# A COMPREHENSIVE MULTI-FACETED APPROACH FOR SIMULTANEOUSLY ANALYZING ORGANIZATIONAL PERFORMANCE MEASURES ESSENTIAL FOR COMPANY SUCCESS IN MANUFACTURING ENTERPRISES

by

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ABSTRACT

Profit, ergonomics, safety, employee morale, quality, efficiency, and productivity are critical components that greatly impact company success within manufacturing organizations. Therefore, it is essential that a valid and reliable systematic approach that encompasses all of these factors be developed for use by top management in today's rapidly changing manufacturing environment. Organizational-level decisions made based upon a single goal or narrow perspective that only considers one of the aforementioned components, such as profit, while ignoring others, such as employee morale, have proven harmful to the long term viability and success of manufacturing companies. Often organizational leaders are not adequately equipped to consider multiple factors that are pertinent to company success due to the complexity associated with considering a large number of organizational variables and the lack of quantitative tools and techniques to assist in this process. Thus, valid, reliable and readily available tools, methods, and techniques for integrating into decision making multiple components of profit, ergonomics, safety, employee morale, quality, efficiency, and productivity are highly needed in today's complex manufacturing business environment. This research responds to the need to develop quantitative models by creating a company success index. This index was developed using an approach to analyze and evaluate multiple factors at the strategic, tactical, and operational levels of an organization that are essential to achieve company success in manufacturing enterprises. The resulting company success index model was validated using information on market share (Specificity = 0%, Sensitivity & Accuracy = 87.5%). Future research related to this topic area should include additional studies to expand upon model validation and verification techniques.

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# LIST OF ACRONYMS/ABBREVIATIONS

AHP – Analytical Hierarchy Process

BSC – Balanced Scorecard

CPM – Critical Performance Measures

FST – Fuzzy Set Theory

KPM – Key Performance Measures

MF – Membership Function

OPM – Organizational Performance Measures

SME – Subject Matter Expert

# CHAPTER ONE: INTRODUCTION

Organizational decisions continue to become more complex for top managers considering the large number of qualitative performance measures that affect company success. Since many qualitative performance measures do not have a quantitative measurement approach, it is unfeasible to integrate them into organizational decision tools and be appropriately combined with other quantitative performance measures. Organizational decision makers frequently face high-risk decisions, which entail large and complex datasets, as well as external factors that influence organizational success. Many organizational leaders do not measure critical performance measures essential to achieve company success or they fail to use the data collected to make better decisions. Any organizational decision maker must first select the appropriate indicators or key performance measures and secondly use the data collected appropriately in order to drive the company to success.

Understanding the significance and complexity of organizational performance measures can help one to develop more realistic tools, methods, and techniques that combine these measures to assist organizational decision makers. Organizational decisions belong to the highest level of the organization (top management) where common concerns are related to general direction, long-term goals, and organizational values. These types of decisions are the most unstructured, uncertain, and risky partly because they reach so far into the future that they are hard to control (Harris, 1998). Company success components proposed in this research are shown in Figure 1.

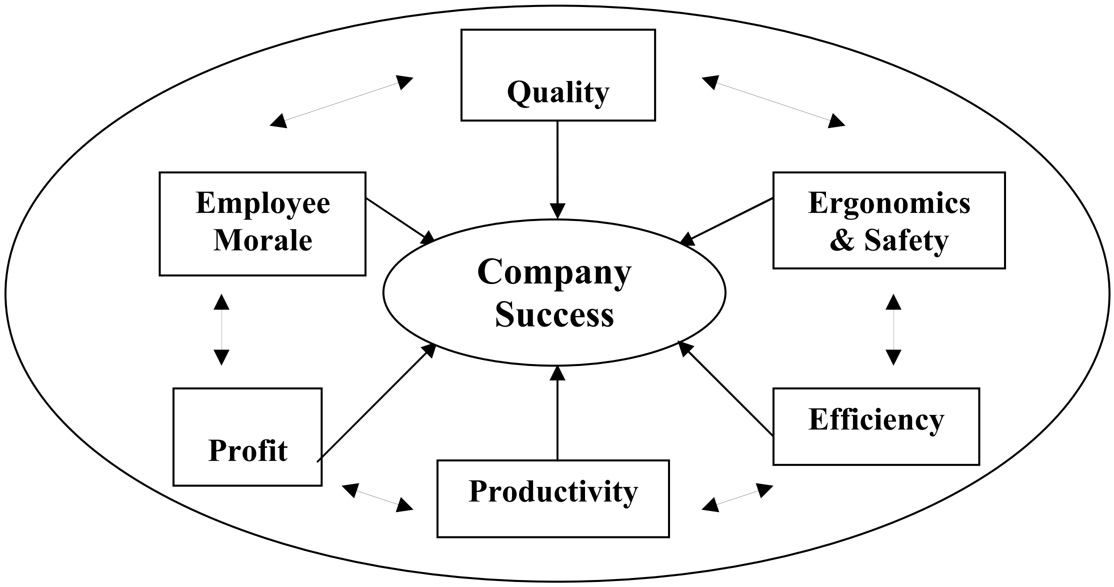



Figure 1 Components of Company Success

Decisions should be made and evaluated at all business levels; unfortunately, many organizations make a large number of decisions at the operational level, which indicates a lack of previous organizational thinking and planning (Harris, 1998). The insufficient early planning creates a reactive organization, which responds to external forces around the business and never obtains control of the organizational goals. Customer satisfaction, supply change, environmental factors, and economic demands compel organizations to achieve a variety of objectives simultaneously, but often these objectives are in conflict. Schiemann and Lingle (1996) compared 58 measurement-managed organizations to 64 non-measurement managed organizations. They found 97% of the measurement-managed organizations reported success with major change efforts, versus only 55% of non-measurement managed organizations.

In addition, Lingle and Schiemann (1996) reported similar differences for being perceived as an industry leader over three years (74% vs. 44%) and being reported as financially ranked in the top third of their industry (83% vs. 52%). Herrera stated that today's organizational performance measures are financial and non-financial, qualitative and quantitative, hard (financial and operating efficiency) and soft (customer satisfaction and employee engagement) (Baltazar, 2007; Teague & Eilon, 1973).

As a result, an in-depth literature review has been conducted in order to identify and use the appropriate organizational measures and metrics, which quantitatively describe a holistic company environment. It has been imperative in this research to identify performance measures for profit, ergonomics, safety, employee morale, quality, efficiency, and productivity that represent company success in manufacturing organizations. The goal of this research has been to determine how the combined effects of profit, productivity, efficiency, quality, employee morale, ergonomics and safety affect company success. Specifically, this research provides a reliable methodology and approach for organizational managers and manufacturing leaders to make wiser decisions and obtain company success. In addition, a series of models (ergonomics and safety, quality, and employee morale) and a company success index has been developed to assess and predict organizational performance in manufacturing organizations.

Lastly, this research effort provides tools, methods, and techniques to measure and assess key organizational success factor variables. Consequently, organizational decision makers will be better equipped to make complex decisions and achieve organizational excellence. The results of this research effort can be benchmarked by other manufacturing organizations and applied to other types of applications, such as service industries or government institutions. In addition, this research helps predict organizational success while providing a reliable performance measure methodology ready to be used by any manufacturing organization.

Although company success has been financially characterized before, a reliable organizational performance methodology that provides a systematic measurement approach based on the company success components identified within this research (profit, productivity, efficiency, quality, employee morale, and safety and ergonomics) has never been developed. In addition, a holistic model to evaluate safety and ergonomics, quality, and employee morale has never been developed. Also, a company success index model that encompasses a large number of quantitative and qualitative key performance measures (such as employee motivation, production volume, trust, etc) essential for manufacturing organizations has never been created. Organizational decision makers are constantly forced to use non-financial measures such as customer satisfaction, employee's trust, and customer loyalty to evaluate company performance, but qualitative data increases the complexity of the decision process. Considering the inevitable situation of dealing with complex systems, a different approach is proposed in this research to successfully combine qualitative and quantitative performance measures to generate index models.

Finally, a company success index has been developed to evaluate the organizational performance level in manufacturing organizations. Data has been collected from two plants (Plant A and B), and each plant belongs to a different subsidiary within the same manufacturing organization. To ensure the robustness of the index and models developed, data from Plant A has been collected and used to develop the aforementioned models and index, and Plant B data has been used to validate them.

# CHAPTER TWO: LITERATURE REVIEW

In order to define effective performance measures, organizations must take into account two critical aspects. First of all, how will the measures support (senior executive performance review and organizational planning) the overall health of the organization? Secondly, how will the measures support daily operations and decision making (Evans & Lindsay, 2002)?

Many studies performed in the 1980's suggest the necessity to pursue more non-financial measures to evaluate the manufacturing organization's performance. Financial performance measurements dominated the traditional manufacturing business, but company success spans far beyond the basic considerations of profit or return on investment (Kaplan & Norton, 1992; Banks & Wheelwright, 1979; Amaratunga & Baldry, 2002; Hayes & Garvin, 1982). The problem in the past was related to the lack of enough performance measures to evaluate company success; recently, the problem is the major proliferation of performance measures. Considering common assumptions and the increase of performance measures observed in recent years, it is no longer clear where the organization's priorities lie (Neely; Busi & Bititci, 2006). Frigo and Krumwiede (1999) reported that in the five years prior to 2000, around 50% of companies attempted to transform their organizational performance systems. By contrast, 85% of organizations planned to have performance measurement initiatives underway by the end of 2004 (Frigo & Krumwiede, 1999). Business leaders need clear indicators to understand how company success can be achieved in manufacturing environments. The integration of information on profit, productivity, efficiency, quality, employee morale, ergonomics and safety performance measures will help establish a “common framework” or methodology to evaluate organizational performance and predict business success in manufacturing applications.

### 2.1 Traditional vs. Non-Traditional Performance Measures

From the 1880s to the 1980s, financial measures such as profit, productivity, and return of investment dominated the performance measures environment, but the world market changed and the introduction of new manufacturing techniques, such as Just in Time (JIT) or Total Quality Management (TQM), changed the traditional and obsolete performance measure perspective. Many researchers such as Banks and Wheelwright, Hayes and Garvin, and Kaplan have criticized financial indicators for leading and promoting short-term thinking because cost accounting focuses on minimization of variance rather than continuous improvement. Even though many organizational decision makers and manufacturing leaders are aware of the tradeoffs of using purely financial measures, a major proliferation of econometric models has been observed recently, including those of Stiglitz (2001), Engle III (2003), Devitt (2001), Frängsmyr (2004), and Bourne, et al. (2000). Table 1 illustrates the comparison between traditional and non-traditional organizations’ performance measures:

Table 1 Organizational Performance Measures Comparison Table (Ghalayini & Noble, 1996)

| Traditional Performance Measures | Non-Traditional Performance Measures |
|---|---|
| Based on traditional accounting system | Based on company strategy |
| Mainly financial measures | Mainly non-financial measures |
| Intended for middle and high managers | Intended for all employees |
| Lagging metrics (weekly or monthly) | On-time metrics (hourly, or daily) |
| Difficult, confusing and misleading | Simple, accurate and easy to use |
| Lead to employee frustration | Lead to employee satisfaction |
| Neglected at the shopfloor | Frequently used at the shopfloor |
| Have a fixed format | Have no fixed format (depends on needs) |
| Do not vary between locations | Vary between locations |
| Do not change over time | Change over time as the need change |
| Intended for monitoring performance | Intended to improve performance |
| Not applicable for JIT, TQM, CIM, etc | Applicable to all |
| Hinders continuous improvement | Help in achieving continuous improvement |

As Ghalayini and Noble (1996) have noted, "It is important to realize that when a company is making a profit it does not necessarily imply that its operations, management and control systems are efficient." Globerson (1985) argues in Ghalayini and Noble (1996) that profit and rate of return are not indicators of organizational success because such indicators do not help to identify specific areas for improvement. Therefore, financial measures alone frequently mislead organizational decision makers to observe with satisfaction the key performance measures essential to achieving company success.

Wang Laboratories developed the SMART model, which consists of an integrated performance measurement system designed to sustain company success (Cross & Lynch, 1988, 1989; Lynch & Cross, 1991). The SMART system is characterized by a four-level performance pyramid, represented by the vision of the organization within the top or highest level of the pyramid followed by the business units level (or second level), which consists of market measures and financial measures. The third level represents the business operating units.  It is characterized by customer satisfaction, flexibility, and productivity, while the fourth level represents departments and work centers, which have implications for quality, delivery, process time, and cost.

The advantage of the strategic measurement analysis and reporting technique (SMART) system is that it attempts to integrate corporate objectives with operational performance indicators, creating a feedback loop between the strategic level and the operational level.  However, this system does not provide any mechanism to identify critical performance measures and metrics for the components described, and it ignores key performance measures related with human capital.

In the 1980's, Dixon developed a performance measurement questionnaire in order to assist managers to identify the organizational improvement needs and to establish an agenda for improvements in performance measure. Dixon's approach and questionnaire help identify the improvement areas of a company and the associated performance measures; furthermore, Dixon evaluates if the existing measurement system supports the improvement efforts.  However, this approach has been designed in order to identify inconsistencies between the current organizational performance measures and company strategy, but fails to indicate how the measures should be selected.

In the 1990s, two economists from Harvard Business School revolutionized the management world with the Balance Scorecard (BSC; Kaplan and Norton, 1992).  These economists identified the necessity of a broader list of performance measures aligned with the business vision, which would lead to breakthrough performance improvements. The dashboard or balanced scorecard is evaluated using financial and non-financial measurements, composed of four major categories: financial, customer, internal, and learning/growth. Also of great assistance was Kaplan and Norton's book *The Balanced Scorecard: Translating Strategy into Action*, which helped many international firms translate their strategy goals into performance measures (Kaplan & Norton, 1996). Kaplan and Norton's original idea was to develop a company success measurement tool; instead, they created a strategic goal measurement tool (Kaplan and Norton, 2003). This tool provides an approach to identify organizational performance measures based on a company's strategy, but it fails to provide a standard list of organizational performance measures and metrics essential to succeed in any manufacturing organization. Also, this technique depends heavily on the quality of the company leaders' vision (strategic level) to identify organizational performance measures; therefore, if company leaders have a narrow view or perspective, the organizational performance measures identified will not appropriately capture the overall performance and health of the organization.

Awards, such as the Malcolm Baldrige National Quality Award, which recognizes performance excellence within the quality field, have become widely used in benchmark analyses to continuously improve organizations. As an effort to improve the level of productivity and quality across U.S. organizations, President Reagan approved the Malcolm Baldrige National Quality Award in 1982 (Evans and Lindsay, 2002). The 2006 award criteria were designed to recognize business excellence based on seven categories: leadership, strategic planning, customer-market focus, information analysis, human resources focus, process management, and business results. These criteria encourage any type of organization to enhance a company's competitiveness, but they only focus on quality (Neely, et al., 2005).

The European Foundation for Quality Management (EFQM) developed a model to achieve organizational excellence as well, which was introduced as the European Quality Award criteria in 1992. The European Model for Business Excellence has become the most important quality excellence framework in Europe, just as the Malcolm Baldridge National Quality Award is in the United States. The EFQM Model of Excellence has been widely used by many European organizations as a self-assessment tool to enhance organizational performance, and it presents a logical interpretation by grouping a few areas as organizational "Enablers" (aim to pursue mission goals and objectives) and others as "Results" (real objective of the assessment). The EFQM model consists of nine criteria points: five are grouped as Enablers (Leadership-10%, People-9%, Policy and Strategy-8%, Partnerships and Resources-9%, and Process-14%) and the other four are grouped as Results (People Results-9%, Customer Results-20%, Society Results-6%, and Key Performance Results-15%). This model provides great criteria to achieve quality excellence through a feedback mechanism between enablers and results, but it fails to provide an approach to achieve company success based on organizational performance measures (Truccolo, 2005; Neely, et al., 2005).

Sink (1985) and Sink and Tuttle (1989) characterized an overall company success model and approach in terms of performance measures. The model identifies the complex interrelationships that exist among seven organizational performance areas: effectiveness, efficiency, quality, productivity, quality of work life, innovation, and profitability. Sink and Tuttle (1989) defined the seven performance areas as follows:

1. *Effectiveness* is the ratio of the actual output over the expected output, or the capability to accomplish things right the first time. Some of the attributes commonly used to measure effectiveness are timeliness, quality, quantity, and price/cost.

2. *Efficiency* is the ratio of resources expected to be consumed over resources actually consumed. The same four attributes of timeliness, quality, quantity, and cost/price are often used to refine the measurement of efficiency.

3. *Quality* is a wide concept that is measured using the following five checkpoints: a) the selection and management of upstream provider systems, b) quality assurance, c) in-process quality management, d) outgoing quality assurance, and e) proactive and reactive assurance that the organizational system is meeting or exceeding customer specifications.

4. *Productivity* is identified as the traditional ratio of output over input. Productivity has been perceived as having the strongest impact on performance, as well as giving insight into effectiveness, efficiency, and quality.

5. *Quality of work life* is the affective response of the people in the organizational system to any number of factors, such as their job, pay, benefits, working conditions, coworkers, supervisors, culture, autonomy, and skill variation. However, indicators such as turnover and absenteeism are often used as correlates of quality of work life.

6. *Innovation* is a key element in order to continuously improve or change whatever it takes to survive and grow; it also moderates the equation between

productivity and profitability. Poor results in this area may also mean failure for an organization in the long term.

7. *Profitability* represents the relationship between revenues and costs (profit-center organizations) or *budgetability* (cost-center organizations), which represents the relationship between what the organizational system established it would do in terms of cost and the actual cost (CBASSE, 1994; Bourque, 2006).

Sink and Tuttle examined the interrelationships among the seven performances criteria by focusing first on effectiveness, secondly on efficiency, and thirdly on quality. Rolstadas (1998) stated that if these three concepts are in place, the result is very likely to be a productive organization. Quality of work life and innovation are viewed as moderators within this approach; therefore, they can both increase and decrease performance. This organizational systems view approach supports the excellence of long-term outcomes, survival, and growth. Sink and Tuttle identified seven organizational performance components as criteria to develop an objectives matrix with goals based on multi-attribute decision theory. Figure 2 represents the relationship of between Kurstedt's management system framework and the Strategic Performance Improvement Planning Process identified by Sink (1990).

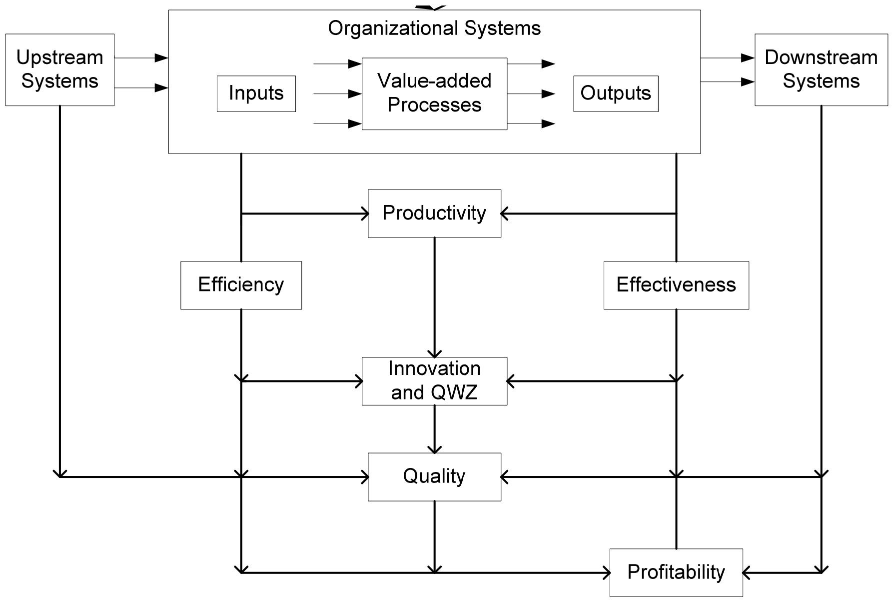



Figure 2 Input/out Analysis with Key Performance Criteria (Sink & Tuttle, 1989; Sink, 1985)

Bourque et al. (2006) considered the Sink and Tuttle approach to be a more comprehensive framework than the BSC, but Bourque et al. also identified that none of the identified models provide a mathematical framework for handling all the performance measures in an integrated manner. Therefore, Bourque et al. proposed a tool for multidimensional performance modeling for software engineering managers through the use of a genetic algorithm (Bourque et al., 2006). The possibility of pursuing a genetic algorithm or the application of neural networks was researched in the early stage of this study, but any of the described techniques requires a large data set, which many organizations do not have. Fuzzy set theory models do not require a large amount of data, leading to a more feasible approach for many manufacturing organizations.

In addition, the Engineering and Physical Sciences Research Council (EPSRC) funded the Integrated Performance Measurement Systems (IPMS) research program. The IPMS was built upon the balanced scorecard and EFQM models using the viable systems structure and resulted in the development of the integrated performance measurement systems reference model (Bititci et al. 2005).

Based on the extended research performed, the organizational performance measurement methods, tools, and techniques evaluated within this research have the following limitations:

- Existing tools are constructed for monitoring and controlling (Bititci et al., 2005).
- Current approaches do not provide a list of key performance measures and metrics.
- Static systems proliferation.
- Existing models do not predict, achieve, or improve future performance.
- Organizational performance frameworks proposed do not provide mathematical models to simultaneously analyze key performance measures.
- Current systems do not stress the importance of time as an organizational performance measure (Bititci et al., 2005).
- No model provides a systematic approach to continuously evaluate key performance measures and identify new ones (Bititci et al., 2005).
- Existing measurement tools require large amount of data.
- Current techniques identify the importance of qualitative data, but do not provide an approach to quantify it.

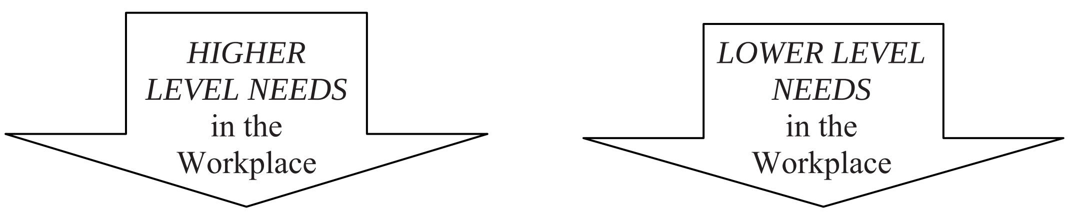
- Existing techniques do not provide a standard list of organizational performance measures for manufacturing industries.
- Existing measurement systems do no review companies' measures that might be in place (Medori and Steeple, 2000).
- Common measures take long time to implement (Noci, 1995 in Gomes et. al, 2004).
- Effective organizational measurement systems must be consistent and definitions should be provided for the performance criteria (CBASSE, 1994).
- Measurement units/metrics must be clearly defined in order to succeed (CBASSE, 1994).

In conclusion, Fuzzy Set Theory has never been used to model organizational performance measures essential to achieve company success considering the components identified in this research: profit, productivity, efficiency, quality, employee morale, ergonomics, and safety.

## 2.2 Employee Morale

Fredrick Herzberg discovered that motivation, as it pertains to improved job performance, was directly related to the upper-two levels of Maslow's hierarchy, esteem and self-actualization needs. Herzberg stated that, in the workplace, esteem and self-actualization are satisfied by the nature of the work itself and the drive to satisfy these needs results in more mature and productive behaviors. Herzberg called these upper-level needs "motivators," and individuals interested in obtaining these needs come into an organization having their lower-level needs met and expecting challenges and opportunity from their work. Sometimes, individuals have a high tolerance for poorer "hygiene factors" such as basic security and social needs if the "motivators" such as esteem and self-actualization needs are present. Herzberg called "maintenance seekers" employees who are particularly preoccupied with "hygiene factors." "Maintenance seekers" are people who may have been denied satisfaction of lower-level needs in the past and have spent most of their lives struggling to have those needs met. Sometimes, "maintenance seekers" are happy to have a good paying job and safe amenable working conditions and do not have a strong drive to stand out or be given higher responsibilities.

Table 2 Herzberg's Theory




| **Motivators**<br>(Esteem & Self Actualization needs)<br>Related to the work itself | **Hygiene Factors**<br>(Basic, Security, & Social needs)<br>Peripheral to the work itself |
|---|---|
| Achievement | Policies and administration |
| Recognition for accomplishment | Supervision |
| Challenging Work | Working conditions |
| Increased Responsibility | Interpersonal relations |
| Growth and Development | Money, security, benefits |

Another research study identified stock gains to be four times higher for "100 Best Companies to Work For." A study by the Great Place to Work Institute finds companies on its "Best Companies to Work For" list to produce four times the gains when compared to two other indexes of the broad market. The Institute's president, Amy

Lyman, states that a strong link between a company's culture and its financial performance exists and that employees' trust is a critical competitive advantage: "Trust contributes to higher levels of cooperation, commitment, lower turnover, less use of sick time, and better customer support" (quoted in Frängsmyr Ed., 2004).

Considering the inevitable situation of dealing with complex systems, which delivers qualitative data, a "cost/benefit" approach, such as contingent valuation, is proposed to quantify the qualitative employee morale measures. This technique allows employees to express how much they are willing to sacrifice out of their paychecks to help their employer provide incentives. In a research study performed by Connelly (2005), employees (even with no children) were willing to take up to $225 a year out of their paychecks to help their employer provide childcare at work. Companies with childcare centers were saving between one-half and twice the cost of the centers, without considering indirect improvements such as reduced turnover, higher productivity, goodwill, lower absenteeism, and improved company image (Alberini, 1995; Evans & Lindsay, 2002).

Contingent valuation, as just described, refers to the method of valuation mainly used in cost/benefit analysis within environmental accounting. The valuation method involves presenting hypothetical situations to a representative sample of the relevant population in order to elicit information about how much they would be willing to pay for specific benefits. The Contingent Valuation technique was applied within this research as a prioritization tool for organizational decision makers using the employee morale model.

# CHAPTER THREE: METHODOLOGY

## 3.0 Research Objectives

To characterize company success within a manufacturing organization, it is imperative to identify performance measures for profit, productivity, efficiency, quality, employee morale, and ergonomics and safety. The goal of this research is to determine how the combined effects of performance measures from profit, productivity, efficiency, quality, employee morale, and ergonomics and safety components affect overall organizational success in manufacturing applications. Specifically, this research has generated reliable models (quality, employee morale, and ergonomics and safety) in order to help organizational managers and leaders make wiser decisions in complex situations. In addition, a company success index model has been developed to assess and predict organizational performance in manufacturing organizations.

Lastly, this research effort provides tools, methods, and techniques to measure and assess organizational performance measures in manufacturing organizations. As a result, organizational decision makers would be better equipped to make complex decisions and improve manufacturing results. This research generates a reliable company success index model ready to be benchmarked by other manufacturing organizations.

## 3.1 Research Objectives, Scope and Approach

Although company success has been financially characterized before, a reliable organizational performance methodology providing a systematic measurement approach based on the company success components identified within this research (profit, productivity, efficiency, quality, employee morale, safety, and ergonomics) has never been developed. Furthermore, quality, employee morale, and safety and ergonomics has never been holistically and quantitatively characterized nor integrated within a company success performance measure index model.

Organizational decision makers are constantly forced to use qualitative data or non-financial measures, such as customer satisfaction, and employees' motivation; however, these types of measures increase the complexity of data analysis (Garengo, 2005).

A company success index model has been developed using data from two manufacturing plants of different subsidiaries within the same organization. This research has identified a methodology or approach to develop the company success index model by accomplishing the steps shown in Figure 3. The flowchart represents the research approach.

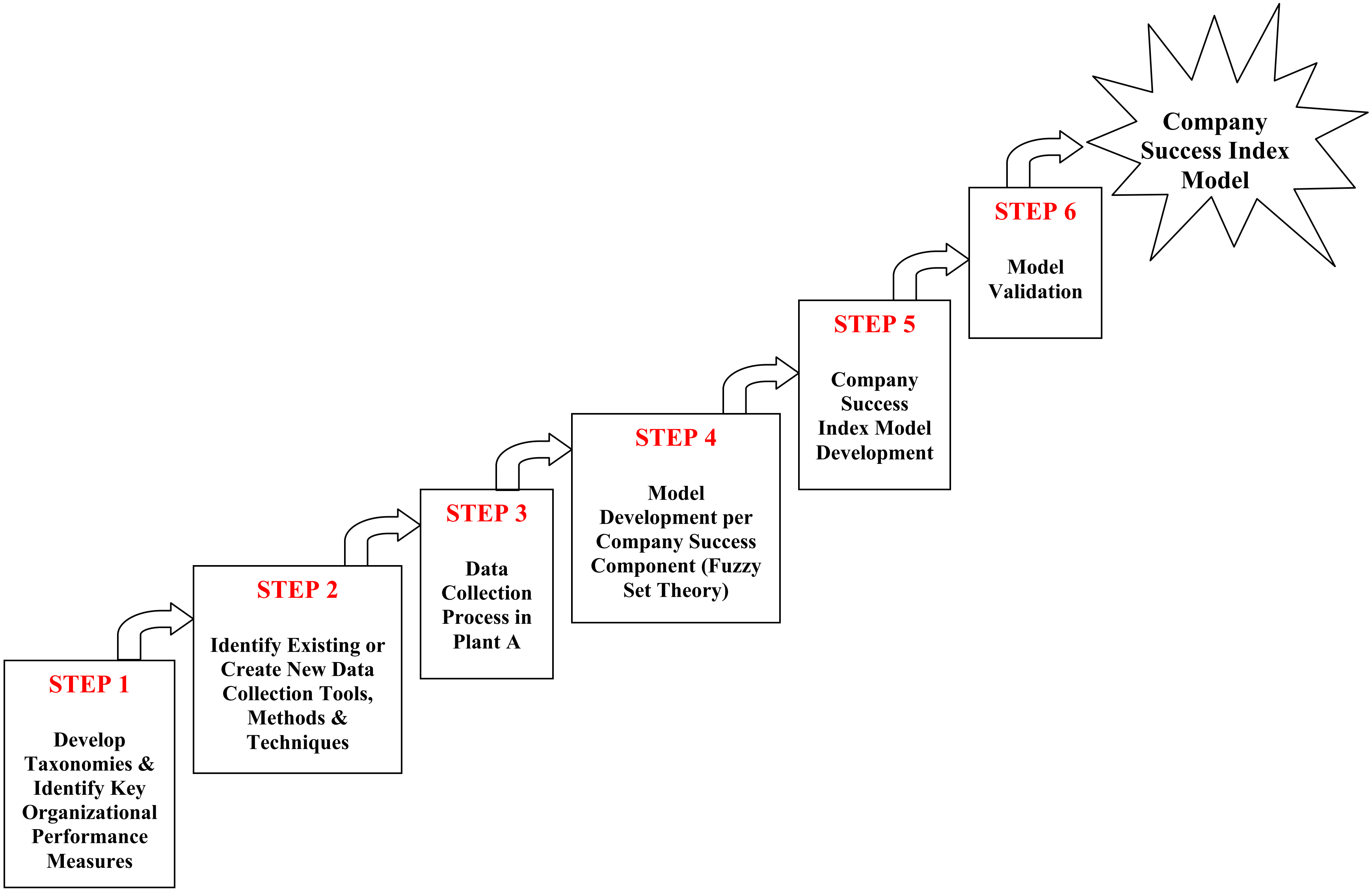



Figure 3 Organizational Performance Measures Methodology

### 3.2 Taxonomies Development/Key Organizational Performance Measures - Step 1

This section describes the research performed in Step 1, which develops taxonomies for all the company success components (profit, productivity, efficiency, quality, employee morale, and ergonomics and safety). The taxonomies developed characterize components, subcomponents, and factor variables affecting organizational success in the manufacturing industry. In addition, key organizational performance measures or metrics have been identified using various techniques, such as a literature review and subject matter experts.

The purpose of developing taxonomies is to simplify and assist the characterization process when a complex problem needs to be solved. The taxonomy structure follows a configuration which facilitates the process of breaking a complex characterization problem into sub-components, leading to a simplistic way to identify the key performance measures affecting company success.

To organizationally characterize the significant components, as well as the associated subcomponents, factor variables, and key performance measures, an extended literature review has been performed and validated by subject matter experts. In addition, a series of existing and new tools, methods, and techniques have been selected or developed within the next section in order to help evaluate the identified key performance measures for company success. Figure 4 illustrates the company success taxonomy, which entails the overall research goal, components, and subcomponents identified within this study.

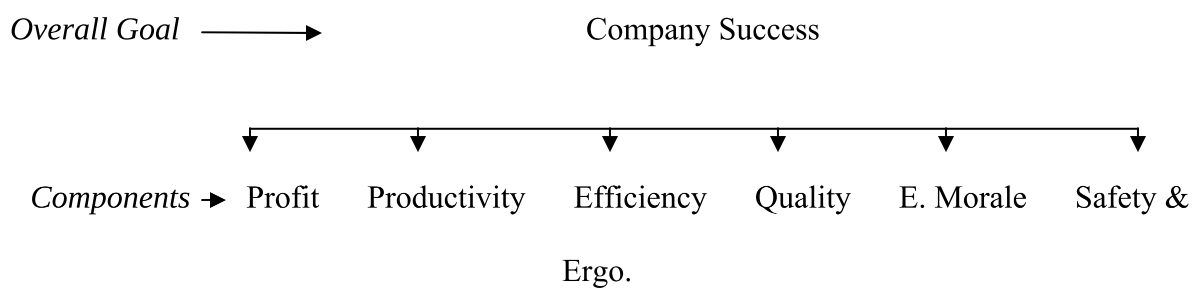



Figure 4 Company Success Taxonomy

Figure 5 shows the profit taxonomy developed, and the subcomponents "revenue" and "expenses," as well as the key performance measures.

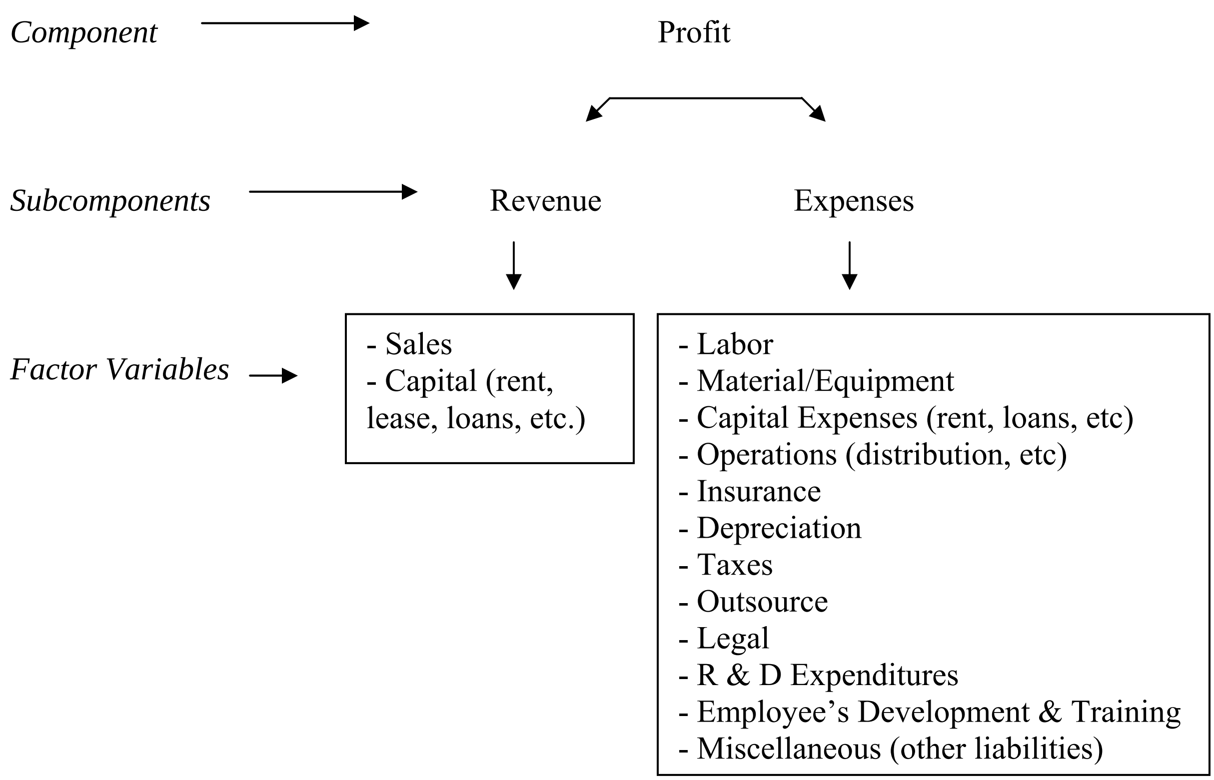



Figure 5 Profit categorization structure

Figure 6 shows the efficiency taxonomy developed, and the subcomponents "resource" and "waste," as well as the key performance measures.

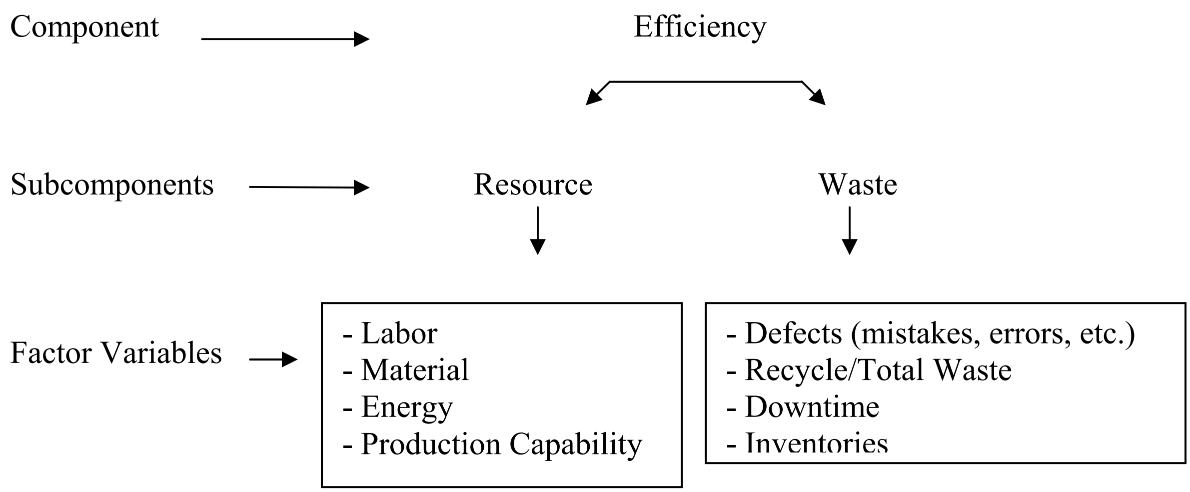



Figure 6 Efficiency categorization structure

Figure 7 shows the quality taxonomy developed, and the subcomponents "customer satisfaction/loyalty" and "quality management/control," as well as the key performance measures essential to achieve organizational success.

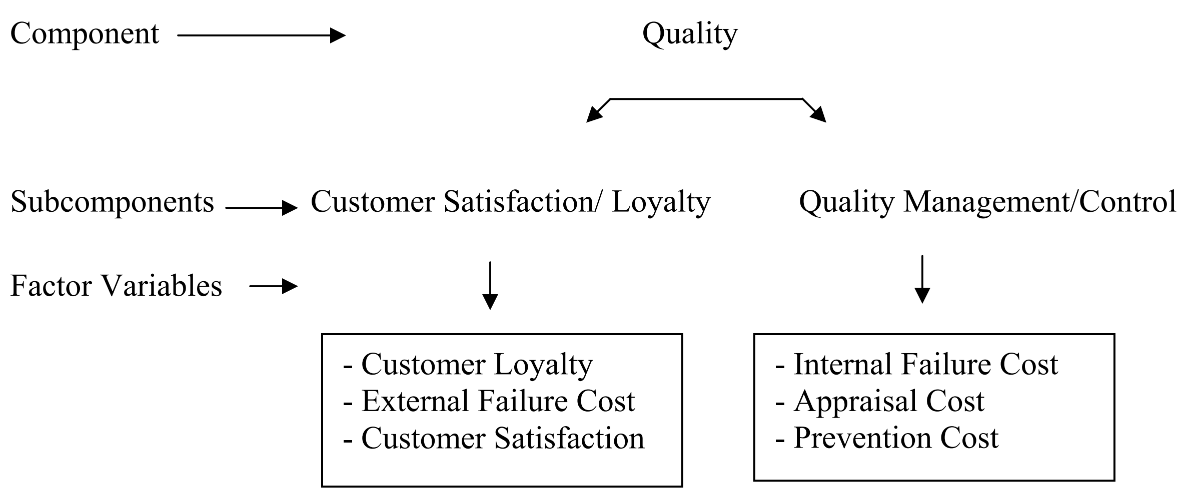



Figure 7 Quality categorization structure

Figure 8 shows the ergonomics and safety taxonomy developed, and the subcomponent "ergonomics and safety control," as well as the key performance measures essential for a successful ergonomics and safety program.

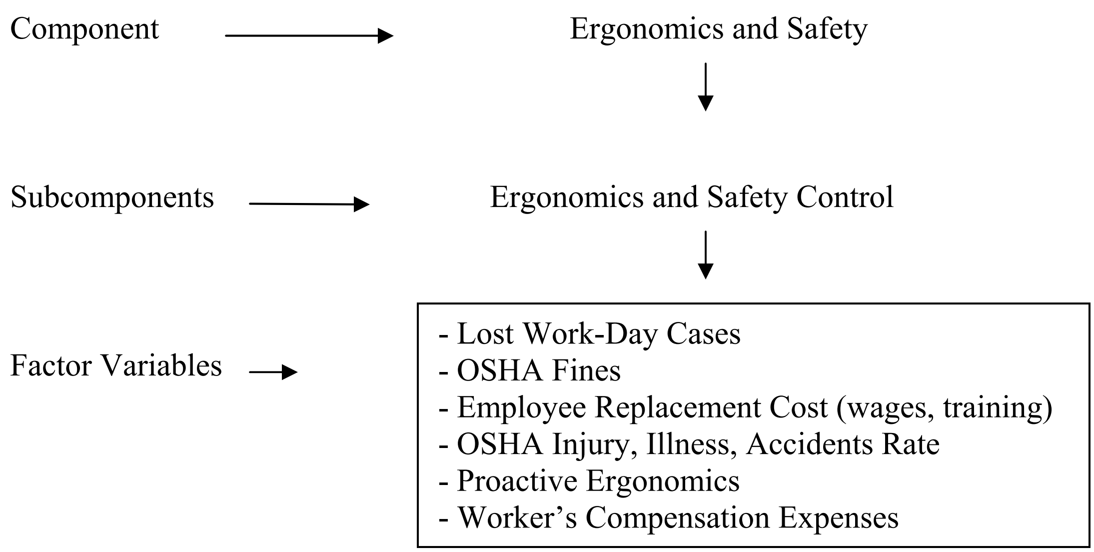



Figure 8 Ergonomics and Safety categorization structure

Figure 9 shows the productivity taxonomy developed, and the subcomponents "output" and "input," as well as the key performance measures.

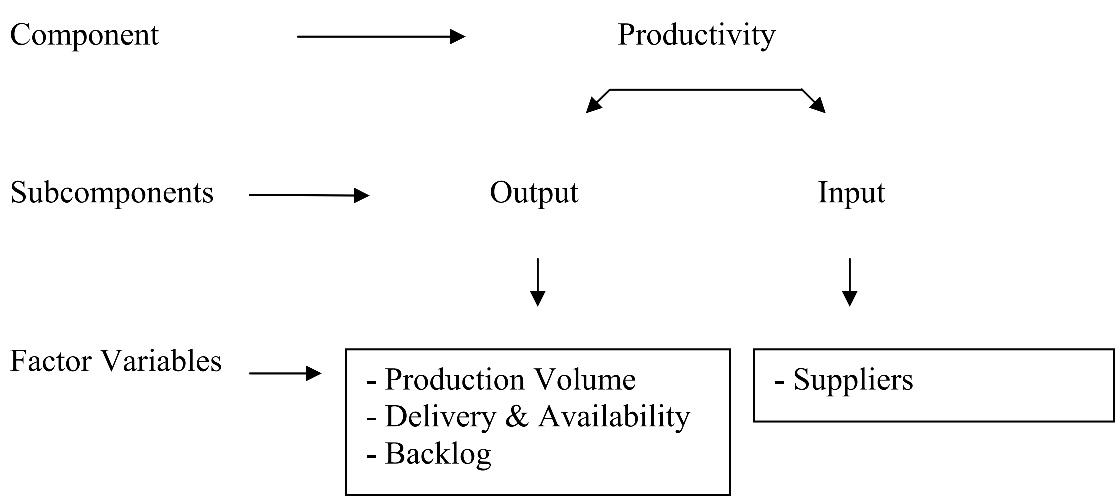



Figure 9 Productivity categorization structure

Figure 10 shows the employee morale taxonomy developed, and the subcomponents "employee engagement" and "work environment," as well as the key performance measures essential to obtain a high employee morale organization.

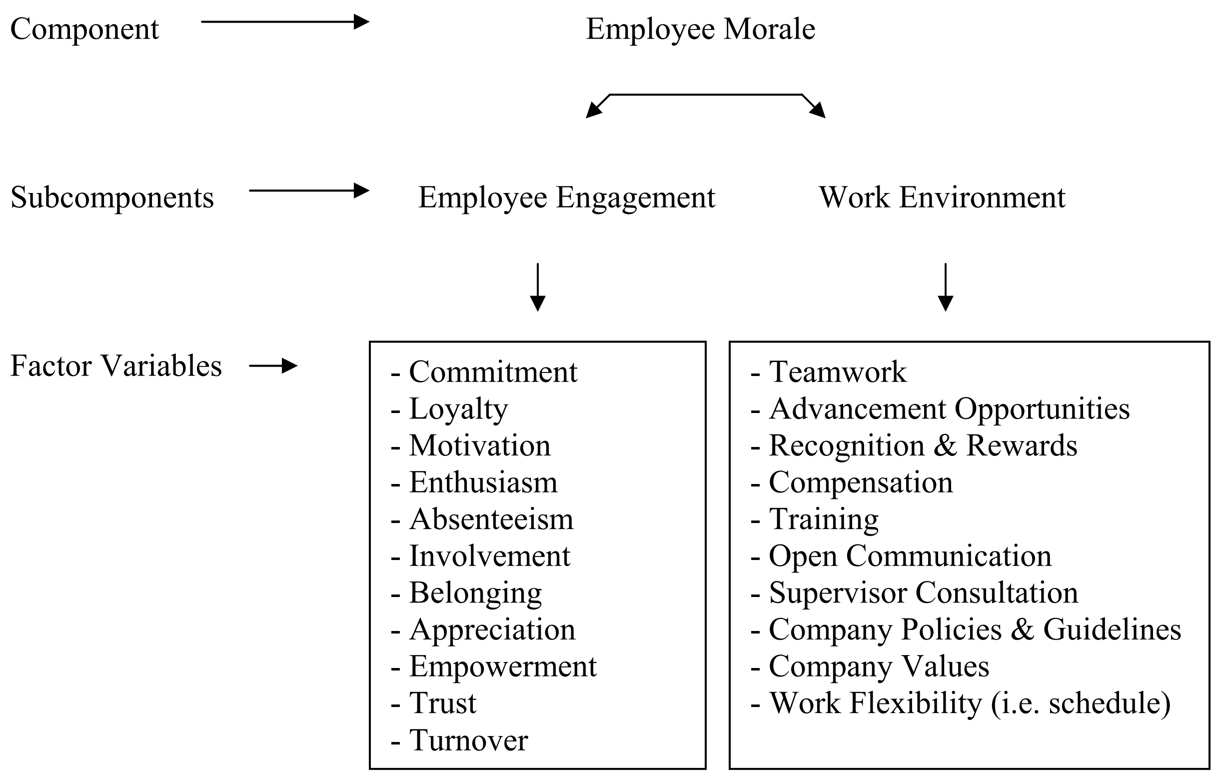



Figure 10 Employee Morale categorization structure

A taxonomy characterization has been developed for every component of the company success framework, which included organizational success subcomponents and factors variables identified after performing an extended literature review on key performance measures in manufacturing organizations. Moreover, three subject matter experts (academician, industry expert, and academician with an extensive industry background) have helped validate the taxonomies developed within this research. Table 3 represents company success characterization, including components, subcomponents, factor variables, and metrics to be used for data collection in the next research step.

Table 3 Company Success Performance Measures/Metrics/Indicators

| *Component* | *Definition* | *Subcomponents* | *Factor Variables* | *Indicators or Metrics* |
|---|---|---|---|---|
| **Profit** | (Revenues) - (Expenses) | Revenue | Sales | Net Sales (operating income) |
| | | | Capital (rent, lease, loans, etc) | Net Worth (non-operating income) |
| | | Expenses | Labor | Wages |
| | | | Material/Equipment | Material Cost |
| | | | Capital expenses (rent, lease, loans, corporate debt, etc) | Capital Cost |
| | | | Operations (distribution, etc) | Operations Cost |
| | | | Insurance | Insurance Premiums |
| | | | Depreciation | % of Depreciation |
| | | | Taxes | Tax (federal, state) |
| | | | Outsource | Outsourcing Cost |
| | | | Legal | Legal Fees |
| | | | R & D Expenditures | R & D, Patent, and Royalties Expenses |
| | | | Employee's Development/Training | Training Cost |
| | | | Miscellaneous (other liabilities) | Miscellaneous Cost |
| **Ergonomics & Safety** | (Human Capabilities) – (Job Requirements) | Ergonomics/ Safety Control | Lost Work-Day Cases | Lost Work-Day Wages Cases |
| | | | Employee Replacement Cost (wages and trainings) | Employee Replacement Cost |
| | | | OSHA Fines | OSHA Fines |
| | | | OSHA Injury & Illness Rate | OSHA Illnesses and Injury Rates |
| | | | Proactive Ergonomics | Cost of Proactive Ergonomics Initiatives |
| | | | Worker's Compensation Expenses | Worker’s Comp. Cost |

| ***Component*** | ***Definition*** | ***Subcomponents*** | ***Factor Variables*** | ***Indicators or Metrics*** |
|---|---|---|---|---|
| **Efficiency** | (Resources Expected Consumed)/ (Resources Actually Consumed) | Resource (direct cost) | Labor | (Expected Labor Cost / Actual Labor Cost) |
| | | | Material | (Expected Material Cost / Actual Material Cost) |
| | | | Energy | (Expected Energy Cost / Actual Energy Cost) |
| | | | Production Capability | Maximum Manpower x (Prod. Volume/Employee) |
| | | Waste (direct cost) | Defects (mistakes, errors, etc) | Defects Cost |
| | | | Recycle/Total Waste | Recycle Recovery/Total Cost |
| | | | Downtime | % of Downtime |
| | | | Inventories | % of Inventory Turnover |
| **Quality** | Quality Perception = (Actual Quality) - (Expected Quality) | Customer Satisfaction/Loyalty | Customer Loyalty | % Repeated Business (Customer buying pattern) |
| | | | External Failure Cost | Customer Complaints and Returns, Product Recall Cost and Warranty Claims, and Product Liability Cost |
| | | | Customer Satisfaction | % Customer Satisfaction |
| | | Quality Management/ Control | Internal Failure Cost | Scrap & Rework Cost, Cost of Corrective Action, Downgrading Cost, and Process Failures |
| | | | Appraisal Cost | Test and Inspection Cost, Instrument Maintenance Cost, Process Measurement, and Control Cost |
| | | | Prevention Cost | Quality Planning Cost, Process Control Costs, Information Systems Costs, Training and General Management Cost |

| ***Component*** | ***Definition*** | ***Subcomponents*** | ***Factor Variables*** | ***Indicators or Metrics*** |
|---|---|---|---|---|
| **Productivity** | (Output) / (Input) | Output | Production Volume | Amount of Units Produced |
| | | | Delivery & Availability | % of On-Time Delivery |
| | | | Backlog | % of Production Orders not Met |
| | | Input | Suppliers | % of on-Time Material Arrival |
| **Employee Morale** | (Actual Employee Satisfaction) – (Expected Employee Satisfaction) | Employee Engagement | Commitment | 1-4 Employee Morale Scale |
| | | | Loyalty | 1-4 Employee Morale Scale |
| | | | Motivation | 1-4 Employee Morale Scale |
| | | | Enthusiasm | 1-4 Employee Morale Scale |
| | | | Absenteeism | Absenteeism rate |
| | | | Involving | 1-4 Employee Morale Scale |
| | | | Belonging | 1-4 Employee Morale Scale |
| | | | Appreciation | 1-4 Employee Morale Scale |
| | | | Empowerment | 1-4 Employee Morale Scale |
| | | | Trust | 1-4 Employee Morale Scale |
| | | | Turnover | Turnover rate |
| | | Work Environment | Teamwork | 1-4 Employee Morale Scale |
| | | | Advancement Opportunities /Promotions | 1-4 Employee Morale Scale |
| | | | Recognition & Rewards | 1-4 Employee Morale Scale |
| | | | Compensation | 1-4 Employee Morale Scale |
| | | | Training | 1-4 Employee Morale Scale |
| | | | Open Communication (leave office door open) | 1-4 Employee Morale Scale |
| | | | Supervisor Consultation (advising, counseling, coaching, mentoring, and listening) | 1-4 Employee Morale Scale |
| | | | Company Policies & Guidelines | 1-4 Employee Morale Scale |
| | | | Company Values (observed on top management & leaders) | 1-4 Employee Morale Scale |
| | | | Work Flexibility (schedule, etc) | 1-4 Employee Morale Scale |

### 3.3 Identify Data Collection Tools, Methods, and Techniques – Step 2

The purpose of this research step is to identify the existing tools, methods, and techniques that an organizational leader frequently uses, which could facilitate the organizational performance measures data collection process. As a result, an organizational leader questionnaire was developed in order to identify decision making challenges frequently encountered at the organizational level. One of the main challenges is the fact that organizational leaders develop the company's strategy or vision, which is shared with the other company levels, such as tactical and operational. However, performance measure systems studied fail to identify and link the organizational performance measures with the other organizational levels (feedback loop). The organizational leader questionnaire was developed initially to identify the organizational decision making challenges, to improve current performance measures system, and to enhance the success of the organization (Appendix A).

In order to identify measurement tools already in use in Plant A, the plant manager questionnaire has been developed and sent along with Table 3 to the plant manager or operations manager. This research step was critical in identifying the key performance measures currently used and the tools utilized to collect the historical data. The plant manager questionnaire developed is included in Appendix B. This questionnaire has played a critical part in the research approach by identifying the data collection tools, methods, and techniques currently utilized within the evaluated organization. In addition, this questionnaire has helped identify historical data in order to simplify the data collection process and to assure the success of the next research step (Step 3 - Data Collection in Plant A). This research step has helped to successfully plan the data collection process and has anticipated potential problems, such as key performance measures, which has never being measured. The plant's manager feedback (Plant A) has been analyzed and summarized to appropriately measure company success components, such as profit, productivity, efficiency, quality, employee morale, ergonomics and safety. The following paragraphs provide an overview of current approaches used within Plant A to characterize and measure the research components identified within this document.

Profit component data was obtained mainly from financial and accounting reports. In addition, tax, legal, and R & D reports provided data for factor variables, such as taxes, legal fees, and R & D expenses. Plant A had traditionally measured this component in terms of gross percentage (before corporate overhead), and in terms of performance to plant's flex budget because Plant A was managed as a cost center (based on a budget). All the historical data for profit was measured in US dollars/year; this component was traditionally measured by comparing performance to the flex budget for the site (a measure of budgetability). Currently, the headquarters of this subsidiary forecasts an annual sales figure, which generates an allocated annual budget for every plant, leading the plant manager to meet the allocated budget and to avoid exceeding it. Operational managers of cost centers had a clear annual operational profit goal to achieve: avoid exceeding the allocated budget, which lead to a limited organizational view, especially if the number of orders was constantly exceeding the headquarters subsidiary's prevision.

Productivity was measured by comparing the actual hours worked (including all indirect labor, such as quality technicians, cycle counters, etc.) to the hours earned (theoretical amount of time it should take) for each unit produced. Tools such as production, delivery, and suppliers' reports were frequently used to collect productivity performance measures identified within this study. Since the production time in Plant A products varied to a large extent (some products only take 3-4 hours, while others take 60 or more hours), the productivity standard was actual hours worked compared to hours earned. Furthermore, Plant A had historical records of production volumes for each product and production line. Inventory was measured by tracking cycle count adjustments, conducting annual full physical inventories, and through the tracking of inventory turns. Plant A had data on how many hours (whether direct or indirect) were worked in each area (departmental/value stream level) of the plant. In addition, the site suppliers were tracked through the subsidiary headquarters, which included on-time delivery performance measures.

The efficiency component was measured similar to how productivity was measured in Plant A, but only compared the direct hours worked on each unit with the hours earned, excluding the indirect labor. The efficiency component looked into the amount of resources used to produce each unit; the lower the amount of resources used and the higher amount of units produced, the better the efficiency level. Budget, accounting, quality, and production reports were the key documents to identify historical data within this component.

The ergonomics and safety program in Plant A had several types of reports such, as the OSHA compliance reports, as well as insurance carrier reports showing worker's compensation expenses. Historical data was successfully identified for the ergonomics and safety component; however, several key performance measures had not been traditionally measured or fully documented, such as proactive ergonomics activities.

The quality component was measured using tools such as calibration and maintenance reports, continuous improvement projects, customer satisfaction surveys and warranty claims reports. Even though this plant had never measured and documented some of the critical performance measures, such as rework percentage or incoming material inspection, some historical data was found for the majority of the organizational performance measures identified within the quality component.

The majority of the employee morale key performance measures had never been measured in Plant A, with the exception of turnover and absenteeism rate. Therefore, since no existing tool was found in the literature review, a new tool was developed to measure the level of employee morale. The survey developed can not only identify the level of employee morale (Appendix C) within the employees, but also the employee's willingness to pay (WTP) or invest on a specific factor improvement. The contingent valuation technique uses the WTP concept to assign a value to an intangible or qualitative key performance measure. This is a sophisticated cost/benefit measurement approach, which puts a financial value on intangible costs and benefits, such as employee motivation. The described survey was designed to measure the level of employee morale in Plant A and B, as well as to identify the employee morale factor variables for which workers will be willing to pay in order to observe an improvement. The WTP concept was used as a prioritization tool for H.R decision makers to identify the most appropriate employee morale factor variables in which to invest their resources.

The number of participants required to take the employee morale survey was calculated by evaluating the power level of the experiment, which was obtained by the sample size *n*, the significance level α, and the size or magnitude of the treatment effects. Considering that 95% confidence interval is commonly used to develop new experiments, the power level was selected depending on the effect size. The power level represents the chance to duplicate the findings obtained on the experiment; therefore, a low power represents a low probability of producing significant results. The power level selected is .80 at α of .05, and effect size of 0.15 requires a sample size of 17 (Keppel, 1994).

Table 4 Table to identify Sample Size Based on Power Level (Keppel, 1994)

| **EFFECT SIZE** | **POWER LEVEL** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **0.10** | **0.20** | **0.30** | **0.40** | **0.50** | **0.60** | **0.70** | **0.80** | **0.90** |
| **α = .05** | | | | | | | | | |
| 0.01 | 21 | 53 | 83 | 113 | 144 | 179 | 219 | 271 | 354 |
| 0.06 | 5 | 10 | 14 | 19 | 24 | 30 | 36 | 44 | 57 |
| 0.15 | 3 | 5 | 6 | 8 | 10 | 12 | 14 | 17 | 22 |

Therefore, eighteen employee morale survey participants were collected to evaluate the employee morale level at Plant A.

### 3.4 Data Collection – Step 3

The first site (Plant A) from Subsidiary 1 is a cost center consisting of 250 full-time employees, which supports two shifts and a small third shift. The industry standard is used to develop the quantifiable company success model, and data from Plant A and B are used to validate the developed models. A glossary of terms was developed in order to avoid any misunderstanding of the key performance measures and metrics identified, as well as to enhance the success and accuracy of the data collection process. Data collection sheets were developed to facilitate the data collection process within the manufacturing plants (Appendix D).

### 3.5 Model Development per Company Success Component Using Fuzzy Set Theory – Step 4

Fuzzy Set Theory (FST) is a modeling technique frequently used where vague concepts and imprecise data are handled, and it is capable of managing both imprecision and uncertainty data (Bonisson, 1980). FST has been used for the development of the linguistic approach where any variable is treated as a linguistic variable (i.e. Low, Medium, and High). Linguistic values are created of a syntactic label, a sentence belonging to a term set, and its semantic value. In addition, FST can be used to translate linguistic terms into numeric values to be used to get aggregate measures when given several inputs. FST characterizes the concept of approximation based on membership functions with a range between 0 and 1, which provides the lower and upper approximations of a concept (Yao, Y.Y & Wong, S. K. M, 1992). Zimmerman identifies the necessity to use mathematical language to map several membership functions and generate FST models.

However, the use of mathematical modeling techniques brings some limitations or challenges. Real situations are not often deterministic or precise, and the description of a real system often requires more detailed data than a human being could ever recognize simultaneously (Schwartz, 1962; and Zimmermann, 1991).

FST provides a good starting point in the development of a conceptual framework and proves to be more useful in the field of pattern classification (Zadeh, 1965).
In addition, FST provides a framework for dealing with problems in the absence of sharply defined criteria of class membership rather the in the presence or absence of variables. FST provides a rigorous mathematical framework in which vague data can be precisely studied (Zimmermann, 1991).

Probability theory has been traditionally used for describing the phenomenon of uncertainty; it deals with the expectation of future events based on something known. However, the uncertainty represented by fuzziness is not the expectation of uncertainty; rather it is the uncertainty resulting from the imprecision of a concept expressed by a linguistic term. Probability is the theory of random events and the likelihood of events (Klir, G. J et al., 1997).

Traditional modeling techniques tend to eliminate or explain uncertainty by excluding factor variables which cannot be explained; this tendency leads to inaccurate models caused by lost data. FST focuses on the possibility rather than a probability of predicting imprecise and uncontrollable data. As a result, it is proposed for a company success index to be developed, which would lead organizational managers and leaders to a more clear understanding and evaluation of company success. In order to develop the company success index, FST was selected as the most feasible technique to quantify company success. Furthermore, linguistic approaches have been previously applied and developed for use in FST, allowing factor variables to be represented as numerical values. One of the most important advantages of using this technique is the opportunity to create a scale to measure company success. A small amount of data was obtained to perform this research; other techniques were investigated and eliminated as feasible options, such as factor analysis, neural networks, principal component analysis, genetic algorithms, regression analysis, etc.

The literature review identified the necessity to develop a mathematical model to evaluate quality, employee morale, and safety/ergonomics within the manufacturing application. The necessity to develop a holistic model (for the described components) capable of evaluating a large number of key performance measures essential for the success of a manufacturing has been identified. Therefore, a series of tools, methods, and techniques capable of assisting with the development of mathematical models has been identified. The following sections cover in detail the proposed approach to solve this challenging mathematical modeling problem (qualitative and quantitative data).

These are some of the disadvantages identified with qualitative methods, such as FST:

1) Results can be misinterpreted because of the subjective biases of people performing the data analyses.
2) Lack of generality of the experience of the few to the experiences of the many.
3) Costly.
4) Perceived as being easy to do.
5) Subjective results.
6) Results may not be replicable.

### 3.5.1 Analytical Hierarchy Process (AHP)

Hierarchical classifications can help show relationships among categories; this research has created a hierarchical category system where taxonomies were developed by organizing data into different levels. In order to evaluate the feasibility of the categories and ratings, subject matter experts were asked to review the relative weights obtained through AHP. Pair-wise comparisons are frequently used to determine the relative importance of each factor variable. Comparisons are made within modules to determine the relationship between the factors identified by the experts. Saaty (1990) developed a rating scale which could be utilized for comparisons where each pair wise comparison is rated on a scale from 1 to 9 . In an AHP analysis, the rating is used to define the degree of preference of one variable over another. The value 1 represents equal importance of the two variables, X and Y, and the value 9 suggests X is more important than Y. The inverse of the values is used if the expert considers that an inverse relationship exists among the variables. Once the pair-wise matrix is developed, the relative weights are obtained from the estimate of the maximum eigenvector of the matrix. The normalized average weighting indicates the relative significance of each factor.

The AHP approach, which consists of a series of goals, criteria, and alternatives, simplifies a complex problem into simple pair-wise comparisons.
AHP is very useful in complex decision-making, and plenty of software have been developed which assists with the development of AHP, such as Expert Choice.
Pair-wise comparison is a problem-solving method that allows the user to determine the relative order or ranking of a group of items resulting in a specific point value. There is a

great variety of software capable of solving AHP, and Expert Choice was selected for this research. The following ratings were used to develop the forms to be sent to all the SME.

1 = x-variable is Equally Important as y-variable

3 = x-variable is Slightly More Important than y-variable

-3 = x-variable is Slightly Less Important than y-variable

5 = x-variable is More Important than y-variable

-5 = x-variable is Less Important than y-variable

7 = x-variable is Highly More Important than y-variable

-7 = x-variable is Highly Less Important than y-variable

9 = x-variable is Extremely More Important than y-variable

-9 = x-variable is Extremely Less Important than y-variable

A pair-wise comparison example was included within the form to assist SMEs (subject matter experts) with the pair-wise comparison process and avoid any misunderstanding. Given the scenario that profit and productivity are to be compared, if the subject matter expert considers profit slightly more important than productivity, then the expert should assign 3 to this scenario as shown in Table 5.

Table 5 SME Sample Form

| **Company Success** **Y-Axis** / **X-Axis** | Profit | Productivity |
|---|---|---|
| Profit | 1 | 3 |
| Productivity | X | 1 |

### *3.5.1.1 Weights*

As discussed in the previous section, a group of SMEs identified the relative importance of company success components and factor variables. This process was performed by comparing each pair of variables or components and ranking them using the following scale: (1, +/-3, +/-5, +/-7, and +/-9). An AHP form was created and distributed to all the SMEs, and it is included within Appendix F.

### *3.5.1.2 Inconsistency Ratio*

The inconsistency ratio is used to evaluate the SMEs' ability to make consistent judgments. Basically, this ratio identifies if the SMEs are coherent or forget prior assessments across the exercise. The presence of inconsistency indicates that a SME is not paying attention or that he or she does not understand the assessment tool. Inconsistency ratios smaller than 0.1 reflect a coherent SME; ratios greater than 0.1 represent a concern (Hallowell, 2007). A series of pair-wise ratio-based comparisons were performed to evaluate SMEs' understanding of company success. This ratio was calculated by evaluating if the whole set of pair-wise comparisons was stacking up in a self-consistent way.

#### *3.5.2.1 Subject Matter Experts (SME)*

SMEs can be used to determine the relative weights of factor variables and assist in the development of FST models. There are different ways to develop membership functions that include direct (experts giving answers to various kinds of questions) and indirect methods (ask experts more general and less biased questions; Klir, Yuan, 1995; Terano et al 1992). This approach is beneficial for multi-faceted and linguistic variables, and the use of SMEs can assist in the quantification of qualitative performance measures.

Furthermore, research performed by McCauley-Bell and Badiru used knowledge acquisition to obtain factor relevance (McCauley-Bell et al., 1996). The scale to develop membership functions was developed using the described approach in this research.

#### *3.5.2.2 Literature Review*

The majority of the membership functions in this research were developed using this literature review approach. Therefore, the grade of membership was defined through the literature review and developed with graphical representation, which shows the degree of membership within the fuzzy set.

Gilb (1999) suggested following these enumerated steps to develop scales for qualitative data: 1) identify any established scales (perform extended literature review); 2) check system requirements to identify any scale; 3) ask yourself: what you are trying to alter and how you would measure success; and 4) in the case of dealing with complex variables, break the component into sub-concepts until a good level of detail has been achieved. This methodology was used in this research to develop a large number of membership functions.

### 3.5.2 Development of Membership Functions

Traditional modeling techniques tend to eliminate or explain uncertainty by excluding factor variables that cannot be explained, leading to inaccurate models caused by lost data. FST focuses on the possibility rather than a probability of predicting imprecise and uncontrollable data. Therefore, a company success index was developed, leading organizational managers and leaders towards a more clear understanding and evaluation of company success. In order to develop the organizational success index, FST was selected as the technique to identify the company success level. In addition, linguistic approaches were previously applied and developed for use in FST allowing factor variables to be used in terms that can be assigned a fuzzy numerical value. One of the most important advantages of using this technique is the opportunity to bring a scale for evaluating an environment conducive to company success.

Traditional uncertainty techniques ignore relevant independent variables from the model while membership functions consider small impact variables within the model development process. The development of membership functions is done through mapping functions, and these types of functions helped to develop predictive models factors such as ergonomics and safety, quality, employee morale, and company success. The goal of membership functions is to map all the variables on an interval [0, 1] ensuring that important information about the response variable is kept and appropriately represented. Membership functions can be developed by performing a literature review or through the use of SMEs. Since linguistic variables differ among experts, membership functions are developed through mapping functions. These are some of the benefits of using the membership function approach and the FST technique:

- The combination of membership functions assisted in the development of FST models which generated indexes capable of predicting organizational performance metrics essential to achieving company success.
- Easy assessment of company performance can be performed by using the described index models; any value less than 1.0 implies that a company is not achieving its best, and 0 represents a low organizational performance. Therefore, companies with an index well below 1.0 should investigate the reasons and improve their performance.
- FST index models allow organizational decision makers to measure and compare performance across multiple divisions. In addition, organizations can use these index models as a benchmarking tool to compare themselves with industry competitors.

### 3.5.3 Mathematical Operands

The model's mathematical operands were developed by assuming linearity. Since the factors have an accumulating effect, an additive model was developed.

### 3.6 Company Success Index Model – Step 5

This research investigated the combined effects of all the critical success factor variables that affect the overall company success (profit, productivity, efficiency, ergonomics and safety, quality, and employee morale), and generated an index capable of measuring relative performance of company success. This model can be benchmarked by other manufacturing organizations and assist others to continuously improve an organization and achieve organizational excellence.

The company success index model is based on a 0-1 scale, where 0-.33 represents a low level of organizational success, .34-.66 a medium level, and .67-1 a high level of company success. Furthermore, this index model is capable of measuring performance across multiple divisions and assisting organizational leaders in the challenging process of multi-variable decisions. The combination of membership functions and models generated a feasible company success index model. The company success index model is shown in chapter four, section 4.1.2.

### 3.7 Company Success Index Model Validation – Step 6

Data obtained from Plants A and B was used to validate the organizational success model developed as well as the quality, ergonomics and safety, and employee morale models. Research efforts pursued in this section were directed toward test and verification of the previously described index and methodology. This effort involved testing and verification of company success index by determining the accuracy, specificity, and sensitivity of the predictive model. Also, predicted capabilities were assessed as well as the robustness of the index. The probability that a statistical test will be positive for a true statistic is sometimes called the test's sensitivity, and the probability that a test will be negative for a negative statistic is sometimes called the specificity.

Several factors must be taken into account in order to design a stable and consistent prediction model. Factors such as accuracy, specificity, sensitivity, consistency, and precision must be taken into consideration before performing an experiment and developing the model. The following formulas were used to calculate accuracy, specificity, and sensitivity:

Equation 1
Sensitivity
Sensitivity = TP/(TP+FN)

Equation 2 Specificity
Specificity = TN/(FP+TN)

Equation 3 Accuracy
Accuracy = TP+TN/(TP+FP+FN+TN

Where:

FP = false-positive

TN = true negative

FN = false-negative

TP = true-positive

Model validation involves running the same experiment in a different environment; therefore, data obtained from the extended literature were used to develop the index models, and data collected over Plant A and B were used to validate the models which are covered in the following chapter.

# CHAPTER FOUR: FINDINGS

## 4.1 Company Success Index Model Development

This model was generated by combining the membership functions developed for some of the components, such as profit, productivity, and efficiency, with the models created for the rest of the company success components, such as quality, ergonomics and safety, and employee morale.

### 4.1.1 Weights

The pair-wise comparison tables are presented in Appendix F; they were sent to three SMEs (academician, industry expert, and academician with an extensive industry background) to obtain their feedback. The glossary of terms presented in Appendix E was attached to the pair-wise comparison forms in order to facilitate the comparison exercise and to avoid misunderstandings and confusion between concepts and terms. Figure 11 represents the company success weights obtained from the AHP performed by Expert Choice.

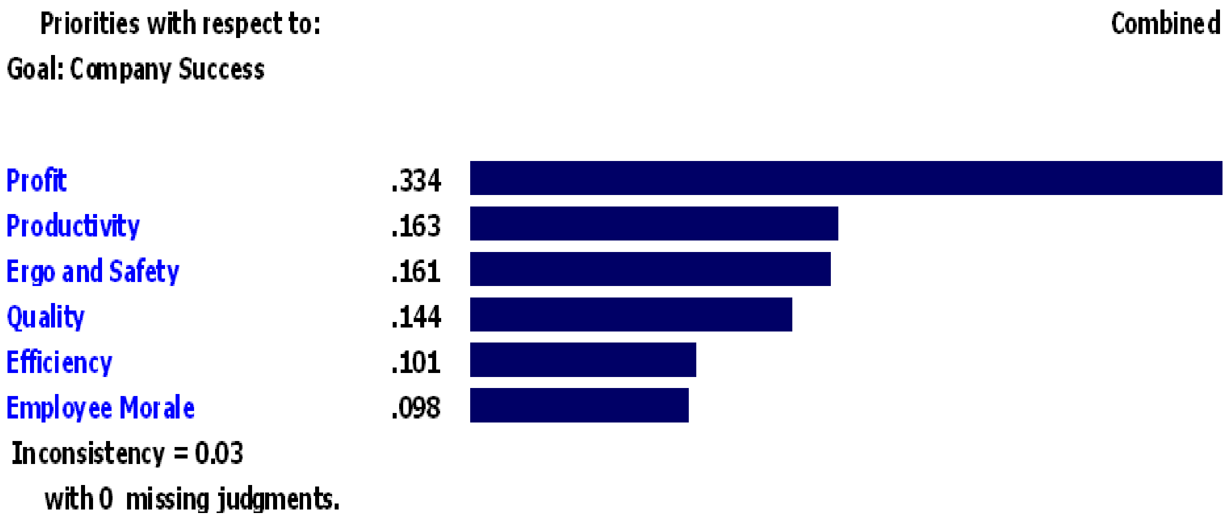



Figure 11Company Success Index Model Weights

### 4.1.2 Company Success Index Model Formulation

The following equation represents the company success index model developed in this research, which was applied in Plants A and B. The additive rule of probability was applied to combine all the company success components identified in this research.

Equation 4 Company Success

$$\begin{aligned} Company.Success(Plant, Year) &= (Wp \times Profit) + (Wpr \times Productivity) \\ &+ (We \times Efficiency) + (Wq \times Quality) + (Wes \times Ergo.Safety) \\ &+ (Wem \times Employee.Morale) \end{aligned}$$

Where (all units are included within Indicators/Metrics column in Table 3):

Company Success (Plant, Year) = Company Success Index Model

Wp = weight of Profit component

Profit = Profit membership function

Wpr = weight of Productivity component

Productivity = Productivity membership function

We = weight of Efficiency component

Efficiency = Efficiency membership function

Wq = weight of Quality component

Quality = Quality Index Model

Wes = weight of Ergonomics and Safety component

Ergonomics and Safety = Ergonomics and Safety Index Model

Wem = weight of Employee Morale

Employee Morale = Employee Morale Index Model

These membership functions and models were combined using additive modeling and were validated by calculating the accuracy, sensitivity, and specificity. Therefore, additive operation was applied to total values (weights multiplied by degrees of membership) obtained from the membership functions and the models developed.

**4.1.3 Company Success Index Model**

Table 6 represents the overall company success membership functions, such as profit, productivity, and efficiency, as well as the model value, such as ergonomics and safety, employee morale, and quality. The table compares the company success index model figures versus the gold standard or market share (based on profit) position of the organization (under study, Plant A and B) in the U.S market. The gold standard selected to evaluate company success was market share, which is the primary goal of any organization (JP Morgan, 2005). Previously developed organizational performance measure models, tools, and approaches considered company success to be highly dependable and solely represented by the organization's strategy. The reality is that no matter how much variation exists between different organizations, the main goal of any company is to own the market or become the market leader.

Table 6 Company Success Membership Function and Model Values vs. Gold Standard for Plants A and B

| Data Source | Year | Profit | Productivity | Efficiency | Quality | Ergo. & Safety | Employee Morale | TOTAL | Gold Standard |
|---|---|---|---|---|---|---|---|---|---|
| Plant A | 2002 | 0.1397 | 0.1630 | 0.0929 | 0.0737 | 0.1201 | 0.0461 | 0.6355 | 0.30 |
| Plant A | 2003 | 0.1637 | 0.1630 | 0.0969 | 0.0736 | 0.1231 | 0.0461 | 0.6663 | 0.30 |
| Plant A | 2004 | 0.1666 | 0.1630 | 0.0969 | 0.0740 | 0.1252 | 0.0461 | 0.6716 | 0.30 |
| Plant A | 2005 | 0.2265 | 0.1630 | 0.1010 | 0.0730 | 0.1251 | 0.0461 | 0.7348 | 0.30 |
| Plant B | 2003 | 0.0081 | 0.1630 | 0.0477 | 0.0735 | 0.1133 | 0.0559 | 0.4614 | 0.17 |
| Plant B | 2004 | 0.0109 | 0.1630 | 0.0731 | 0.0717 | 0.1125 | 0.0559 | 0.4870 | 0.17 |
| Plant B | 2005 | 0.0165 | 0.1630 | 0.0731 | 0.0778 | 0.0827 | 0.0559 | 0.4690 | 0.17 |
| Plant B | 2006 | 0.0173 | 0.1630 | 0.1003 | 0.0741 | 0.1375 | 0.0559 | 0.5481 | 0.16 |

### 4.1.4 Company Success Index Model Validation

From the table, it can be observed how company success for Plant A is higher than for Plant B. This makes sense since the majority of the company success component models and membership functions developed were identifying this trend. Market share or company success gold standard follows the following scale: Low 0-10%, Medium 11-20%, and High 21-100%. Table 7 represents the scale developed to interpret the company success figures.

Table 7 FST for Company Success

| Fuzzy Set Theory Level | Degrees of Membership |
|---|---|
| Low | 0-.33 |
| Medium | .34-.66 |
| High | .67-1 |

Table 8 compares the Company Success linguistic results versus the Gold Standard linguistic values. The majority of the results match, with the exception of Plant A in the year 2002.

Table 8 Company Success Model vs. Gold Standard Fuzzy Values for Plants A and B

| Location | Year | C.S Model | Gold Standard (Market Share) |
|---|---|---|---|
| Plant A | 2002 | Medium | High |
| Plant A | 2003 | High | High |
| Plant A | 2004 | High | High |
| Plant A | 2005 | High | High |
| Plant B | 2003 | Medium | Medium |
| Plant B | 2004 | Medium | Medium |
| Plant B | 2005 | Medium | Medium |
| Plant B | 2006 | Medium | Medium |

Table 9 shows the validation calculations performed over the company success model.

Table 9 Sensitivity, Specificity, and Accuracy Values of Company Success Model

| Gold Standard (Market Share) | | | | |
|---|---|---|---|---|
| Company Success Model | | True | False | |
| | Positive | TP = 7 | FP = 0 | 7/(7+0) = 100% |
| | Negative | FN = 1 | TN = 0 | 0/1 |
| | | Sensitivity 7/(7+1) = 87.5% | Specificity 0/0 | Accuracy 7/8 = 87.5% |

## 4.2 Fuzzy Index Models for Company Success Components

After performing an extended literature review, no deterministic models representing ergonomics and safety, quality, and employee morale components were found. The purpose of developing these models not only assists with the development of a company success index model which is the overall goal of this research, but also provides the option to evaluate these components individually. The following index models were developed applying FST; therefore, a membership function was developed for each factor variable characterized within each model and combined using mathematical operands to develop the index model. The following section shows the process followed to develop the ergonomics and safety index model.

### 4.2.1 Ergonomics & Safety Index Model Formulation

After performing an extended literature review in ergonomics and safety, no deterministic model was found to evaluate and combine factor variables such as annual replacement costs (extra wages generated by an injury, illness, or accident), lost work-day cases, OSHA fines, OSHA recordable cases, workers' compensation expenses, and proactive ergonomics activities. Additive mathematical operands were applied to combine all the ergonomics and safety membership functions and develop the mathematical model. The following equation represents the ergonomics and safety model.

Equation 5 Ergonomics & Safety

$$E.S(Plant, Year) = (W_{WW} \times WW) + (W_{LWDC} \times LWDC) + (W_{OSHA} \times OSHA) + (W_{I\,I} \times II) + (W_{PE} \times PE) + (W_{WC} \times WC)$$

Where (all units are included within Indicators/Metrics column in Table 3):

$E.S$ = Ergonomics and Safety Value per Plant, Year

$W_{WW}$ = Replacement Cost Weight

$WW$ = Replacement Cost Degrees of Membership

$W_{LWDC}$ = Lost Work-Day Cases Weight

$LWDC$ = Lost Work-Day Cases Degrees of Membership

$W_{OSHA}$ = OSHA Fines Weight

$OSHA$= OSHA Fines Degrees of Membership

$W_{II}$ = OSHA Injury & Illness Weight

$II$ = OSHA Injury & Illness Degrees of Membership

$W_{PE}$ = Proactive Ergonomics Weight

$PE$ = Proactive Ergonomics Degrees of Membership

$W_{WC}$ = Workers' Compensation Weight

$WC$ = Workers' Compensation Degrees of Membership

The following section includes the weights obtained for all the ergonomics and safety factor variables, a critical step in the development of fuzzy models.

*4.2.1.1 Weights*

The pair-wise comparison tables are represented in Appendix F; they were sent to three subject matter experts (academician, industry expert, and academician with an extensive industry background) to obtain their feedback. The glossary of terms represented in Appendix E was attached to the pair-wise comparison forms to facilitate the comparison exercise and avoid misunderstanding and confusion between concepts and terms. Figure 12 represents the ergonomics and safety weights obtained from the AHP performed by Expert Choice.

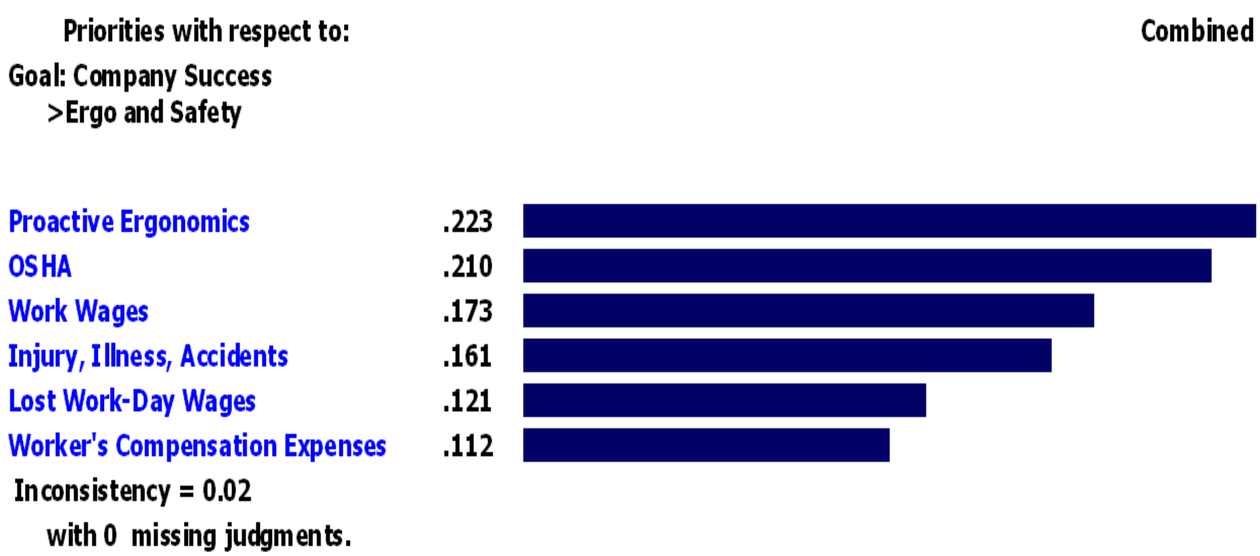



Figure 12 Ergonomics and Safety Index Model Weights

The Ergonomics and Safety inconsistency ratio was evaluated (.02), which is smaller than 0.1. Therefore, the ratio obtained reflects coherent judgments and opinions given by the SMEs.

#### *4.2.1.2 Membership Functions*

The extended literature review performed in the initial research stages helped to identify a scale for every company success component and assist in the development of membership functions. In the majority of the cases, an existing scale was not found, leading the membership function to be developed based on industry data.

There are many types of membership functions such as linear, triangular, trapezoidal, Gaussian, bell, sigmoid, but two were selected and applied to solve this research. Linear membership functions were selected to characterize the employee morale variables obtained from a survey, and sigmoid membership functions were applied to the rest of the company success variables.

1. Linear membership functions are represented by a straight line and are the simplest type of MF. There are two states of linear fuzzy sets: the increasing state which goes from zero to one degree of membership, and the decreasing state which is the opposite (goes from one to zero degrees of membership). This MF is represented by a range and a slope that is characterized by a 45 degree angle.
2. Sigmoid/logistic MF are also called S-curve MF and are represented by increasing and decreasing nonlinear functions. A growing sigmoidal MF goes from the left-hand side which represents no membership to the extreme right-hand side of the graph which represents a complete membership. Sigmoidal MF are represented by three parameters: $\alpha$ which represents zero membership value, $\beta$ the inflection point or the 50% membership point, and $\gamma$ which represents complete membership value. S-curve MF represents continuous cumulative distribution functions and is commonly used to model population dynamics. Sigmoid membership functions

are commonly applied in situations such as average income of executives on the East Cost, mean-time-between-failure (MTBF) of a hard disk drive or any dynamic value that approximates a continuous random variable (Cox, 1994).

Equation 6 Sigmoidal Membership Function

$$S(x;a,\beta,\gamma)=\begin{cases}0\rightarrow \chi\le\alpha\\ 2\left(\left(\chi-\alpha\right)/\left(\gamma-\alpha\right)\right)^2\rightarrow\alpha\le\chi\le\beta\\ 1-2\left(\left(\chi-\gamma\right)/\left(\gamma-\alpha\right)\right)^2\rightarrow\beta\le\chi\le\gamma\\ 1\rightarrow\chi\ge\gamma\end{cases}$$

Where,

α= 0 degree of membership

β= 0.5 degree of membership or inflection point

γ= 1 degree of membership

Tables 10 and 11 represent ergonomics and safety data obtained from Plant A and B. These data were used to validate the ergonomics and safety membership functions developed using manufacturing industry scales or historical behavior.

Table 10 Ergonomics and Safety Data from Plant A

| Factor Variable | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|
| Replacement Cost | $0 | $0 | $0 | $0 |
| Lost Work-Day Cases | .98 | 1.56 | 2.91 | 2.77 |
| OSHA Fines | $0 | $0 | $0 | $0 |
| OSHA Recordable Inj. & Illness Rate | 1.95 | 3.1 | 4 | 4.93 |
| Replacement Machinery & Damaged Material | $0 | $0 | $0 | $0 |
| Proactive Ergonomics | $10,290 | $10,395 | $10,490 | $10,577 |
| Workers' Compensation | $0.09 | $0.07 | $0.06 | $0.06 |

Table 11 Ergonomics and Safety Data from Plant B

| Factor Variable | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| Replacement Cost | $0 | $0 | $0 | $0 | $0 |
| Lost Work-Day Cases | 2.96 | 3.83 | 3.91 | 7.45 | 3.28 |
| OSHA Fines | $0 | $0 | $0 | $0 | $0 |
| OSHA Recordable Cases | 2.96 | 3.83 | 3.91 | 7.45 | 3.28 |
| Replacement Machinery & Damaged Material | $0 | $0 | $0 | $0 | $5,465 |
| Proactive Ergonomics | $8,640 | $8,640 | $12,047 | $8,640 | $24,742 |
| Workers' Compensation | $0.07 | $0.1 | $0.25 | $0.13 | $0.17 |

The following section shows in detail the development of the replacement cost membership function for each necessary to characterize the ergonomics and safety index model.  A membership function per ergonomics and safety factor variable was developed to appropriately characterize the component and its impact in achieving company success.

4.2.1.2.1 Replacement Cost Membership Function

The replacement cost generated after an accident, injury or illness has occurred in the workplace was estimated by multiplying the median lost work days by the salary rate of the manufacturing industry. Since no scale was found within the literature review, the number of days away from work published by Bureau of Labor Statistics was used to develop a replacement cost scale. The historical data obtained represents the median days of work-related musculoskeletal disorders that required days away from work and the standard hourly rate values of the manufacturing industry from 1994 to 2006. A sigmoidal MF was selected to represent the replacement cost factor variable, and the Figure 13 represents the replacement cost MF obtained from plotting the amount in dollars within the X-axis and the degrees of membership within the Y-axis (BLS, 2007).

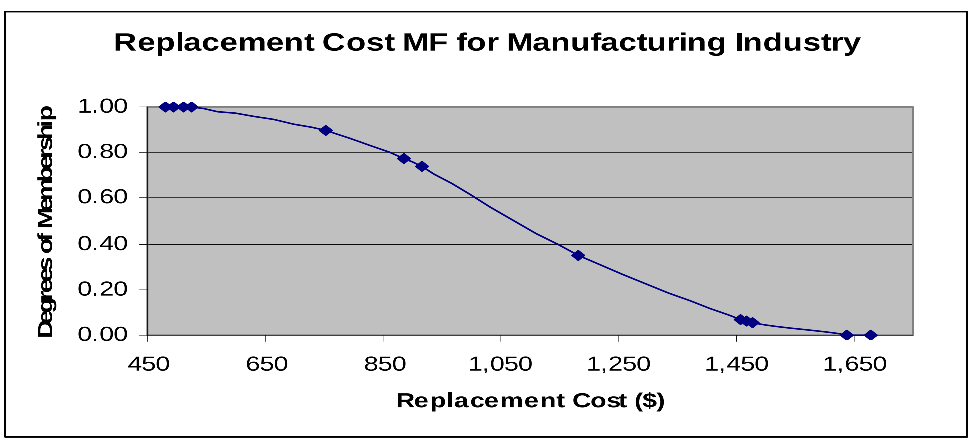



Figure 13 Replacement Cost Membership Function

The previous graph shows when the cost is $1,650, the degree of membership is 0 so it does not belong with the set of values represented in the function; however, a $481 cost fully belongs to the membership function since the degree of membership is 1. Table 12 includes all the historical data obtained from the manufacturing industry to develop the replacement cost or X-axis, and the degrees of membership or Y-axis.

Table 12 Replacement Cost Membership Function Values for the Manufacturing Industry (BLS, 2007)

| Year | Days away from work | Average Salary/day ($) | X - Replacement Cost ($) | Y - Degrees of Membership |
|---|---|---|---|---|
| 1994 | 5 | 96.32 | 481.60 | 1.00 |
| 1995 | 5 | 98.72 | 493.60 | 1.00 |
| 1996 | 5 | 102 | 510.00 | 1.00 |
| 1997 | 5 | 105.12 | 525.60 | 1.00 |
| 1998 | 7 | 107.6 | 753.20 | 0.90 |
| 1999 | 8 | 110.8 | 886.40 | 0.77 |
| 2000 | 8 | 114.56 | 916.48 | 0.74 |
| 2001 | 10 | 118.08 | 1,180.80 | 0.35 |
| 2002 | 12 | 122.32 | 1,467.84 | 0.06 |
| 2003 | 13 | 125.92 | 1,636.96 | 0.00 |
| 2004 | 13 | 129.2 | 1,679.60 | 0.00 |
| 2005 | 11 | 132.48 | 1,457.28 | 0.07 |
| 2006 | 11 | 134.4 | 1,478.40 | 0.06 |

Table 13 represents the replacement cost or X-axis, the degrees of membership or Y-axis, and the total value for Plants A and B. The total value was obtained by multiplying the degrees of membership by the weights, a critical step in the development of the ergonomics and safety index model.

Table 13 Replacement Cost Membership Function Values for Plants A and B

| Source Data | Year | Days away from Work | Average Salary/day ($) | X - Replacement Cost ($) | Y - Degrees of Membership | Total Value |
|---|---|---|---|---|---|---|
| Plant A | 2002 | 1 | 122.32 | 122.32 | 0.8201 | 0.1419 |
| Plant A | 2003 | 2 | 125.92 | 251.84 | 0.9264 | 0.1603 |
| Plant A | 2004 | 4 | 129.2 | 516.8 | 0.9983 | 0.1727 |
| Plant A | 2005 | 4 | 132.48 | 529.92 | 0.9967 | 0.1724 |
| Plant B | 2002 | 6 | 122.32 | 733.92 | 0.9113 | 0.1577 |
| Plant B | 2003 | 8 | 125.92 | 1007.36 | 0.6148 | 0.1064 |
| Plant B | 2004 | 8 | 129.2 | 1033.6 | 0.5754 | 0.0995 |
| Plant B | 2005 | 16 | 132.48 | 2119.68 | 0.2699 | 0.0467 |
| Plant B | 2006 | 10 | 134.4 | 1344 | 0.1569 | 0.0272 |

#### 4.2.1.2.2 Lost Work-Day Cases Membership Function

The lost work-day cases were represented by the lost work-day rate, which is calculated by multiplying the total number of lost work days for the year by 200,000, the result is then divided by the number of employee labor hours at the organization. Since no scale was found within the literature review, the number of cases with days away from work, job transfer, or restriction published by Bureau of Labor Statistics was used to develop a lost work-day cases scale. The historical data obtained represents the annual value of the manufacturing industry from 1992 to 2005. A sigmoidal MF was selected to represent the lost work-day cases factor variable; Figure 14 represents the lost work-day cases MF obtained from plotting the frequency rate within the X-axis and the degrees of membership within the Y-axis.

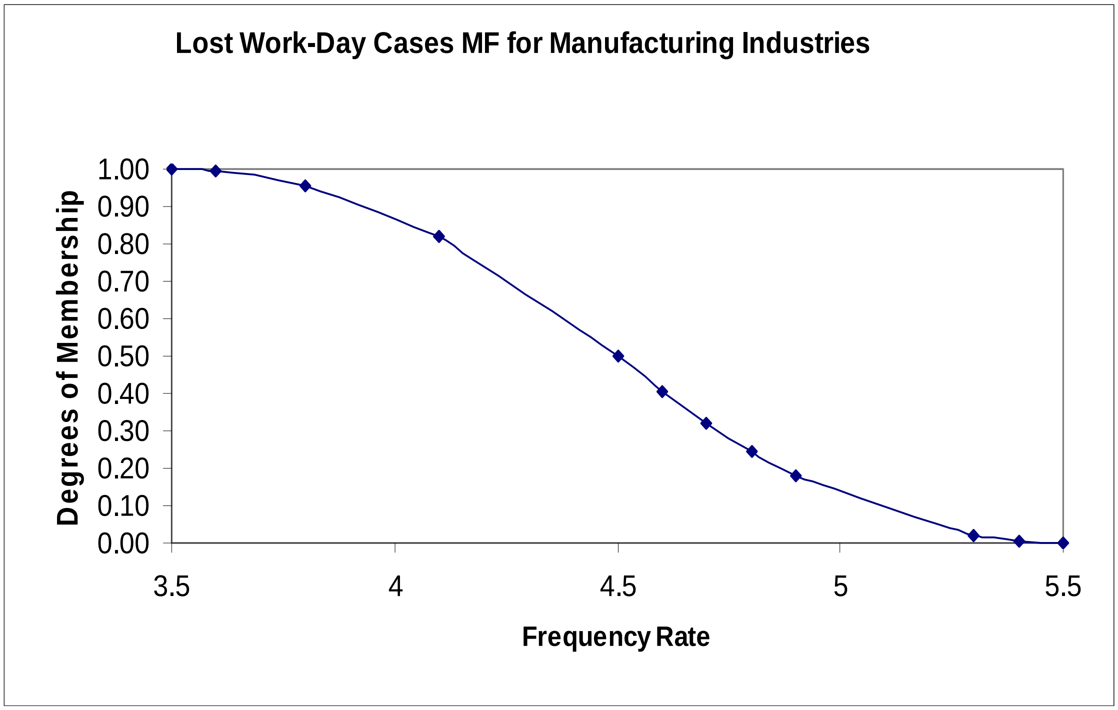



Figure 14 Lost Work-Day Cases Membership Function

The previous graph shows when the frequency rate is 5.5, the degree of membership is 0 so it verily belongs to the function; however, a 3.5 frequency rate fully belongs to the membership function since the degree of membership is 1. Table 14 includes all the historical data obtained from the manufacturing industry to develop the lost work-day cases or X-axis, and the degrees of membership or Y-axis.

Table 14 Lost Work-Day Cases (Frequency Rate) Membership Function Values for the Manufacturing Industry (BLS, 2006)

| Year | X - No. of Cases away from Work | Y - Degrees of Membership |
|---|---|---|
| 1992 | 5.4 | 0 |
| 1993 | 5.3 | 0.02 |
| 1994 | 5.5 | 0 |
| 1995 | 5.3 | 0.02 |
| 1996 | 4.9 | 0.18 |
| 1997 | 4.8 | 0.25 |
| 1998 | 4.7 | 0.32 |
| 1999 | 4.6 | 0.41 |
| 2000 | 4.5 | 0.5 |
| 2001 | 4.1 | 0.82 |
| 2002 | 4.1 | 0.82 |
| 2003 | 3.8 | 0.96 |
| 2004 | 3.6 | 1 |
| 2005 | 3.5 | 1 |

Table 15 represents the lost work-day cases or X-axis, the degrees of membership or Y-axis, and the total value for Plants A and B. The total value was obtained by multiplying the degrees of membership by the weights, a critical step in the development of the ergonomics and safety index model.

Table 15 Lost Work-Day Cases Membership Function Values for Plants A and B

| Source Data | Year | X - No. of Cases away from Work | Y - Degrees of Membership | Total Value |
|---|---|---|---|---|
| Plant A | 2002 | 0.98 | 1 | 0.1210 |
| Plant A | 2003 | 1.56 | 1 | 0.1210 |
| Plant A | 2004 | 2.91 | 1 | 0.1210 |
| Plant A | 2005 | 2.77 | 1 | 0.1210 |
| Plant B | 2002 | 2.96 | 1 | 0.1210 |
| Plant B | 2003 | 3.83 | 0.95 | 0.1144 |
| Plant B | 2004 | 3.91 | 0.92 | 0.1108 |
| Plant B | 2005 | 7.45 | 0 | 0.0000 |
| Plant B | 2006 | 3.28 | 1 | 0.1210 |

#### 4.2.1.2.3 OSHA Fines Membership Function

Since no scale was found within the literature review, inspections performed in the manufacturing industry by the Occupational Safety & Health Administration (Department of Labor) was used to develop an OSHA fines scale. The historical data obtained represents the individual manufacturing organizations privately owned in the U.S from 1996 to 2006. OSHA inspection information for manufacturing industry (SIC 31, 32, and 33) was obtained to develop the OSHA fines membership function, which is represented in dollars. This function provides information regarding the OSHA cases which entailed a violation or multiple violations, and the amount assigned by OSHA after conducting inspections and negotiations (OSHA, 2007). A sigmoidal MF was selected to represent the OSHA Fines factor variable; Figure 15 represents the membership function developed from plotting the amount of fines in dollars within the X-axis and the degrees of membership within the Y-axis.

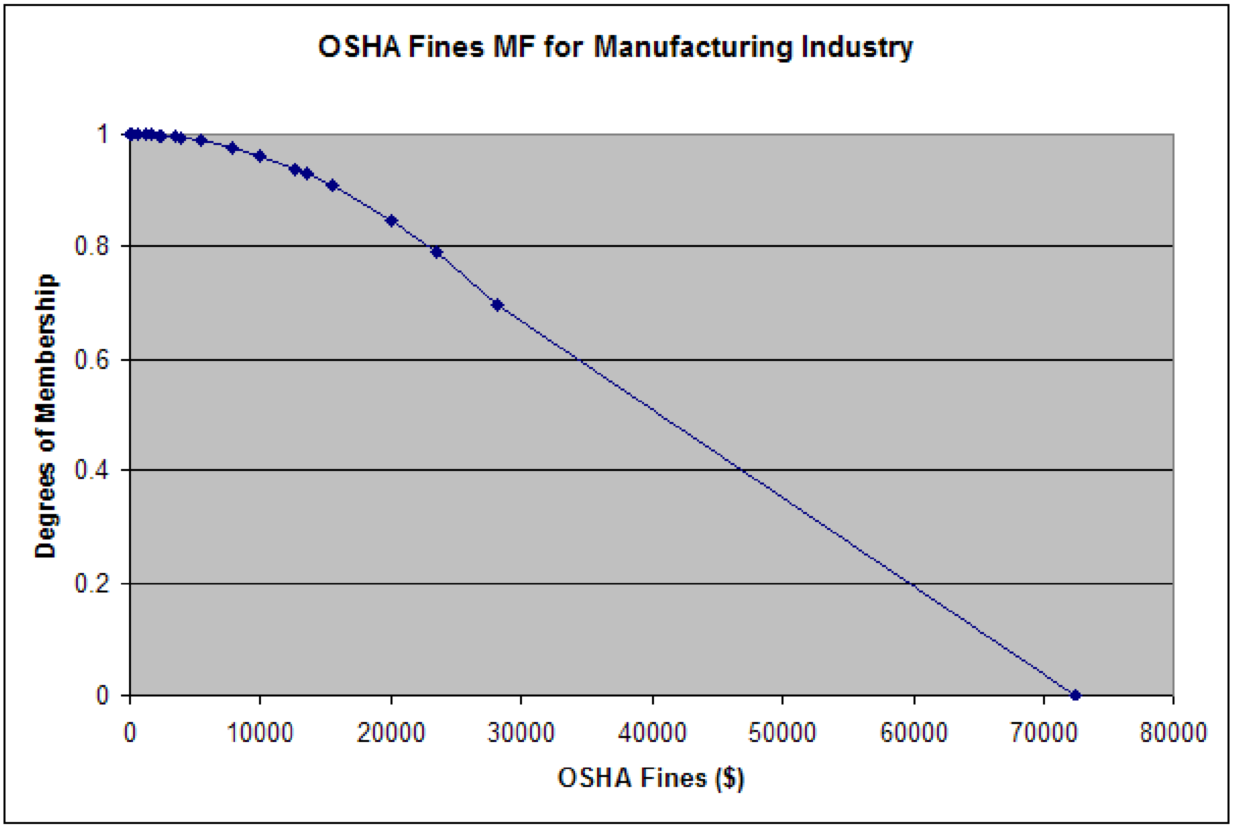



Figure 15 OSHA Fines Membership Function

The previous graph shows when the cost is $72,500, the degree of membership is 0 so it barely belongs to the function; however, a $0 cost fully belongs to the membership function since the degree of membership is 1. Table 16 includes all the historical data obtained from the manufacturing industry to develop the OSHA fines or X-axis, and the degrees of membership or Y-axis.

Table 16 OSHA Fines for Manufacturing Industry (OSHA, 2007)

| **X - OSHA Fines ($)** | **Y - Degrees of Membership** |
|---|---|
| 0 | 1 |
| 200 | 1.0000 |
| 600 | 0.9999 |
| 1275 | 0.9994 |
| 1700 | 0.9989 |
| 2200 | 0.9982 |
| 2400 | 0.9978 |
| 3400 | 0.9956 |
| 3900 | 0.9942 |
| 5400 | 0.9889 |
| 7875 | 0.9764 |
| 10000 | 0.9620 |
| 12700 | 0.9386 |
| 13650 | 0.9291 |
| 15500 | 0.9086 |
| 20000 | 0.8478 |
| 23472 | 0.7904 |
| 28265 | 0.6960 |
| 72500 | 0 |

Table 17 represents the OSHA fines or X-axis, the degrees of membership or Y-axis, and the total value for Plants A and B. The total value was obtained by multiplying the degrees of membership by the weights, a critical step in the development of the ergonomics and safety index model.

Table 17 OSHA Fines Membership Function Values for Plants A and B

| Source Data | Year | X – OSHA Fines ($) | Y - Degrees of Membership | Total Value |
|---|---|---|---|---|
| Plant A | 2002 | 0 | 1 | 0.2100 |
| Plant A | 2003 | 0 | 1 | 0.2100 |
| Plant A | 2004 | 0 | 1 | 0.2100 |
| Plant A | 2005 | 0 | 1 | 0.2100 |
| Plant B | 2002 | 0 | 1 | 0.2100 |
| Plant B | 2003 | 0 | 1 | 0.2100 |
| Plant B | 2004 | 0 | 1 | 0.2100 |
| Plant B | 2005 | 0 | 1 | 0.2100 |
| Plant B | 2006 | 0 | 1 | 0.2100 |

4.2.1.2.4 OSHA Injury, and Illness Membership Function

The OSHA injury and illness MF was developed using incident rate which is calculated by multiplying the number of recordable cases by 200,000; the result is then divided by the number of labor hours at the organization. Since no scale was found within the literature review, the OSHA incidence rate published by the Bureau of Labor Statistics was used to develop the OSHA injury and illness scale. The historical data obtained represents the annual value of the manufacturing industry from 1992 to 2005. A sigmoidal MF was selected to represent the OSHA injury and illness rate. Figure 16 shows the OSHA recordable incidence rate MF, which represents the manufacturing industry historical data obtained from the Bureau of Labor Statistics.

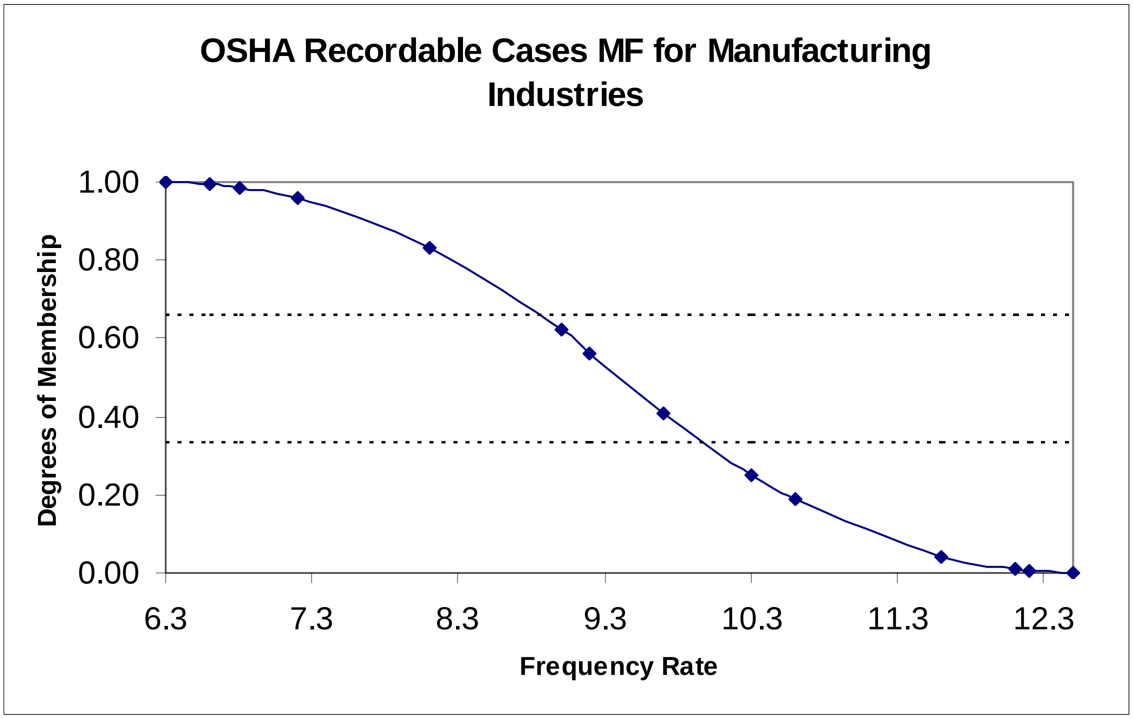



Figure 16 OSHA Recordable Membership Function

The previous graph shows that, when the frequency rate is 12.5, the degree of membership is 0, so it barely belongs to the function; however, the 6.3 frequency rate fully belongs to the membership function because the degree of membership is 1. The following table represents the numeric values obtained from the OSHA recordable MF, which is represented by a sigmoidal shape in the previous figure. The table includes the year, the OSHA rate or X-value, and the degrees of membership or Y-value.

Table 18 OSHA Recordable Membership Function Values for the Manufacturing Industry (BLS, 2006)

| **Year** | **X - OSHA Injury Rate** | **Y - Degrees of Membership** |
|---|---|---|
| 1992 | 12.5 | 0 |
| 1993 | 12.1 | 0.01 |
| 1994 | 12.2 | 0 |
| 1995 | 11.6 | 0.04 |
| 1996 | 10.6 | 0.19 |
| 1997 | 10.3 | 0.25 |
| 1998 | 9.7 | 0.41 |
| 1999 | 9.2 | 0.56 |
| 2000 | 9 | 0.62 |
| 2001 | 8.1 | 0.83 |
| 2002 | 7.2 | 0.96 |
| 2003 | 6.8 | 0.99 |
| 2004 | 6.6 | 1 |
| 2005 | 6.3 | 1 |

The following table represents the OSHA recordable MF values or X-values obtained in Plants A and B. Also represented are the degrees of membership or Y-values, and the total value obtained by multiplying the degrees of membership by the weights were included.

Table 19 OSHA Recordable Membership Function Values for Plants A and B

| Source Data | Year | X - OSHA Injury Rates | Y - Degree of Membership | Total Value |
|---|---|---|---|---|
| Plant A | 2002 | 1.95 | 1 | 0.1610 |
| Plant A | 2003 | 3.1 | 1 | 0.1610 |
| Plant A | 2004 | 4 | 1 | 0.1610 |
| Plant A | 2005 | 4.93 | 1 | 0.1610 |
| Plant B | 2002 | 5.24 | 1 | 0.1610 |
| Plant B | 2003 | 6.46 | 1 | 0.1610 |
| Plant B | 2004 | 7.11 | 0.97 | 0.1562 |
| Plant B | 2005 | 7.77 | 0.90 | 0.1449 |
| Plant B | 2006 | 6.07 | 1 | 0.1610 |

#### 4.2.1.2.5 Proactive Ergonomics Membership Function

Many activities can be identified and considered as proactive in ergonomics and safety, but the most important is development and support, within an organization, of an ergonomics and safety program that can be measured by the cost of maintaining an Ergonomics program in place. NIOSH published a report entitled Elements of Ergonomics Programs: A Primer Based on Workplace Evaluations of Musculoskeletal Disorders, which identifies the key elements of an ergonomics program. The following elements are critical to developing and sustaining an ergonomics program successfully (NIOSH Publication No. 97-117).

1. Management commitment and supervision
2. Worksite analysis
3. Injury prevention or control

4. Injury management
5. Training and education

In order to develop the proactive ergonomics membership function, the cost of developing and supporting a full ergonomics program was used. Three SME were interviewed, and a minimum and maximum cost of developing and maintaining an ergonomics and safety program within a manufacturing plant of 250-500 employees was obtained. The following sigmoidal membership function was developed to represent the proactive ergonomics MF.

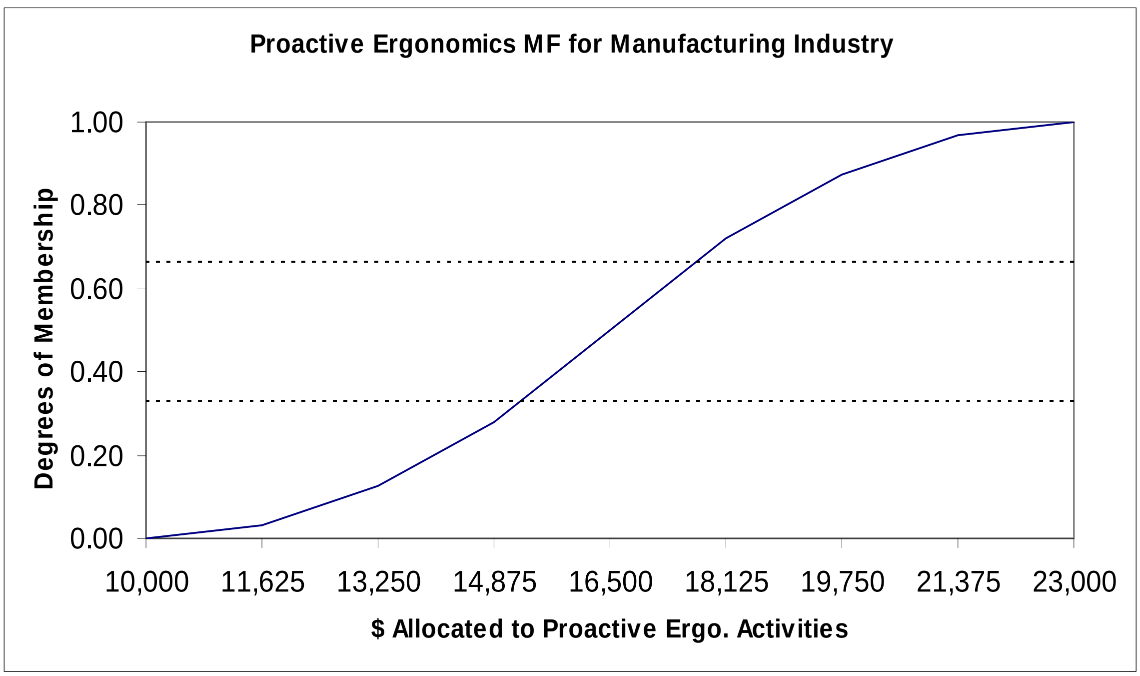



Figure 17 Proactive Ergonomics Membership Function

The previous graph shows that, when the cost is $10,000, the degree of membership is 0, so it barely belongs to the function; however, the $23,000 cost fully belongs to the membership function because the degree of membership is 1. The following table represents the manufacturing industry range of annual spending in a full ergonomics program. The X-values represent the proactive ergonomics and safety cost, and the degrees of membership are represented by the Y-values.

Table 20 Proactive Ergonomics Membership Function Values for the Manufacturing Industry

| X - Proactive Ergonomic Activities | Y - Degrees of Membership |
|---|---|
| 10,000 | 0.00 |
| 11,625 | 0.03 |
| 13,250 | 0.13 |
| 14,875 | 0.28 |
| 16,500 | 0.50 |
| 18,125 | 0.72 |
| 19,750 | 0.88 |
| 21,375 | 0.97 |
| 23,000 | 1.00 |

The following table represents the money allocated to proactive ergonomics activities or X-values, the degrees of membership or Y-values, and the total values (obtained by multiplying the degrees of membership by the weights) from Plants A and B.

Table 21 Proactive Ergonomics Membership Function Values for Plants A and B

| Data Source | Year | X - Proactive Ergonomic Activities | Y - Degrees of Membership | Total Value |
|---|---|---|---|---|
| Plant A | 2002 | 10,290 | 0.00 | 0.0002 |
| Plant A | 2003 | 10,395 | 0.00 | 0.0004 |
| Plant A | 2004 | 10,490 | 0.00 | 0.0006 |
| Plant A | 2005 | 10,577 | 0.00 | 0.0009 |
| Plant B | 2002 | 8,640 | 0.00 | 0.0000 |
| Plant B | 2003 | 8,640 | 0.00 | 0.0000 |
| Plant B | 2004 | 12,047 | 0.05 | 0.0111 |
| Plant B | 2005 | 8,640 | 0.00 | 0.0000 |
| Plant B | 2006 | 24,742 | 1.00 | 0.2230 |

#### 4.2.1.2.6 Workers' Compensation Membership Function

The workers' compensation MF was developed based on the average costs per hour worked (ECEC) found in a National Compensation Survey —"Compensation Cost Trends, Employer Costs for Employee Compensation"— published by the Bureau of Labor Statistics. This value represents the insurance premium annually spent to protect a manufacturing organization. The historical data obtained represent the annual values of the manufacturing industry from 1986 to 2006. A sigmoidal MF was selected to represent the workers' compensation factor variable. The following figure represents the workers' compensation MF for the manufacturing industry. The X-axis represents the cost per hour worked by year, based on insurance premiums, and the Y-axis represents the degrees of membership obtained.

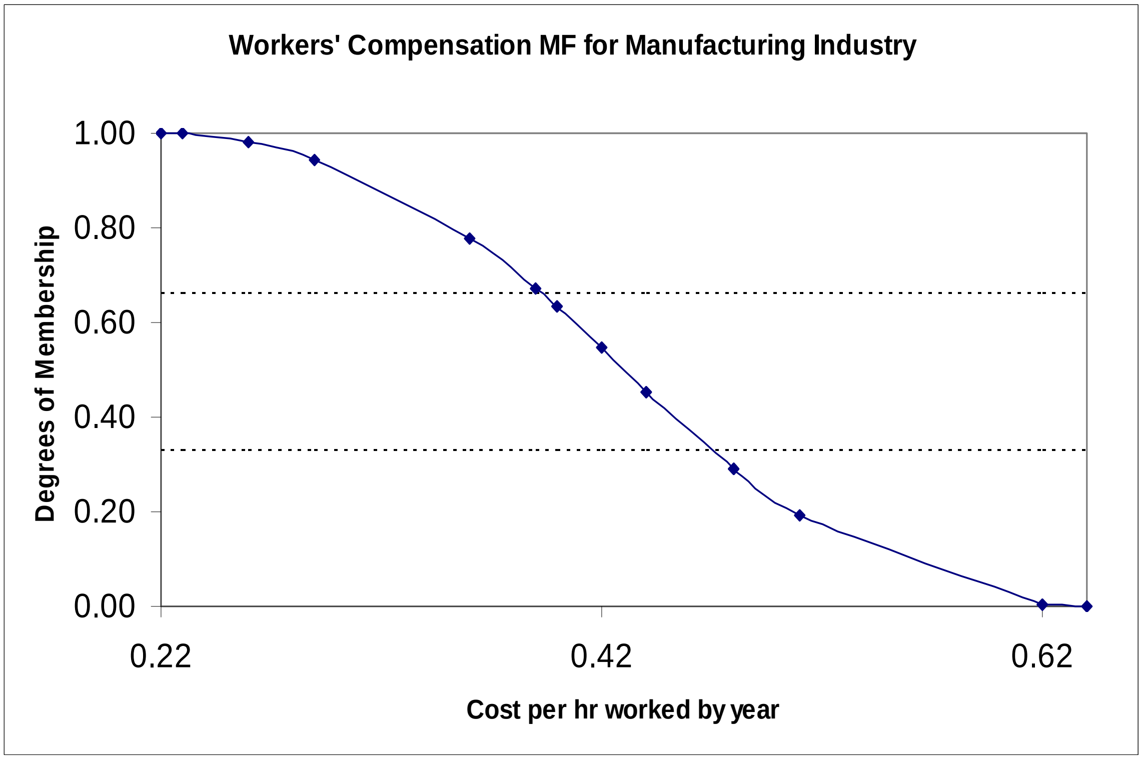



Figure 18 Workers' Compensation Membership Function

The previous graph shows that, when the cost per hour is \$.62, the degree of membership is 0, so it barely belongs to the function; however, \$.22 cost per hour fully belongs to the membership function because the degree of membership is 1. The following table represents the X-values or workers' compensation expenses annually observed (1986-2006) in the manufacturing industry and the degrees of membership or Y-values obtained.

Table 22 Workers' Compensation Membership Function Values for the Manufacturing Industry (BLS, 2006)

| Year | X – Workers' Compensation | Y – Degrees of Membership |
|---|---|---|
| 1986 | 0.22 | 1.00 |
| 1987 | 0.23 | 1.00 |
| 1988 | 0.26 | 0.98 |
| 1989 | 0.29 | 0.94 |
| 1990 | 0.36 | 0.78 |
| 1991 | 0.39 | 0.67 |
| 1992 | 0.42 | 0.55 |
| 1993 | 0.44 | 0.45 |
| 1994 | 0.48 | 0.29 |
| 1995 | 0.48 | 0.29 |
| 1996 | 0.48 | 0.29 |
| 1997 | 0.51 | 0.19 |
| 1998 | 0.48 | 0.29 |
| 1999 | 0.44 | 0.45 |
| 2000 | 0.4 | 0.63 |
| 2001 | 0.4 | 0.63 |
| 2004 | 0.62 | 0.00 |
| 2005 | 0.64 | 0.00 |
| 2006 | 0.62 | 0.00 |

The following table represents the workers' compensation expenses or X-values observed in Plant A and B, the degrees of membership or Y-values, and the total values (calculated by multiplying the degree of membership by the weights).

Table 23 Workers' Compensation Membership Function Values for Plants A and B

| Source Data | Year | Workers' Compensation Expenses | Degrees of Membership | Total Value |
|---|---|---|---|---|
| Plant A | 2002 | 0.09 | 1 | 0.1120 |
| Plant A | 2003 | 0.07 | 1 | 0.1120 |
| Plant A | 2004 | 0.06 | 1 | 0.1120 |
| Plant A | 2005 | 0.06 | 1 | 0.1120 |
| Plant B | 2002 | 0.07 | 1 | 0.1120 |
| Plant B | 2003 | 0.1 | 1 | 0.1120 |
| Plant B | 2004 | 0.25 | 0.99 | 0.1109 |
| Plant B | 2005 | 0.13 | 1 | 0.1120 |
| Plant B | 2006 | 0.17 | 1 | 0.1120 |

The following section focuses on the ergonomics and safety model developed by combining all the membership functions obtained from the manufacturing industry.

#### *4.2.1.3 Ergonomics and Safety Index Model*

The following table represents all the value of the Ergonomics and Safety Index Model.

Table 24 Ergonomics and Safety Model Overview

| Data Source | Year | OSHA Fines | L.W.D.C | Replacement Cost | Injury Rates | Proactive Act | W.C | TOTAL |
|---|---|---|---|---|---|---|---|---|
| Plant A | 2002 | 0.2100 | 0.1210 | 0.1419 | 0.1610 | 0.0002 | 0.1120 | 0.7461 |
| Plant A | 2003 | 0.2100 | 0.1210 | 0.1603 | 0.1610 | 0.0004 | 0.1120 | 0.7647 |
| Plant A | 2004 | 0.2100 | 0.1210 | 0.1727 | 0.1610 | 0.0006 | 0.1120 | 0.7773 |
| Plant A | 2005 | 0.2100 | 0.1210 | 0.1724 | 0.1610 | 0.0009 | 0.1120 | 0.7773 |
| Plant B | 2003 | 0.2100 | 0.1144 | 0.1064 | 0.1610 | 0.0000 | 0.1120 | 0.7038 |
| Plant B | 2004 | 0.2100 | 0.1108 | 0.0995 | 0.1562 | 0.0111 | 0.1109 | 0.6985 |
| Plant B | 2005 | 0.2100 | 0.0000 | 0.0467 | 0.1449 | 0.0000 | 0.1120 | 0.5136 |
| Plant B | 2006 | 0.2100 | 0.1210 | 0.0272 | 0.1610 | 0.2230 | 0.1120 | 0.8542 |

#### *4.2.1.4 Ergonomics and Safety Index Model Validation*

This section represents the validation process applied to assess the accuracy, sensitivity, and specificity of the ergonomics and safety model. Therefore, the model developed was compared against a gold standard to perform the discussed statistical techniques. OSHA guidelines were selected as the ergonomics gold standard, and key safety practices were included to develop the gold standard tool entitled, "OSHA Ergonomics and Safety Guidelines Assessment." The developed assessment consists of nineteen questions (eight addressing key ergonomics factors and the other eleven related to safety factors) that are presented in Appendix G. The following table provides the results obtained from evaluating the ergonomics and safety level using the gold standard tool on Plants A and B.

Table 25 Ergonomics/Safety Gold Standard Values for Plants A and B

| **Ergonomics & Safety Assessment** | | |
|---|---|---|
| **Question** | **Tifton** | **Blackville** |
| 1 | 1 | 0.25 |
| 2 | 1 | 0 |
| 3 | 0.75 | 0.25 |
| 4 | 1 | 0.75 |
| 5 | 1 | 1 |
| 6 | 1 | 0.75 |
| 7 | 1 | 1 |
| 8 | 1 | 1 |
| 9 | 1 | 1 |
| 10 | 1 | 1 |
| 11 | 1 | 1 |
| 12 | 1 | 1 |
| 13 | 1 | 1 |
| 14 | 1 | 1 |
| 15 | 0.75 | 0.75 |
| 16 | 0.25 | 0.75 |
| 17 | 0.75 | 0.75 |
| 18 | 0 | 0.75 |
| 19 | 0.5 | 0.75 |
| **TOTAL** | **0.84** | **0.78** |

The following table represents an overview of the total values obtained from the ergonomics and safety membership functions generated from the model development process. The total ergonomics and safety-model numeric values obtained for each plant and year are included within the next table, as well as the gold standard values obtained from the OSHA Ergonomics and Safety Guidelines.

Table 26 Ergonomics & Safety Membership Function Values vs. Gold Standard for Plants A and B

| Data Source | Year | TOTAL | Gold Standard |
|---|---|---|---|
| Plant A | 2002 | 0.7461 | 0.84 |
| Plant A | 2003 | 0.7647 | 0.84 |
| Plant A | 2004 | 0.7773 | 0.84 |
| Plant A | 2005 | 0.7773 | 0.84 |
| Plant B | 2003 | 0.7038 | 0.78 |
| Plant B | 2004 | 0.6985 | 0.78 |
| Plant B | 2005 | 0.5136 | 0.78 |
| Plant B | 2006 | 0.8542 | 0.78 |

The following table represents the interpreted ergonomics and safety model results and the gold standard level obtained from Plants A and B at different years. This table is necessary for calculating the accuracy, sensitivity, and specificity values within the ergonomics and safety model developed within this research.

Table 27 Ergonomics/Safety Model vs. Gold Standard Fuzzy Values for Plant A and B

| Location | Year | Ergo. & Safety Model | Gold Standard |
|---|---|---|---|
| Plant A | 2002 | High | High |
| Plant A | 2003 | High | High |
| Plant A | 2004 | High | High |
| Plant A | 2005 | High | High |
| Plant B | 2003 | High | High |
| Plant B | 2004 | High | High |
| Plant B | 2005 | Medium | High |
| Plant B | 2006 | High | High |

The following table represents the process of calculating the accuracy, sensitivity, and specificity of the ergonomics and safety model developed within this research.

Table 28 Sensitivity, Specificity, and Accuracy Values of Ergonomics and Safety Model

| Gold Standard (Ergonomics & Safety Assessment) | | | | |
|---|---|---|---|---|
| Ergo. & Safety Model | | True | False | |
| | Positive | TP = 7 | FP = 0 | 7/(7+0) = 100% |
| | Negative | FN = 1 | TN = 0 | 0/(1+0)=0 |
| | | Sensitivity<br>7/(7+1) = 87.5% | Specificity<br>0/0 | Accuracy<br>7/8 = 87.5% |

### 4.2.2 Quality Index Model Formulation

After performing an extended literature review in quality, the cost of quality model created by Crosby was identified as the most appropriate approach to characterize and evaluate quality. The cost of quality model consists of four factor variables: prevention cost, appraisal cost, internal failure cost, and external failure cost. However, within this research, a holistic approach to characterizing quality was applied by adding a couple of new factor variables, such as customer satisfaction and customer loyalty.

The following mathematical model represents the quality index model developed to evaluate this company success-critical component in manufacturing organizations. Additive mathematical operands were used to group the quality membership functions obtained per factor variable.

Equation 7 Quality

$$Q(Plant, Year) = (W_{PC} \times PC) + (W_{AC} \times AC) + (W_{IC} \times IC) + (W_{EC} \times EC) + (W_{CS} \times CS) + (W_{CL} \times CL)$$

Where (all units are included within Indicators/Metrics column in Table 3):

Wpc = Prevention Cost Weight

PC = Prevention Cost Degrees of Membership

Wac = Appraisal Cost Weight

AC = Appraisal Cost Degrees of Membership

Wic = Internal Failure Cost Weight

IC = Internal Failure Cost Degrees of Membership

Wec = External Failure Cost Weight

EC = External Failure Cost Degrees of Membership

Wcs = Customer Satisfaction Cost Weight

CS = Customer Satisfaction Cost Degrees of Membership

Wcl = Customer Loyalty Cost Weight

CL = Customer Loyalty Cost Degrees of Membership

#### *4.2.2.1 Weights*

The pair-wise comparison tables are presented in Appendix F; they were sent to three subject matter experts (an academician, an industry expert, and an academician with an extensive industry background) in order to obtain their feedback. The glossary of terms presented in Appendix E was attached to the pair-wise comparison forms in order to facilitate the comparison exercise and to avoid misunderstanding and confusion between concepts and terms. The following figure represents the quality weights obtained from the AHP performed by Expert Choice.

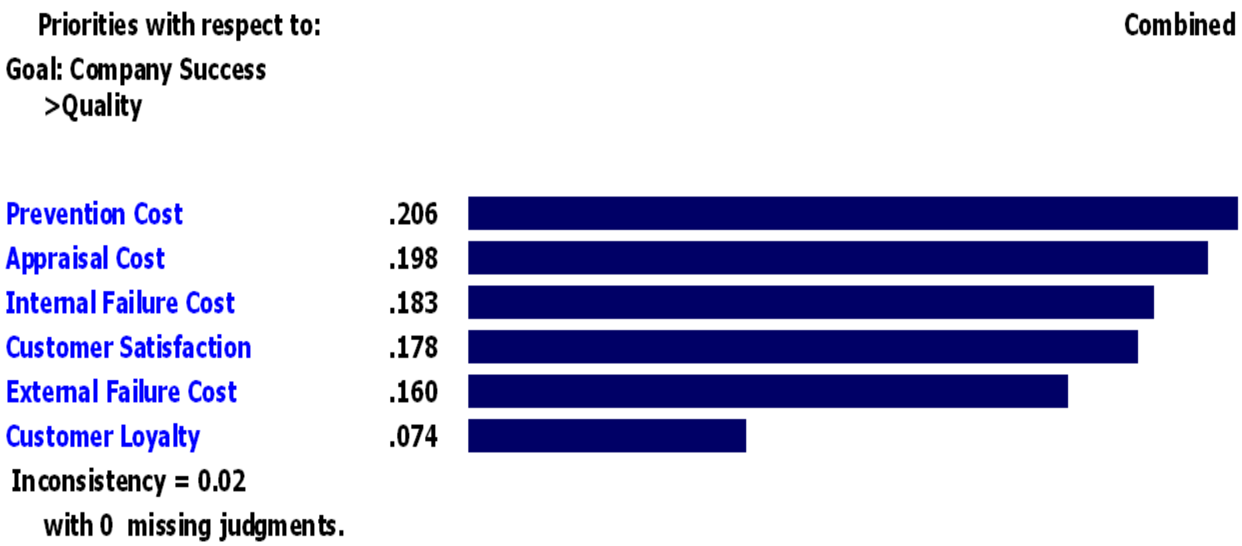



Figure 19 Quality Index Model Weights

The inconsistency ratio identified was .02; therefore, the weights are acceptable for use because the SME were consistent (smaller than 0.1). The following section describes the development of the quality membership functions necessary to model the quality component.

#### *4.2.2.2 Membership Functions*

The following table represents the quality data obtained from Plants A and B for validating the quality index model developed within this research. These data was used to validate the quality membership functions developed using manufacturing industry scales or historical behavior obtained through an extensive literature review.

Table 29 Quality Data from Plant A

| **Subcomp.** | **Factor Variable** | **2002** | **2003** | **2004** | **2005** |
|---|---|---|---|---|---|
| **Customer Satisfaction** | Customer Loyalty | 83.1% | 81.05% | 79% | 76.95% |
| | External Failure Cost | $393,041 | $428,714 | $464,387 | $489,491 |
| | Customer Satisfaction | 91% | 90.5% | 90% | 89.5% |
| **Quality Management & Control** | Internal Failure Cost | $260,633 | $269,027 | $262,382 | $332,211 |
| | Appraisal Cost | $16,000 | $7,268 | $13,777 | $10,557 |
| | Prevention Cost | $67,688 | $46,313 | $706 | $1,638 |

Table 30 Quality Data from Plant B

| **Subcomp.** | **Factor Variables** | **2002** | **2003** | **2004** | **2005** | **2006** |
|---|---|---|---|---|---|---|
| **Customer Satisfaction** | Customer Loyalty | 94% | 93.73% | 93.20% | 92.83% | 92.63% |
| | External Failure Cost | N/A | $ 336,285 | $1,446,108 | $1,365,416 | $1,752,494 |
| | Customer Satisfaction | 77.8% | 78.4% | 77.6% | 84.8% | 85.2% |
| **Quality Management & Control** | Internal Failure Cost | $500,000 | $578,244 | $636,862 | $986,904 | $1,349,819 |
| | Appraisal Cost | $8,500 | $8,500 | $8,553 | $8,540 | $8,709 |
| | Prevention Cost | $0 | $0 | $0 | $71,928 | $65,232 |

The following section shows in detail the development of the customer loyalty membership function necessary to characterize the quality index model. A membership function for each quality factor variable was developed to characterize appropriately the component and its impact in achieving company success.

4.2.2.2.1 Customer Loyalty Membership Function

Extended research was performed to identify a customer loyalty scale, and the scale was found within Campanella's book, *Principles of Quality Cost* (Campanella, 1990). A sigmoidal MF was selected to represent customer loyalty.


Figure 20 Customer Loyalty Membership Function

The previous graph shows that, when the customer is 82% loyal, the degree of membership is 0 so it barely belongs to the function; however, 100% customer loyalty fully belongs to the membership function because the degree of membership is 1. The following table represents the percentages of customer loyalty obtained from the industry scale and their degrees of membership or Y-values.

Table 31 Customer Loyalty Membership Function Values for the Manufacturing Industry (Campanella, 1990).

| **X - Customer Loyalty** | **Y - Degrees of Membership** |
|---|---|
| 82 | 0.00 |
| 83 | 0.01 |
| 84 | 0.02 |
| 85 | 0.06 |
| 86 | 0.10 |
| 87 | 0.15 |
| 88 | 0.22 |
| 89 | 0.30 |
| 90 | 0.40 |
| 91 | 0.50 |
| 92 | 0.60 |
| 93 | 0.70 |
| 94 | 0.78 |
| 95 | 0.85 |
| 96 | 0.90 |
| 97 | 0.94 |
| 98 | 0.98 |
| 99 | 0.99 |
| 100 | 1.00 |

The customer loyalty membership function was developed using the industry data, where the parameters consist of Max = 100 and Average = 91, with a Min value of

82. The following table contains the percentage of customer satisfaction or X-values obtained from the subsidiary headquarters of Plants A and B manufactured products. The degrees of membership or Y-values and the total value were calculated per year.

Table 32 Customer Loyalty Membership Function Values for Plants A and B

| Year | Data Source | X -Customer Loyalty | Y -Degrees of Membership | Total Value |
|---|---|---|---|---|
| 2002 | Plant A | 83 | 0.0062 | 0.0005 |
| 2003 | Plant A | 81 | 0.0062 | 0.0005 |
| 2004 | Plant A | 79 | 0.0556 | 0.0041 |
| 2005 | Plant A | 77 | 0.0000 | 0.0000 |
| 2003 | Plant B | 93.7 | 0.7550 | 0.0559 |
| 2004 | Plant B | 93.2 | 0.7146 | 0.0529 |
| 2005 | Plant B | 92.8 | 0.6800 | 0.0503 |
| 2006 | Plant B | 92.6 | 0.6620 | 0.0490 |

#### 4.2.2.2.2 Customer Satisfaction Membership Function

The customer-satisfaction membership function was developed using the American Customer Satisfaction Index published by the ASQ and the University of Michigan. This index is published quarterly and is applied to different industry sectors (ACSI, 2006). The ACSI scale was used to develop a sigmoidal MF that represents customer satisfaction for the manufacturing industry.

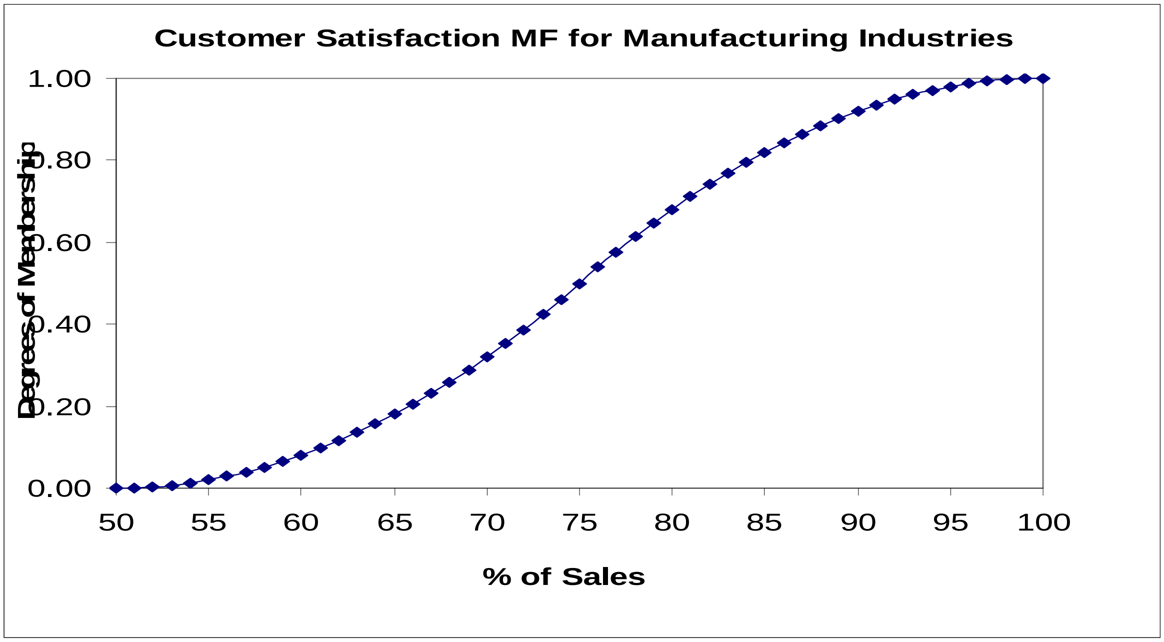



Figure 21 Customer Satisfaction Membership Function

The previous graph shows that, when the customer is 50% satisfied, the degree of membership is 0, so it barely belongs to the function; however, 100% customer satisfaction fully belongs to the membership function because the degree of membership is 1. The previous graph shows that, when the cost is $72,500, the degree of membership is 0, so it barely belongs to the function; however, $0 cost fully belongs to the membership function because the degree of membership is 1. The following table was generated from the previous figure, and it represents the X-values or percentage of customer satisfaction and the degrees of membership or Y-values.

Table 33 Customer Satisfaction Membership Function Values for the Manufacturing Industry (ACSI, 2006).

| X - Customer Satisfaction | Y - Degrees of Membership |
|---|---|
| 50 | 0.00 |
| 60 | 0.08 |
| 70 | 0.32 |
| 75 | 0.50 |
| 80 | 0.68 |
| 90 | 0.92 |
| 100 | 1.00 |

The following table represents the customer satisfaction data collected over Plant A and B as well as the degrees of membership or Y-values and the total values, which are the multiplication of the degrees of membership by the weights.

Table 34 Customer Satisfaction Membership Function Values for Plants A and B

| Year | Data Source | X-Customer Satisfaction | Y-Degrees of Membership | Total Value |
|---|---|---|---|---|
| 2002 | Plant A | 91 | 0.9352 | 0.1665 |
| 2003 | Plant A | 90.5 | 0.9278 | 0.1651 |
| 2004 | Plant A | 90 | 0.9200 | 0.1638 |
| 2005 | Plant A | 89.51 | 0.9120 | 0.1623 |
| 2002 | Plant B | 77.8 | 0.6057 | 0.1078 |
| 2003 | Plant B | 78.4 | 0.6268 | 0.1116 |
| 2004 | Plant B | 77.6 | 0.5986 | 0.1065 |
| 2005 | Plant B | 84.8 | 0.8152 | 0.1451 |
| 2006 | Plant B | 85.2 | 0.8248 | 0.1468 |

#### 4.2.2.2.3 External Failure Cost Membership Function

The external failure cost membership function was developed based on Campanella's external failure cost experienced by manufacturing organizations generating revenues between $100 to 150 millions.  Therefore, Campanella's values were used to develop the external failure cost MF and evaluate Plants A and B (Campanella, 1990).   The following figure shows a sigmoidal MF, which was used to represent the external failure cost factor variable.

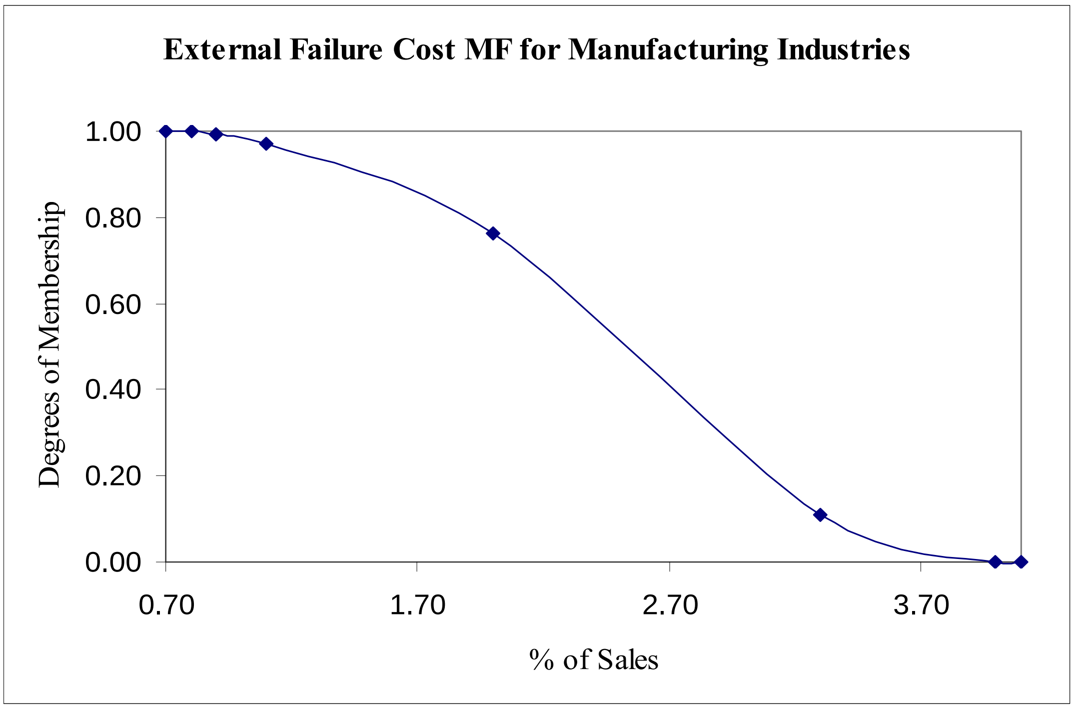



Figure 22 External Failure Cost Membership Function

The previous graph shows that, when the cost as a percentage of sales is 4, the degree of membership is 0, so it barely belongs to the function; however, 8% of cost as a percentage of sales fully belongs to the membership function because the degree of membership is 1.  The following table represents the numeric results of the membership function represented in the previous figure.   The X-values represent the external failure cost as the percentage of sales, and the Y-values represent the degrees of membership.

Table 35 External Failure Cost Membership Function Values for the Manufacturing Industry

| X-External Cost | Y-Degrees of Membership |
|---|---|
| 0.7 | 1.00 |
| 0.8 | 1.00 |
| 0.9 | 0.99 |
| 0.9 | 0.99 |
| 0.9 | 0.99 |
| 1.1 | 0.97 |
| 2 | 0.76 |
| 3.3 | 0.11 |
| 4 | 0.00 |
| 4.1 | 0.00 |

The following table represents the external cost as a percentage of sales, the degrees of membership or Y-values, and the total values for Plants A and B. The total values represent the level of representation of external failure cost within the quality index model.

Table 36 External Failure Cost Membership Function Values for Plants A and B

| Year | Data Source | X-External Cost | Y-Degrees of Membership | Total Value |
|---|---|---|---|---|
| 2002 | Plant A | 0.44 | 0.9883 | 0.1581 |
| 2003 | Plant A | 0.45 | 0.9892 | 0.1583 |
| 2004 | Plant A | 0.478 | 0.9915 | 0.1586 |
| 2005 | Plant A | 0.419 | 0.9863 | 0.1578 |
| 2003 | Plant B | 0.31 | 0.9737 | 0.1558 |
| 2004 | Plant B | 1.25 | 0.9477 | 0.1516 |
| 2005 | Plant B | 0.97 | 0.9874 | 0.1580 |
| 2006 | Plant B | 1.6 | 0.8599 | 0.1376 |

4.2.2.2.4 Internal Failure Cost Membership Function

The internal failure cost membership function was developed using the industry data provided by Campanella in his book *Principles of Quality Costs* (Campanella, 1990).

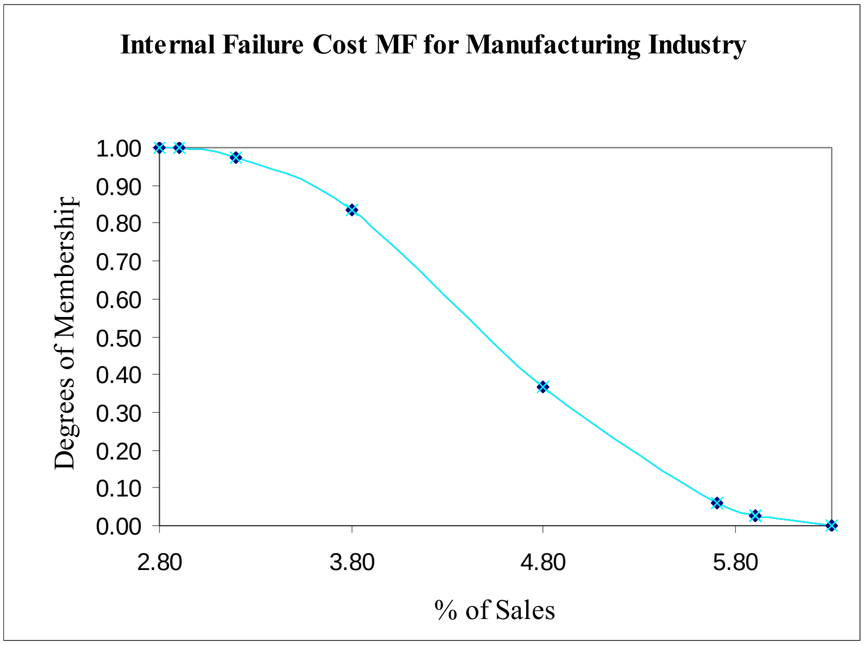



Figure 23 Internal Failure Cost Membership Function

The previous graph shows that, when the cost as a percentage of sales is 6.3, the degree of membership is 0, so it barely belongs to the function; however, 2.8% of cost as a percentage of sales fully belongs to the membership function because the degree of membership is 1. The following table represents the scale values obtained from the literature review and the degrees of membership. This table represents the numeric values obtained from the previous figure.

Table 37 Internal Failure Cost Membership Function Values for the Manufacturing Industry

| X-Internal Cost | Y-Degrees of Membership |
|---|---|
| 2.8 | 1.00 |
| 2.9 | 1.00 |
| 3.2 | 0.97 |
| 3.8 | 0.84 |
| 4.8 | 0.37 |
| 5.7 | 0.06 |
| 5.9 | 0.03 |
| 5.9 | 0.03 |
| 5.9 | 0.03 |
| 6.3 | 0.00 |

The following table represents the internal failure cost values collected over Plants A and B, which are represented by X. In addition, the degrees of membership or Y-values and the total values are included.

Table 38 Internal Failure Cost Membership Function Values for Plants A and B

| Year | Data Source | X-Internal Cost | Y-Degrees of Membership | Total Value |
|---|---|---|---|---|
| 2002 | Plant A | 0.29 | 1.00 | 0.1830 |
| 2003 | Plant A | 0.28 | 1.00 | 0.1830 |
| 2004 | Plant A | 0.27 | 1.00 | 0.1830 |
| 2005 | Plant A | 0.28 | 1.00 | 0.1830 |
| 2003 | Plant B | 0.53 | 1.00 | 0.1830 |
| 2004 | Plant B | 0.55 | 1.00 | 0.1830 |
| 2005 | Plant B | 0.7 | 1.00 | 0.1827 |
| 2006 | Plant B | 1.25 | 0.97 | 0.1773 |

4.2.2.2.5 Appraisal Cost Membership Function

Appraisal cost MF was developed using Campanella's cost of quality figures representing manufacturing organization generating $100 - $150 M in profit (Campanella, 1990). The following figure represents the appraisal cost MF, characterized by a sigmoidal MF.

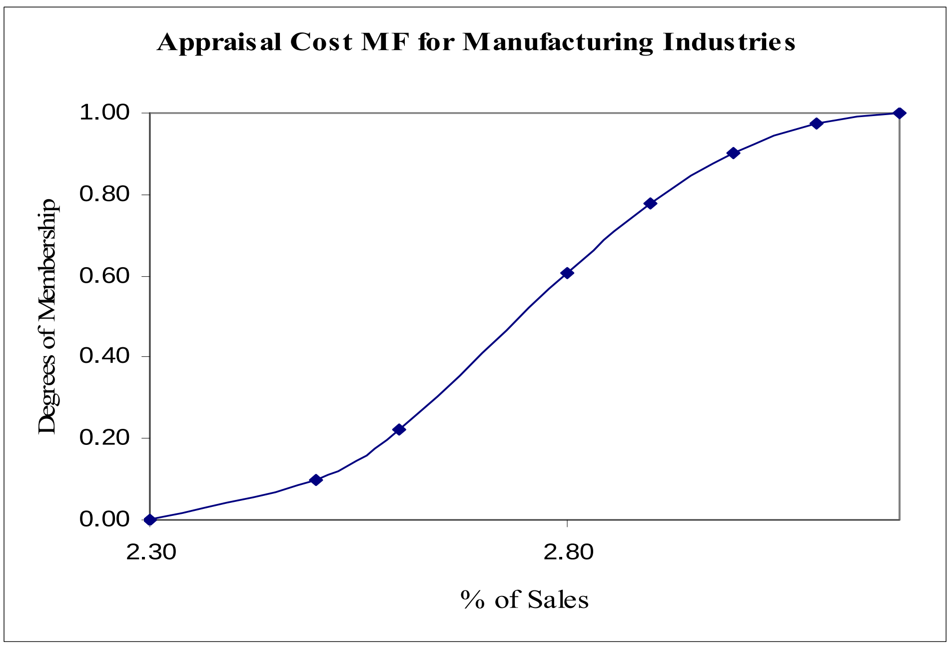



Figure 24 Appraisal Cost Membership Function

The previous graph shows that, when the cost as a percentage of sales is 2.3, the degree of membership is 0, so it barely belongs to the function; however, 3.2% of cost as a percentage of sales fully belongs to the membership function because the degree of membership is 1. The following table represents the X-values or appraisal cost as a percentage of sales and the Y-values or degrees of membership.

Table 39 Appraisal Cost Membership Function Values for the Manufacturing Industry (Campanella, 1990).

| X-Appraisal Cost | Y-Degrees of Membership |
|---|---|
| 2.3 | 0.00 |
| 2.3 | 0.00 |
| 2.3 | 0.00 |
| 2.5 | 0.10 |
| 2.6 | 0.22 |
| 2.8 | 0.60 |
| 2.9 | 0.78 |
| 3 | 0.90 |
| 3.1 | 0.98 |
| 3.2 | 1.00 |

The following table represents appraisal cost as a percentage of sales as well as the degrees of membership and the total values for Plants A and B. The following values were used to validate the quality index model.

Table 40 Appraisal Cost Membership Function Values for Plants A and B

| Year | Data Source | X-Appraisal Cost | Y-Degrees of Membership | Total Value |
|---|---|---|---|---|
| 2002 | Plant A | 0.018 | 0.0100 | 0.0020 |
| 2003 | Plant A | 0.008 | 0.0100 | 0.0020 |
| 2004 | Plant A | 0.014 | 0.0100 | 0.0020 |
| 2005 | Plant A | 0.009 | 0.0100 | 0.0020 |
| 2003 | Plant B | 0.008 | 0.0100 | 0.0020 |
| 2004 | Plant B | 0.007 | 0.0100 | 0.0020 |
| 2005 | Plant B | 0.006 | 0.0100 | 0.0020 |
| 2006 | Plant B | 0.008 | 0.0100 | 0.0020 |

4.2.2.2.6 Prevention Cost Membership Function

The prevention cost MF was developed using Campanella's values used to portray an average manufacturing organization regenerating profits of $100-150 M. Therefore, the cost of prevention was measured as a percentage of sales, which is represented in the following figure by a sigmoidal MF (Campanella, 1990).

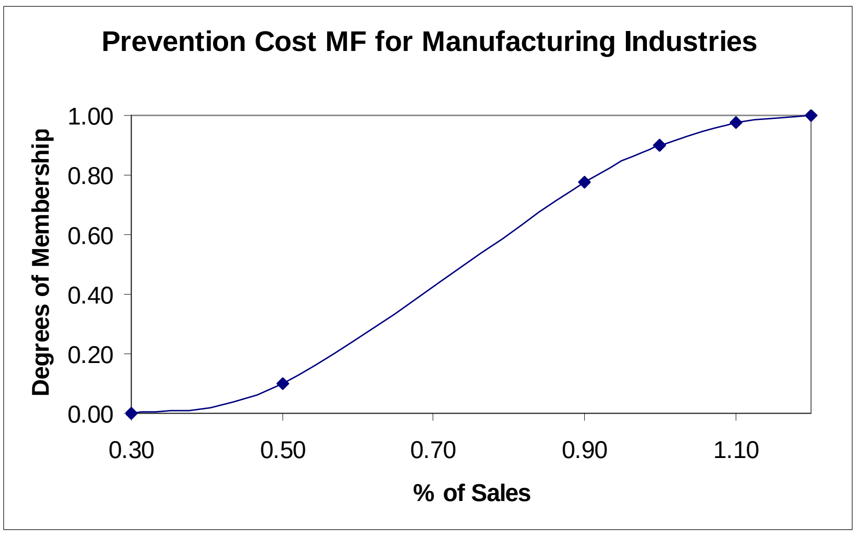



Figure 25 Prevention Cost Membership Function

The lower and upper boundaries of the prevention cost MF are 0 and 1.2% of cost as a percentage of sales, respectively (Figure 25; Table 41). The previous figure shows when the cost as a percentage of sales is 0.3, the degree of membership is 0 so it barely belongs to the function; however, 1.2% of cost as a percentage of sales fully belongs to the membership function since the degree of membership is 1. These values represent the average manufacturing industry generating profits of $100 - $150 M.

Table 41 Prevention Cost Membership Function Values for the Manufacturing Industry (Campanella, 1990).

| X-Prevention Cost | Y-Degrees of Membership |
|---|---|
| 0.3 | 0.00 |
| 0.3 | 0.00 |
| 0.5 | 0.10 |
| 0.9 | 0.78 |
| 1 | 0.90 |
| 1 | 0.90 |
| 1 | 0.90 |
| 1 | 0.90 |
| 1.1 | 0.98 |
| 1.2 | 1.00 |

Table 42 presents the prevention cost, degrees of membership, and total values obtained in Plants A and B. The total values were entered into the quality index model developed in order to validate the model.

Table 42 Prevention Cost Membership Function Values for Plants A and B

| Years | Data Source | X-Prevention Cost | Y-Degrees of Membership | Total Value |
|---|---|---|---|---|
| 2002 | Plant A | 0.076 | 0.01 | 0.0021 |
| 2003 | Plant A | 0.049 | 0.01 | 0.0021 |
| 2004 | Plant A | 0.0007 | 0.01 | 0.0021 |
| 2005 | Plant A | 0.001 | 0.01 | 0.0021 |
| 2003 | Plant B | 0 | 0.01 | 0.0021 |
| 2004 | Plant B | 0 | 0.01 | 0.0021 |
| 2005 | Plant B | 0.05 | 0.01 | 0.0021 |
| 2006 | Plant B | 0.06 | 0.01 | 0.0021 |

### *4.2.2.3 Quality Index Model*

The quality index model was applied to Plants A and B. Because the cost of quality was not applied within Plants A and B, representing this component was difficult. A low cost usually represents a good quality level; however, when the value is low because data could not be provided, a low value no longer or truly represents a good quality level. This problem was observed with internal, external, appraisal, and prevention cost membership functions. The following calculations were performed to evaluate the quality component within Plants A and B.

Quality Index Model for Plant A

Q (Plant A, 2002) = 0.0021+ 0.0020+ 0.1830 + 0.1581 + 0.1665 + 0.0005 = 0.5121

Q (Plant A, 2003) = 0.0021 + 0.0020+ 0.1830 + 0.1583 + 0.1651+ 0.0005 = 0.5110

Q (Plant A, 2004) = 0.0021+ 0.0020+ 0.1830 + 0.1586 + 0.1638 + 0.0041 = 0.5136

Q (Plant A, 2005) = 0.0021 + 0.0020+ 0.1830 + 0.1578 + 0.1623 + 0.0000 = 0.5072

Quality Index Model for Plant B

Q (Plant B, 2003) = 0.0021+ 0.0020+ 0.1830 + 0.1558 + 0.1116 + 0.0559 = 0.5103

Q (Plant B, 2004) = 0.0021+ 0.0020+ 0.1830 + 0.1516 + 0.1065 + 0.0529 = 0.4981

Q (Plant B, 2005) = 0.0021+ 0.0020+ 0.1827 + 0.1580 + 0.1451 + 0.0503 = 0.5402

Q (Plant B, 2006) = 0.0021+ 0.0020+ 0.1773 + 0.1376 + 0.1468 + 0.0490 = 0.5148

#### *4.2.2.4 Quality Index Model Validation*

Table 43 was developed to group all the membership functions data or total value generated for each plant and year. The total quality index model values and the gold standard values were also included. The gold standard values were obtained from applying the cost of quality concept to evaluate Plants A and B because this approach has been traditionally used as the best way to measure overall quality within organizations.

Table 43 Quality Membership Function Values vs. Gold Standard for Plants A and B

| Location | Year | Prev. C | Appr. C | Inter. C | Exter. C | C. Satis | C. Loyal | TOTAL | Gold Standard |
|---|---|---|---|---|---|---|---|---|---|
| Plant A (02) | 2002 | 0.0021 | 0.0020 | 0.1830 | 0.1581 | 0.1665 | 0.0005 | 0.5121 | 0.3452 |
| Plant A (03) | 2003 | 0.0021 | 0.0020 | 0.1830 | 0.1583 | 0.1651 | 0.0005 | 0.5110 | 0.3453 |
| Plant A (04) | 2004 | 0.0021 | 0.0020 | 0.1830 | 0.1586 | 0.1638 | 0.0041 | 0.5136 | 0.3457 |
| Plant A (05) | 2005 | 0.0021 | 0.0020 | 0.1830 | 0.1578 | 0.1623 | 0.0000 | 0.5072 | 0.3449 |
| Plant B (03) | 2003 | 0.0021 | 0.0020 | 0.1830 | 0.1558 | 0.1116 | 0.0559 | 0.5103 | 0.3429 |
| Plant B (04) | 2004 | 0.0021 | 0.0020 | 0.1830 | 0.1516 | 0.1065 | 0.0529 | 0.4981 | 0.3387 |
| Plant B (05) | 2005 | 0.0021 | 0.0020 | 0.1827 | 0.1580 | 0.1451 | 0.0503 | 0.5402 | 0.3447 |
| Plant B (06) | 2006 | 0.0021 | 0.0020 | 0.1773 | 0.1376 | 0.1468 | 0.0490 | 0.5148 | 0.3190 |

This conversion was necessary in order to validate the quality index model developed within this research. The values obtained using the model developed within this research show many similar levels as the cost of quality approaches (COQ).

Table 44 Quality Model vs. Gold Standard Fuzzy Values for Plants A and B

| Location | Year | Quality Model | Gold Standard (COQ) |
|---|---|---|---|
| Plant A | 2002 | Medium | Medium |
| Plant A | 2003 | Medium | Medium |
| Plant A | 2004 | Medium | Medium |
| Plant A | 2005 | Medium | Medium |
| Plant B | 2003 | Medium | Medium |
| Plant B | 2004 | Medium | Medium |
| Plant B | 2005 | Medium | Medium |
| Plant B | 2006 | Medium | Low |

Table 45 shows the sensitivity, specificity, and accuracy calculations obtained in the validation process. The values obtained represent 100% sensitivity, 0% specificity, and 87.5% of accuracy.

Table 45 Sensitivity, Specificity, and Accuracy Values of Quality Model

| Gold Standard (COQ) | | | | |
|---|---|---|---|---|
| Quality Model | | True | False | |
| | Positive | TP = 7 | FP = 1 | 7/(7+1) = 87.5% |
| | Negative | FN = 0 | TN = 0 | 0/0 |
| | | Sensitivity 7/(7+0) = 100% | Specificity 0/1=0 | Accuracy 7/8 = 87.5% |

### 4.2.3 Employee Morale Index Model Formulation

An employee morale theory and model was proposed to holistically characterize the employee morale with two subcomponents: employee engagement and work environment. The Ferreras' Theory considers that every organization has a series of controllable employee morale factor variables which are based on the work environment created by the organization and a series of uncontrollable employee morale factor variables based on employee engagement, which is not influenced by the organization. Ferreras' Theory is similar to Herzberg's Theory which identified employee engagement factor variables as "motivators" and work environment factor variables as "Hygiene Factors." In addition, a prioritization approach was developed using the contingent valuation technique, which follows a cost/benefit analysis approach. One of the benefits of using the described technique was the ability to prioritize employee morale decisions based on employees' willingness to pay (WTP). A sample of the employee population was studied based on Ferreras' Theory (Table 46).

Table 46 Ferreras' Theory

| **Employee Engagement** | **Work Environment** |
|---|---|
| Commitment | Teamwork |
| Loyalty | Advancement Opportunities |
| Motivation | Recognition & Rewards |
| Enthusiasm | Compensation |
| Absenteeism | Training |
| Turnover | Open Communication |
| Involving | Supervisor Consultation |
| Belonging | Company Policies & Guidelines |
| Appreciation | Company Values |
| Empowerment | Work Flexibility (schedule, etc) |
| Trust | |

An employee morale survey was developed to measure and evaluate Ferreras' Theory variables represented Table 46. The purpose of the employee morale survey is to convert qualitative data, such as motivation level, to quantitative values using the 1-4 survey scale in combination with the WPT section in order to prioritize the employee morale decisions using the ROI approach.

The following mathematical model was formulated to represent the employee morale model or Ferreras' model:

Equation 8 Employee Morale

$$E.M(Plant, Year) = WE + EE$$

Where:

$WE$ - represents the "Work Environment" sub-component

$EM$ - represents the "Employee Morale" component

EE - represents the "Employee Engagement" sub-component

In order to obtain the identified employee morale subcomponents, the following mathematical equations were used:

Equation 9 Work Environment

$$W.E(Plant, Year) = (W_1 \times X_1) + (W_2 \times X_2) + (W_3 \times X_3) + (W_4 \times X_4) + (W_5 \times X_5) + (W_6 \times X_6) + (W_7 \times X_7) + (W_8 \times X_8) + (W_9 \times X_9) + (W_{10} \times X_{10})$$

Where (all units are included within Indicators/Metrics column in Table 3):

**WE** - represents the "Work Environment" sub-component

- $w_1$ - represents the weight of "Open Communication"
- $X_1$ – Level of "Open Line of Communication with Management"
- $w_2$ - represents the weight of "Recognition & Rewards"
- $X_2$ - Level of "Recognition & Rewards by Management"
- $w_3$ - represents the weight of "Advancement Opportunities"

- $X_3$ - Level of "Advancement Opportunities"
- $w_4$ - represents the weight of "Teamwork"
- $X_4$ - Level of "Teamwork"
- $w_5$ - represents the weight of "Compensation"
- $X_5$ - Level of "Compensation"
- $w_6$ - represents the weight of "Training"
- $X_6$ - Level of "Training Opportunities"
- $w_7$ - represents the weight of "Supervisory Consultation"
- $X_7$ - Level of "Comfortable Consulting Employee's Supervisor"
- $w_8$ - represents the weight of "Company Policies & Guidelines"
- $X_8$ - Level of "Fair Company Policies & Guidelines"
- $w_9$ - represents the weight of "Company Values"
- $X_9$ - Level of "Better Company Values within an organization"
- $w_{10}$ - represents the weight of "Work Flexibility"
- $X_{10}$ - Level of "More Work Flexibility"

Equation 10 Employee Engagement

$$E.E(Plant, Year) = (W_{11} \times X_{11}) + (W_{12} \times X_{12}) + (W_{13} \times X_{13}) + (W_{14} \times X_{14}) + (W_{15} \times X_{15}) + (W_{16} \times X_{16}) + (W_{17} \times X_{17}) + (W_{18} \times X_{18}) + (W_{19} \times X_{19}) + (W_{20} \times X_{20}) + (W_{21} \times X_{21})$$

Where (all units are included within Indicators/Metrics column in Table 3):

**EE** - represents the "Employee Engagement" sub-component

- $w_{11}$ - represents the weight of "Belonging"
- $X_{11}$ - Level of "Belonging to a Work Team/Work Family"

- $w_{12}$ - represents the weight of "Involving"
- $X_{12}$ - Level of "Involvement in Decision Making and Company Activities"
- $w_{13}$- represents the weight of "Enthusiasm"
- $X_{13}$ - Level of "Enthusiastic about your Job"
- $w_{14}$ - represents the weight of "Motivation"
- $X_{14}$ - Level of "Motivation"
- $w_{15}$ - represents the weight of "Commitment"
- $X_{15}$ - Level of "Commitment and Devotion to Work"
- $w_{16}$ - represents the weight of "Loyalty"
- $X_{16}$ - Level of "Loyal to the organization"
- $w_{17}$ - represents the weight of "Trust"
- $X_{17}$ - Level of "Trust in Management"
- $w_{18}$ - represents the weight of "Appreciation"
- $X_{18}$ - Level of "Appreciation by Supervisor"
- $w_{19}$ - represents the weight of "Empowerment"
- $X_{19}$ - Level of "Empowerment to Make Own Decisions"
- $X_{20}$ – Percentage of "Absenteeism"
- $w_{20}$ - represents the weight of "Absenteeism"
- $X_{21}$ – Percentage of "Turnover"
- $w_{21}$ - represents the weight of "Turnover"

#### *4.2.3.1 Weights*

Weights were obtained from the Expert Choice software after inputting the SME opinion (Figure 26). The pairwise comparison was performed in order to apply the AHP technique.

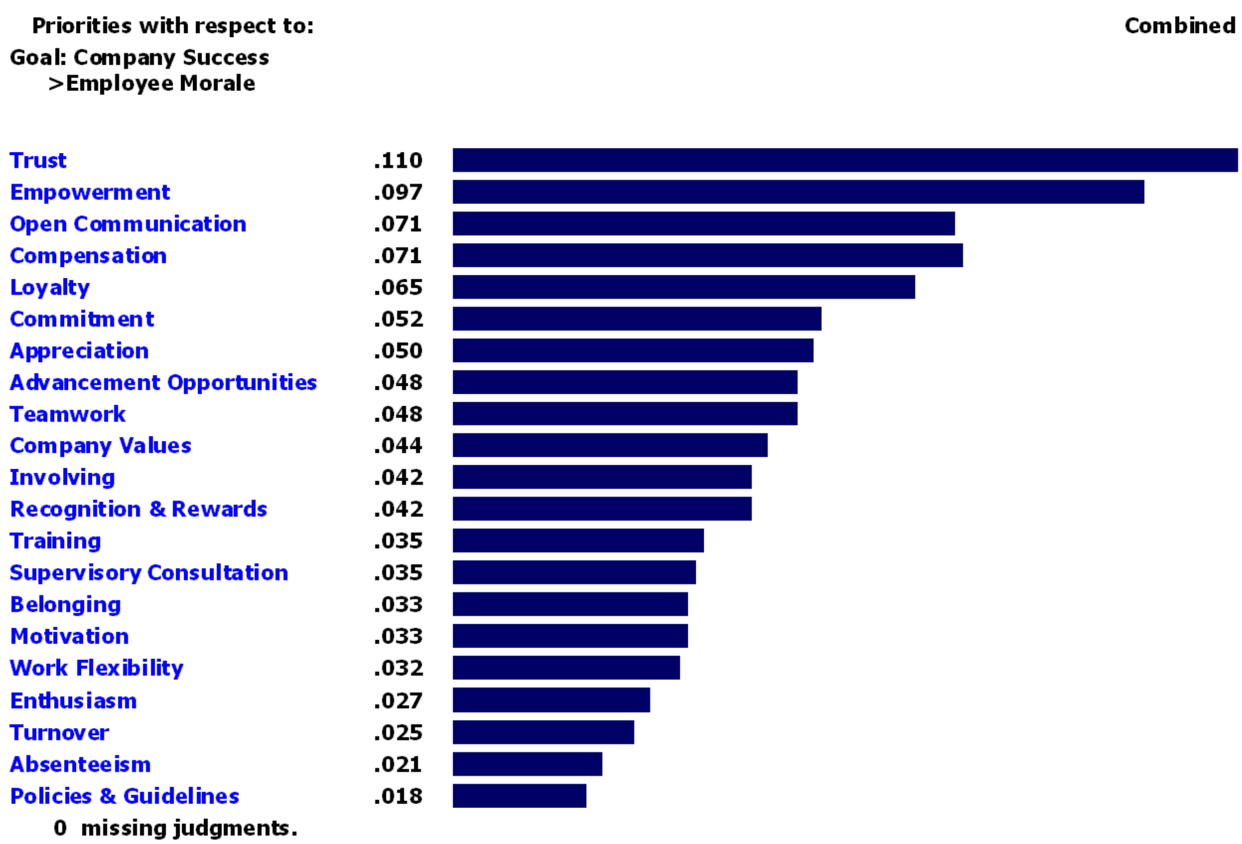


Figure 26 Employee Morale Index Model Weights

#### *4.2.3.2 Employee Morale Membership Functions*

There are twenty-one variables identified in the employee morale component, and these variables were collected using two approaches. First, historical data was obtained for two factors: absenteeism rate and turnover rate. Second, the other nineteen factor variables were collected using a employee morale survey developed in this research.

#### 4.2.3.2.1 Employee Morale Membership Functions – Employee Morale Survey

The employee morale survey was distributed with the permission of the HR manager and the plant manager in Plant A (Appendix C). The following list represents the prerequisites for survey participants:

- Males and Females
- Over the age of 18
- Workers from any department within the organization (especial emphasis is applied on manufacturing line work-force)
- Full-time employees with a minimum of 6 month seniority (to make sure the participant has been exposed to the organizational culture, and workplace environment)

The following graph represents the linear membership function obtained from the employee morale survey. A linear membership function was selected to represent all the factor variables obtained from the survey because the scale of the tool lends itself to representation with a linear model. The employee morale data obtained from Plant A is also represented in the following figure.

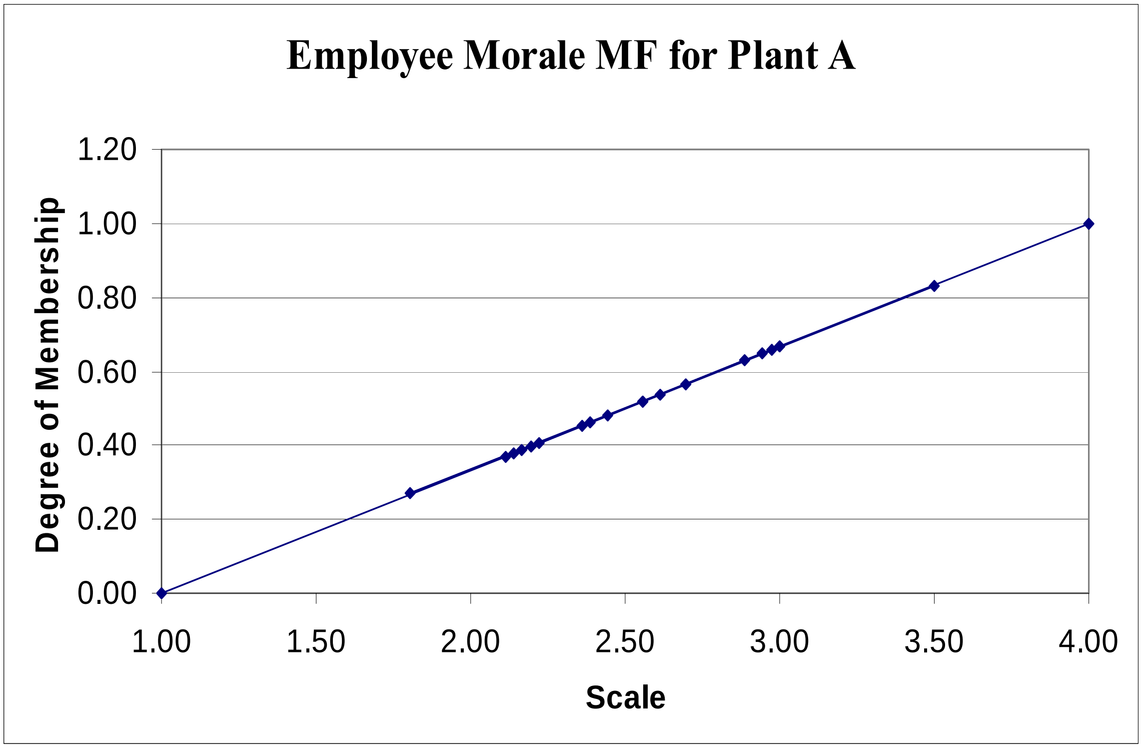



Figure 27 Employee Moral MF for Manufacturing Industry in Plant A

The lower and upper boundaries of the employee morale MF are scores of 1 and 4, respectively (Figure 27; Table 47). The previous graph shows when the employee scares 1 in the employee morale survey, the degree of membership is 0 so it barely belongs to the function; however, a score of 4 represents an employee that fully belongs to the organization since the 1 is the degree of membership.

Table 47 Employee Morale Survey Results in Plant A

| Subcomponent | Factor Variable | X – Employee Morale Level (0-1) | Y - Degrees of Membership | Total Value |
|---|---|---|---|---|
| Work Environment | Open Communication | 2.14 | 0.38 | 0.03 |
| | Recognition & Rewards | 2.44 | 0.48 | 0.02 |
| | Advancement Opportunities | 2.11 | 0.37 | 0.02 |
| | Teamwork | 2.89 | 0.63 | 0.03 |
| | Compensation | 2.36 | 0.45 | 0.03 |
| | Training | 2.17 | 0.39 | 0.01 |
| | Supervisory Consultation | 2.94 | 0.65 | 0.02 |
| | Company Policies & Guidelines | 2.39 | 0.46 | 0.01 |
| | Company Values | 2.61 | 0.54 | 0.02 |
| | Work Flexibility | 3 | 0.67 | 0.02 |
| | Belonging | 2.19 | 0.4 | 0.01 |
| Employee Engagement | Involvement | 1.81 | 0.27 | 0.01 |
| | Enthusiasm | 2.97 | 0.66 | 0.02 |
| | Motivation | 2.56 | 0.52 | 0.02 |
| | Commitment | 3.5 | 0.83 | 0.04 |
| | Loyalty | 3 | 0.67 | 0.04 |
| | Trust | 2.22 | 0.41 | 0.04 |
| | Appreciation | 2.69 | 0.56 | 0.03 |
| | Empowerment | 2.56 | 0.52 | 0.05 |

The WTP technique was used to generate a prioritization tool and assist organizational leaders or HR managers to make wiser decisions related to human capital. The following data can be used as a prioritization tool to enhance the results obtained from the employee morale survey. One of the advantages of using the following technique is that it allows company managers to identify the highest ROI decision based on employees' feedback. Table 48 presents the amount of money eighteen participants from Plant A were willing to give up in order to observe an improvement in the specified factor variable.

Table 48 Willingness to Pay for Plant A

| **Plant A - Willingness to Pay (% of Employees)** | | | | | |
|---|---|---|---|---|---|
| **Factor Variable** | **$0** | **$1** | **$5** | **$20** | **$50** |
| Belonging | 56% | 11% | 5% | 16% | 11% |
| Open Communication | 56% | 11% | 16% | 5% | 11% |
| Recognition & Rewards | 67% | 0% | 28% | 5% | 0% |
| Involvement | 72% | 11% | 5% | 5% | 5% |
| Enthusiasm | 67% | 11% | 5% | 11% | 5% |
| Advancement Opportunities | 56% | 11% | 16% | 11% | 5% |
| Motivation | 61% | 16% | 5% | 11% | 5% |
| Commitment | 67% | 22% | 5% | 5% | 0% |
| Loyalty | 72% | 11% | 0% | 11% | 5% |
| Trust | 72% | 16% | 0% | 5% | 5% |
| Appreciation | 72% | 11% | 5% | 0% | 11% |
| Empowerment | 61% | 22% | 11% | 0% | 5% |
| Teamwork | 78% | 5% | 11% | 5% | 0% |
| Compensation | 56% | 5% | 11% | 5% | 22% |
| Training | 61% | 5% | 22% | 5% | 5% |
| Supervisory Consultation | 72% | 5% | 11% | 5% | 5% |
| Company Policy & Guidelines | 72% | 5% | 11% | 5% | 5% |
| Company Values | 67% | 11% | 5% | 5% | 11% |
| Work Flexibility | 78% | 0% | 0% | 16% | 5% |

Figure 28 represents the linear membership function for employee morale and includes historical data obtained from Plant B. The following data was converted and fitted into the employee morale membership function based on the historical data gathered in 2003.

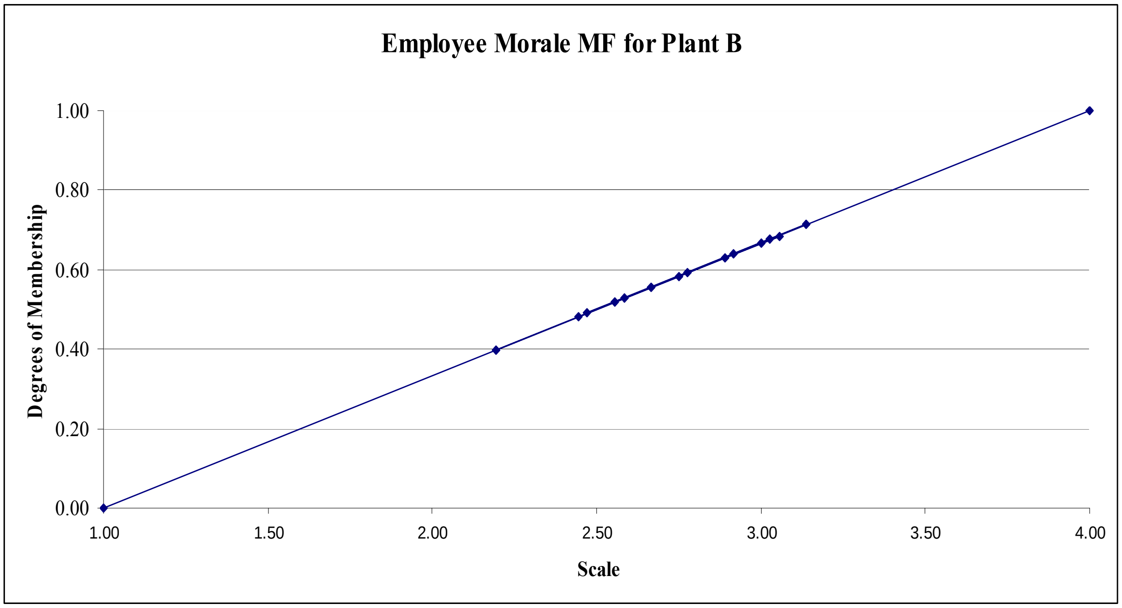



Figure 28 Employee Morale MF for Manufacturing Industry in Plant B

The lower and upper boundaries of the employee morale MF at Plant B are scores of 1 and 4, respectively (Figure 28; Table 49). The previous graph shows when the employee scares 1 in the employee morale survey, the degree of membership is 0 so it barely belongs to the function; however, a score of 4 represents an employee that fully belongs to the organization since the 1 is the degree of membership. This data was converted and fitted into Ferreras' model in order to validate the employee morale index model. In addition, the degrees of membership and the total value obtained from multiplying the weights by the degrees of membership are included as well.

Table 49 Employee Morale Survey Results in Plant B

| Subcomponent | Factor Variable | X - Employee Morale | Y - Degrees of Membership | Total Value |
|---|---|---|---|---|
| Work Environment | Open Communication | 3 | 0.67 | 0.05 |
| | Recognition & Rewards | 2.19 | 0.4 | 0.02 |
| | Advancement Opportunities | 2.56 | 0.52 | 0.02 |
| | Teamwork | 2.92 | 0.64 | 0.03 |
| | Compensation | 3.06 | 0.69 | 0.05 |
| | Training | 2.67 | 0.56 | 0.02 |
| | Supervisory Consultation | 2.44 | 0.48 | 0.02 |
| | Company Policies & Guidelines | 2.58 | 0.53 | 0.01 |
| | Company Values | 2.56 | 0.52 | 0.02 |
| | Work Flexibility | 2.58 | 0.53 | 0.02 |
| Employee Engagement | Belonging | 2.89 | 0.63 | 0.02 |
| | Involvement | 2.19 | 0.4 | 0.02 |
| | Enthusiasm | 2.75 | 0.58 | 0.02 |
| | Motivation | 3.03 | 0.68 | 0.02 |
| | Commitment | 3.14 | 0.71 | 0.04 |
| | Loyalty | 2.78 | 0.59 | 0.04 |
| | Trust | 2.67 | 0.56 | 0.06 |
| | Appreciation | 2.47 | 0.49 | 0.02 |
| | Empowerment | 3.14 | 0.71 | 0.07 |

Table 50 can be used as a prioritization technique in combination with the employee morale survey results in order to address the most important human capital necessities and invest wisely (best ROI) on improving the employee morale level within the organization.

Table 50 Willingness to Pay for Plant B

| Plant B - Willingness to Pay (% of Employees) | | | | | |
|---|---|---|---|---|---|
| **Factor Variable** | **$0** | **$1** | **$5** | **$20** | **$50** |
| Belonging | 56% | 11% | 5% | 16% | 11% |
| Open Communication | 61% | 5% | 16% | 5% | 11% |
| Recognition & Rewards | 72% | 0% | 22% | 5% | 0% |
| Involvement | 72% | 11% | 5% | 5% | 5% |
| Enthusiasm | 67% | 11% | 5% | 16% | 0% |
| Advancement  Opportunities | 56% | 11% | 16% | 16% | 0% |
| Motivation | 67% | 16% | 0% | 11% | 5% |
| Commitment | 67% | 22% | 5% | 5% | 0% |
| Loyalty | 72% | 11% | 0% | 11% | 5% |
| Trust | 72% | 16% | 0% | 5% | 5% |
| Appreciation | 72% | 11% | 5% | 0% | 11% |
| Empowerment | 61% | 22% | 11% | 0% | 5% |
| Teamwork | 78% | 5% | 11% | 5% | 0% |
| Compensation | 56% | 5% | 11% | 5% | 22% |
| Training | 61% | 5% | 22% | 5% | 5% |
| Supervisory Consultation | 72% | 5% | 11% | 5% | 5% |
| Company Policies & Guidelines | 72% | 0% | 16% | 0% | 11% |
| Company Values | 67% | 11% | 5% | 5% | 11% |
| Work Flexibility | 78% | 0% | 0% | 16% | 5% |

#### 4.2.3.2.2 Absenteeism Rate Membership Function

An extended literature review was performed to find an absenteeism scale to develop a MF, but only historical data was found for the manufacturing industry. Historical data was obtained from a Bureau of Labor Statistics report entitled “Labor Turnover or Total Separations, 2006”, and was used to develop the absenteeism MF (Figure 29).

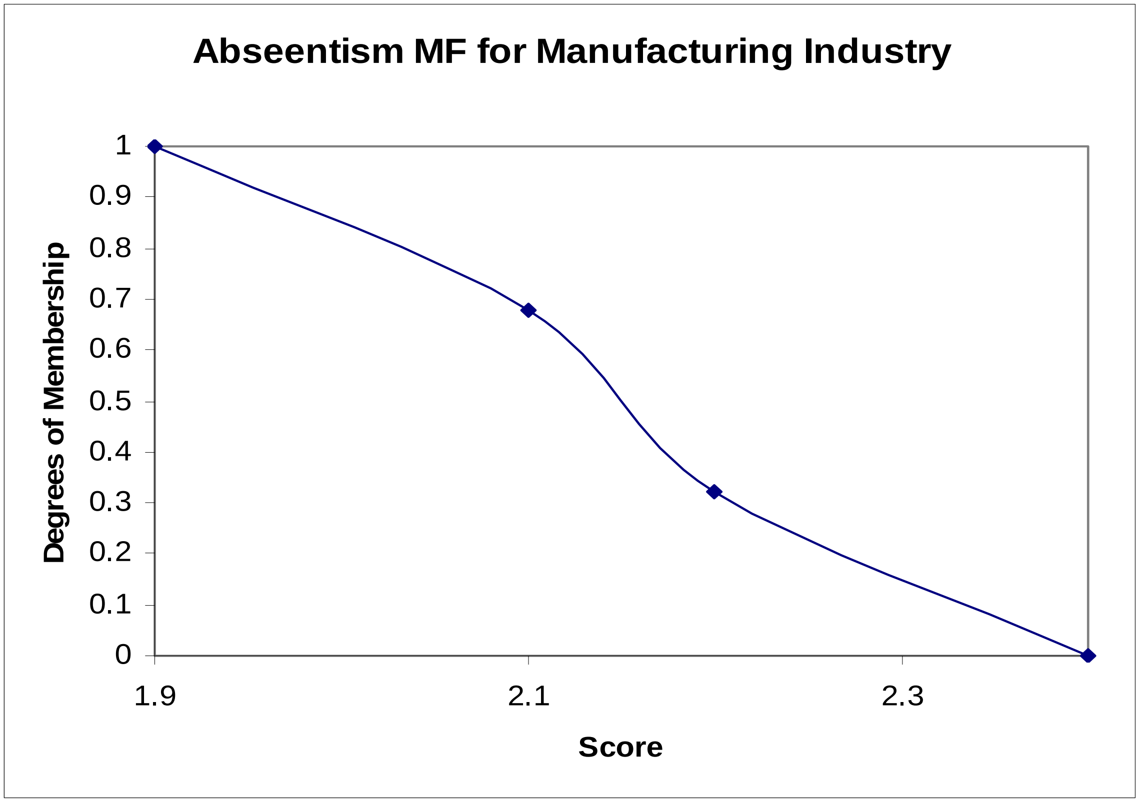



Figure 29 Absenteeism Membership Function

The lower and upper boundaries of the Absenteeism MF are 2.4 and 1.9% absenteeism, respectively (Figure 29; Table 51). The previous graph shows when the absenteeism rate is 2.4%, the degree of membership is 0 so it barely belongs to the function; however, a 1.9% represents an absenteeism rate that fully belongs to the membership function (1 degree of membership). This membership function represents the absenteeism rate for the manufacturing industry.

Table 51 Absenteeism Membership Function Values for the Manufacturing Industry (BLS, 2006).

| Year | X-Absenteeism Rate | Y-Degrees of Membership |
|---|---|---|
| 2001 | 2.2 | 0.32 |
| 2002 | 2.1 | 0.68 |
| 2003 | 1.9 | 1 |
| 2004 | 2.4 | 0 |

Table 52 represents the absenteeism rate observed in facilities A and B, which was utilized to validate the employee morale index model developed within this research.

Table 52 Absenteeism Membership Function Values for Plants A and B

| Data Source | X-Absenteeism Rate | Y-Degrees of Membership | Total Value |
|---|---|---|---|
| Plant A | 4.80 | 0 | 0 |
| Plant A | 5.00 | 0 | 0 |
| Plant A | 5.00 | 0 | 0 |
| Plant A | 5.00 | 0 | 0 |
| Plant A | 7.00 | 0 | 0 |
| Plant B | 6.35 | 0 | 0 |
| Plant B | 7.46 | 0 | 0 |
| Plant B | 7.8 | 0 | 0 |
| Plant B | 7.95 | 0 | 0 |

4.2.3.2.3 Turnover Membership Function

The U.S Department of Labor publishes the labor turnover or total separations annually with monthly figures, and this report was selected to develop the turnover MF. No scale was found, but historical data was used from this report to develop Figure 30 (BLS, 2006).

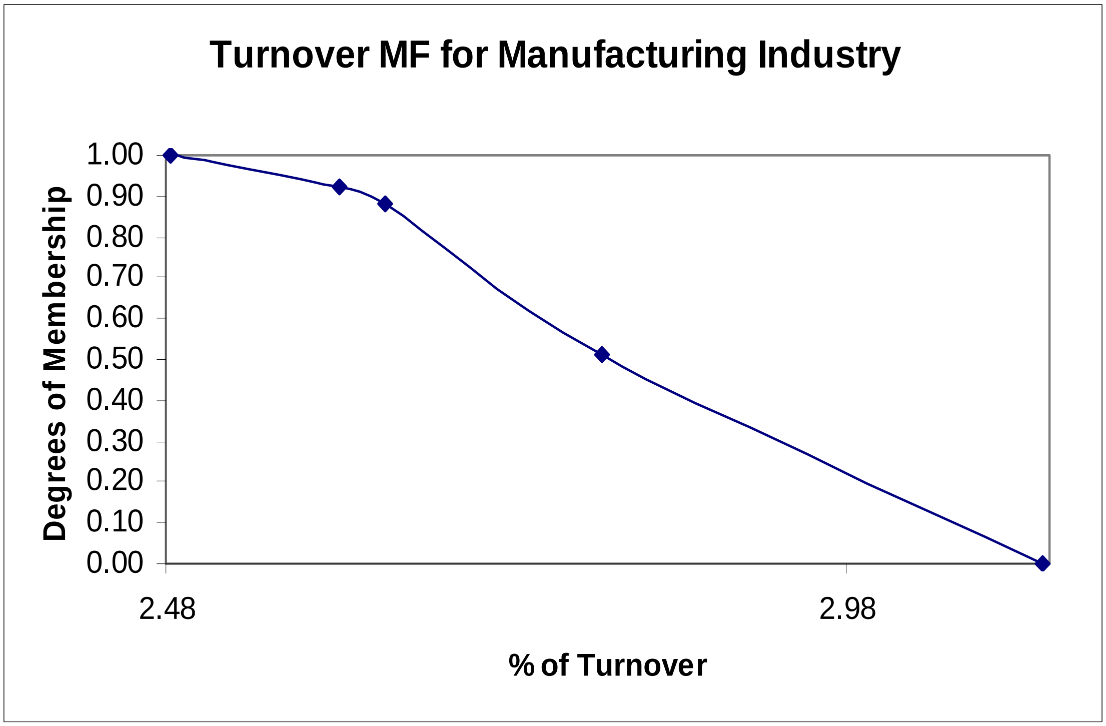



Figure 30 Turnover Membership Function

The lower and upper boundaries of the absenteeism MF are 3.13 and 2.48% turnover, respectively (Figure 30; Table 53).The previous graph shows when the turnover rate is 3.13%, the degree of membership is 0 so it barely belongs to the function; however, a 2.48% represents a turnover rate that fully belongs to the membership function (1 degree of membership). Table 53 presents a point of reference for the manufacturing industry, and it can be used by other organizations to evaluate their turnover performance vs. the industry average.

Table 53 Turnover Membership Function Values for the Manufacturing Industry

| Turnover Rate | X-Degrees of Membership |
|---|---|
| 2.48 | 1.00 |
| 2.48 | 1.00 |
| 2.61 | 0.92 |
| 2.64 | 0.88 |
| 2.80 | 0.51 |
| 3.13 | 0.00 |

Table 54 presents the turnover data collected over Plants A and B, which was used to validate the employee morale index model. Therefore, the turnover rate values were fitted into the MF to identify their degrees of membership as well as the total value which is represented by a multiplication of the Y-values and the weights.

Table 54 Turnover Membership Function Values for Plants A and B

| Data Source | X-Turnover Rate | Y-Degrees of Membership | Total Value |
|---|---|---|---|
| Plant A | 8.10 | 0.00 | 0.00 |
| Plant A | 9.20 | 0.00 | 0.00 |
| Plant A | 11.00 | 0.00 | 0.00 |
| Plant A | 15.30 | 0.00 | 0.00 |
| Plant A | 23.00 | 0.00 | 0.00 |
| Plant B | 7.4 | 0.00 | 0.00 |
| Plant B | 8.1 | 0.00 | 0.00 |
| Plant B | 9.4 | 0.00 | 0.00 |
| Plant B | 11.2 | 0.00 | 0.00 |

#### *4.2.3.3 Employee Morale Index Model*

Table 55 presents the data collected in Plants A and B. This is the only model that suffers from a limited amount of data collected. Unfortunately, this component was never measured or evaluated before in detail; therefore, more data should be collected in the future.

Table 55 Employee Morale Survey Results in Plants A & B

| **Location** | **Plant A** | **Plant B** |
|---|---|---|
| **Year** | **2005** | **2003** |
| Absenteeism | 0 | 0 |
| Turnover | 0 | 0 |
| Open Communication | 0.03 | 0.05 |
| Recognition & Rewards | 0.02 | 0.02 |
| Advancement Opportunities | 0.02 | 0.02 |
| Teamwork | 0.03 | 0.03 |
| Compensation | 0.03 | 0.05 |
| Training | 0.01 | 0.02 |
| Supervisory Consultation | 0.02 | 0.02 |
| Company Policies & Guidelines | 0.01 | 0.01 |
| C. Values | 0.02 | 0.02 |
| Work Flexibility | 0.02 | 0.02 |
| Belonging | 0.01 | 0.02 |
| Involvement | 0.01 | 0.02 |
| Enthusiasm | 0.02 | 0.02 |
| Motivation | 0.02 | 0.02 |
| Commitment | 0.04 | 0.04 |
| Loyalty | 0.04 | 0.04 |
| Trust | 0.04 | 0.06 |
| Appreciation | 0.03 | 0.02 |
| Empower. | 0.05 | 0.07 |
| **TOTAL (Ferreras' Model)** | **0.47** | **0.57** |
| E. Morale value for C. Success Model | 0.04606 | 0.05586 |

#### *4.2.3.4. Employee Morale Index Model Validation*

A Great Place to Work was used as the gold standard to validate the employee morale model developed or Ferreras' model. Levering stated that "A Great Place to

Workplace for" is defined by an employee as: 'trust the employer, have pride on the job performed, and enjoy the coworkers". A Great Place to Work approach was applied within this research by using a checklist that reviews the characteristics of the best companies to work (Levering, 1988). The checklist was developed based on the following four categories: employment, job, workplace rules, and the stake in success. A Great Place to Work checklist is included within Appendix H, but a snapshot is shown in Table 56.

Table 56 A Great Place to Work Checklist

| **Checklist for a Great Place to Work** | | | |
|---|---|---|---|
| **Basic Terms of Employment** | **The Job** | **Workplace Rules** | **Stake in Success** |
| 1. Fair pay and benefits: a) compare well with similar employers b) square with company's ability to pay | 4. Maximizes individual responsibility for how job is done | 7. Reduces social and economic distinctions between management and other employees | 13. Shares rewards from productivity improvements |
| 2. Commitment to job security | 5. Flexibility about working hours | 8. Right to due process | 14. Shares profits |
| 3. Commitment to safe and attractive working environment | 6. Opportunities for growth:<br>a) promotes from within<br>b) provides training<br>c) recognizes mistakes as part of learning | 9. Right to information | 15. Shares ownership |
| | | 10. Right to free speech | 16. Shares recognition |
| | | 11. Right to confront those in authority | |
| | | 12. Right not to be part of the family | |

The gold standard results obtained are shown in Table 57. The Great Place to Work checklist was used to evaluate Plant A and B, and assist in the validation process.

| 0 | 0.25 | 0.5 | 0.75 | 1 |
|---|---|---|---|---|
| **Not @ All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

Table 57 Great Place to Work Gold Standard Values for Plant A and B

| **Employee Morale Assessment** | | |
|---|---|---|
| **Question** | **Plant A** | **Plant B** |
| 1 | 0.25 | 0.5 |
| 2 | 0.75 | 0.75 |
| 3 | 1 | 0.75 |
| 4 | 0.5 | 0.75 |
| 5 | 0.75 | 0.5 |
| 6 | 0.5 | 0.75 |
| 7 | 0.5 | 0.75 |
| 8 | 0.5 | 0.75 |
| 9 | 0.25 | 0.75 |
| 10 | 0.25 | 0.75 |
| 11 | 0.25 | 0.75 |
| 12 | 0.25 | 0.5 |
| 13 | 0.5 | 0.25 |
| 14 | 0.5 | 0.5 |
| 15 | 0.5 | 0.5 |
| 16 | 0.25 | 0.25 |
| **TOTAL** | **0.46875** | **0.609375** |

Table 58 presents the employee morale level obtained in different years and facilities, and the gold standard level observed. After performing an extensive literature review, the 100 Best Companies to Work For index was used as a gold standard.

Therefore, a comparison between Ferreras' Model and the 100 Best Companies to Work for Index Model was performed.

Table 58 Employee Morale or Ferreras' Model vs. Gold Standard Fuzzy Values for Plant A & B

| Location | Year | Ferreras' Model | Gold Standard (Great Place to Work) |
|---|---|---|---|
| Plant A | 2002 | Medium | Medium |
| Plant A | 2003 | Medium | Medium |
| Plant A | 2004 | Medium | Medium |
| Plant A | 2005 | Medium | Medium |
| Plant B | 2003 | Medium | Medium |
| Plant B | 2004 | Medium | Medium |
| Plant B | 2005 | Medium | Medium |
| Plant B | 2006 | Medium | Medium |

Table 59 shows the sensitivity, specificity, and accuracy calculation performed over the employee morale index model developed. The results represent that a successful Employee Morale model was developed.

Table 59 Sensitivity, Specificity, and Accuracy Values of Employee Morale Model

| Gold Standard (Great Place to Work) | | | | |
|---|---|---|---|---|
| Quality Model | | True | False | |
| | Positive | TP = 8 | FP = 0 | 8/8 = 100% |
| | Negative | FN = 0 | TN = 0 | 0/0 |
| | | Sensitivity 8/(8+0) = 100% | Specificity 0/0 | Accuracy 8/8 = 100% |

## 4.3 Membership Functions for Company Success Components

The purpose of this section is to discuss in detail the development of profit, productivity, and efficiency membership functions and the process followed to identify the performance of Plant A and B within these areas. Profit, productivity, and efficiency did not need the development of fuzzy index models since these company success components have been modeled deterministically in the past. In other words, deterministic models currently exist to measure and analyze performance of these areas within manufacturing applications. Therefore, the purpose of developing membership functions for the following components is to convert their data into fuzzy terminology in order for all components to be in equal form in the overall company success index model.

### 4.3.1 Profit Membership Function

A profit membership function was developed for manufacturing industries based on historical data obtained through an extensive literature review. Table 60 presents the seasonally adjusted net income after tax average of 8,400 U.S. manufacturing corporations based on the U.S. Department of Commerce report entitled “Quarterly Financial Report for Manufacturing, Mining, and Trade Corporations: 2006” (U.S. Census Bureau, 2006). The industry average or X-values and the corresponding degrees of membership or Y-values necessary to develop profit membership function are included. Profit is commonly characterized by a deterministic model which is represented by Revenue minus Expenses; a membership function was developed to represent this component.

Equation 11 Profit

$$\text{Pr}\,ofit\left(Plant\,,Year\,\right) = \text{Re}\,venue\ -\ Expenses$$

Where (all units are included within Indicators/Metrics column in Table 3):

Profit (Plant, Year) = Profit membership function

Revenue = Sales (annually)

Expenses = which entails following factor variables: Labor, Material, Variable Overhead, Fixed Overhead, Variable Cost, Income Tax, Legal Fees, and R & D Expenses

A Sigmoidal membership function was selected to reflect the profit component (Figure 31). The smaller the Profit amount, the lower is the degree of membership that represents the fuzzy set. Degree of membership increases as profit increases.

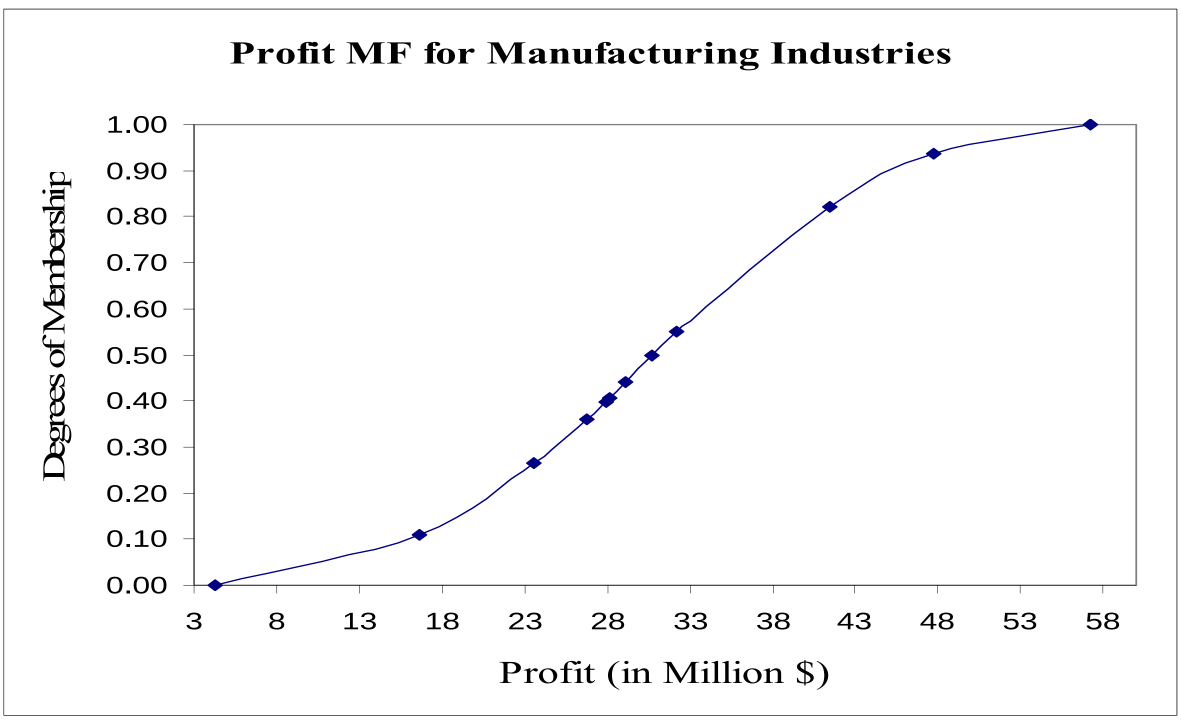



Figure 31 Profit Membership Function

The lower and upper boundaries of the profit MF are $4.29M and $57.24M profit, respectively (Figure 31; Table 60).The previous graph shows when the cost is $4.29M, the degree of membership is 0 so it barely belongs to the function; however, $57.24 cost fully belong to the membership function since the degree of membership is 1. Table 60 presents the average, maximum, and minimum values obtained from the industry data, and these values provide a good summary of the developed membership function.

Table 60 Profit Membership Function Values for the Manufacturing Industry (U.S. Census Bureau, 2006).

| Year | X - Profit per Organization (in million $) | Y - Degrees of Membership |
|---|---|---|
| 1995 | 23.61 | 0.27 |
| 1996 | 26.80 | 0.36 |
| 1997 | 29.14 | 0.44 |
| 1998 | 27.93 | 0.40 |
| 1999 | 30.71 | 0.50 |
| 2000 | 32.17 | 0.55 |
| 2001 | 4.29 | 0 |
| 2002 | 16.66 | 0.11 |
| 2003 | 28.18 | 0.41 |
| 2004 | 41.41 | 0.82 |
| 2005 | 47.73 | 0.94 |
| 2006 | 57.24 | 1.00 |
| **Average** | **30.49** | **.5** |
| **Max** | **57.24** | **1** |
| **Min** | **4.29** | **0** |

Table 61 presents all the profit data collected over Plant A. The original profit characterization approach was developed for a profit center (Figure 5 and Table 3); this approach was not applied within Plant A because this site is a cost center. Therefore, this plant is managed with an allocated budget based on a forecasting model used by the subsidiary's headquarter. Consequently, the profit component characterization was adapted to a budgetability approach in order to avoid accuracy issues by appropriately validating the profit model.

Table 61 Profit Data from Plant A

| **Subcomp.** | **Factor Variable** | **2002** | **2003** | **2004** | **2005** |
|---|---|---|---|---|---|
| **Revenue** | Sales | $89,255,457 | $95,164,838 | $97,210,700 | $116,748,863 |
| **Expenses** | Labor | $3,966,841 | $4,346,313 | $4,988,984 | $5,785,441 |
| | Material | $38,932,943 | $40,983,172 | $42,433,426 | $52,058,829 |
| | Var. O/H | $5,081,634 | $5,633,951 | $5,340,723 | $6,306,243 |
| | Fixed O/H | $5,571,857 | $6,135,467 | $5,563,287 | $5,898,804 |
| | Var. Cost | $47,981,417 | $50,963,436 | $52,763,133 | $64,150,514 |
| | Income Tax | $3,878,532 | $3,736,103 | $4,308,780 | $5,993,600 |
| | Legal Fees | $1,650,000 | $1,870,000 | $2,296,000 | $3,080,000 |
| | R & D Expenses | $1,652,434 | $1,696,950 | $1,740,909 | $1,576,122 |

Table 62 presents the summarized data obtained from Plant A such as total revenue and expenses as well as the overall annual profit of Plant A.

Table 62 Summarized Profit Data from Plant A

| **Year** | **2002** | **2003** | **2004** | **2005** |
|---|---|---|---|---|
| Revenue | $89,255,457 | $95,164,838 | $97,210,700 | $116,748,863 |
| Expenses | $60,734,240 | $64,401,956 | $66,672,109 | $80,699,040 |
| **Profit** | **$28,521,217** | **$30,762,882** | **$30,538,591** | **$36,049,823** |

The profit values obtained from Plant A were plotted in the X-axis within the profit membership function in order to identify the corresponding Y-values or the degrees of membership within the fuzzy set. Table 63 presents the profit values or X-values and the corresponding degrees of membership or Y-values within the Profit membership function. In addition, the total value which represents the multiplication of the degrees of membership by the weights obtained by AHP method was included.

Table 63 Profit Membership Function Values for Plant A

| **Year** | **X – Profit (M $)** | **Y - Degrees of Membership** | **Total Value** |
|---|---|---|---|
| 2002 | 28.5 | 0.42 | 0.1397 |
| 2003 | 30.5 | 0.49 | 0.1637 |
| 2004 | 30.8 | 0.50 | 0.1666 |
| 2005 | 36 | 0.68 | 0.2265 |

Table 64 presents all the profit data collected over Plant B. This plant is a cost center; therefore, a budgetability approach has been applied to this site as well.

Table 64 Profit Data from Plant B

| Data Collection Sheet for Factor Variables of PROFIT | | | | | | |
|---|---|---|---|---|---|---|
| **Subcomp.** | **Factor Variables** | **2002** | **2003** | **2004** | **2005** | **2006** |
| **Revenue** | Sales | $87,702,081 | $108,123,975 | $115,634,267 | $140,804,357 | $107,616,354 |
| **Expenses** | Labor | $5,830,646 | $6,662,875 | $7,865,005 | $10,055,279 | $9,484,963 |
| | Material | $59,171,530 | $67,151,500 | $70,430,497 | $90,930,194 | $94,961,479 |
| | Var. O/H | $1,221,253 | $8,762,331 | $9,900,780 | $10,640,997 | $9,895,246 |
| | Fixed O/H | $5,480,083 | $6,362,835 | $5,906,512 | $6,110,756 | $7,881,411 |
| | Var. Cost | $72,247,292 | $88,939,588 | $93,826,574 | $117,085,725 | $122,221,000 |
| | Income Tax | $1,008,579 | $615,139 | $2,636,452 | $5,097,067 | $7,411,914 |
| | Legal Fees | $902,836 | $1,334,400 | $1,959,261 | $2,556,348 | $2,642,192 |
| | R & D Expenses | $1,809,648 | $1,917,682 | $2,116,946 | $2,620,607 | $2,289,640 |

Table 65 presents the summarized data obtained from Plant B which includes total revenue and expenses as well as the overall annual profit of Plant B.

Table 65 Summarized Profit Data from Plant B

| **Year** | **2002** | **2003** | **2004** | **2005** | **2006** |
|---|---|---|---|---|---|
| Revenue | $87,702,081 | $108,123,975 | $115,634,267 | $140,804,357 | $107,616,354 |
| Expenses | $81,448,438 | $99,169,644 | $106,445,745 | $133,470,503 | $142,446,157 |
| **Profit** | **$6,253,643** | **$8,954,331** | **$9,188,522** | **$7,333,854** | **($34,829,803)** |

Table 66 presents the profit values or X-values and the corresponding degrees of membership or Y-values within the Profit membership function for Plant B. In addition, the total value that represents the multiplication of the degrees of membership by the weights obtained by AHP method was included.

Table 66 Profit Membership Function Values for Plant B

| Plant B | X - Profit (M $) | Y - Degrees of Membership | Total Value |
|---|---|---|---|
| 2002 | 6.3 | 0.02 | 0.0081 |
| 2003 | 9 | 0.05 | 0.0165 |
| 2004 | 9.2 | 0.05 | 0.0173 |
| 2005 | 7.3 | 0.03 | 0.0109 |
| 2006 | -35 | 0 | 0 |

### 4.3.2 Productivity Membership Function

An extended literature review was performed to identify productivity data from the manufacturing industry. Several options were found: labor productivity measured by output per worker; multifactor productivity, measured by economic growth; efficiency improvements; returns to scale; and reallocation of resources (Bureau of Labor Statistics, 2006). However, the annual average capacity utilization of manufacturing plants was selected as the appropriate measure to evaluate the productivity component. The U.S. Department of Commerce report entitled "Survey of Plant Capacity" provides the desired data based on 17,000 manufacturing organizations feedback with a 90% confidence level (U.S. Census Bureau, 2007). The following equation was used to calculate the production percentage (Capacity Utilization):

Equation 12 Production

$$\Pr oduction(Plant, Year) = \Pr oductionVolume / (\Pr oductionVolume + Back\log)$$

Where (all units are included within Indicators/Metrics column in Table 3):

Production (Plant, Year) = Production Membership Function or Capacity Utilization

Production Volume = amount of units produced

Backlog = amount of units never built

Figure 32 presents the developed membership function for productivity. A sigmoidal membership function was selected to characterize the productivity component.

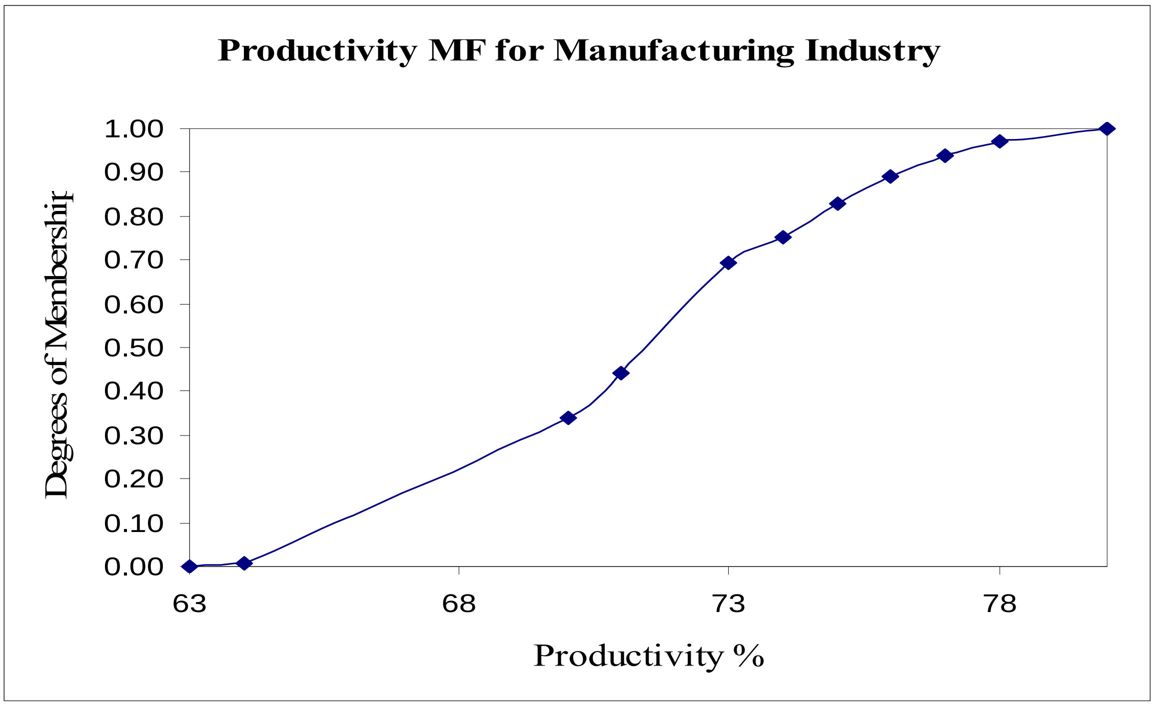



Figure 32 Productivity Membership Function

The lower and upper boundaries of the productivity MF are 63 and 80%, respectively (Figure 32; Table 67). The previous graph shows when the productivity rate is 63, the degree of membership is 0 so it barely belongs to the function; however, 80% productivity rate fully belongs to the membership function since the degree of membership is 1.

Table 67 Productivity Membership Function Values for the Manufacturing Industry (U.S. Census Bureau, 2007)

| **Year** | **X - Productivity % (Capacity Utilization)** | **Y – Degrees of Membership** |
|---|---|---|
| 1989 | 78 | 0.97 |
| 1990 | 77 | 0.94 |
| 1991 | 77 | 0.94 |
| 1992 | 77 | 0.94 |
| 1993 | 78 | 0.97 |
| 1994 | 80 | 1 |
| 1995 | 76 | 0.89 |
| 1996 | 76 | 0.89 |
| 1997 | 75 | 0.83 |
| 1998 | 73 | 0.69 |
| 1999 | 74 | 0.75 |
| 2000 | 71 | 0.44 |
| 2001 | 64 | 0.01 |
| 2002 | 63 | 0 |
| 2003 | 64 | 0.01 |
| 2004 | 70 | 0.34 |
| 2005 | 71 | 0.44 |
| **Average** | **73.2** | **.5** |
| **Max** | **80** | **1** |
| **Min** | **63** | **0** |

Table 68 presents all the productivity data collected over Plant A, which was used to evaluate the productivity level within this site.

Table 68 Productivity Data from Plant A

| **Subcomp.** | **Factor Variable** | **2002** | **2003** | **2004** | **2005** |
|---|---|---|---|---|---|
| **Output** | Production Volume | 43,174 units | 45,805 units | 49,011 units | 52,740 units |
| | Delivery | 60.3% | 61.0% | 61.70% | 60.10% |
| | Backlog | 6,300 units | 10,263 units | 5,334 units | 8,391 units |
| **Input** | Suppliers | 86% | 82% | 80% | 78% |

Even though all the data from the previous table was collected, only production volume and backlog was used to calculate the capacity utilization of Plant A. Therefore, production volume was divided by summation of the amount of units produced and the backlog or amount of units never built (Table 69).

Table 69 Summarized Productivity Data from Plant A

| **Year** | **2002** | **2003** | **2004** | **2005** |
|---|---|---|---|---|
| **Capacity Utilization (Productivity Rate)** | 87% | 82% | 90% | 86% |

Table 70 presents the capacity utilization from the manufacturing industry or X-values, and degrees of membership or Y-values of Plant A. The total value is based on the multiplication of degrees of membership and the weights obtained from AHP.

Table 70 Productivity Membership Function Values for Plant A

| **Year** | **X - Productivity % (Capacity Utilization)** | **Y - Degrees of Membership** | **Total Value** |
|---|---|---|---|
| 2002 | 87 | 1 | 0.1630 |
| 2003 | 82 | 1 | 0.1630 |
| 2004 | 90 | 1 | 0.1630 |
| 2005 | 86 | 1 | 0.1630 |

Table 71 presents all the productivity data collected over Plant B, which was used to calculate the productivity level.

Table 71 Productivity Data from Plant B

| Subcomp. | Factor Variable | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| **Output** | Production Volume | 274,889 units | 303,273 units | 359,291 units | 334,393 units |
| | Delivery | 65% | 65% | 60.47% | 56.79% |
| | Backlog | 7,752 units | 22,321 units | 7,761 units | 6,855 units |
| **Input** | Suppliers | 80% | 85% | 80% | 90% |

Even though all the data from the previous table was collected, only production volume and backlog was used to calculate the capacity utilization of Plant B (Table 72).

Table 72 Summarized Productivity Data from Plant B

| Year | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|
| **Capacity Utilization (Productivity Rate)** | 97 | 93 | 98 | 98 |

Table 73 presents the productivity percentage or X-values, degrees of membership or Y-values, and the total value obtained by multiplying the degrees of membership by the weights.

Table 73 Productivity Membership Function Values for Plant B

| Year | X - Productivity % (Capacity Utilization) | Y - Degrees of Membership | Total Value |
|---|---|---|---|
| 2003 | 97 | 1 | 0.1630 |
| 2004 | 93 | 1 | 0.1630 |
| 2005 | 98 | 1 | 0.1630 |
| 2006 | 98 | 1 | 0.1630 |

#### 4.3.3 Efficiency Membership Function

An extended literature review was performed in order to identify an efficiency scale to develop the efficiency membership function. The following equation represents the efficiency calculation performed.

Equation 13 Efficiency

$$Efficiency\,(Plant\,,Year\,) = Labor\ + Material\ + Energy\ + \Pr oductionCa\ pability$$
$$+ (1 - Defects\,) + \operatorname{Re} cycle\ + (1 - Downtime\,) + (1 - Inventorie\ s)$$

Where (all units are included within Indicators/Metrics column in Table 3):

Efficiency (Plant, Year) = Efficiency Membership Function

Labor = Expected Labor Cost / Actual Labor Cost

Material = Expected Material Cost / Actual Material Cost

Energy = Expected Energy Cost / Actual Energy Cost

Production Capability = Maximum Manpower x (Production Volume/Total No. of Employees)

Defects = Defect percentage

Recycle = recycle recovery/total waste

Downtime = % of downtime

Inventories = % of inventory turnover

Overall plant efficiency scale was identified by a couple of subject matter experts to be the same as labor efficiency. Therefore, Table 74 presents the efficiency scale used to develop this component membership function which was represented by a Sigmoidal MF.

Table 74 Efficiency Industry Scale

| Industry Scale | Efficiency % |
|---|---|
| Low | 65-79 |
| Medium | 80-85 |
| High | 86-100 |

Figure 33 presents the efficiency membership function which is characterized by a sigmoidal MF; it was developed using the efficiency scale obtained from SME.

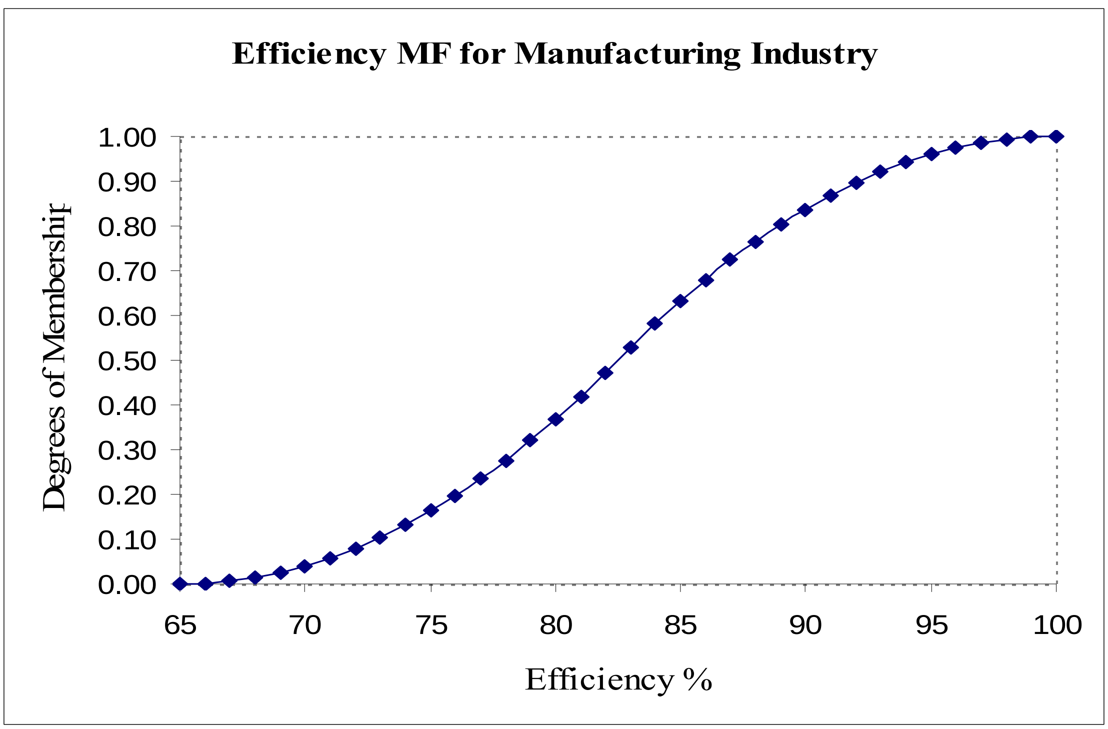



Figure 33 Efficiency Membership Function

The lower and upper boundaries of the efficiency MF are 65 and 100%, respectively (Figure 9=33; Table 75). The previous graph shows when the efficiency percentage is 65, the degree of membership is 0 so it barely belongs to the function; however, 100% efficiency fully belongs to the membership function since the degree of membership is 1.

Table 75 Efficiency Membership Function Values for the Manufacturing Industry

| **X - Efficiency %** | **Y - Degrees of Membership** |
|---|---|
| 65 | 0.00 |
| 70 | 0.04 |
| 75 | 0.16 |
| 80 | 0.37 |
| 81 | 0.42 |
| 82 | 0.47 |
| 83 | 0.53 |
| 84 | 0.58 |
| 85 | 0.63 |
| 90 | 0.84 |
| 95 | 0.96 |
| 100 | 1.00 |
| **Average- 82.5** | **.5** |
| **Min.- 65** | **0** |
| **Max.- 100** | **1** |

Tables 76 and 77 present the efficiency data collected over Plant A. All the metrics were expressed in ratios in order to be easily combined for model validation. Some factor variables, such as defects, downtime, and inventory, were subtracted from 1 in order to be appropriately included in the overall efficiency calculation.

Table 76 Efficiency Data from Plant A

| Subcomp. | Factor Variable | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|
| **Resource** (ONLY direct cost) | Labor | 0.99 | 0.95 | 0.93 | 0.89 |
| | Material | 1.03 | 1.00 | 1.03 | 0.91 |
| | Energy | 1.06 | 1.16 | 1.08 | 0.89 |
| | Production Capability | 0.85 | 0.85 | 0.83 | 0.84 |
| **Waste** (ONLY direct cost) | Defects | 1-0.11=.89 | 1-0.105=.89 | 1-0.104=.90 | 1-0.065=.93 |
| | Recycle | 0.937 | 1.04 | 1.641 | 1.47 |
| | Downtime | 1-0.1=.9 | 1-0.1=.9 | 1-0.1=.9 | 1-0.1=.9 |
| | Inventories | 1-0.175=.82 | 1-0.185=.81 | 1-0.239=.76 | 1-0.245=.76 |

Table 77 Summarized Efficiency Data from Plant A

| Year | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|
| **% of Efficiency** | 97% | 100% | 100% | 100% |

Table 78 presents the efficiency percentage or X-values and the corresponding degrees of membership or Y-values, as well as the total value obtained from multiplying the degrees of membership by the weights. The total values were obtained by multiplying the degrees of membership by the SME weights generated through the AHP. The purpose of calculating the total values is to fit them within company success model.

Table 78 Efficiency Membership Function Values for Plant A

| Plant A | Efficiency % | Degrees of Membership | Total Value |
|---|---|---|---|
| 2002 | 97 | 0.99 | 0.0995 |
| 2003 | 100 | 1.00 | 0.1010 |
| 2004 | 100 | 1.00 | 0.1010 |
| 2005 | 100 | 1.00 | 0.1010 |

Tables 79 and 80 present the data collected in Plant B. As observed, factor variables, such as defects, downtime, and inventories, were subtracted from 1 in order to be appropriately included within the efficiency calculation.

Table 79 Efficiency Data from Plant B

| **Subcomp.** | **Factor Variable** | **2003** | **2004** | **2005** | **2006** |
|---|---|---|---|---|---|
| Resource (ONLY direct cost) | Labor | 0.81 | 0.72 | 0.79 | 0.91 |
| | Material | 0.82 | 0.69 | 0.68 | 0.94 |
| | Energy | 0.85 | 0.92 | 0.82 | 1.22 |
| | Production Capability | 0.69 | 0.67 | 0.93 | 0.91 |
| Waste (ONLY direct cost) | Defects | 1-0.13=.87 | 1-0.149=.85 | 1-0.112=.89 | 1-0.1323=.87 |
| | Recycle | 0.616 | 1.224 | 1.038 | 1.4507 |
| | Downtime | 1-0.018=.98 | 1-0.018=.98 | 1-0.045=.96 | 1-0.037=.96 |
| | Inventories | 1-0.1028=.9 | 1-0.1105=.89 | 1-0.1307=.87 | 1-0.1171=.88 |

The following table represents the overall percentage of efficiency obtained from averaging all the factor variable values.

Table 80 Summarized Efficiency Data from Plant B

| **Year** | **2002** | **2003** | **2004** | **2005** |
|---|---|---|---|---|
| Efficiency % | 76% | 85% | 85% | 100% |

Table 81 presents the percentage of efficiency or X-values, the degrees of membership or Y-values, and the total values generated by multiplying the degrees of membership by the weights.

Table 81 Efficiency Membership Function Values for Plant B

| Plant B | Efficiency % | Degrees of Membership | Total Value |
|---|---|---|---|
| 2003 | 76 | 0.20 | 0.0200 |
| 2004 | 85 | 0.63 | 0.0639 |
| 2005 | 85 | 0.63 | 0.0639 |
| 2006 | 100 | 1.00 | 0.1010 |

# CHAPTER FIVE: CONCLUSION

This research has generated a company success index model for manufacturing enterprises that utilizes organizational performance measures. Organizational performance measures such as profit, productivity, efficiency, quality, employee morale, and ergonomics and safety were combined to generate an overall organizational model, which will enhance the decision-making process for leaders within manufacturing industries. The proposed methodology or approach provides an organizational measurement system ready to be benchmarked by any manufacturing organization (independently of unions). In addition, this research has identified and developed a reliable model for quantifying quality, employee morale, ergonomics and safety, and company success which enhances the prediction and control of these critical areas within an organization. Furthermore, this research has created a series of reliable tools, methods, and techniques that can be readily used by organizational leaders and operational managers to augment their decision making in a highly dynamic environment. Additionally, non-linear models have been created to appropriately characterize constantly changing organizational environments consisting of large amounts of qualitative and quantitative data. Thus, the organizational success index model and methodology developed in this research will provide organizational managers with a systematic approach to analyze complex decisions impacting company performance and business strategy. Furthermore, all the developed models may be used as a comparison tool for any manufacturing facility interested in evaluating their organizational performance against the industry average among various manufacturing enterprises. The company success index model was developed using three membership functions describing profit, productivity, and efficiency as well as three fuzzy index models characterizing ergonomics and safety, quality, and employee morale.

The membership functions provided an exceptional mapping approach to fit industry average data without losing important information that traditional modeling techniques would have eliminated or not taken into account. Components such as profit, productivity, and efficiency have been modeled in previous research; therefore, it was not necessary to develop fuzzy models for the purpose of this research. However, it was necessary to develop membership functions to appropriately combine these components with factors of quality, employee morale, and ergonomics and safety. Using membership functions to successfully combine all the company success components was necessary to ensure that the corresponding degree of membership was identified for each component within the fuzzy model: degrees of membership (0-1 range). Furthermore, additive modeling was applied to combine the individual component models to determine an aggregate value for company success. The relative weights of each individual component obtained from applying AHP to SME opinions were multiplied by degrees of membership obtained from the membership functions and developed models.

The company success index model results were compared to the gold standard currently used by industries, which in this case is the market share position of the organization within the U.S market. Market share from JP Morgan reports was selected as the gold standard to evaluate company success since this is the primary goal of any organization. Previously developed organizational performance measure models, tools, and approaches considered company success to be highly dependable and solely represented by the organization's strategy. The reality is that no matter how much variation exists between different organizations, the main goal of any company is to become the market leader. The resulting research model was validated considering information on market share (Specificity = 0%, Sensitivity & Accuracy = 87.5%). The company success index created in this research was 87% accurate in determining company success in the manufacturing plants analyzed in the study.

After performing an extended literature review in ergonomics and safety, no deterministic model was found to exist that evaluated and combined factor variables such as annual replacement cost (extra wages generated by an injury, illness, or accident), lost work-day cases, OSHA fines, OSHA recordable cases, workers' compensation expenses, and proactive ergonomics activities to present an overall aggregate describing ergonomics and safety; therefore, an ergonomics and safety model was developed within this research. Additive mathematical operands were applied to combine all the ergonomics and safety membership functions and develop the mathematical model. The ergonomics and safety model was validated (sensitivity = 87.5%, specificity = 0%) and the resulting model was 87 % accurate in representing the ergonomics and safety level of manufacturing organizations.

Furthermore, after performing an extended literature review on quality, the cost of quality model was identified as the most appropriate approach to characterize and evaluate quality. The cost of quality model consists of four cost factor variables: prevention, appraisal, internal failure, and external failure. A holistic approach was created to characterize organizational level quality in this research by adding new factor variables such as customer satisfaction and customer loyalty. A successful quality index model was developed and validated (100% sensitivity, 0% specificity, and 87.5% accuracy); the resulting model was 87% accurate in representing the level of quality in a manufacturing organization.

Also, an employee morale index model was developed and an employee morale survey created. The index model includes an organizational decision aspect, the WTP prioritization technique ready to be used by H.R managers or corporate leaders to make wiser ROI human capital decisions. After performing an extensive literature review on employee morale, the 100 Best Companies to Work For index was used as a gold standard for model comparison. Therefore, a comparison between the Ferreras' Model and the 100 Best Companies to Work For Index Model was performed. This model was validated (sensitivity = 100%, specificity = 0%, and accuracy = 100%). This research effort has produced a valid overall company success index as well as individual models describing level of employee morale, quality, and ergonomics and safety that can be implemented to augment decision making in manufacturing organizations.

## 5.0 Contributions to the Body of Knowledge

Company success was characterized by profit, productivity, efficiency, quality, employee morale, and ergonomics and safety components which affect overall manufacturing enterprises. The combined effect of these components was obtained through mathematical modeling capable of integrating sixty-four metrics with different units. Company success was characterized and reliable models were generated to assist organizational managers and leaders making wiser decisions in complex situations. Furthermore, a company success index model was developed to assess and predict organizational performance in manufacturing organizations. Lastly, this research effort provides tools, methods, and techniques to measure and assess organizational performance measures in manufacturing organizations such as the organizational leader questionnaire, and employee morale survey. This research generated a reliable company success index model ready to be benchmarked by other manufacturing organizations.

## 5.1 Example Applying Research to an Existing Manufacturing Organization

The methodology and approach developed in this research can be applied to any manufacturing enterprise, independent of the type of product manufactured. To illustrate how this methodology and approach can be applied, an example has been generated based on the Boeing Company. If Boeing wanted to implement this research methodology, this organization would have to complete steps 5.2.1 to 5.2.6

### Step 1 - Taxonomies Development/Key Organizational Performance Measures

The first step is to develop taxonomies for all the company success components (profit, productivity, efficiency, quality, employee morale, and ergonomics and safety) to be evaluated. The taxonomies characterize components, subcomponents, and factor variables affecting organizational success in the aerospace manufacturing industry. In addition, key organizational performance measures or metrics should be identified using various techniques, such as a literature review and subject matter experts. Moreover, SMEs from the aerospace industry should be used to validate the taxonomies developed within the Boeing application. A table similar to Table 3 should be developed, since indicators and metrics are critical to appropriately measure and evaluate all the models created.

**Step 2 - Identify Data Collection Tools, Methods, and Techniques (as shown in page 32)**

Existing tools, methods, and techniques currently in place at the Boeing company should be evaluated to identify historical data that can be obtained for the use in model creation. The organizational leader questionnaire should be administered to Boeing executives to facilitate the organizational performance measures data collection process. The organizational leader questionnaire was developed initially to identify the organizational decision making challenges and to improve current performance measures system, and to enhance the success of the organization (Appendix A).

Furthermore, the plant manager questionnaire developed should be sent along with a version of Table 3 (modified for the aerospace manufacturing industry) to the plant manager or operations manager. This step is critically important since this research has been developed for the strategic, tactical, and operational level; a connection between these three organizational levels must be identified. Also, this research step is important in identifying the key performance measures currently used and the tools utilized to collect the historical data. The plant manager questionnaire developed is included in Appendix B.

**Step 3 - Data Collection**

Information about the manufacturing plants to be included in the model generator within the study should be obtained at this point of the process. A glossary of terms needs to be developed to avoid any misunderstanding of the key performance measures and metrics identified, as well as to enhance the success and accuracy of the data collection process. Also, data collection sheets shown in Appendix D should be provided to facilitate the data collection process within the manufacturing plants.

**Step 4 - Model Development per Company Success Component Using Fuzzy Set Theory (as shown in pages 37-46)**

The following concepts and techniques must be considered within this research step:

- Literature review must be performed in order to find industry data from the aerospace manufacturing industry. The more historical data found, the more accurate the index model will be. Otherwise, SMEs will have to provide data based on their expert opinions.
- The development of membership functions is a key part of developing FST models. The MFs should be developed based on the data obtained from the literature review or SMEs.
- Utilize an Analytical Hierarchy Process (AHP) to identify the weights to be used for the various factor variables within the index models; SMEs must fill out the form included in Appendix F. A pair-wise comparison exercise must be developed for use with the SMEs in order to run an AHP analysis. The weights can be obtained after inputting the SMEs feedback into Expert Choice. The inconsistency ratio must be observed to assure that the SMEs judgments were consistent. The following equations are examples of membership functions for models developed in this research.

Equation 14 Profit

$$\Pr ofit\left(Plant, Year\right) = \mathrm{Re}\, venue - Expenses$$

Where (all units are included within Indicators/Metrics column in Table 3):

Profit (Plant, Year) = Profit membership function

Revenue = Sales (annually)

Expenses = which entails following factor variables: Labor, Material, Variable Overhead, Fixed Overhead, Variable Cost, Income Tax, Legal Fees, and R & D Expenses. The following equation represents productivity.

Equation 15 Productivity

$$\Pr oduction\left(Plant, Year\right) = \Pr oductionVo\ lume / \left(\Pr oductionVo\ lume + Back\ \log\right)$$

Where (all units are included within Indicators/Metrics column in Table 3):

Production (Plant, Year) = Production Membership Function or Capacity Utilization

Production Volume = amount of units produced

Backlog = amount of units never built. The following membership function represents efficiency.

Equation 16 Efficiency

$$Efficiency\left(Plant, Year\right) = Labor + Material + Energy + \Pr oductionCa\ pability + (1 - Defects) + \mathrm{Re}\, cycle + \left(1 - Downtime\right) + \left(1 - Inventorie\ s\right)$$

Where (all units are included within Indicators/Metrics column in Table 3):

Efficiency (Plant, Year) = Efficiency Membership Function

Labor = Expected Labor Cost / Actual Labor Cost

Material = Expected Material Cost / Actual Material Cost

Energy = Expected Energy Cost / Actual Energy Cost

Production Capability = Maximum Manpower x (Production Volume/Total No. of Employees)

Defects = Defect percentage

Recycle = recycle recovery/total waste

Downtime = % of downtime

Inventories = % of inventory turnover. The following model represents ergonomics and safety

Equation 17 Ergonomics and Safety Model

$$E.S(Plant, Year) = (W_{WW} \times WW) + (W_{LWDC} \times LWDC) + (W_{OSHA} \times OSHA) + (W_{II} \times II) + (W_{PE} \times PE) + (W_{WC} \times WC)$$

Where (all units are included within Indicators/Metrics column in Table 3):

$E.S$ = Ergonomics and Safety Value per Plant, Year

$W_{WW}$ = Replacement Cost Weight

$WW$ = Replacement Cost Degrees of Membership

$W_{LWDC}$ = Lost Work-Day Cases Weight

$LWDC$ = Lost Work-Day Cases Degrees of Membership

$W_{OSHA}$ = OSHA Fines Weight

$OSHA$= OSHA Fines Degrees of Membership

$W_{II}$ = OSHA Injury & Illness Weight

$II$ = OSHA Injury & Illness Degrees of Membership

$W_{PE}$ = Proactive Ergonomics Weight

$PE$ = Proactive Ergonomics Degrees of Membership

$W_{WC}$ = Workers' Compensation Weight

$WC$ = Workers' Compensation Degrees of Membership.

The following model represents quality.

Equation 18 Quality Model

$$Q(Plant, Year) = (W_{PC} \times PC) + (W_{AC} \times AC) + (W_{IC} \times IC) + (W_{EC} \times EC) + (W_{CS} \times CS) + (W_{CL} \times CL)$$

Where (all units are included within Indicators/Metrics column in Table 3):

Wpc = Prevention Cost Weight

PC = Prevention Cost Degrees of Membership

Wac = Appraisal Cost Weight

AC = Appraisal Cost Degrees of Membership

Wic = Internal Failure Cost Weight

IC = Internal Failure Cost Degrees of Membership

Wec = External Failure Cost Weight

EC = External Failure Cost Degrees of Membership

Wcs = Customer Satisfaction Cost Weight

CS = Customer Satisfaction Cost Degrees of Membership

Wcl = Customer Loyalty Cost Weight

CL = Customer Loyalty Cost Degrees of Membership.

The following model represents employee morale.

Equation 19 Employee Morale Model

$$E.M\left(Plant, Year\right) = WE + EE$$

Where:

EM - represents the "Employee Morale" component

WE - represents the "Work Environment" sub-component

EE - represents the "Employee Engagement" sub-component

In order to obtain the identified employee morale subcomponents, the following mathematical equations were used:

Equation 20 Work Environment

$$W.E\left(Plant, Year\right) = \left(W_1 \times X_1\right) + \left(W_2 \times X_2\right) + \left(W_3 \times X_3\right) + \left(W_4 \times X_4\right) + \left(W_5 \times X_5\right) + \left(W_6 \times X_6\right) + \left(W_7 \times X_7\right) + \left(W_8 \times X_8\right) + \left(W_9 \times X_9\right) + \left(W_{10} \times X_{10}\right)$$

Where (all units are included within Indicators/Metrics column in Table 3):

**WE** - represents the "Work Environment" sub-component

- $w_1$ - represents the weight of "Open Communication"
- $X_1$ – Level of "Open Line of Communication with Management"
- $w_2$ - represents the weight of "Recognition & Rewards"
- $X_2$ - Level of "Recognition & Rewards by Management"
- $w_3$ - represents the weight of "Advancement Opportunities"
- $X_3$ - Level of "Advancement Opportunities"
- $w_4$ - represents the weight of "Teamwork"
- $X_4$ - Level of "Teamwork"

- $w_5$ - represents the weight of "Compensation"
- $X_5$ - Level of "Compensation"
- $w_6$ - represents the weight of "Training"
- $X_6$ - Level of "Training Opportunities"
- $w_7$ - represents the weight of "Supervisory Consultation"
- $X_7$ - Level of "Comfortable Consulting Employee's Supervisor"
- $w_8$ - represents the weight of "Company Policies & Guidelines"
- $X_8$ - Level of "Fair Company Policies & Guidelines"
- $w_9$ - represents the weight of "Company Values"
- $X_9$ - Level of "Better Company Values within an organization"
- $w_{10}$ - represents the weight of "Work Flexibility"
- $X_{10}$ - Level of "More Work Flexibility"

Equation 21 Employee Engagement

$$E.E(Plant, Year) = (W_{11} \times X_{11}) + (W_{12} \times X_{12}) + (W_{13} \times X_{13}) + (W_{14} \times X_{14}) + (W_{15} \times X_{15}) + (W_{16} \times X_{16}) + (W_{17} \times X_{17}) + (W_{18} \times X_{18}) + (W_{19} \times X_{19}) + (W_{20} \times X_{20}) + (W_{21} \times X_{21})$$

Where (all units are included within Indicators/Metrics column in Table 3):

**EE** - represents the "Employee Engagement" sub-component

- $w_{11}$ - represents the weight of "Belonging"
- $X_{11}$ - Level of "Belonging to a Work Team/Work Family"
- $w_{12}$ - represents the weight of "Involving"
- $X_{12}$ - Level of "Involvement in Decision Making and Company Activities"
- $w_{13}$- represents the weight of "Enthusiasm"
- $X_{13}$ - Level of "Enthusiastic about your Job"

- $w_{14}$ - represents the weight of "Motivation"
- $X_{14}$ - Level of "Motivation"
- $w_{15}$ - represents the weight of "Commitment"
- $X_{15}$ - Level of "Commitment and Devotion to Work"
- $w_{16}$ - represents the weight of "Loyalty"
- $X_{16}$ - Level of "Loyal to the organization"
- $w_{17}$ - represents the weight of "Trust"
- $X_{17}$ - Level of "Trust in Management"
- $w_{18}$ - represents the weight of "Appreciation"
- $X_{18}$ - Level of "Appreciation by Supervisor"
- $w_{19}$ - represents the weight of "Empowerment"
- $X_{19}$ - Level of "Empowerment to Make Own Decisions"
- $X_{20}$ – Percentage of "Absenteeism"
- $w_{20}$ - represents the weight of "Absenteeism"
- $X_{21}$ – Percentage of "Turnover"
- $w_{21}$ - represents the weight of "Turnover"

**Step 5 - Company Success Index Model (as shown in pages 46-47)**

Combining all the critical success factor variables that affect the overall company success (profit, productivity, efficiency, ergonomics and safety, quality, and employee morale) was essential to generate an index capable of measuring relative performance of company success. The following company success index model could be benchmarked by other aircraft manufacturing organizations, and assist others to continuously improve organizational performance and achieve business excellence.

Equation 22 Company Success Index Model

$$Company.Success(Plant,Year) = (Wp \times Profit) + (Wpr \times Productivity)$$
$$+ (We \times Efficiency) + (Wq \times Quality) + (Wes \times Ergo.Safety)$$
$$+ (Wem \times Employee.Morale)$$

Where (weights do have units and the rest of the variables are represented by degrees of membership):

Company Success (Plant, Year) = Company Success Index Model

Wp = weight of Profit component

Profit = Profit membership function

Wpr = weight of Productivity component

Productivity = Productivity membership function

We = weight of Efficiency component

Efficiency = Efficiency membership function

Wq = weight of Quality component

Quality = Quality Index Model

Wes = weight of Ergonomics and Safety component

Ergonomics and Safety = Ergonomics and Safety Index Model

Wem = weight of Employee Morale

Employee Morale = Employee Morale Index Model. The weights are obtained from applying AHP to SMEs opinions such as figure 11.

**Step 6 - Company Success Index Model Validation (as shown in pages 47-50)**

Sensitivity, specificity, and accuracy calculations must be performed to validate all the models. Gold standards must be identified and linguistic scales must be developed to appropriately validate all the index models. Accuracy, specificity, and sensitivity formulas (equation 1, 2, and 3) should be used to make the appropriate calculations.

## 5.2 Future Research

Future studies may be performed to expand validation efforts of models created in this research. Based on the limited time frame, the proposed models have been initially validated (two plants in this study); however, a larger amount of data from different manufacturing industries or plants can assist with a more extensive validation approach. Additionally, data from high-risk industries can be used to further validate the ergonomics and safety models created, since the data used to validate these models was obtained from a low-risk-type industry. Additionally, Ferreras' employee morale model needs to be farther validated by increasing the number of participants surveyed from different manufacturing industries.

Within a 1-3 year time horizon and with additional expertise, this research could be expanded upon to create a forecasting and optimization model for overall company success. Such models will provide organizational leaders with tools to not only predict, but also use time associated variables and probabilities to optimize decision-making using organizational constraints. Finally, future research efforts could focus on using the Central Limit Theorem (CLT) to determine range levels for classifying the output of the index models such as employee morale, ergonomics and safety, quality, and company success.   As described in this research study, linguistic modeling was used to develop categories to appropriately interpret the results.

# APPENDIX A – ORGANIZATIONAL LEADER QUESTIONNAIRE

*Instructions:* An organizational leader should fill out this questionnaire. Please include the job description along with your answers.

1. What type of organizational decisions you most frequently encounter?

2. How are your decisions the majority of the times? Please, assign a percentage to the following categories: (simple vs. complex, expected vs. unexpected, etc)

   a. Simple_____%
   b. Complex _____%
   c. Expected_____%
   d. Unexpected_____%
   e. Have enough information_____%
   f. Do not have enough information_____%
   g. Other:_______________________________________________________

3. What are the external and uncontrollable forces that affect organizational decisions?

4. Would you use something else besides your experience to make organizational decisions? Y N

5. What type of organizational decisions would you like help with?

   a. Daily decisions
   b. Monthly decisions
   c. Annually decisions
   d. Other:_______________________________________________________

6. What organizational decisions are the most challenging?

   a. The ones related with employees
   b. The ones that must be made without having all the information
   c. The ones that must be made having too much information
   d. Other:_______________________________________________________

7. What type of information would you need to make more appropriate organizational decisions?

8. What is the importance that each component has in making organizational decisions? Please, prioritize them (considering *1-most important* and *6-least important*).

   a. Profit
   b. Productivity
   c. Efficiency

d. Quality
e. Safety & Ergonomics
f. Employee Morale

9. Do you determine the importance of each component or are they determined by your immediate supervisor?

10. What is the most stressful factor when you have to make an organizational decision?

*Comments and Suggestions:* (if you consider there is any additional information which would help me design a decision tool that fits your necessities, please express your comments/suggestions in this section). Thank you for your valuable time and consideration!

# APPENDIX B – PLANT MANAGER QUESTIONNAIRE

*Instructions:* The plant manager or operations manager should fill out this questionnaire with the assistance of managers in charge of the following areas: profit (accounting manager), productivity (production manager), efficiency (demand forecasting manager), quality (quality manager), ergonomics and safety (safety and ergonomics managers), and employee morale (human resources manager).

1. Have the following components been measured at your plant? (Y/N)
    a. Profit
    b. Productivity
    c. Efficiency
    d. Employee Morale
    e. Safety
    f. Ergonomics
    g. Quality

2. Have the following subcomponents been measured at your plant? (Y/N)
    a. Revenue
    b. Expenses
    c. Output (Production performance)
    d. Input (Suppliers performance)
    e. Resource (Resource efficiency)
    f. Waste (Waste efficiency)
    g. Work Environment
    h. Employee's Engagement
    i. Customer Satisfaction
    j. Quality Management & Control
    k. Ergonomics and Safety Management & Control

3. How do you evaluate employee's safety and ergonomics? Do you use any key performance measures identified within Table 4, such as OSHA recordable, etc?

4. How do you evaluate quality within your organization? Do you use any key performance measures identified within Table 4, such as rework %, etc?

5. How do you evaluate plant's efficiency? Do you use any key performance measures identified within Table 4, such as production capability, etc?

6. How do you evaluate plant's productivity? Do you use any key performance measures identified within Table 4, such as production volume, etc?

7. How do you evaluate employee's morale within your plant? Do you use any key performance measures identified within Table 4, such as absenteeism rate, employee's motivation, etc?

8. Do you offer professional development training and learning opportunities to your workers?

9. What type of audits do you perform (ISO 9001, OSHA audits, etc)?

10. Do you have a union in your plant? If Yes, explain how's working out?

11. Do you have continuous improvement activities in your plant (Six-Sigma, Lean activities, etc)? Please, explain.

11. Do you perform customer satisfaction surveys, and customer loyalty studies?

12. Have you ever measured the employee's morale level within your plant? If so, how?

# APPENDIX C – EMPLOYEE MORALE SURVEY

Department: __________________ Sex: M F Age: _______ Seniority: _____

This Employee Morale assessment tool has been designed to reveal what's your Employee Morale level based on a couple of areas: "Work Environment" and "Employee Engagement." Please mark your response to each of the questions below using the following scale:

Always = 4 points
Usually = 3 points
Sometimes = 2 points
Rarely = 1 points

---

**Belonging**

____ 1. I feel a part of "the (Company Name) family"

____ 2. I am treated more as a partner/team member than as an employee.

Is "feeling as if you belong to a work team/work family" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to have the "feeling of belonging to a work team/work family"?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Open Communication**

____ 3. Information is openly shared between management and employees.

____ 4. Management gives all of the information I need to perform my job tasks.

Is "having an open line of communication with management" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to have "an open line of communication with management"?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Recognition & Rewards**

____ 5. At (Company Name), we are rewarded for our performance and for striving to achieve excellence.

____ 6. My supervisor recognizes the extra effort and actions I do to perform the best job at (Company Name).

Is "being recognized and rewarded by management" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to be "recognized and rewarded by management"?

0-----------------1-------------------5-------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Involving**

____ 7. My opinion is listened to by management when making decisions involving my work tasks.

____ 8. I am involved in (Company Name) extra-curricular activities such as sporting teams, etc.

Is "being involved in decision making" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much are you willing to sacrifice out of your paycheck per year to "become more involved in decision making and company activities"?

0-----------------1-------------------5-------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Enthusiasm**

____ 9. I find my work interesting and fulfilling.

____ 10. I feel like a contributor to (Company Name) success.

Is "being enthusiastic about your job" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much are you willing to sacrifice out of your paycheck per year to "become more enthusiastic about your job"?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Advancement Opportunities**

____ 11. (Company Name) provides plenty of opportunities for personal growth.

____ 12. (Company Name) provides technical training so that I can advance in my career.

Is "being provided with advancement opportunities" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to be "provided with more advancement opportunities"?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Motivation**

____ 13. At my department, the motivation level is <u>moderate to high</u> on a daily basis.

____ 14. My work gives me a feeling of personal accomplishment.

Is "feeling motivated" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to feel "more motivated"?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Commitment**

____ 15. I am dedicated to improving my performance every day.

____ 16. I am devoted to the work tasks assigned.

Is "being committed to work" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to feel “more committed and devoted to work”?

0-----------------1-------------------5-------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Loyalty**

____ 17. I am proud of being a (Company Name) employee.

____ 18. I would like to grow and achieve my career goals within (Company Name).

Is “being loyal to (Company Name)” an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to become “more loyal to (Company Name)”?

0-----------------1-------------------5-------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Trust**

____ 19. I believe (Company Name) has high level of ethics.

____ 20. I trust top management’s integrity.

Is “being able to trust management” an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to have “more trust in management”?

0-----------------1-------------------5-------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Appreciation**

____ 21. My supervisor always listens to my suggestions.

____ 22. My supervisor always shows appreciation for every extra effort I put into my work.

Is “being appreciated by your supervisor” an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to be "more appreciated by your supervisor"?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Empowerment**

____ 23. My manager gives me enough opportunities to take an active role as a leader.

____ 24. My job gives me enough opportunities and independence to use my skills and abilities to make my own decisions.

Is "being empowered to make your own decisions" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to be "more empowered to make your own decisions"?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Teamwork**

____ 25. People within my group or department cooperate with each other rather than compete.

____ 26. My supervisor encourages teamwork and cooperation to achieve targeted goals.

Is "working in teams" an important factor for you to achieve High Employee Morale? Yes or No (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to have more "teamwork"?
0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Compensation**

____ 27. I am satisfied with my wages.

____ 28. I would prefer working based on performance rather than for hourly rates or salary.

Is "being compensated" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to have "more compensation"?

0-----------------1------------------5------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Training**

____ 29. My employer provides plenty resources and training opportunities.

____ 30. (Company Name) facilitates ongoing training to upgrade my skills.

Is "being provided with training opportunities" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to be "provided with more training opportunities"?

0-----------------1------------------5------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Supervisor Consultation**

____ 31. I feel comfortable talking to my supervisor whenever there is a problem.

____ 32. I like knowing my supervisor's point of view whenever I have to make an important decision.

Is "feeling comfortable consulting your supervisor" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to feel "more comfortable consulting your supervisor"?

0-----------------1------------------5------------------20----------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Company Policies & Guidelines**

____ 33. Policies and procedures are explained adequately within (Company Name).

____ 34. Work policies are fair in this plant.

Are "fair company policies & guidelines" an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to have “fair company policies & guidelines”?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Company Values**

____ 35. My personal values are similar to (Company Name) values.

____ 36. Organizational values such as honesty, integrity, and ethics are observed at (Company Name).

Are “company values such as ethics and integrity” an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to observe “better company values within (Company Name)”?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

**Work Flexibility**

____ 37. I am satisfied with the work flexibility provided for my schedule.

____ 38. I am able to plan my vacation and take off the days I need.

Is “Work Flexibility” an important factor for you to achieve High Employee Morale? **Yes** or **No** (circle correct answer).

How much would you be willing to sacrifice out of your paycheck per year to have “more work flexibility”?

0------------------1--------------------5--------------------20------------------50
No $ Very Little $ Moderate amount of $ High amount of $ A lot of $

# APPENDIX D – DATA COLLECTION SHEETS

| Data Collection Sheet for Factor Variables of PROFIT | | | | |
|---|---|---|---|---|
| ***Subcomponent*** | ***Factor Variables*** | ***Indicators or Metrics (Annual Figures)*** | ***Point of Contact*** | ***Comments*** |
| **Revenue** | Sales | Net Sales (Production Revenue generated by units produced, and part sold) | Accounting Manager (Subsidiary Headquarters) | Please make sure this figure is consistent within several documents |
| **Expenses** | Labor | Wages (Direct Labor) | Accounting Manager (Plant) | This figure should consider only "Direct Labor". |
| | Material | Material Cost (raw material - exclude parts, containers, and supplies) | Accounting Manager (Plant) | These figures represent only raw material (excluding parts, containers, and supplies) |
| | Variable O/H | Variable Overhead Cost | Accounting Manager (Plant) | Please provide a list in detail of all the items considered within each category (e.g., Temporary labor). |
| | Fixed O/H | Fixed Overhead Cost | Accounting Manager (Plant) | Please provide a list in detail of all the items considered within each category (e.g., Salaries for executive employees). |
| | Variable Cost | Variable Cost | Accounting Manager (Plant) | Please provide a list in detail of all the items considered within each category. Is Var. Cost = Material Cost + Dir. Labor Cost + Var. O/H? |
| | Income Taxes | (Overall State Income Tax + Federal Income Tax) x Plant Sales % | Accounting Manager (Subsidiary Headquarters) | Income Taxes are not paid at the plant level since the plant is a cost center. |
| | Legal Fees | Overall Corporate Charge (Corporate Premium) x Plant Sales % | Accounting Manager (Subsidiary Headquarters) | This figure may include the cost for all the plants of this subsidiary; if so, please specify. |
| | R & D Expenditures | R & D Cost (Customize products + Obsolete + Extension + New + Value Engineering) | R & D Manager (Subsidiary Headquarters) | This figure may include the cost for all the plants of this subsidiary; if so, please specify. |

| Data Collection Sheet for Factor Variables of PRODUCTIVITY | | | | |
|---|---|---|---|---|
| ***Subcomponent*** | ***Factor Variables*** | ***Indicators or Metrics (Annual Figures)*** | ***Point of Contact*** | ***Comments*** |
| **Output** | Production Volume | Production Volume | Production Manager (Plant) | Please, check production reports |
| | Delivery | % of On-Time Delivery Products to Customers | Production Manager (Plant) | Delivery date = (Lead times + Material avail.) |
| | Backlog | % of Production Units not Met or No. of Orders not Met | Production Schedulers (Plant ) | Please make sure this figure represents all the manufacturing lines |
| **Input** | Suppliers | % of On-Time Material Arrival | Purchase Manager (Subsidiary Headquarters) | |

| Data Collection Sheet for Factor Variables of EFFICIENCY | | | | |
|---|---|---|---|---|
| ***Subcomponent.*** | ***Factor Variables*** | ***Indicators or Metrics (Annual Figures)*** | ***Point of Contact*** | ***Comments*** |
| **Resource** (ONLY direct cost) | Labor | (Expected Labor Cost per unit / Actual Labor Cost per unit) | Accounting Manager (Subsidiary Headquarters & Plant) | Expected figure obtained from forecasting model or budget approved by Subsidiary Headquarters and actual values from the plant |
| | Material | (Expected Material Cost per unit / Actual Material Cost per unit) | Accounting Manager (Subsidiary Headquarters & Plant) | Expected figure obtained from forecasting model or budget approved by Subsidiary Headquarters and actual values from the plant |
| | Energy | (Expected Energy Cost per unit / Actual Energy Cost per unit) | Accounting Manager (Plant) | Energy = Utilities (Power + Gas + Water & Sewer). Figure obtained from accounting reports |
| | Production Capability | Max. Manpower x (Prod. Volume/Employee) | Production Manager or Accounting Manager (Plant) | Production Capability (Max. Productivity) can be measured by Man Power Capacity. Please, provide the amount of units built and cost by the number of employees (specify part-time and full-time) |
| **Waste** (ONLY direct cost) | Defects | Actual defects cost or First Pass Yield (mistakes, errors, etc) | Quality Engineer or Quality Manager | Please check quality control reports or audits (if the plant is in compliance with ISO 9001, etc) |
| | Recycle | Recycle Recovery/ Total Waste Cost | Accounting Manager (Plant) | Recycle recovery = Scrap recovery. Total Waste cost = scrap cost + waste disposal. |
| | Waiting | Idle Time or Downtime | Production Manager (Plant) | Please advise if this data has ever been recorded since I may have to collect it or estimate it myself |
| | Inventories | % of Inventory Turnover (Finished goods) | Inventory Manager (Plant) | May be available on Dash Board reports. Warning: Please let me know the accuracy of these figures |

| Data Collection Sheet for Factor Variables of QUALITY | | | | |
|---|---|---|---|---|
| ***Subcomponent*** | ***Factor Variables*** | ***Indicators or Metrics (Annual Figures)*** | ***Point of Contact*** | ***Comments*** |
| **Customer Satisfaction** | Customer Loyalty | % of Repeated Customers (based on purchasing trends) | Marketing Manager (Subsidiary Headquarters) | Please specify it this figure represents overall subsidiary products. |
| | External Failure Cost | Cost due to Customer Complaints, Returns, and Warranty Claims | Customer Service Manager (Subsidiary Headquarters) | Please specify if this figure represents (Warranty Administration + Field Service + Tech Support) |
| | Customer Satisfaction | % of Customer Satisfied | Marketing Manager (Subsidiary Headquarters) | Please specify it this figure represents overall subsidiary products. |
| **Quality Management & Control** | Internal Failure Cost | Cost due to Rework, Corrective Actions, and Process Failures | Quality Manager, Quality Control Engineer (Plant) | Please specify the figure provided. Advice if Rework % is not measured. |
| | Appraisal Cost | Cost due to Test, Inspections, Process Measurement and Control, and Instrument Maintenance | Production Schedulers, Quality Assurance Engineer, and Calibration Engineer (Metrology) at the Plant | Please specify the figure provided. |
| | Prevention Cost | Cost due Quality Planning, Process Control, and Training | Quality Manager (Plant) | If you do not have this figure, please provide an estimate based on improvement projects worked that support proactive quality activities, such as 6-Sigma projects. |

| Data Collection Sheet for Factor Variables of ERGONOMICS & SAFETY | | | |
|---|---|---|---|
| ***Factor Variables*** | ***Indicators or Metrics (Annual Figures)*** | ***Point of Contact*** | ***Comments*** |
| Employee Replacement Cost | Employee Replacement Cost Generated by an Injury (such as employee replacement, and trainings) | Safety Manager | If you do not know, please provide an annual estimate |
| Lost Work-Day Cases | Frequency Rates | Safety Manager | No. of cases involving days away from work, restricted work, or job transfer |
| OSHA Fines | OSHA Cost | Safety Manager | Based on OSHA fines |
| OSHA Recordable Cases | Frequency Rates | Safety Manager | Only injuries and illnesses that fall under OSHA category |
| Proactive Ergonomics | Cost of Proactive Ergonomics such as training, assessments, ergonomics program maintenance | Safety Manager | If you don't know, please try to recall all these type of activities and provide an estimated time or cost/yr |
| Workers' Compensation Expenses | Insurance Premium | Safety Manager | Closed and open workers' comp. cases up to date |

| Data Collection Sheet for Factor Variables of EMPLOYEE MORALE | | | | |
|---|---|---|---|---|
| ***Subcomponent*** | ***Factor Variables*** | ***Indicators or Metrics (Annual Figures)*** | ***Point of Contact*** | ***Comments*** |
| **Employee Engagement** | Commitment | 1-4 Survey Scale & Willingness to Pay (WTP) | Myself | Employee Morale Survey |
| | Loyalty | | | |
| | Motivation | | | |
| | Enthusiasm | | | |
| | Absenteeism | Absenteeism Rate | HR Manager | |
| | Involving | 1-4 Survey Scale & Willingness to Pay (WTP) | Myself | Employee Morale Survey |
| | Belonging | | | |
| | Appreciation | | | |
| | Empowerment | | | |
| | Trust | | | |
| | Turnover | Turnover Rate | HR Manager | |
| **Work Environment** | Teamwork | 1-4 Survey Scale & Willingness to Pay (WTP) | Myself | Employee Morale Survey |
| | Advancement Opportunities /Promotions | | | |
| | Recognition & Rewards | | | |
| | Compensation | | | |
| | Training | | | |
| | Open Communication | | | |
| | Supervisor Consultation | | | |
| | Company Policies & Guidelines | | | |
| | Company Values | | | |
| | Work Flexibility | | | |

# APPENDIX E – GLOSSARY

*Quality Terms*

- Customer Loyalty - % of repeat customers based on annual amount spent.
- Customer Satisfaction - % of customer satisfied with products.
- Prevention Costs

  -*Quality Planning Costs* include salaries of individuals associated with quality planning and problem-solving teams, the development of new procedures, new equipment design, and reliability studies.

  -*Process Control Costs* include costs spent on analyzing production processes and implementing process control plans.

  -*Information Systems Costs* include expenses to develop data requirements and measurements.

  -*Training and General Management Costs* included internal and external training programs, clerical staff expenses (secretarial or assistant), and miscellaneous supplies.

- Appraisal Costs

  -*Test and Inspection Costs* are costs associated with incoming materials, work-in-process, and finished goods (including equipment costs and salaries).

  -*Instrument Maintenance Costs* arise from calibration and repair of measuring instruments.

  -*Process Measurement and Control Costs* involve the time spent by workers to gather and analyze quality measurements.

- Internal Failure Costs

  -*Scrap & Rework Costs* include material, labor, and overhead.

  -*Costs of Corrective Action* arise from time spent determining the causes of failure and correcting production problems.

  -*Downgrading Costs* include revenue lost when selling a product at a lower price when it does not meet specifications.

  -*Process Failures Costs* include unplanned machine downtime or unplanned equipment repair.

- External Failure Costs

-*Costs due to Customer Complaints and Returns* include rework on returned items, cancelled orders, and freight premiums.

-*Product Recall Costs and Warranty Claims* include the cost of repair or replacement as well as associated administrative costs.

-*Product Liability Costs* result from legal actions and settlements.

(Cost of Quality definitions obtained from Evans and Lindsay, 2002).

*Profit Terms*

- Sales - Net sales (Production Revenue generated by units produced, and part sold)
- Labor - Wages of direct labor.
- Material - Material cost of raw material, excluding parts, containers, and supplies.
- Variable Overhead – Variable expenses of a business which cannot be attributed to any specific business activity, but are still necessary for the business to function. For example, temporary workers wages are included within this category.
- Fixed Overhead Cost – Fixed expenses of an organization that cannot be attributed to any specific business activity but are necessary for the business to function. For example, executive salaries are included within this category
- Variable Cost – A cost which varies as the production level varies. Producing more adds to variable cost, and producing less reduces variable cost.
- Income Taxes - State and federal income tax generated by sales.
- Legal Fees – Expenses allocated to legal activities or corporate premium for legal coverage.
- Research and Development Expenditures - Cost due to research and development efforts, such as customize products, obsolete, extension, new products, and value engineering.

*Productivity Terms*

- Production Volume - Total amount of units built per year.
- Delivery - % of on-time units delivered to customer.

- Backlog – amount of orders not met.
- Suppliers - % of on-time material arrival from suppliers.

*Efficiency Terms*

- Labor - Expected labor cost / Actual labor cost per unit.
- Material - Expected material cost / Actual material cost per unit.
- Energy - Expected energy cost / Actual energy cost per unit.
- Production Capability - Maximum manpower x (Production Volume / Employee).
- Defects - defects cost or actual no. of defects or [1- (first pass yield)].
- Recycle – Recycle recovery (scrap + trimming) / Total waste cost (scrap cost + waste disposal).
- Downtime – Downtime cost or % of downtime caused by machine, material, planning.
- Inventories - % of inventory turnover on finished goods.

*Ergonomics & Safety Terms*

- Replacement Cost - Employee replacement cost after an injury has occurred.
- Lost Work-Day Cases – Frequency rates of lost work day cases.
- OSHA – OSHA fines.
- OSHA Recordable – Frequency rates of OSHA injuries or illnesses.
- Proactive Ergonomics – Cost of proactive ergonomics, such as awareness training, ergonomics assessments or cost to maintain an ergonomics program.
- Worker's Compensation – Workers' compensation expenses, such as insurance premiums.

*Employee Morale Terms*

- Absenteeism - Absenteeism rate.
- Turnover - Turnover rate.

# APPENDIX F – AHP DATA COLLECTION SHEETS

The following ratings were used to develop the forms to be sent to all the Subject Matter Experts. A pair wise comparison example was included within the form to avoid any misunderstanding.

1 = x-variable is *Equally Important* as y-variable
3 = x-variable is *Slightly More Important* than y-variable
-3 = x-variable is *Slightly Less Important* than y-variable
5 = x-variable is *More Important* than y-variable
-5 = x-variable is *Less Important* than y-variable
7 = x-variable is *Highly More Important* than y-variable
-7 = x-variable is *Highly Less Important* than y-variable
9 = x-variable is *Extremely More Important* than y-variable
-9 = x-variable is *Extremely Less Important* than y-variable

Example: If comparing Profit and Productivity, you consider that Profit is slightly more important than Productivity; then, you would enter a value of 3. Therefore, Productivity will be slightly less important than Profit.

| **Company Success** | Profit | Productivity |
|---|---|---|
| Profit | 1 | 3 |
| Productivity | X | 1 |

1. Please rate each factor comparison in relation to its impact on the "productivity" of a company.

**Y-Axis**

| **Productivity** **X-Axis** | Production Volume | Delivery | Backlog/# of Orders not Met | Suppliers |
|---|---|---|---|---|
| Production Volume | 1 | X | X | X |
| Delivery | | 1 | X | X |
| Backlog/# of Orders not Met | | | 1 | X |
| Suppliers | | | | 1 |

2. Please rate each factor comparison in relation to its impact on the "profit" of a company.

**Y-Axis**

| **Profit** (X-Axis) | Sales | Labor | Material | Variable O/H | Fixed O/H | Variable Cost | Income Taxes | Legal Fees | R & D Expenditures |
|---|---|---|---|---|---|---|---|---|---|
| Sales | 1 | X | X | X | X | X | X | X | X |
| Labor | | 1 | X | X | X | X | X | X | X |
| Material | | | 1 | X | X | X | X | X | X |
| Variable O/H | | | | 1 | X | X | X | X | X |
| Fixed O/H | | | | | 1 | X | X | X | X |
| Variable Cost | | | | | | 1 | X | X | X |
| Income Taxes | | | | | | | 1 | X | X |
| Legal Fees | | | | | | | | 1 | X |
| R & D Expenditures | | | | | | | | | 1 |

3. Please rate each factor comparison in relation to its impact on the "overall success" of a company.

**Y-Axis**

**X-Axis**

| **Company Success** | Profit | Productivity | Quality | Efficiency | Safety & Ergonomics | Employee Morale |
|---|---|---|---|---|---|---|
| Profit | 1 | X | X | X | X | X |
| Productivity | | 1 | X | X | X | X |
| Quality | | | 1 | X | X | X |
| Efficiency | | | | 1 | X | X |
| Safety & Ergonomics | | | | | 1 | X |
| Employee Morale | | | | | | 1 |

4. Please rate each factor comparison in relation to its impact on the "efficiency" of a company.

| **Y-Axis** **Efficiency** / **X-Axis** | Labor | Material | Energy | Production Capability | Defects | Recycle | Waiting | Inventories |
|---|---|---|---|---|---|---|---|---|
| Labor | 1 | X | X | X | X | X | X | X |
| Material | | 1 | X | X | X | X | X | X |
| Energy | | | 1 | X | X | X | X | X |
| Production Capability | | | | 1 | X | X | X | X |
| Defects | | | | | 1 | X | X | X |
| Recycle | | | | | | 1 | X | X |
| Waiting | | | | | | | 1 | X |
| Inventories | | | | | | | | 1 |

5. Please rate each factor comparison in relation to its impact on the "quality" of a company.

| **Y-Axis** **Quality** / **X-Axis** | Customer Loyalty | External Failure Cost | Customer Satisfaction | Internal Failure Cost | Appraisal Cost | Prevention Cost |
|---|---|---|---|---|---|---|
| Customer Loyalty | 1 | X | X | X | X | X |
| External Failure Cost | | 1 | X | X | X | X |
| Customer Satisfaction | | | 1 | X | X | X |
| Internal Failure Cost | | | | 1 | X | X |
| Appraisal Cost | | | | | 1 | X |
| Prevention Cost | | | | | | 1 |

7. Please rate each factor comparison in relation to its impact on the "ergonomics and safety" of a company.

**Y-Axis**

**X-Axis**

| **Ergonomics & Safety** | Replacement Cost | Lost Work-Day Wages | OSHA | Injury, Illness, accidents | Proactive ergonomics | Worker's Comp |
|---|---|---|---|---|---|---|
| Replacement Cost (employee replacement, and trainings) | 1 | X | X | X | X | X |
| Lost Work-Day Wages | | 1 | X | X | X | X |
| OSHA | | | 1 | X | X | X |
| Injury, Illness, and accidents | | | | 1 | X | X |
| Proactive ergonomics | | | | | 1 | X |
| Worker's Comp | | | | | | 1 |

7. Please rate each factor comparison in relation to its impact on the “employee morale” of a company.

**Y-Axis**

| **Employee Morale**<br>**X-Axis** | Absenteeism | Turnover | Belonging | Involving | Enthusiasm | Motivation | Commitment | Loyalty | Trust | Appreciation | Empowerment | Open Comm. | Recognition & Rewards | Advancement Opportunities | Teamwork | Compensation | Training | Supervisory Consultation | Company Policies & Guidelines | Company Values | Work Flexibility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Absenteeism | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Turnover | | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Belonging | | | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Involving | | | | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Enthusiasm | | | | | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Motivation | | | | | | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Commitment | | | | | | | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Loyalty | | | | | | | | 1 | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Trust | | | | | | | | | 1 | X | X | X | X | X | X | X | X | X | X | X | X |
| Appreciation | | | | | | | | | | 1 | X | X | X | X | X | X | X | X | X | X | X |
| Empowerment | | | | | | | | | | | 1 | X | X | X | X | X | X | X | X | X | X |
| Open Comm. | | | | | | | | | | | | 1 | X | X | X | X | X | X | X | X | X |
| Recognition & Rewards | | | | | | | | | | | | | 1 | X | X | X | X | X | X | X | X |
| Advancement Opportunities | | | | | | | | | | | | | | 1 | X | X | X | X | X | X | X |
| Teamwork | | | | | | | | | | | | | | | 1 | X | X | X | X | X | X |

| **Y-Axis Employee Morale** / **X-Axis** | Absenteeism | Turnover | Belonging | Involving | Enthusiasm | Motivation | Commitment | Loyalty | Trust | Appreciation | Empowerment | Open Comm. | Recognition & Rewards | Advancement Opportunities | Teamwork | Compensation | Training | Supervisory Consultation | Company Policies & Guidelines | Company Values | Work Flexibility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Compensation | | | | | | | | | | | | | | | | 1 | X | X | X | X | X |
| Training | | | | | | | | | | | | | | | | | 1 | X | X | X | X |
| Supervisory Consultation | | | | | | | | | | | | | | | | | | 1 | X | X | X |
| Company Policies & Guidelines | | | | | | | | | | | | | | | | | | | 1 | X | X |
| Company Values | | | | | | | | | | | | | | | | | | | | 1 | X |
| Work Flexibility | | | | | | | | | | | | | | | | | | | | | 1 |

# APPENDIX G – OSHA ERGONOMIC AND SAFETY GUIDELINES ASSESSMENT

The purpose of this tool is to assess OSHA Ergonomic and Safety Guidelines over any organization. Each set of guidelines will address a particular task, and there are three major parts: 1) Program management recommendations for management practices addressing ergonomic hazards in the industry or task; 2) Worksite analysis recommendations for worksite/workstation analysis techniques geared to the specific operations that are present in the industry or task; and 3) Hazard control recommendations that contain descriptions of specific jobs and detail the hazards associated with the operation, possible approaches to controlling the hazard, and the effectiveness of each control approach.

---

1. To what extent does your ergonomics program address the ergonomic hazards in your industry or task?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

2. Are there specific hazards prevalent conditions in your industry or task? (0) **Y** **(1) N** (circle correct answer).

3. To what extent does your ergonomics program address the specific control methods that are available for the ergonomic hazards present in your industry?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

4. To what extent does your ergonomics program include a mechanism for reporting injuries, symptoms, and hazards, which may be related to ergonomics in the workplace?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

5. Are you responding to these reports? **(1) Y** **(0) N**

6. To what extent does your ergonomics program reflect a process for evaluating the nature and causes of injuries, which may be related to ergonomics in the workplace?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

7. Do you have a process for identifying, implementing, and evaluating measures to reduce injuries? **(1) Y (0) N**

8. Do you have quantitative data or other information demonstrating the program's provisions effectiveness in reducing the number of ergonomic hazards or the number and severity of workplace injuries related to ergonomics? **(1) Y (0) N**

9. Are exits properly identified and lighted, and are exit paths clear?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Never** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

10. Is the emergency lighting operable?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Never** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

11. Has the fire alarm been tested?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Never** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

12. Are portable fire extinguishers available? Are extinguishers serviced/tagged annually?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Never** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

13. Is the sprinkler system operable and tested regularly?

| **0** | **0.25** | **0.5** | **0.75** | **1** |
|---|---|---|---|---|
| **Never** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

14. Are combustibles and trash controlled?

| 0 | 0.25 | 0.5 | 0.75 | 1 |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

15. Is lighting protection installed on towers, steeples, or spires?

| 0 | 0.25 | 0.5 | 0.75 | 1 |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

16. Has a licensed electrician inspected electrical wiring?

| 0 | 0.25 | 0.5 | 0.75 | 1 |
|---|---|---|---|---|
| **Never** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

17. Are state inspection certificates on file and current?

| 0 | 0.25 | 0.5 | 0.75 | 1 |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

18. Is there a preventive maintenance service contract in effect on heating/air conditioning equipment?

| 0 | 0.25 | 0.5 | 0.75 | 1 |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

19. Is exterior illumination adequate? Are all lights functioning?

| 0 | 0.25 | 0.5 | 0.75 | 1 |
|---|---|---|---|---|
| **Not at All** | **Sometimes** | **Regularly** | **Frequently** | **Always** |

# APPENDIX H – CHECKLIST FOR A GREAT PLACE TO WORK

The purpose of this tool is to assess Employee Morale over your organization. Each set of guidelines will address a particular task, and there are three major parts: 1) Basic Terms of Employment meaning company's compensation policies relating time and money exchange between the organization and the employees; 2) The Job representing how and when jobs are to be done and who is to them; 3) Workplace Rules ; 4) Stake in Success. Every category should be scored based on the following scale:

0 0.25 0.5 0.75
1

Not at All Sometimes Regularly
Frequently Always

Basic Terms of Employment

1. Fair pay and benefits:
   a. Compare well with similar employers
   b. Square with company's ability to pay
2. Commitment to job security
3. Commitment to safe and attractive working environment

The Job

1. Maximizes individual responsibility for how job us done
2. Flexibility about working hours
3. Opportunities for growth:
   a. Promotes from within
   b. Provides training
   c. Recognizes mistakes as part of learning

Workplace Rules

1. Reduces social and economic distinctions between management and other employees
2. Right to due process
3. Right to information
4. Right to free speech
5. Right to confront those in authority
6. Right not to be part of the family/team

Stake in Success

1. Shares rewards from productivity improvements
2. Shares profits
3. Shares ownership
4. Shares recognition

NOTE: A great workplace cannot be equated with the presence or absence of a particular set of policies or practices. What's important is the quality of the relationship that gets developed between the company and its employees. With that in mind, we can use this checklist as a way of taking the pulse of a company's workplace relationships. Great place to work tend to have most or all of the attributes listed above.

# APPENDIX I – IRB HUMAN SUBJECTS PERMISSION LETTER

University of Central Florida

Office of Research & Commercialization

May 11, 2007

Ana M. Ferreras
6115 Sellinger Lane
Orlando, FL 32808

Dear Ms. Ferreras:

With reference to your protocol #07-4396 entitled, "A Comprehensive Multi-Faceted Approach for Simultaneously Analyzing Organizational Performance Measures Essential for Company Success," I am enclosing for your records the approved, expedited document of the UCFIRB Form you had submitted to our office. **This study was approved on 5/10/2007. The expiration date for this study will be 5/9/2008.** Should there be a need to extend this study, a Continuing Review form must be submitted to the IRB Office for review by the Chairman or full IRB at least one month prior to the expiration date. This is the responsibility of the investigator.

Please be advised that this approval is given for one year. Should there be any addendums or administrative changes to the already approved protocol, they must also be submitted to the Board through use of the Addendum/Modification Request form. Changes should not be initiated until written IRB approval is received. Adverse events should be reported to the IRB as they occur.

Should you have any questions, please do not hesitate to call me at 407-823-2901.

Please accept our best wishes for the success of your endeavors.

Cordially,

Joanne Muratori

Joanne Muratori
IRB Coordinator
(FWA00000351 Exp. 5/7/2010, IRB00001138)

Copies: IRB File
Lesia L. Crumpton-Young, Ph.D.

JM:jt

12201 Research Parkway • Suite 501 • Orlando, FL 32826-3246 • 407-823-3778 • Fax 407-823-3299

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