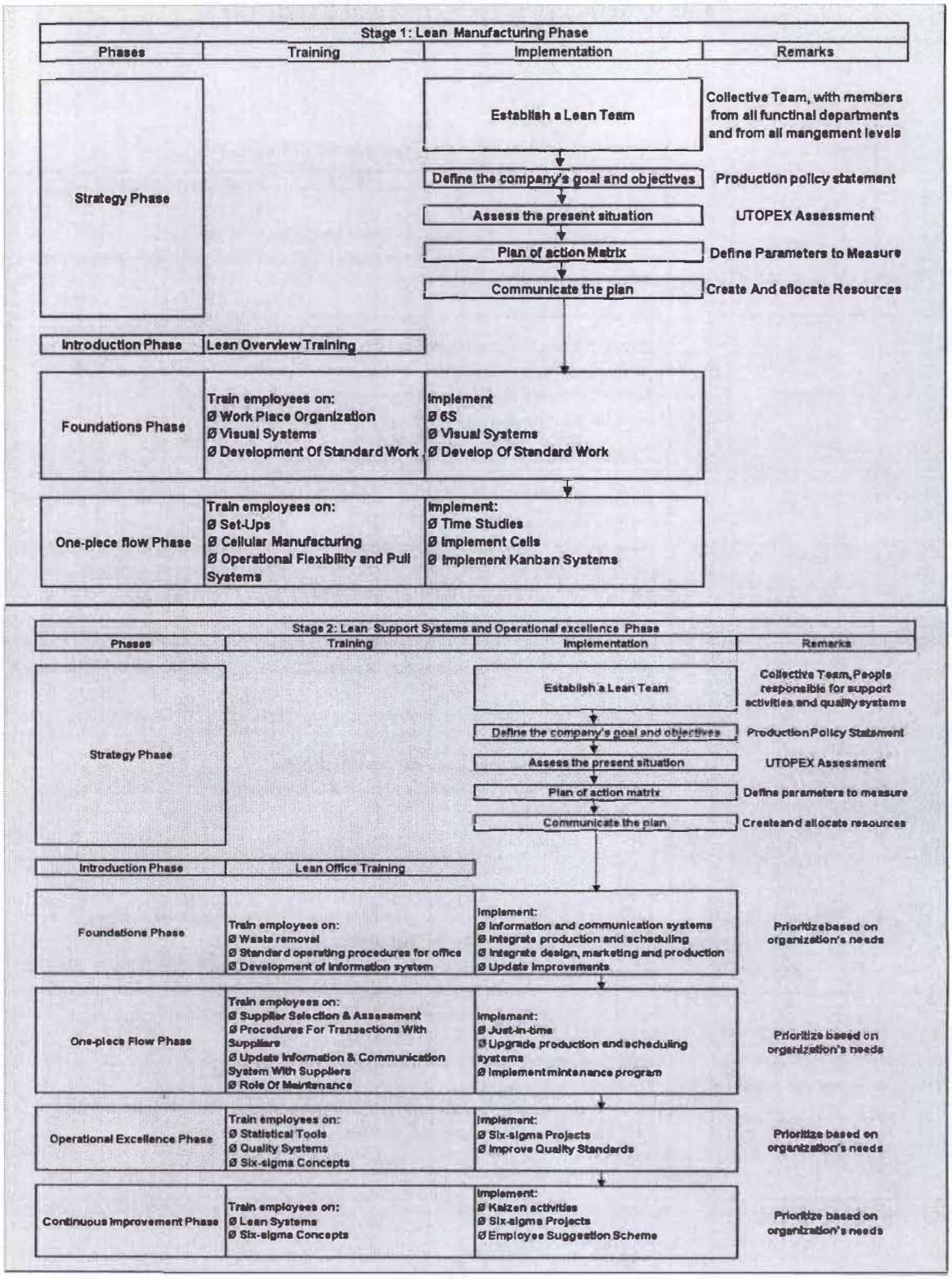


Figure 15. Proposed Lean Program

Proposed Roadmap: This proposed strategic road map incorporates actions that needs to be taken in the areas of lean manufacturing systems, lean support systems, operational excellence and cultural sustainability as data have been collected for all the above-mentioned categories through the UTOPEX survey. The proposed strategic road map has been developed in two stages, which are as follows:

Stage 1: The Lean Manufacturing Phase

Stage 2: The Lean Support Systems and Operational Excellence Phase

Comparison of Two Assessment Methods

The scores from both methods are compared in Table 10 and subsequently hypothesis testing is presented for the lean manufacturing systems category, as the results from lean manufacturing systems category are common for both assessment methodologies. Consider the hypothesis testing for the difference in the means for the lean manufacturing systems category.

$H_0 : \mu_1 - \mu_2 = \Delta_0$ (The means are equal, indicating no significant difference in the results.)

$H_1 : \mu_1 - \mu_2 \neq \Delta_0$ (Reject the null hypothesis, indicating a difference in the results.)

Using $\alpha = 0.05$

Choose the $\Delta_0 = 5\%$ (Giving leverage since the exact same results are not expected for the assessments, which are subjective evaluation)

Table 10. Results Comparison

Methodology		VMEP(UT)	UTOPEX
Lean Manufacturing			
	Value stream Analysis	NA	53.80
	Communication on the production floor	51.00	53.71
	Visual Systems (6s) and Work Place Organization	57.00	61.08
	Mistake Proofing	54.00	56.11
	Standard Operating Procedures	39.00	40.88
	Setups and changeovers	32.00	36.88
	Balanced Production	18.00	21.38
	Cellular Manufacturing		49.30
	Operational Flexibility	39.00	41.11
	Pull Production System/Kanban System	7.00	13.89
	Continuous improvement/Kaizen activities	48.00	48.13
Lean Enterprise			
	Design and Development	NA	45.86
	Manufacturing and Production Control	NA	48.71
	Supplier Assessment	NA	40.71
	Information Systems and Analysis	NA	46.29
	Maintenance Program Assessment Questionnaire	38.00	42.86
Operational Excellence			
	Define	NA	47.14
	Measure	NA	47.71
	Analyze	NA	38.29
	Improve	NA	37.57
	Control	NA	44.14
	People issues in quality and variation reduction	NA	48.29
Cultural Sustainability			
	Vision development	NA	54.00
	Customer focus	NA	58.60
	Human Resource Development and Management	NA	58.00
	Leadership	NA	57.00
	Top Management Analysis	NA	56.90
	Middle Management Analysis	NA	49.40
	Lower Management Analysis	NA	59.90

$\overline{x_1} = 38.333$ (*Mean for lean manufacturing systems from the conventional method*)

$\overline{x_2} = 41.220$ (*Mean for lean manufacturing systems from the UTOPEX method*)

$\sigma_1 = 16.897$ (*Standard Deviation for lean manufacturing systems from the conventional method*)

$\sigma_2 = 15.891$ (*Standard Deviation for lean manufacturing systems from the UTOPEX method*)

The test statistic is:

$$t_0 = \frac{\overline{x_1} - \overline{x_2} - \Delta_0}{[S_p]\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

$$S_p^2 = \frac{(n_1 - 1)s^2_1 + (n_2 - 1)s^2_2}{n_1 + n_2 - 2}$$

$$S_p^2 = \frac{(9-1)(16.897)^2 + (9-1)(15.891)^2}{9+9-2}$$

$$S_p^2 = 269.016$$

$$S_p = 16.401$$

$$t_0 = \frac{38.333 - 41.220 - 5}{[16.401]\sqrt{\frac{1}{9} + \frac{1}{9}}}$$

$$t_0 = -1.02$$

$\alpha = .05 \quad v = 16$

$t_{\alpha,v} = 1.746$

Since $t_\alpha > t_0$ *the null hypothesis cannot be rejected*

The hypothesis results reveal that the null hypothesis cannot be rejected, showing the compatibility between the two types of assessments. Since the UTOPEX assessment methodology yields performance measurement results for lean manufacturing systems, support systems, operational excellence and sustainability of culture for continuous improvement whereas the conventional method yields results only for lean manufacturing systems it is preferable to use UTOPEX method instead of conventional method. Apart from the hypothesis results, the following are reasons in favor of the usage of UTOPEX over the conventional method.

- It is quite evident from the analysis of the scores provided by the two methods that UTOPEX is a comprehensive and sequential survey on all the delineated functions of an organization. It collects more detailed information, which can be used to develop a better strategic roadmap.
- The conventional method collects information only on lean manufacturing aspects whereas UTOPEX focuses not only on manufacturing aspects but also on support systems, operational excellence and cultural sustainability.
- UTOPEX is an online system, which does not require any usage of papers and is highly flexible as it can incorporate changes in the assessment instantaneously. This reduces lead-time for assessments and conserves resources.
- UTOPEX is an online system, which is highly user-friendly and is accessible any time from anywhere whereas the conventional method requires a greater commitment of time from employees as well as lean experts.
- UTOPEX is an online system, which makes it possible to obtain recommendations from multiple experts instantaneously from different parts of

the world, whereas the conventional method requires presence of lean experts at the plant.

- UTOPEX is an online system, which supports data collection from multiple users, ensuring detailed and correct information about particular functional area from different individuals working in those particular functional areas.
- UTOPEX also satisfies all the requirements for new assessment tools developed in the literature review.

Conclusion

Companies are vigorously implementing lean techniques to increase their organizational profitability. These lean implementation programs include short-term as well as long-term projects. Despite the availability of information to employees, very few have been able to imitate the Toyota Production System successfully. The initial step of lean implementation is to determine an organization's current state, develop a future strategy. This can be accomplished by developing a comprehensive assessment tool, which uses information from members of the organization to develop strategies for themselves. The lean assessment tool should focus not only on technical aspects of lean production but also on support systems, operational excellence and the sustainability of a culture that encourages continuous improvement. The UTOPEX assessment tool has been developed to satisfy the requirements above. The tool is automated using ASP (Active Server Pages) and a relational database management tool (Microsoft Access). The software tool provides flexibility for the data collection and is extremely powerful as it has the flexibility to deploy any changes in the assessment in a very short time.

Scope of Future Study

- The software assessment tool provides an automated compilation of results, which can be utilized by lean experts to recommend changes in an organization. Future study should lead to the development of an intelligent expert system, which will suggest automated recommendations based on the analysis of the data. These data could be used directly to build a future strategy for the implementation of lean systems.
- The literature review shows that production systems can be classified based on the type of production processes, order fulfillment strategies, and cycle times between consecutive production units. The type of production system determines the adoption of lean tools [13]. In future studies the lean assessment can be developed for each type of production systems and can be incorporated into the software, hence achieving the status to provide highly customized assessments.
- The assessment tool can be improved further by adding some other facets of lean implementation, which might not have been included in the present assessment tool.

APPENDIX

Appendix A: Survey

Notes:

- For each of the following questions, rate your organization on a scale of 0-10
- Moderate level of performance, you might rate it at 5.
- Organization has excellent performance; you might rate it at 9 or 10.
- Organization does not practice the activity or has poor performance; you might rate it at 1.
- Your point rating for each question should reflect how well your organization does in this particular area.

Section I: Assessment for Lean Manufacturing

Value stream Analysis

- The concept of Value Stream Mapping has been successfully implemented to eliminate waste from the system.
- All the products have been mapped and physically segregated into identical process streams.
- The concept of Takt time is understood and communicated.
- Rate your contact time to lead time ratio.
- Reduction of waste is focused on our manufacturing line.
- Flow of material (keeping in mind inventory build up and ability to trace given item at any time) is maintained through the manufacturing line.
- Rate your process design in terms of using takt time.
- Bottleneck analysis is used to identify the pace maker production process

- Super market concepts are used to maintain well-defined WIP in manufacturing line.
- Rate your production line in terms of "practice of paced release of work to production, one Kanban at a time and paced withdrawal of finished goods at its cell"?
- Rate your " ability to make every part every day" (then every shift, then hour or pallet of pitch) in the fabrication process upstream of the pacemaker process.
- Rate your production line for functioning frequently as a team to make an effort to streamline your manufacturing line.

Communication

Management's communication with workers

- Rate your management's success in communicating organization's objectives to the work force.
- Rate your management's effort to collect and communicate customer feedback to work force.
- Employees role for achievement of company goals are communicated to the work force.
- Management communicates quality values and standards to the work force.
- Management communicates with the workforce to understand their level of job satisfaction.
- Management communicates with the workforce to develop a long-term and short-term strategies for customer focus and satisfaction.

Workforce Communication

- The workforce is well organized in empowered teams to address performance, quality, or safety issues.
- Problems in the production process are detected and investigated often after their first occurrence.
- Production support staff, technicians and engineers are involved in assessing the problems.
- Upstream production workers receive feedback on problems concerning downstream processes.
- The production support staff, technicians and engineers talk to the production operators and obtain their input.
- An organized system is maintained to communicate problems to middle or upper management.
- There is a standard procedure for passing information between shifts, and it works smoothly.
- Well-established shift-to-shift communication exists on maintenance activities.

Visual Systems (6s) and Work Place Organization

Sort

- Production and support areas are free of unnecessary materials, items, or scrap.
- There is an assigned place for all materials, tools, and equipment so that everything is in its place.
- The plant floor has lines or signs that distinguish work areas, material drop, and inventory staging areas.

- Workstations have clear distinction between production materials, maintenance tools and support tools.

Stabilize

- Tools, gauges, and fixtures are arranged neatly and appropriately stored.
- The aisles are painted to clearly distinguish between work areas and movement areas.
- Storage areas are freshly painted.
- Everything around the work place is organized ergonomically.
- Tools, jigs, and fixtures have assigned part numbers and are stored in specific locations.

Shine

- Cleaning equipment is easily accessible, stored neatly, and available when needed.
- It is established practice to wipe all the grime and dirt on the machines and equipment.
- It is established practice to check for leaks, overflows, etc., on the equipment and repair problems.

Sustain

- Every necessary item (tool, material, container, or part rack) is labeled and easy to find.
- The employee knows where to find the required tools or machine parts and replaces them at their proper location.

- Responsibilities are assigned and the workstations or cells regularly audited for 6S.
- The 6S responsibilities are posted in the form of a checklist to evaluate their respective cells or work areas.
- All the employees are trained in 6S and visual control practices.
- All the check sheets describing inventory and tracking quality defects are updated regularly at each workstation.

Standardize

- The site management boards are visible at each production line or process.
- Site management boards are arranged neatly and in an orderly fashion without outdated, torn or soiled announcements.
- Sufficient production data, job descriptions, safety, and operation instructions are included on the site management boards.
- All the employees are familiar with these boards and follow the instructions written on them.
- The site management boards are regularly updated and maintained.
- The teams of production members conduct weekly audits to monitor the entire process of 6S and visual control implementation.
- The entire manufacturing process in this department can be controlled visually.

Safety

- Safety is the primary concern of the facility.
- Emergency exits are clear and prominently visible.
- Stop switches and breakers are marked by color codes for visibility.

- Storage boxes, containers, and materials are always neat and at right angles.
- Protective gear is provided for the safety of employees.
- Training is provided on safety issues.
- Workers are encouraged to practice safety procedures.
- Safety procedures are checked frequently and revised for improvement.

Mistake Proofing

- There is an active team responsible for analyzing production defects and identifying mistake-proofing opportunities.
- Employees are provided with formal training on the principles of mistake proofing.
- Mistake-proofing check sheets are being regularly checked and updated.
- Mistake-proofing devices and methods are implemented.
- Mistake-proofing devices and methods are used for both manual as well as automated processes.
- The downstream operator inspects the output of the upstream operator for defects.
- The operator is allowed to stop the production line if a defective part is identified.
- The equipment and process are equipped with an-don lights that draw attention immediately.
- There are sufficient mechanical checks to aid the operator in better judgment during manual processes or tasks.

Standard Operating Procedures

- Every production process has its own standard operating procedures, which are posted within view of the workers performing the process.
- Operators individually perform their processes according to standard operating procedures.
- The standard operating procedures are developed with reference to time study and operator input.
- The standard operating procedures are audited for improvements and time dated regularly.
- The in-process stock is standardized and maintained to develop the process sheets.
- The operator regularly updates and reviews the standard process and method sheets.
- The process of job design and standardization involves operators as well as support personnel.
- The operators are regularly trained to follow the process of job design and standardization.

Setups and changeovers

SOP for changeovers

- The standard operating procedures for each changeover operation are developed and in effect.
- The standard operating procedures are developed with reference to internal setups and external setups.

- The tools are arranged around the workstation based on standard operating procedures for changeovers.
- There is an clear distinction between work for workers and changeover specialists.
- The changeovers are performed according to the changeover operating procedures.
- The changeover specialists regularly update and review the standard process and method sheets.
- The changeover standard operating procedures are audited for improvements.
- The process of changeover involves operators as well as support personnel.
- The concerned individuals are regularly trained to follow the process of changeovers.
- Changeover time is visibly tracked and posted at each workstation.

Process of changeover

- The entire changeover is scheduled well in advance.
- All the team members are well informed about the changeover schedules.
- The product design and component specifications are regularly standardized so that the changeover time is reduced.
- Rate your changeover time to go from the last good part of the current run to the first good part of the next run.
- The SMED/quick changeover activities are focused on bottleneck operations.
- New changeover procedures and ideas are encouraged and implemented.

- New changeover procedures and ideas are standardized and repeated in other areas of the plant.
- Special tools and equipments are developed and used to reduce the time and labor involved in the changeover process.
- There is a system in place for advanced setup and verifications of tools and fixtures so as to reduce the setup time during changeover.
- Parallel operations can be performed at the workstation during changeover.
- All the changeover tools and equipment are well maintained.

Balanced Production

- The supplier is requested to schedule frequent small deliveries evenly over a period to level the production schedule.
- Rate your effectiveness in using mixed modeling production to meet the flexible demand.
- The batch size remains constant throughout the production process.
- Takt time is updated regularly.
- The entire production team knows Takt time and Takt time determines the pace of production in the plant.
- Takt time is used as a basis to determine process cycle times and to allocate the work throughout the production process.
- The production process is designed to alter the process cycle times to correspond to the new Takt time.
- The process in production cells is balanced so that the difference between the cycle times of linked processes is negligible.

Cellular Manufacturing

- U shaped lines and machine cells are implemented and the equipment is positioned in a logical manner.
- Product family lays out all operations and equipment.
- All operations are linked with a maximum of one unit of production between each operation.
- There is evidence that a support structure is in place to support cells.
- The operators in the cell perform multiple operations to maximize their productive time.
- Small and flexible machines are used within the manufacturing cells.
- There are colored lines drawn indicating the work, storage area and travel paths within the cell.
- The product/component travel distance is measured, analyzed and reduced by moving equipment and workstations closer.
- The suppliers schedule frequent and small deliveries evenly over the production period.

Operational Flexibility

- Each cell is capable of handling multiple products.
- The production workers are cross-trained on multiple products or lines.
- Job rotation is done to ensure that each worker maintains proficiency in each job within or across the cell/line.

- Flow can be diverted in and out of cells to increase or decrease speed of production in order to meet the TAKT time.
- All workers know and understand the TAKT time requirements for their individual processes.
- The component travel is measured and analyzed, and an effort is made to reduce this travel time.
- The workers demonstrate the ability to respond quickly and effectively to variations in demand, changes in cycle time and operations.
- The machines are right sized for the operation or manufacturing process.
- The workstations are built on the concept of one-piece flow.

Pull Production System/Kanban System

- The requirement of down stream process is the driving force of the production line.
- The material flow or movement in the plant is based on the make-one, move-one concept.
- The team clearly understands and follows the true pull system.
- The team has been given adequate training on the principles of implementation of shop floor material pull systems.
- The target and actual hourly output as well as shift production requirements and timing are displayed at each cell.
- The production cells are capable of adapting to changes in customer demand by changing the production schedule.

- The production supervisors are not motivated to produce more parts than the subsequent process requires.
- Part flow diagrams/charts are displayed at the flow line and the operator understands and follows them.
- The throughput time for a particular line is known and understood by the employees.

Continuous improvement/Kaizen activities

- There is a clear strategy or mechanism for continuous improvement in the plant.
- There is a formalized measurement system in place that defines customer expectations and improvement targets and that measures progress.
- There are necessary resources, organization, and infrastructure in the plant to support the Kaizen process.
- Kaizen projects/events are structured and planned.
- Kaizen activities are conducted frequently to improve the workflow.
- Results of kaizen activities are sustained and maintained.
- All the employees have been trained to implement continuous improvement methods
- There is a suggestion process in place to solicit ideas for improvements from all employees and to recognize their work.
- The employees are empowered to work in order to reduce and eliminate the waste.
- The employees understand the relationship between standardization and continuous improvement.

- Successes have been recognized and expanded throughout the facility.
- The product/process value streams undergo examination for continuous improvement on a regularly scheduled basis.
- Root-cause-analysis meetings are often held to determine the root cause for repeated problems.
- The process/product improvements are regularly updated on the Kaizen improvement sheets.
- Most of the product/process improvements are made through product innovations.

Section II: Assessment for Lean Enterprise

Design and Development

- There is involvement of suppliers in design and product planning activities.
- The supplier input is solicited and responded to with product changes and enhancements.
- Suppliers are included in new product design at the earliest phase to reduce cost and maximize quality.
- Multifunctional teams, including manufacturing personnel, are included in the new product development process and production planning activities.
- Operational input is solicited from different departments and responded to with product changes and enhancements.
- The voice of the customer is fully integrated in new product designs, and the customer requirements allow optimization of the company and supplier's manufacturing capabilities.
- Tools such as Quality Function Deployment, Design of Experiments, Failure Mode Effects Analysis, and Design for Manufacturability and Assembly are used in the design process.
- The Design for Manufacturability, Assembly Manual and Process FMEA's are living documents that reflect lessons learned related to achieving perfect quality at least cost.
- The product development cycle is continually improved, and the company leads the industry for new product time to market.

Manufacturing and Production Control

Forecast

- There is consistent and proper usage of forecasting methodologies to avoid huge inventories.
- Other departments, beyond manufacturing to plan their resources, use forecasting methodologies.
- Schedules are leveled to match forecasted demand for a defined period such as a week or month, and models are sequenced for a smooth flow and to minimize inventories.
- Customer demand is well understood, and metrics exist to measure performance against customer requirements.
- Forecasting methods are used to aggregate capacity and material planning and to set inventory levels for the pull system.

Production Planning Operations

- The organization is able to utilize capacity analysis to schedule processes.
- A master production planning system is used in leveling production for smooth shop operations.
- Production Planning Operations can utilize shop floor information for more detailed capacity planning decisions.
- Sales and operations planning processes are in place ensuring that all disciplines of the company are aligned around demand, inventory levels, and production rates for the next three to six months.

- A combination of the pull system and live customer orders manages the flow of material into and through the factory.
- The master scheduler ensure that required amount of capacity is in place and that the pull system is tuned to meet customer demand.
- The facility has implemented mixed model scheduling to reduce lead times and inventory levels.
- Standard guidelines have been developed for operating different positions in the organization.
- The organization system has the ability to run on its information system rather than on people running the system.

Scheduling

- Scheduling ensures that the appropriate raw materials are available.
- Scheduling ensures that the appropriate tooling is available.
- The schedule is aimed at the bottleneck process.
- The production schedule ensures that all the departments are in alignment to the demand and inventory level for the next few months.
- The schedule is leveled to match the forecasted demand so as to minimize the inventory.
- The suppliers are regularly contacted to gain more visibility regarding the forecasts of the upcoming requirements.
- The scheduling changes are accurately and quickly implemented.
- There is a master schedule to ensure that the pull system is tuned to meet the customer demand.

- The schedule is capable of meeting the variations in the demand.

Information Systems and Analysis

With Suppliers

- There is a cohesive system for electronic communication and data sharing with suppliers.
- There is a shop floor data collection and dissemination system that supports material flow and the JIT system.
- Suppliers are issued forecasts electronically (EDI or the Net) at least three to six months out to gain visibility of upcoming needs (orders).
- Suppliers of expensive components are sent schedules frequently and deliver frequently.
- Suppliers of inexpensive component are sent schedules less frequently and deliver less frequently.
- Schedules for both expensive and inexpensive materials are either generated from the pull system or live customer orders.

With customers

- There is a cohesive system for electronic communication and data sharing with customers.
- There is a system for communicating the status of customer orders.
- There is transparency in communicating production issues with customers.
- Customers' feedback is collected and grievances are satisfied.
- Customers' feedback is collected and used to develop better production systems.

Communication within organization

- There are management information systems that support performance analysis and managerial decision-making to assist production activities.
- The information system supports quality-planning requirements.
- The Quality-related database uses customer data, internal company performance, cost and financial data to drive continuous improvement.
- Data are reliable, consistent, timely, and easily accessible.
- A criterion has been established to compare company's performance with competitors and best-in-class benchmarks.
- Information systems to bench mark and use these data as a source of innovative ideas for continuous improvement are in place.
- Use of operational performance data to establish priorities for short-term improvements in areas such as cycle time, productivity, and waste management is in place.
- There is strength in the integration of customer, performance, financial, market, and cost data to improve decision-making in production activities.

Supplier Assessment

System for suppliers

- Adaptation or established system are used for selection and control of suppliers and sub-suppliers.
- There is an established system for regular evaluation of suppliers for cost, quality, and delivery.
- There is an identification of key suppliers and rationalizing the supplier base.

- There is a system to establish gain-sharing relationships with key suppliers.
- There is a system to involve suppliers in the development of parts.
- There is a strategy that translates the organization's business plan into supply base requirements.
- Supply chain management fully satisfies the requirements of your quality system.
- Contractor and subcontractor quality system development goals are in compliance with your quality system.
- The system assures contractor and subcontractor investment in lean systems and continuous improvement.
- Rate your supplier for having current customers who can recommend them with regard to their ability to meet customer requirements for quality and delivery.

Procedures

- Standard operating procedures for purchases exist and are evaluated regularly.
- The system is capable of ensuring adherence to the standard operating procedures.
- There is a documented procedure to inspect incoming material.
- There is a documented procedure to transfer specified design input requirements to purchasing documents.
- There are documented procedures for control, verification, storage and maintenance of customer-supplied material.

Suppliers' quality

- Supplier's engineering and development expertise meet your production requirements.

- Suppliers are capable of producing at specified quality levels for manufacturing process or processes.
- Rate your supplier for submission of an acceptable First Piece Production Sample complete with required inspection analysis or by historic evaluation.
- Rate your supplier for demonstrated continuous improvement in quality performance toward a goal of > 95% Average.
- Suppliers have a documented quality policy understood at all levels of organization.
- Rate your supplier's current manufacturing capacity for flexibility.
- Your suppliers are competitive on performance of quality in comparison with suppliers of your competitors.

Suppliers' Delivery

- The suppliers for the manufacturing process or processes are capable of producing specified delivery levels.
- Rate your suppliers for demonstrated continuous improvement in delivery performance toward a goal of > 95% Average.
- The suppliers are evaluated on their ability to maintain delivery requirements.
- Rate your suppliers' understanding of concept of just in time and supporting your production.
- Suppliers understand and agree on the concept of financial penalties for missed deliveries.
- Your suppliers are competitive on performance of delivery in comparison with suppliers of your competitors.

Suppliers' Costs

- Suppliers for the manufacturing process or processes are capable of producing specified cost levels.
- Suppliers' costs are based on common industrial standards of calculation.
- Suppliers agree on period-based cost reduction.
- Your suppliers are competitive on performance of cost in comparison with suppliers of your competitors.

Maintenance Program Assessment

Maintenance Practices

- Implementation of maintenance organization with specific lines of authority, responsibility and accountability is in place.
- Inclusion of administrative controls is used to ensure effective implementation and control of maintenance activities.
- Rate the knowledge of total productive maintenance within the work force.
- A total productive maintenance schedule is assigned and followed for each machine / equipment.
- The TPM schedule is posted near each workstation/cell so that it is easily visible for the operator.
- All the machines have the necessary safety devices in place.
- Safety devices are well maintained and replaced when they break down.
- The machine/equipment downtime is tracked regularly.
- The self-life of machine spare parts is monitored.

- Communication interfaces between maintenance and other departments have been defined and implemented.
- Maintenance work is performed safely in accordance to applicable occupational safety and health requirements.
- Preventive maintenance tasks are scheduled based on operating experience, vendor recommendations, engineering analysis, cost/benefit analysis and reliability considerations.
- Surveillance tests, including functional tests where appropriate, are performed and documented for facility equipment.
- Trending data are acquired and used as part of the maintenance program.
- Corrective maintenance is performed in a timely manner to return equipment to service or full performance.
- Recurring maintenance problems are identified and eliminated by correcting the root causes for the problems.
- Corrective maintenance ensures that conditions causing failure or degradation in performance are identified, analyzed, and corrected.

Documentation

- Documentation of maintenance policies, goals and objectives are established for all maintenance personnel.
- Written performance standards are developed, communicated to maintenance personnel, and are implemented for maintenance activities.
- A good documented preventive maintenance system is maintained that helps in improving the machine/equipment uptime.

- The maintenance records are posted near the production and the support equipment, and are accurately maintained and updated regularly.

Maintenance activities for workers

- The operating workers are given sufficient training on the basics of TPM.
- Operating workers understand that preventive maintenance responsibilities are focused on increasing process utilization and minimizing cycle time variation.
- The preventive maintenance responsibilities are well defined for production workers and maintenance workers.
- Sufficient time has been allotted in the daily schedule for workers to perform their preventive maintenance and cleaning duties.
- Production workers are rewarded for performing the maintenance activities.

Training and People Issues

- The required knowledge, skills, and abilities have been defined based on analysis of job duties and responsibilities.
- A program exists for established and implemented training and qualification programs for managers, supervisors, planners and craft personnel.
- Qualified personnel conduct on-the-job training of the maintenance workers.
- Maintenance-training programs are periodically evaluated and improved based on feedback from trainees, maintenance supervisors, the maintenance manager and facility performance.
- Provisions are made for transferring lessons learned from ongoing maintenance activities and root cause analyses to other facilities.

- A sufficient number of properly trained management, supervision, and craft personnel are available to perform required maintenance functions.

Evaluation

- The company periodically evaluates and identifies areas that could be improved by the maintenance program.
- Management periodically reviews a broad range of performance indicators to identify potential program improvements.
- The production workers use results from external audits, self-assessments, and internal audits to identify and implement improvements in the maintenance program.
- The production workers evaluate maintenance operation data from other facilities or sites to identify potential improvements in their own maintenance program.

Section III: Assessment for Operational Excellence

Define

- The company has clearly defined its quality goals for internal processes and delivery performance.
- The company has clearly defined the level of customer satisfaction it intends to achieve.
- The company has derived quality goals from the feedback provided by its customers.
- Customer's quality requirements are addressed early and integrated into all phases of the production and delivery processes.
- The company analyzes and improves processes to achieve better quality, performance and cycle time through the use of process simplification, waste reduction, process research and testing, use of alternative technologies and benchmarking.
- The company monitors supplier performance to ensure that the company's quality requirements are met and gives relevant feedback to suppliers.
- The company uses detailed criteria to regularly conduct a quality assessment of systems, processes, practices, products and services.
- The company uses assessment results to improve practices, products and services and to verify that the results lead to effective actions.

Measure

- The company has defined the key metrics to be measured for processes.
- The company has reviewed all the key metrics for validity and reliability.

- The company regularly reviews all the measurement methods for improvements.
- Types of data to be measured from processes have been clearly identified and classified.
- Standard methods for collecting data such as check sheets and automatic gauging, are widely used.
- Analyzing and interpreting measurement systems capability to measure process parameters is practiced.
- The company maintains effective control and integrity of standards and measurement devices.
- The company uses appropriate gauges to measure performance.
- Gauges are calibrated on a regular basis.
- Calibration systems are reviewed and corrected for any deviations on a regular basis.
- A personnel training is provided for the use of appropriate measurement methods for parameters.

Analyze

- Statistical results are applied to draw valid conclusions on processes.
- Statistical tools are applied to determine whether the current state is as good as the process can be.
- Processes are analyzed to determine essential activities to correct the processes.
- Analysis is done to determine the suitable resources to be utilized for projects.
- There is a clear understanding and application of fundamental concepts of statistical tools like hypothesis testing, regression analysis, probability analysis,

tests for means, variances, and proportions paired-comparison tests, Goodness-of-fit tests, Analysis of variance (ANOVA) etc) on your processes.

- There is an analysis to determine possible factors that would cause failure of the project.

Improve

- How effective is the company in determining the work breakdown structure?
- How well does the company determine the activities essential for success of the project?
- Prototype model test of the designs are conducted to obtain results for analysis.
- There is usage of tools like PPAP, FMEA, QFD and others to design implementation plans.
- The company implements kaizen activities to improve the process.
- The company applies statistical tools to validate the results for improvement.
- Project management concepts are applied to plan multiple projects.
- Project management concepts are applied to integrate various subprojects to optimize the use of resources and to maximize the shared results.

Control

Project control

- The company is able to carry out the planning of work.
- The company is able ability to carry out good estimation in terms of cost quality and time of project.
- Well-defined tasks are developed in the project.

- The company is able to maintain disciplined budgeting and authorization for projects.
- The company is able to develop the system to report timely progress/resource utilization.
- The company is able to develop systems for periodic re-estimating in terms of time and cost.
- Established periodic comparison of actual and planned activities.

Risk Management

- Projects are developed with risk strategies.
- Risk management procedures, risk management plans and other risk documentation are produced.
- Qualitative or quantitative risk analysis is performed.
- The main areas of uncertainty are identified and their likelihood of occurrence and impact are assessed.
- The company is able to focus on risk reduction using different tools.
- Fallback options are developed for project management.
- Contingency plans are made and practiced.
- Suppliers' risk management capabilities are assessed.

Quality Control

- Detailed designs are upgraded to satisfy customers' demand.
- Rate the designing and conducting processes within quality control.
- Statistical tools are applied to enhance the quality of the project.

- How effectively has statistical Process Control been implemented in all processes?
- If an SPC program has been implemented, how do you rate your adherence to the program?
- How effective is your system for conducting and implementing problem solving?
- Rate your quality system in conducting and utilizing process capability studies
- Rate your quality system's ability to conduct and use designed experiments.
- Rate your quality system's ability to conduct and use key variable studies.
- Rate your quality system's ability to meet customer specifications or tolerance requirements.

Cost control

- Operation costs are defined and everyone knows the cost of operation.
- All functions are involved in the business planning process.
- Maintenance and service costs are measured and progress toward improvement in targets is recorded.
- Performance is measured by variance to budget.
- There is an effective system for controlling variances and identifying the variances in each department/area.
- There are improvement targets established for each variance category and actions have been identified to reduce each variance type.
- Costs of reworks have been decreased over the period of time and recorded for future reference.

People issues in quality and variation reduction

- People are trained to master their assigned job and certified to meet productivity and quality standards.
- Production personnel adhere to the defined processes and methods.
- Improvements in the capability of people is encouraged and progress is tracked and posted at each workstation.
- Each worker has been trained in a problem solving methodology and involved in problem identification and resolution.
- Quality and productivity objectives are communicated to all personnel and progress toward targets and trends are posted at each workstation or machine cell.
- Each worker understands the concept of delivering excellent quality parts to internal (next operations) and external customers.
- The organization understands the value of six sigma philosophy, goals, and definition.
- The organization understands and distinguishes interrelationships between business systems and processes.
- The organization understands leadership roles in the deployment of six-sigma.
- Rate your organization for linking projects to organizational goals.
- Rate your organization's use of risk analysis in processing of projects.
- Each person in every department is held responsible for his or her own quality. All personnel have been instructed in the basics of statistical process control and understand the fundamentals of defect prevention.
- Customer quality is our highest priority.

- Scheduled meetings are held with contract workers and full-time employees to review the improvement in progress toward customer quality and internal quality measures.
- Employees have access to information, resources and support to meet or exceed customer quality, cost and on-time delivery.
- All employees participate in waste elimination programs such as inventory, scrap, rework, idle workers and equipment, inspection, and other non-value added operations.
- Teams have the authority to determine the root cause for problems as well as to implement corrective actions that permanently solve the problem, and make changes in the system that prevent the problems.

Section IV: Assessment for Cultural Sustainability

Vision development

- Competitive analyses of key measures are the company's foundation for business planning.
- Benchmarking of key processes and systems are foundations for the company's continuous improvement program.
- Your business plan defines long and short-term goals that are in support of the company's vision and mission statements.
- Continuous improvement in every aspect of the business is an integral part of the company's culture, and quality leadership is a priority.
- There is a focus on simplifying or flattening the organizational structure and eliminating non-value added functions.
- The company expresses includes its quality policies, practices and values on public responsibility issues such as business ethics, public health and safety, environmental protection and waste management.

Customer focus

- A process for determining customer satisfaction is in place and key performance metrics, trends, and targets are documented.
- Rate customer satisfaction in terms of on-time delivery.
- Continuous improvement measures of customer quality and delivery performance are tracked over time against improvement targets and competitors' performance.

- A customer service level has been established and sustained throughout the organization and the company does not compromise its commitment to customer satisfaction.
- A system is in place that focuses on the reduction of variation and waste and results in measurable customer quality improvements and cost reductions.
- An improvement program is in place that reduces the time to market from product concept to full production, and measures are used to track progress against improvement targets.
- Processes and products are designed with the intent of meeting the market's demand for mass customization.

Human Resource Development and Management

- Integrity in the company's dealings with employees, customers, and suppliers is never compromised.
- The company uses employee-related data to improve the effectiveness of the entire workforce at all organization levels.
- The company has specific mechanisms to promote employee contributions and to provide feedback, individually and in groups, on quality and performance objectives.
- The company has specific mechanisms to increase employee empowerment, responsibility and innovation.
- The company conducts skills assessment for all employees and uses the results to develop education and training programs that improve quality skills and knowledge.

- The company provides quality-related training for new and existing employees and tracks the percentage of employees receiving training and the amount of training hours received by employees annually.
- The company evaluates and improves the effectiveness of education and training including delivery systems, subsequent job performance improvement and overall employee development.
- The company's performance, recognition, promotion, compensation, reward, and feedback systems support quality and performance objectives.
- The company has key indicators such as cooperation, participation and employee satisfaction that are used to evaluate and improve performance and recognition processes.
- The company offers special services to employees, such as counseling, assistance, recreational or cultural opportunities, non-work-related education, or outplacement.
- The company tracks key indicator of employee's morale such as satisfaction, safety, absenteeism and turnover.

Leadership

- The personal actions of management demonstrate, communicate and reinforce a future vision, customer focus and quality values.
- The management has created clearly defined quality values and communicated those values both internal and external to the company.

- Executives provide leadership through visible involvement in quality values, planning for quality, recognizing employee contributions and communicating quality values outside the company.
- Evaluation of seniors is done on their effectiveness as leaders and their involvement in creating customer-focused quality values.
- Top management has been provided training to lead and work with other employees.
- The company's organizational structure effectively and efficiently enhances the attainment of the company's customer, quality, innovation, and cycle time objectives.

Top Management Analysis

- The management/group visibly promotes lean business systems in providing education to middle and lower managements.
- Management encourages or mandates employees at all levels to participate in lean business system initiatives.
- Managers and supervisors are held accountable for implementing lean business system activities.
- Involvement and implementation in lean business systems are a part of the formal review process for managers and supervisors.
- Management has shown a sense of appreciation for managers and employees for lean business systems initiatives and continuous improvement innovations.
- Management invests resources (including capital and people's time) in identifying and implementing lean business system initiatives.

- Management has formed cross-functional teams for lean business implementations, problem solving continuous improvement and containment.
- Employee concerns about job security related to the elimination of waste are addressed.
- Rate addressing of employee concerns about rewards for lean business systems involvement.
- The organization has an established philosophy or policy statement that articulates what the organization is trying to accomplish with the lean business systems approach.

Middle Management Analysis

- Managers and supervisors believe in implementing lean business system activities.
- Managers and supervisors understand principles of lean business systems.
- Middle management has been involved in the development of company vision and strategies.
- Middle management has taken an interest in implementing lean activities and continuous improvement.
- Middle management has taken steps toward educating workers to understand lean principles.
- Middle management has involved workers in forming teams to implement lean initiatives.
- Middle management has been provided training to implement lean systems.

- Middle management does not have job insecurity relating to the elimination of waste.
- Middle management understands the rewards for improvising lean business systems.
- Middle management does not hesitate to delegate power.
- Middle management is willing to share the limelight with its workers.

Lower Management Analysis

- Workers believe that implementing lean business system activities will help and improve the performance of the company.
- Workers have been involved in the development of company vision and strategies.
- Workers have faith that top management will listen to their suggestions.
- Workers know organizational vision and strategies.
- Workers have been educated about lean business system activities.
- Workers are encouraged to begin and/or join cross-functional team works.
- People are trained to master their assigned job and certified in their ability to meet productivity and quality standards.
- Workers are masters of their own work and are held accountable for their work.
- Workers have a healthy and constructive relationship with middle management.
- Workers have a healthy and constructive relationship with top management.
- Workers do not have job insecurity related to the elimination of waste.
- Workers understand the rewards for improvising lean business systems.
- Workers are recognized and awarded for their lean initiatives.

Appendix B: Usage of UTOPEX Software Tool

The roles of four main users of UTOPEX software tool are explained as below.

- **Administrator:** This user is responsible for controlling and managing the assessment tool. Administrator logs into the tool using Internet explorer (front end) to signup companies for the assessment, to allot lean programs (time for the assessments), to add experts who will view scores and provide recommendations for improvement, to add questionnaire based on the type of organization and to deploy changes to the assessment. All the data is stored in relevant database tables (MS Access-backend) through ASP programming (intermediate).
- **Company:** This user is responsible for deploying the assessment in the organization. The organization logs into the tool using Internet Explorer (front end) to validate and change organization profile, to assign the participants to take assessment and to view the recommendations for improvement provided by experts.
- **Participants:** This user is responsible for providing answers to the assigned questions on ordinal scale. This user can access UTOPEX through Internet explorer and is authorized to only provide responses to the assigned questionnaire
- **Experts**: This user is responsible for compiling the results of the assessment and for providing recommendations based on the obtained results.

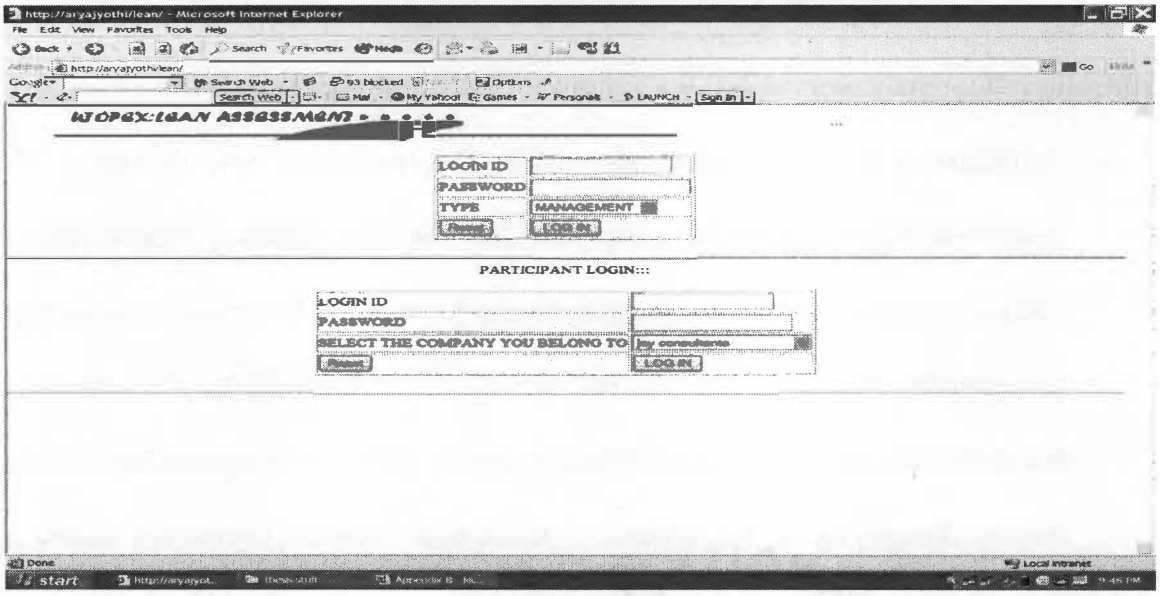


Figure 1b. Login Page

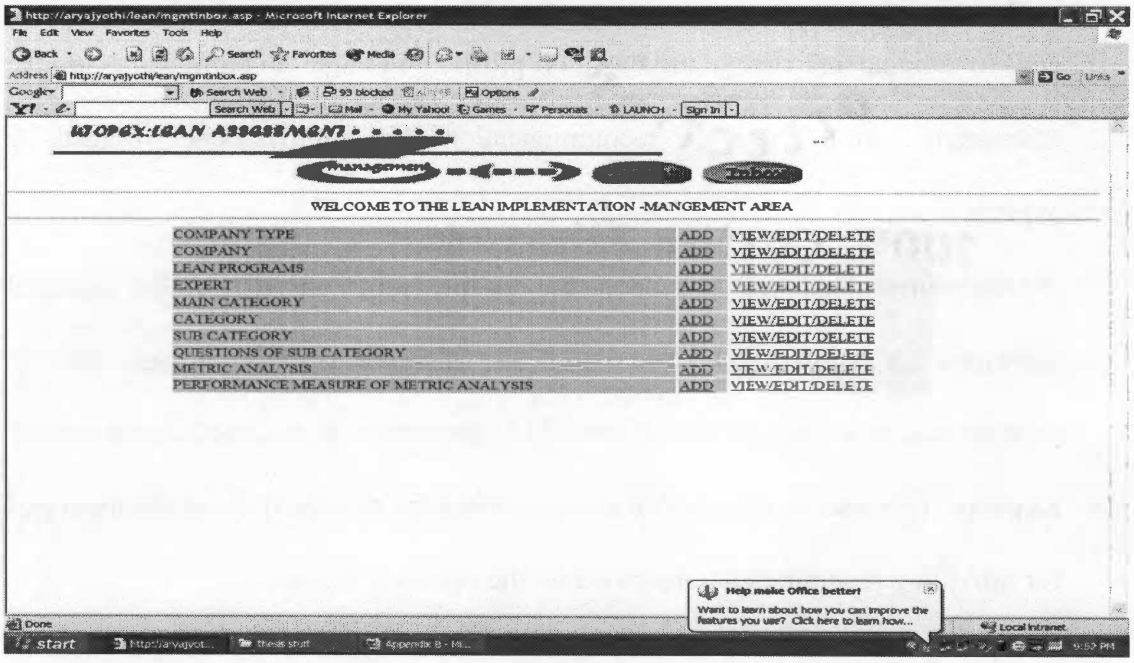


Figure 2b. Administrator Inbox

The figure 1b above presents the login page through which all the above-mentioned users can enter the tool for its usage.

Administrator Functions

Figure 2b above shows all functions available to the administrator. These functions and their role are explained in detail to illustrate the usage of tool.

Company Type: Click on link "COMPANY TYPE" to choose the category of production system to which the organization belongs. Company type option, provides flexibility, to design lean assessments based on the type of production system. The examples of different type of companies are repetitive production type, continuous production type, or job-shop production.

Company: Click on link "COMPANY" to add, edit, view and delete the company for assessment. Figure 3b shows the form for designed to register the organization for the assessment.

Lean Programs: Figure 4b shows the web page to assign lean assessment program to the organization obtained by clicking on lean programs option. The lean programs option can also used to provide the flexibility to edit view and delete the assigned lean programs to felicitate customer (organizations) requirement.

Experts: The administrator/manager adds experts, who will suggest recommendations based on the scores generated. The administrator/manager of the site has the right to edit, view and delete the profile of the experts.

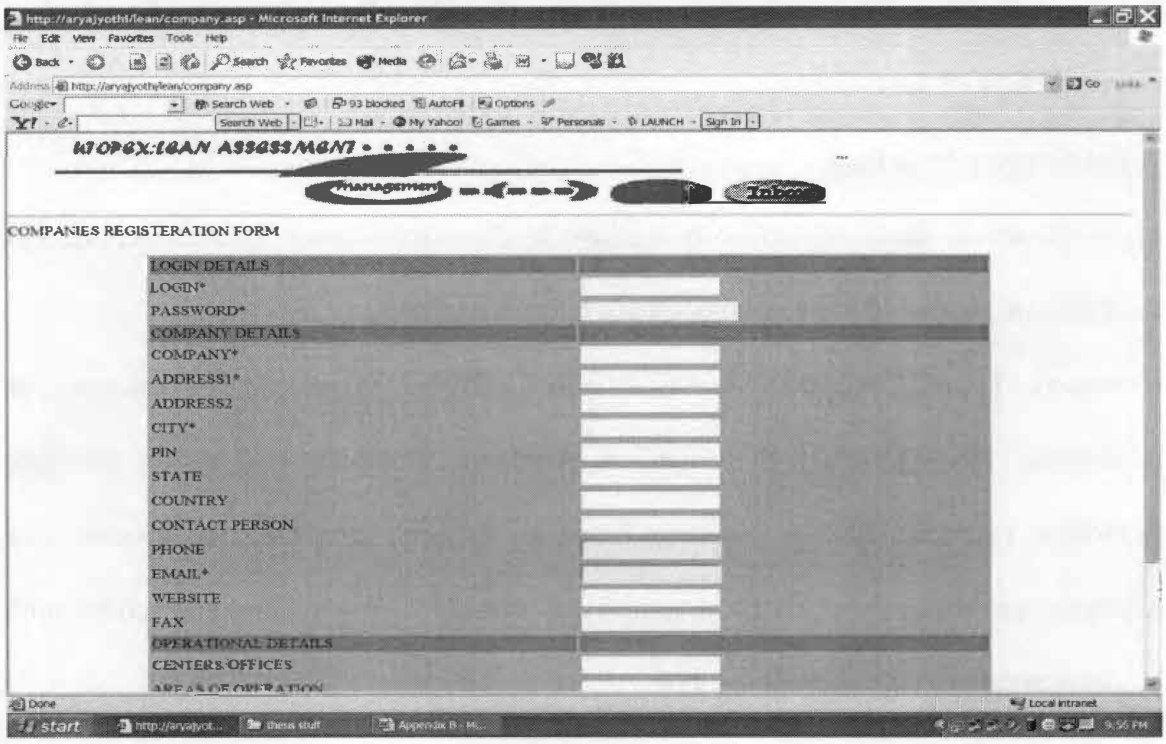


Figure 3b. Company Registration Form

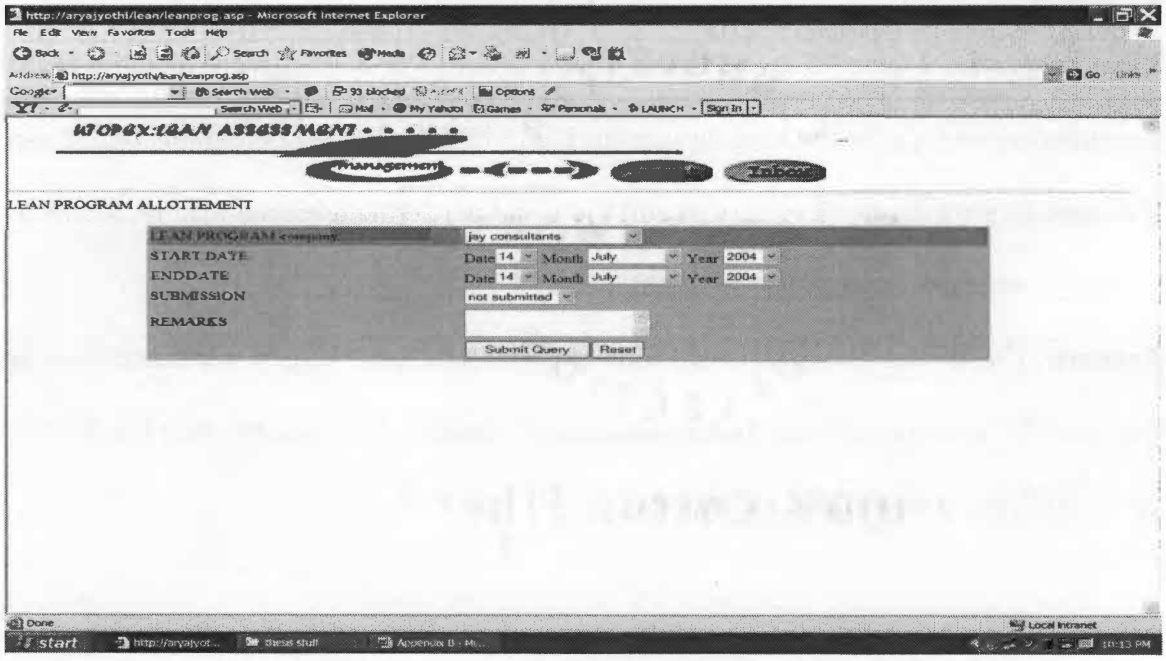


Figure 4b. Lean Programs Option

Main Category: This option provides the flexibility to add different categories of assessment based on the organization's production type. The main categories for repetitive manufacturing type are lean manufacturing, lean support systems, operational excellence and cultural sustainability. Any number of categories can be added. The administrator is provided with a facility to edit, view or delete a category whenever needed.

Category: Four main categories as mentioned are further divided into categories. This option is provided to add different categories to each main category. For example: Value stream mapping is a category of lean manufacturing system.

Sub-Category: The categories are in turn divided into sub-categories. This option is provided to include comprehensive questionnaire on different categories. These subcategories can be added, deleted, viewed and edited as needed with the help of "sub category" option. For example: SOP for operation and SOP for changeovers are sub categories of standard operation procedures category in lean manufacturing main category.

Questions of sub-category: Set of questions is added to subcategories to be answered by the participants of lean assessment. These questions can be modified any time according to the requirement of the organization. Any number of questions can be added to the subcategories. Figure 5b shows the page to add the questions.

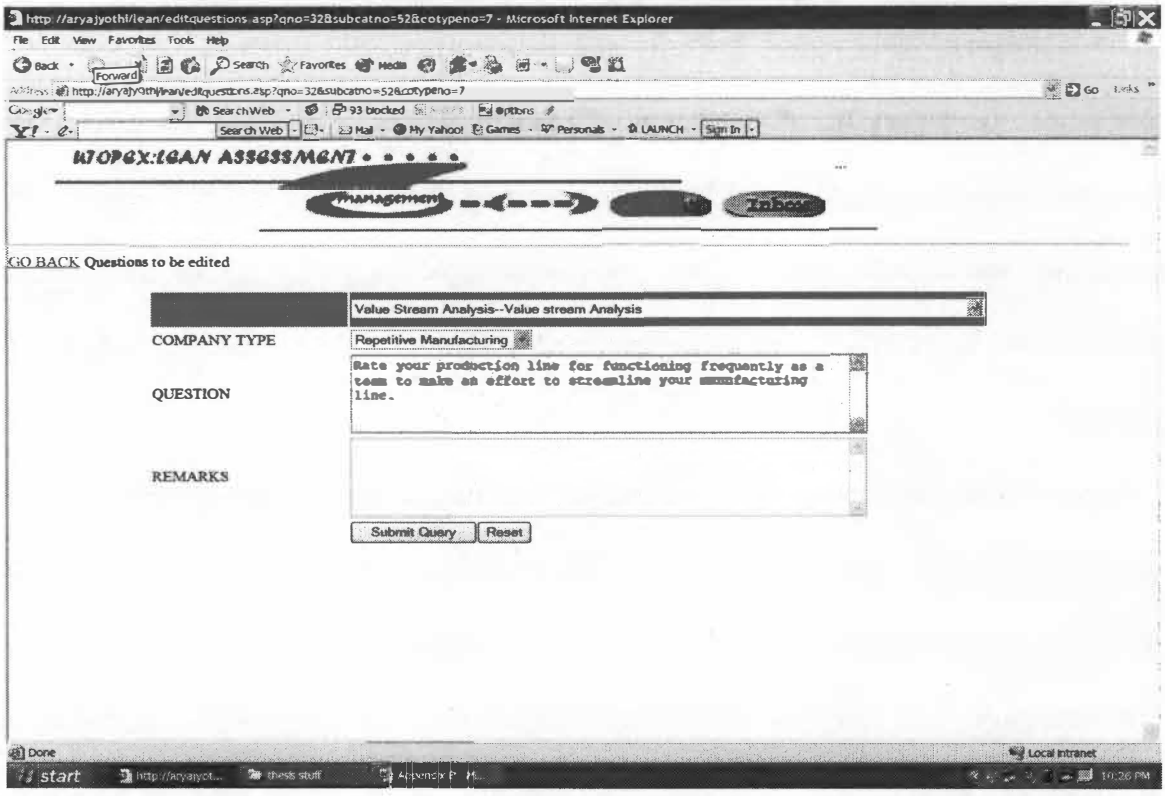
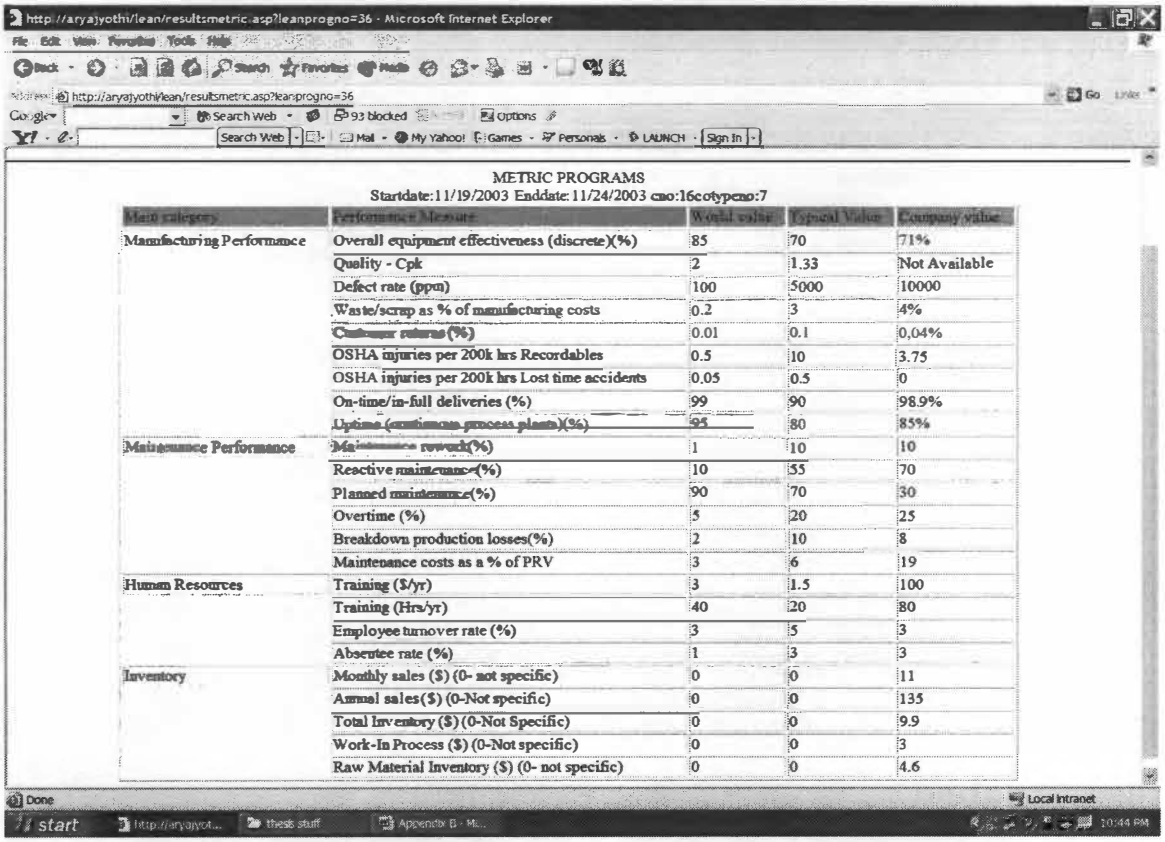


Figure 5b. Addition of Questions

Metric Analysis: Metric analysis questionnaire is used to collect numerical figures for certain defined parameters, which will be compared against accepted standards. These questions can be added, modified, viewed or deleted by the administrator/manager as per the requirement of the organization.

Performance measure of metric analysis: Numerical values for certain defined parameters for metrics analyses are further classified based on their functionality like manufacturing performance, maintenance performance, inventory management and others. These measures can also be deleted, viewed or edited based on the need of organization. Figure 6b below shows various metrics collected for the comparison against accepted standards.



METRIC PROGRAMS
Startdate:11/19/2003 Enddate:11/24/2003 cno:16cotypeno:7

Main category	Performance Measure	World value	Typical Value	Company value
Manufacturing Performance	Overall equipment effectiveness (discrete)(%)	85	70	71%
	Quality - Cpk	2	1.33	Not Available
	Defect rate (ppm)	100	5000	10000
	Waste/scrap as % of manufacturing costs	0.2	3	4%
	Customer returns(%)	0.01	0.1	0.04%
	OSHA injuries per 200k hrs Recordables	0.5	10	3.75
	OSHA injuries per 200k hrs Lost time accidents	0.05	0.5	0
	On-time/in-full deliveries (%)	99	90	98.9%
	Uptime (continuous process plants)(%)	95	80	85%
Maintenance Performance	Maintenance rework(%)	1	10	10
	Reactive maintenance(%)	10	55	70
	Planned maintenance(%)	90	70	30
	Overtime (%)	5	20	25
	Breakdown production losses(%)	2	10	8
	Maintenance costs as a % of PRV	3	6	19
Human Resources	Training ($/yr)	3	1.5	100
	Training (Hrs/yr)	40	20	80
	Employee turnover rate (%)	3	5	3
	Absentee rate (%)	1	3	3
Inventory	Monthly sales ($) (0- not specific)	0	0	11
	Annual sales($) (0-Not specific)	0	0	135
	Total Inventory ($) (0-Not Specific)	0	0	9.9
	Work-In Process ($) (0-Not specific)	0	0	3
	Raw Material Inventory ($) (0- not specific)	0	0	4.6

Figure 6b. Metrics Analysis

Company Functions

The roles of various links, provided to an organization in the deployment of UTOPEX assessment are explained in detail below.

View Lean Programs: This icon helps the organization to find the allotted dates for lean assessment. The company also uses this icon to submit the completion of assessment after conforming that all the participants have answered their respective questionnaire.

Edit: This option enables organization to submit the completed questionnaire prior to the last date of submission which helps to reduce lead time of assessment and get suggestions from experts at faster rate.

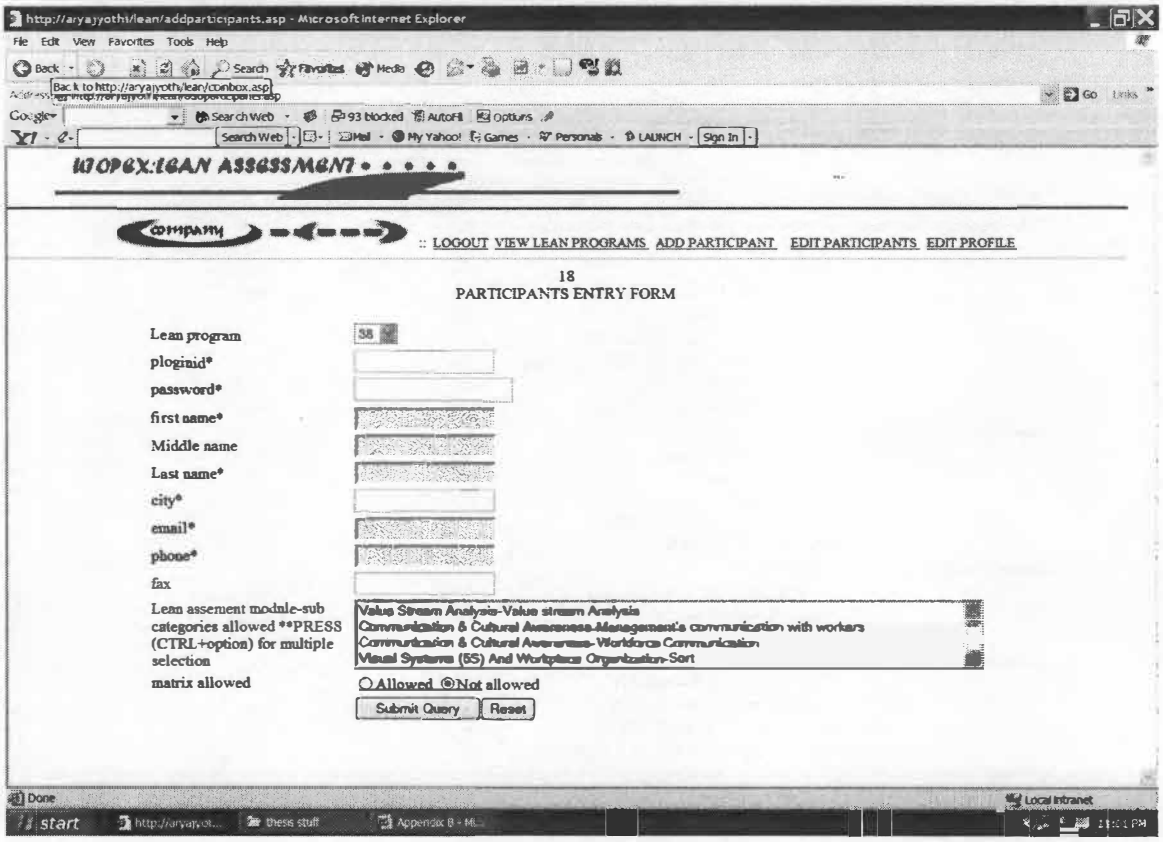


Figure 7b. Addition of Participants

Add Participants: Figure 7b above shows page used to add participants for lean assessment. Any number of participants can be added. There is flexibility to selectively assign participants to take the questionnaire related only to his/her work area.

Edit Participant: Through this link organization can delete or add the participants to any category whenever needed.

Edit Profile: This option provides organization to edit the profile of the organization whenever needed.

View Expert Suggestions: By clicking on this link organization can view the suggestions posted by different experts after the completion of the assessment.

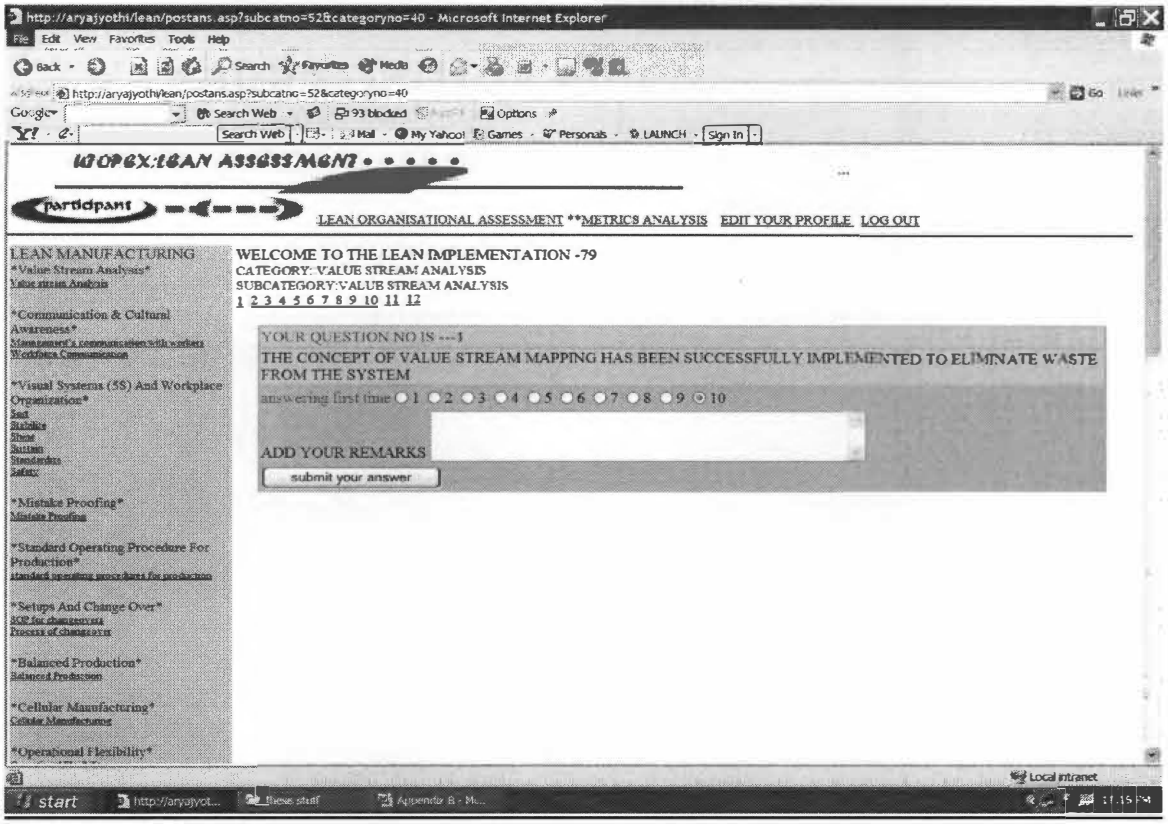


Figure 8b. Response to Questions

Participant Functions

Answer to the questionnaire: Figure 8b shows the page through which a participant will provide his responses to the questionnaire. Participants will provide responses to the questions from different categories assigned to him on an ordinal scale. These responses will be automatically compiled after the completion of assessment and the scores will be utilized to develop strategic road map for lean implementation.

Edit Profile: This option provides the participant flexibility to edit his profile if needed.

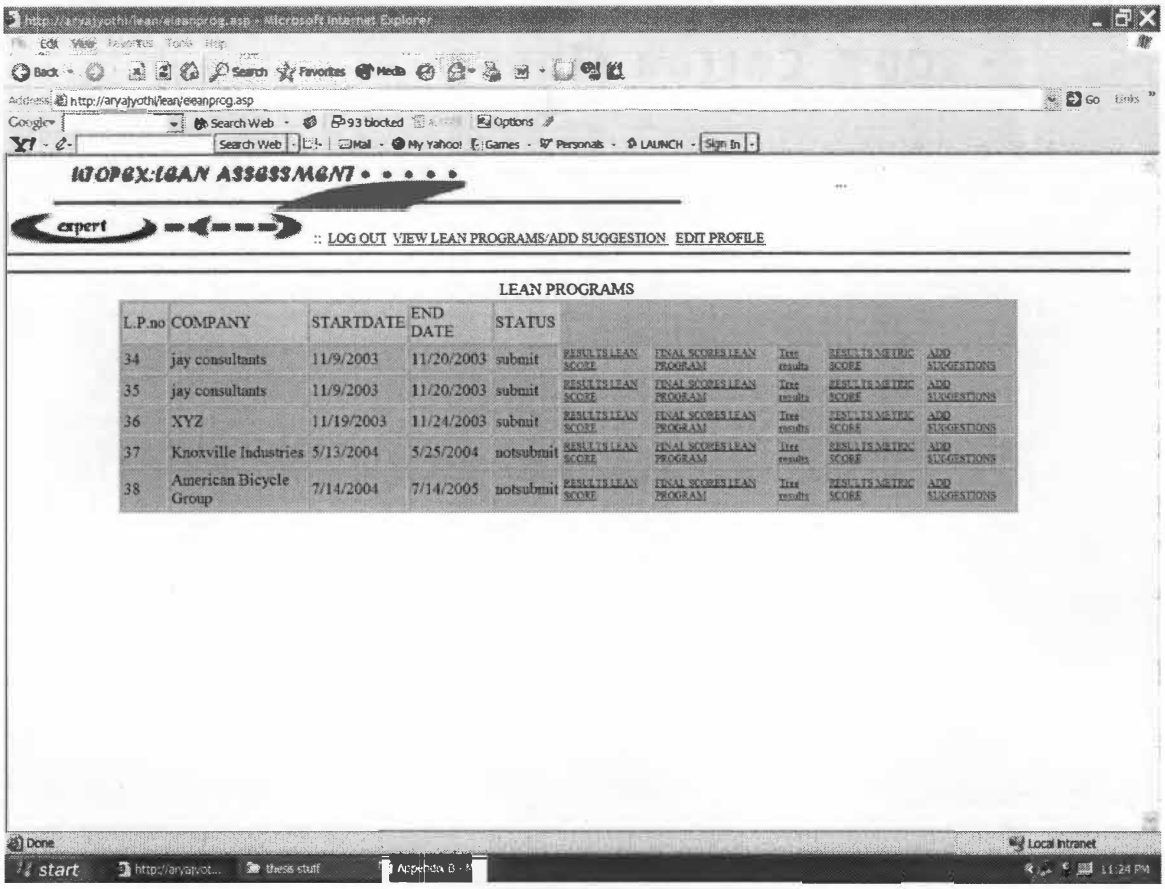


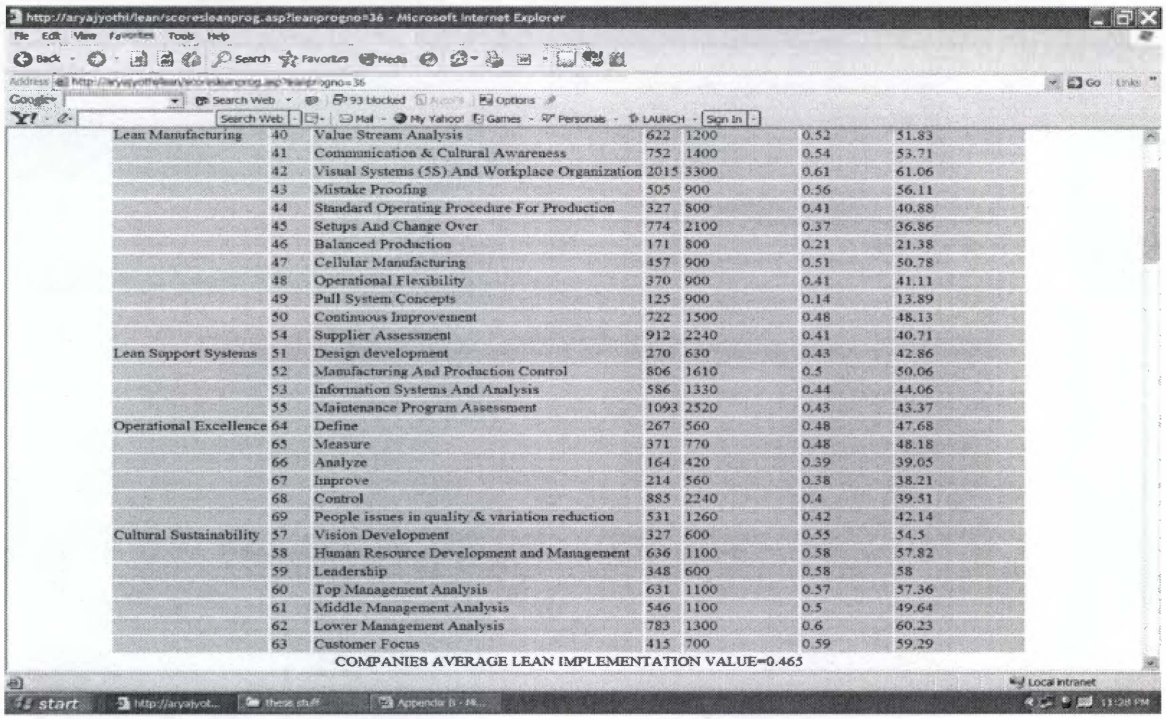
Figure 9b. Tools for Experts

Expert Functions:

After completion of the assessment, the experts are displayed with the table shown in figure 9b that helps them to compile the results, to view the scores and to provide suggestions based on the scores.

Compile Results: Once the organization submits the assessment, the expert can automatically compile the results to view the scores.

Final Scores: Experts using this option can view grand total, average score and percentage score for each categories of lean assessment and bar charts for each categories of lean assessment are displayed automatically.



Lean Manufacturing	40	Value Stream Analysis	622	1200	0.52	51.83
	41	Communication & Cultural Awareness	752	1400	0.54	53.71
	42	Visual Systems (5S) And Workplace Organization	2015	3300	0.61	61.06
	43	Mistake Proofing	505	900	0.56	56.11
	44	Standard Operating Procedure For Production	327	800	0.41	40.88
	45	Setups And Change Over	774	2100	0.37	36.86
	46	Balanced Production	171	800	0.21	21.38
	47	Cellular Manufacturing	457	900	0.51	50.78
	48	Operational Flexibility	370	900	0.41	41.11
	49	Pull System Concepts	125	900	0.14	13.89
	50	Continuous Improvement	722	1500	0.48	48.13
	54	Supplier Assessment	912	2240	0.41	40.71
Lean Support Systems	51	Design development	270	630	0.43	42.86
	52	Manufacturing And Production Control	806	1610	0.5	50.06
	53	Information Systems And Analysis	586	1330	0.44	44.06
	55	Maintenance Program Assessment	1093	2520	0.43	43.37
Operational Excellence	64	Define	267	560	0.48	47.68
	65	Measure	371	770	0.48	48.18
	66	Analyze	164	420	0.39	39.05
	67	Improve	214	560	0.38	38.21
	68	Control	885	2240	0.4	39.51
	69	People issues in quality & variation reduction	531	1260	0.42	42.14
Cultural Sustainability	57	Vision Development	327	600	0.55	54.5
	58	Human Resource Development and Management	636	1100	0.58	57.82
	59	Leadership	348	600	0.58	58
	60	Top Management Analysis	631	1100	0.57	57.36
	61	Middle Management Analysis	546	1100	0.5	49.64
	62	Lower Management Analysis	783	1300	0.6	60.23
	63	Customer Focus	415	700	0.59	59.29

COMPANIES AVERAGE LEAN IMPLEMENTATION VALUE=0.465

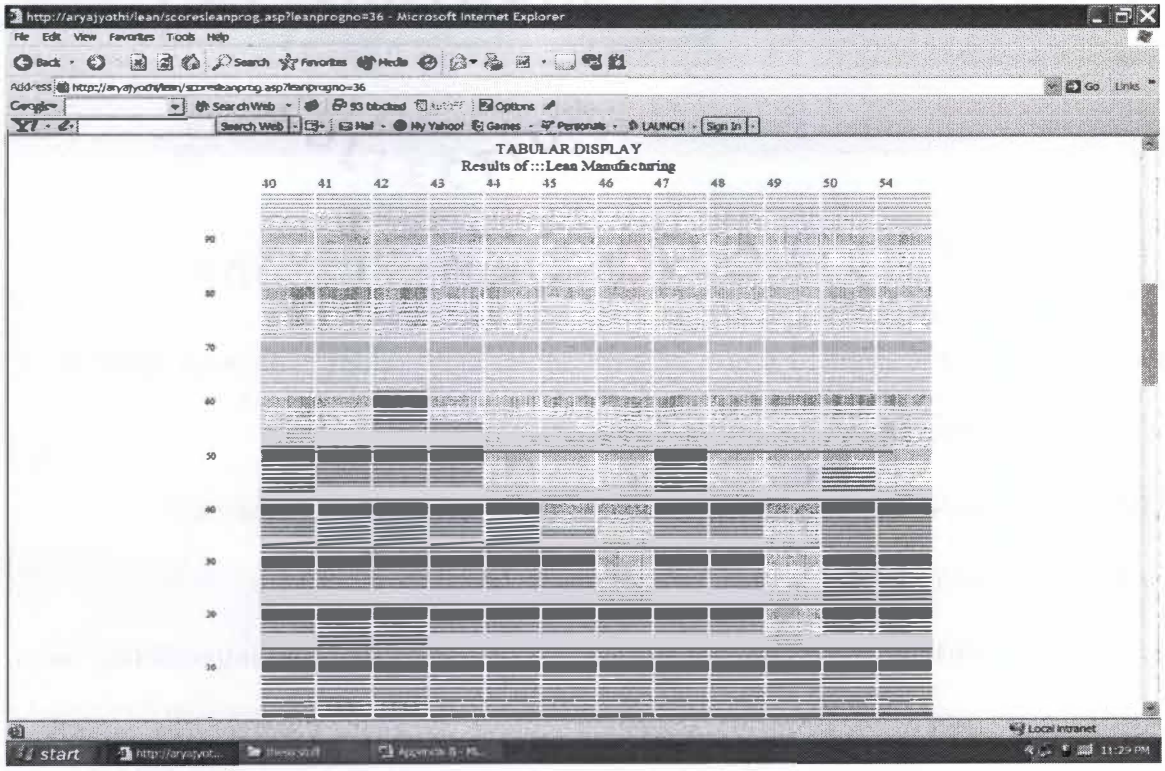


Figure 10b. Final Scores

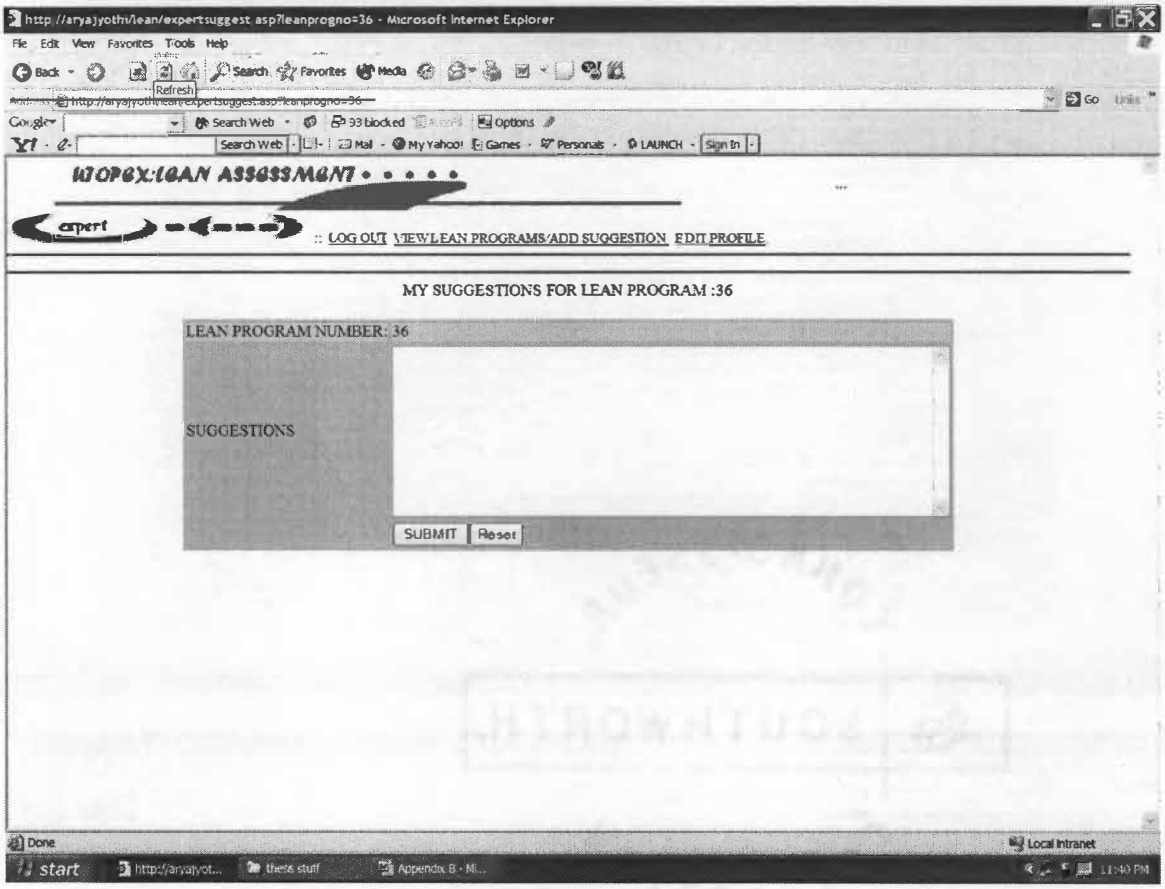


Figure 11b. Expert Recommendations

Table Results: The detailed scores of each sub-category along with total, grand total, average score and percentage score is displayed.

Metric Analysis score: The numerical values for certain defined parameters for metrics analysis scores for comparison against accepted standard are displayed.

Add Suggestions: The experts can provide recommendations for improvement after viewing the scores of the company. Figure 11b above shows the page used by experts to add recommendations in the suggestion box.

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VITA

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