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-Creating an assessment process for small to medium size manufacturers


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SMART MANUFACTURING DIAGNOSTIC SYSTEM (SMDS)

Creating an assessment process for small to medium size manufacturers

A Thesis submitted to the
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By

David Le

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Committee Chair: Professor Ashraf Genaidy
Abstract

Objective: The objective of this study is to develop and validate a self-diagnostic tool to evaluate system performance small to medium size manufacturing enterprises in order to allow quick and informed decisions to be made. The tool will be utilized to quickly grasp the current situation, align management thinking and identify the bases in which to develop an improvement plan.

Background: Manufacturing in the US is facing many challenges. The Bureau of Labor Statistics stated since July 2000, manufacturing has lost 2.3 million jobs. The increase in global competition has an extreme impact on small to medium size manufacturers. The shift towards global outsourcing has put small to medium size manufacturing companies in head-to-head competition across the world.

Methods: A pilot version of the tool was developed through literature research on existing manufacturing enterprises and interviews with manufacturing professionals. A pilot was conducted on a small North American manufacturing company and administered at the company site to the president, vice president of manufacturing and two front line managers. Due to some confusion during testing of the pilot version, a revised version consisted of detailed explanation and examples.

Results: The pilot study highlighted key items of this manufacturer…

Management Alignment: When comparing the results of the management participants, it could be seen that management thinking was not aligned. This was most notably displayed by the president’s and the vice president’s results. The tool allowed for management to convey a summary of their thinking and identify differences, which provided a starting point from which cohesive work goals could be developed.

Focus on “Quality”: There was an immediate concern about the level of quality and its impact on overall performance. Quality problems stemmed from both supplier and in-house performance.
It is equally emphasized in all targeted future results, that quality enhancements were needed in order to achieve future goals.

*Sustaining the work environment:* The targeted future condition results indicated that the work current work environment was highly energized and that the current condition needed to be sustained. The management and employee relationship is currently an advantage that should not be overlooked. This base is necessary in order to develop a workforce with problem solving skills.

*Lack of a strategic planning process:* A Weak strategic planning process was found to be a common demand on the Support subsystem by all management. This weakness does not create an immediate threat, however is necessary if targeted future condition is to be achieved.

**Conclusion:** The tool utilized in this study has shown a quick and effective way to gather essential information to begin the decision-making process in a small to medium size manufacturing enterprise. The pilot study also showed several additional uses of the tool. Large manufacturing organizations can use the tool to evaluate suppliers. An additional use for large manufacturers would be utilization in single work cells that make up the organization. This tool should support the efforts of small to medium size manufacturers in the US to increase their competitiveness.
ACKNOWLEDGMENTS

The guidance, suggestions and recommendations made by Dr. Ashraf Genaidy of the Mechanical, Industrial, and Nuclear Engineering department at University of Cincinnati, and by Dr. Richard Shell of the Mechanical, Industrial, and Nuclear Engineering department at University of Cincinnati were greatly appreciated. The recommendations of all professors were incorporated where possible.
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Section 1 - Introduction

A. Importance of manufacturing in the United States

According to the U.S. Commerce Department, manufacturing alone contributed 22 percent of economic growth between 1992 and 2000 (see figure 1). With this impact it can be seen that manufacturing plays a significant role in the process of generating economic growth and contributes to the high living standards in the U.S. (Popkin, 2003). The manufacturing innovation process (see figure 2) starts with an idea for a new product or process, prompting investments in research and development. The research and development (R&D) successes lead to investments in capital equipment and workers, to “spillovers” that benefit manufacturing and other economic sectors. This process greatly impacts the U.S. economy and the way we live. Its main contributions are explained in the following sections.

Manufacturing growing the economy

Manufacturing growth spawns additional economic activity and jobs than any other economic sector (Popkin, 2003). The Commerce Department’s Bureau of Economic Analysis (BEA) calculated that for every $1 that is spent on a final manufactured product, an additional $0.67 is generated in other manufactured intermediate parts and components, which are usually produced by a small to medium size manufacturer. It also generates $0.76 in products that are non-manufacturing related, which are mainly service related. This can be seen in the automotive industry. The production of automobiles requires raw materials such as coal and iron, it also requires the purchase
of capital equipment such as welding robots and requires the purchase of services such as health insurance for the employees.

*Manufacturing inventing the future*

U.S. Manufacturers are responsible for almost two-thirds of all private sector R&D - $127 billion in 2002, which was 67% of total private R&D (NSF, 2002). This R&D will eventually lead to capital investments, which in turns lead to the creation of more jobs. Investment in research and development is the single most important source of technological advance that leads to higher productivity and increases the living standards for those in the U.S. (Manufacturing Institute, 2003). The increase in productivity allows for cheaper products for the population. This innovation process is the key to past, present and future prosperity; therefore it is critical that the manufacturing sector remain viable enough to sustain these standards.

**B. Manufacturing’s Facing Challenges**

Manufacturing is facing many challenges. The Bureau of Labor Statistics stated since July 2000, manufacturing has lost 2.3 million jobs (see figure 3). Manufacturing output has shown virtually no growth since December 2001 (reference). A major challenge to the U.S. manufacturing base and the innovation process is the rising cost of producing in the U.S. The cost of doing business in the U.S. is rising dramatically. This is due to healthcare costs, litigation, and regulation. As a result, many U.S. manufacturers shut down or move production overseas to countries where they do not face the same difficulties. These difficulties contribute to the intense global competition, where the
competitor enjoys these advantages over U.S. manufacturers. Large manufacturers often times capitalize on global competition, by being able to source cheaper supplier parts and components. However, this global competition has a major impact on the small to medium size manufacturers.

*The impact to small and medium size manufacturers*

The increase in global competition has extreme impact on small to medium size manufacturers. For example, the U.S. automotive manufacturers once provided a steady market for the small and medium size supplier of parts and components. The manufacturers now operate on a global basis; therefore an increase in auto sales does not automatically translate into increased orders of domestic parts and components. The shift towards global outsourcing has put small to medium size manufacturing companies in head-to-head competition with suppliers across the world.

Therefore, it is becoming ever important for manufacturing organizations to be able to change with the current environment and to continuously improve in order to keep the innovation process alive. Large manufacturers, often times have ample resources to dedicate to understanding current operating conditions, identify weaknesses and create action plans to strengthen them. Small to medium size manufacturers, must dedicate most of their resources to run current operations, many times being forced into a viscous cycle of fighting fires. This equates to an inadequate infrastructure that cannot support growth or change, which is needed to survive in today’s market. With the decrease in small to medium size manufacturers in the U.S., the manufacturing
innovation process with slowly diminish, which may eventually lead to a lower standard of living. Therefore, a tool must be created that can quickly evaluate all critical areas of the manufacturing enterprise and can assist managers in reinforcing their intuition in order to make timely, informed and effective decisions.

C. Objective

The study objective is to develop and validate a self-diagnostic tool to evaluate system performance in a manufacturing enterprise in order to allow quick and informed decisions to be made. The tool will measure both the effectiveness and efficiency of the entire enterprise. The study will be centered on small to medium size manufacturers in North America.

At the enterprise level the tool will be used to:

1) Assess efficiencies of all the systems, which is the index of input and output.
2) Assess effectiveness of all the systems, which is the quality of the output.
3) Quickly grasp current operating conditions.
4) Starting point from which to develop guidelines to move from current situation to targeted future condition.
5) Align all management thinking.
Section 2 – Survey of Literature

A. Performance Measurement Systems

Throughout manufacturing history, many systems have been developed, mostly through trial and error. Companies implementing them have merely taken on “buzz” words, such as “lean” or “just-in-time”. Due to the trial and error method of creating these systems, they are mainly industry’s “best practices” at that time.

A literature survey indicates that most business models conform to two main typologies: hierarchical models and balanced models.

For hierarchical performance measurement systems (PMS), cost and non-cost performance measures are laid on different levels of aggregation until they form an economic-financial measure. Some vertical models, however, do not translate into financial performance but provide a synthesis of low-level measures into more aggregated indicators. PMSs are used for purposes of planning, control and benchmarking. Most performance measures consist of cost, time, flexibility and quality variables. Financial indication is a very important indicator, however gives a narrow perspective and does not take sustainability into account. This method for some manufacturers with limited resources could be time consuming.

The balanced scorecard (BSC) was developed in the early 1990s (Figge, et. al., 2002) to integrate different approaches to business performance. The BSC monitors simultaneous improvements on the economical, environmental and social performance of businesses to achieve the firm’s strategy. The BSC moves from the traditional
assumption that invested capital is the only determinant of business performance. ‘Soft’ factors such as intellectual capital, knowledge creation, or customer orientation also play a key role in business performance. The balance scorecard approach encompasses some intangible resources utilized by the system, however, for manufacturers with limited resources this process could be time consuming.

These methods of performance measurement do not take into account the resources required by the system to generate performance levels. For example, cost per unit could be an indicator, however, that indicator alone would not explain that manufacturing processes were outsourced or kept in-house, which created a negative or positive environment for existing employees. The best case would be to utilize the best attributes from each performance measurement system, depending on the extent of information needed. The tool which is being tested could be utilized daily due to its need for minimal resources.
Section 3 - Methods

Smart Manufacturing Diagnostics will be a critical checklist that will allow managers to quickly evaluate the entire enterprise, identifying both strong and weak areas. Strategic action plans can then be formulated to maximize strong areas and to strengthen weak areas.

A. Development of pilot version

*Development Roadmap* (see figure 4)

A pilot version of the tool was developed through literature research on existing manufacturing enterprises and interviews with manufacturing professionals. The research was done on Lean Manufacturing, the Toyota Production System, Total Quality Management, operations management and production system design. The manufacturing enterprise outline was developed along with all of its supporting elements. The manufacturing consists of 32 elements distributed between four inter-related subsystems. (See figure 5.)

1. Production (9 elements) – which addressed the systems required to bring a specific product from raw materials to finished product and into the hands of the customer. The assessment would allow managers to identify bottlenecks and waste as well as current advantages to leverage.

2. Total Quality Management (5 elements) – which addressed the systems required to assure a quality product to the customer. The assessment would allow managers to begin to identify systems that housed the root cause quality problems as well as realizing strong critical systems, which may have been taken for granted.
(3) Human-at-Work (8 elements) – which addressed the systems required to create a fully utilized workforce. The assessment of these systems would allow managers to realize necessities needed to create and develop this workforce and well as identify factors which hindered growth and performance.

(4) Support (10 elements) – which addressed the supporting systems needed to maximize current operations as well as systems needed to develop a foundation for future operational success. The assessment would allow managers to identify strengths and weaknesses of current conditions and necessary changes needed for the future.

Work System Compatibility
The Work System Compatibility (WSC) concept was utilized to gauge performance of the elements in the subsystems. Each element of the manufacturing enterprise was to be evaluated to the extent in which it was a demand or an energizer with respects to its impact upon the total system. A demand is a characteristic of an element of a manufacturing system that negatively affects system performance (e.g., low work pay has a negative impact on performance). An energizer is a characteristic of an element of a manufacturing system that positively affects system performance (e.g., a pay raise has a positive impact on performance) (see figure 6).

The extent to which an element created a demand or energizer was assessed using one of the following levels: “not at all”, “a little”, “moderately”, “a lot”, and “entirely”. There are four ways to assess each element (see figure 7): a) a demand and not an energizer, b) an energizer and not a demand, c) both demand and energizer, and d) not
a demand or not and energizer. The results plotted on a graph in which “Demand” was the y-axis and “Energizer” the x-axis would show a summary of effectiveness vs. efficiency. This method quickly allows the measurement of the impact that each element has on the system.

**B. Testing of pilot version**

The tool was first tested on a small North American manufacturing company. The test was administered at the company site to the president, also an accountant, vice president of manufacturing, also an engineer and two front line managers, one with a associate’s degree in business, the other with only work experience. Brief instructions were given on the use of the tool and a brief definition of a demand and an energizer were explained. The tool was then distributed to each participant to utilize separately to measure the current performance of the manufacturing enterprise and to set a realistic target for future operating conditions. This future condition should be an indication of what operating level performance should be in order to succeed. The results were then collected and analyzed by the UC team. Feedback given by the participants signified that there was not a unified understanding of all the elements in the sub-systems and the performance rating system of the tool.

**C. Development of revised pilot version**

Due to some confusion during testing of the pilot version, a revised version consisted of detailed explanation and examples of each element and examples of situations in which
the elements were demand and energizers. (See table 2-5.) The revised pilot version testing will be conducted at a later date.
Section 4 - Results

A. President – Current condition
The president has an accounting background and is the top decision maker of the organization. The results of the current situation indicate that all the subsystems are currently at a low operating level (see figure 8). This signifies an overall weak enterprise. The common weak point in the Production subsystem and the Quality subsystem that puts high demand on the subsystems is the supplier performance (see figure 9 & 10). Supplier delivery and supplier quality are ranked very weak in their respective subsystems and require immediate action. Task content, problem solving and communication systems are hindering the creation of a fully utilized workforce, however the multifunctional job requirements allow for job enrichment as well as higher workloads (see figure 11). The lack of a strategic planning process system and the inability to level production puts high demand on the Support subsystem (see figure 12).

B. President – Targeted future condition
The president's targeted future condition requires immediate action to enhance overall quality; this should be done through better supplier management (see figure 28). In order to achieve the Quality subsystem targeted future condition, systems must be created to allow for customer feedback, enhancement of supplier quality and focus on in-house quality (see figure 30). Sustaining the current environment and enhancing problem-solving skills is needed to create a more productive workforce (see figure 31).

C. Vice President – Current condition
The vice-president has an engineering background and is the second key decision maker in manufacturing behind the president. Overall the results indicate that the manufacturing enterprise is currently balanced at a high operating level (see figure 13). Supplier delivery is both a high demand and energizer indicating the Production subsystem heavily relies on supplier performance for overall performance (see figure 14).

D. Vice president – Targeted future condition
The Vice president result for the future condition is to sustain the current condition (see figure 33). Areas of improvement are the strategic planning system (see figure 36) and in-house quality (see figure 35).

E. Line Manager #1 – Current condition
Line manager #1’s background is an associate in business. The results indicate the all subsystems are balanced at a low operating level, which is similar to the president’s results (see figure 18). Immediate areas of concern that are high demands on the system are work rhythm (see figure 19), supplier quality (see figure 20), problem solving (see figure 21) and occupational health and safety (see figure 22).

F. Line Manager #1 – Targeted future condition
The targeted future condition results indicate that the manager believes little can be done in terms of improvement (see figure 38). However, some key items were singled
out for improvement, those being quality, both in-house and supplier (see 39 & 40),
workforce problem solving (see figure 41) and occupational health and safety (see
figure 42).

G. Line Manager #2 – Results

Line manager #2 has no college education and has worked his way up through the
management levels. Figure 23 shows the summary of Line Manager #2 results, which
indicate a somewhat balanced operating condition at a mid to high performance level.
Two major demands on the system are quality (see figure 25) and manufacturing
technology (see figure 24). The results of line manager #2 maybe flawed, since a lack
of understanding was expressed while conducting the test.
Section 5 – Discussion

A. Management Alignment

When comparing the results of the management participants, it can be seen that management thinking is not aligned. This is most notably displayed by the president’s and the vice president’s results. Their different backgrounds could have influenced their results. The president’s results indicated low operating conditions, which could have been derived from financial performance due to his accounting background. The vice president’s results indicate a high operating condition; his engineering background could have merely evaluated operations, paying little attention to financial performance. Line management results of the occupational health and safety of the support subsystem indicate a high demand on the system, while upper management results show it to be a high energizer. This disconnect could be from upper management’s view of actual recordable injuries as oppose to line management’s view of actual working conditions. This shows another disconnect between management thinking. The summaries present a situation that all management results indicate a different evaluation of the current situation. This tool has allowed for management to convey a summary of their thinking in order to identify differences. This should provide a starting point for which cohesive work goals can be developed.

B. Focus on “Quality”
All levels of management results indicate poor quality is a major demand on the system. There is immediate concern about the level of quality and its impact on overall performance. Quality problems stem from both supplier and in-house performance. It is equally emphasized in all targeted future results, that quality enhancements are needed in order to achieve future goals.

C. Sustaining the work environment

All management results indicated a work environment that was highly energized, which indicate a good company culture. The targeted future condition results indicate that this condition needs to be sustained. This management and employee relationship is currently an advantage that should not be overlooked. This base is necessary in order to develop a workforce with problem solving skills, which was indicated in the president’s results (see figure 31).

D. Lack of a strategic planning process

A Weak strategic planning process was found to be a common demand on the Support subsystem by all management. This weakness does not create an immediate threat, however is necessary if targeted future condition is to be achieved. The tool tested in this study has given management a starting point of where to begin the strategic planning process.

E. Additional applications of SMED
Providing an Educational Tool

The tested diagnostic tool can be utilized as an educational tool. Through the pilot study, it was determined that the individual skill level would determine affect the results. The tool itself could be used to level up management’s understanding of the entire enterprise and identify the factors which should be considered in decision making.

Work cells as business units

Large manufacturers could utilize the to manage individual work cells as separate business units. This would allow management to move the ability to make decisions closer to the working level and also develop front line management to think on an enterprise level, by allowing to manage their own operations.

Supplier Assessment

With sourcing strategies becoming ever crucial for large manufacturers, additional resources will be required to manage the growing supply base. Large manufacturers can utilize the tool to assess its suppliers quickly in order to develop sourcing decisions. Utilization of the tool could assist in maximizing large manufacturer’s resources dedicated to managing suppliers.
Section 6 – Conclusion

A. Proposed SMART MANUFACTURING DIAGNOSTIC SYSTEM

The tool utilized in this study has shown a quick and effective way to gather essential information to begin the decision-making process in a manufacturing enterprise. The visual displays allow for easy communication of perceived operating summaries that allow management to align their thinking and discuss critical issues. The results show the elements that require improvement by increasing the demand level, the energizer level or both. If combined with a company’s strategy and business priorities it is possible to develop action plans that will ensure better compatibility, and ultimately, better performance outcomes.

B. Further Development

*Competitor comparison with common indicators*

In order to a conduct quick assessment of current competitive condition, a set of common indicators should be developed. These should be predefined measurements that indicate market share or profit margin. This will provide immediate information about the competitive positioning and the urgency of action, which should be the first step in the overall process.

*Supplementary performance indicators*

To assess the validity of the results, they have to be compared with external measures of the business: productivity, safety and organizational health. If the combination of the indexes shows strong association with external indicators, it would support the
hypothesis that those indexes are predictors of performance outcomes. These indicators will further assess the subsystems and their elements.

Guidelines for action plan development

Defining the current situation is the first step, however, what to do from there is essential to an organization’s performance. Guidelines should be developed for the subsystems according to the results. These could be general solution methods for each element. This would give management a better starting position in which they can develop a detailed action plan.
References


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<td>Production flow</td>
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<tr>
<td>There are bottlenecks in the system that requires certain processes to stand idle at times.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work Rhythm</td>
<td>In house pace of production can be adjusted to meet the rate of customer demand without affecting overall cost, therefore not creating inventory and receiving the same amount of profit per product.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In house pace of production does not match customer demand. This could be producing a faster rate then customer need, therefore creating inventory or it could be not producing enough to meet customer demand. The customer can be final customer or the next process.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changeover Techniques</td>
<td>Changeover techniques are efficient and are a strategic advantage to produce variety of product.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment changeover is a burden and is time consuming.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier delivery</td>
<td>Supplier deliveries are reliable and on time.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier deliveries are often late resulting in halt production therefore causing a loss.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Handling</td>
<td>Material handling is efficient by utilizing the correct balance of human and automation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material handling is burdensome and is inefficient.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Utilization</td>
<td>Material utilization is efficient and maximizes the full use of all purchase materials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material utilized to produce a product is used inefficiently resulting in a loss.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing Technology</td>
<td>Technology is fully utilized to create an efficient and balanced system.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing technology present is not sufficient for producing current product resulting in extra resources.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard operations</td>
<td>Standard operations are well followed by all employees.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard operations are weak and are not always followed by all employees of the system.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality at the source</td>
<td>Demand</td>
<td>Energizer</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Quality problems are found downstream and must be corrected by rework.</td>
<td>Quality is built into the system through various processes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance Reduction</td>
<td>Variances are out of tolerance therefore causing defect to the product.</td>
<td>Variances are in control therefore reducing possibility of defect.</td>
<td></td>
</tr>
<tr>
<td>Supplier Quality Management</td>
<td>Quality of the supplier is deficient therefore halting production.</td>
<td>Supplier quality is dependable and reduces cost of the product.</td>
<td></td>
</tr>
<tr>
<td>Customer involvement</td>
<td>No customer feedback is used to make future decisions.</td>
<td>Customer’ opinions are utilized to make business decisions.</td>
<td></td>
</tr>
<tr>
<td>Information and feedback</td>
<td>Information needed to make decisions is not readily available and no feedback is given on current condition.</td>
<td>Information needed to make business decisions are easily accessible and feedback is given on the current condition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Demand</td>
<td>Energizer</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Multi-functionality</td>
<td>Employees cannot multi-task to create a more efficient system.</td>
<td>Employees can multi-task in order to create a more efficient system.</td>
<td></td>
</tr>
<tr>
<td>Problem solving</td>
<td>Employees do not take responsibility or are involved in problems solving of the system.</td>
<td>Employees take responsibility to solve problems to the system.</td>
<td></td>
</tr>
<tr>
<td>Empowerment</td>
<td>Employees are not empowered to make changes to the system.</td>
<td>Employees are empowered to make changes in order to improve the system.</td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>Employees are not coordinated in a way that creates an efficient system.</td>
<td>Team members are coordinated in a way that creates an efficient system.</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>Communication systems are weak.</td>
<td>Strong communication systems are present in the system.</td>
<td></td>
</tr>
<tr>
<td>Innovation/Creativity</td>
<td>Innovation and creativity of employees is not fully utilized.</td>
<td>Innovation and creativity of employees is fully utilized to enhance the overall performance of the system.</td>
<td></td>
</tr>
<tr>
<td>Physical work condition</td>
<td>Work environment consumes a lot of resources and is difficult to sustain.</td>
<td>Work environment is balanced in order to create a efficient system and can be sustained.</td>
<td></td>
</tr>
<tr>
<td>(Work environment)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical working condition</td>
<td>Physical task content is boring and monotonous.</td>
<td>Task content fully utilizes the employee. It is not boring or monotonous.</td>
<td></td>
</tr>
<tr>
<td>(Task Content)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# TABLE 5: SUPPORT SUBSYSTEM

<table>
<thead>
<tr>
<th></th>
<th>Demand</th>
<th>Energizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-functional product</td>
<td>All areas do not work simultaneously in creating the product.</td>
<td>Groups work simultaneously to create a product meeting everyone’s needs.</td>
</tr>
<tr>
<td>design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layout</td>
<td>The system layout is not conducive to an efficient system.</td>
<td>The layout allows for good communication and efficiency to the system.</td>
</tr>
<tr>
<td>Process planning</td>
<td>Process Planning does not satisfy all parts of the system.</td>
<td>Process planning satisfies all parts of the system making it efficient.</td>
</tr>
<tr>
<td>Production leveling</td>
<td>Production plan and manufacturing system are unbalanced causing</td>
<td>Production plan and manufacturing system is balanced so that the system</td>
</tr>
<tr>
<td></td>
<td>inefficiencies.</td>
<td>is most efficient.</td>
</tr>
<tr>
<td>Inventory</td>
<td>Inventory is in excess which results in a loss.</td>
<td>Inventory levels are enough to support the system but not a waste.</td>
</tr>
<tr>
<td>Total preventative</td>
<td>Total preventative maintenance is not completed and often leads to</td>
<td>Total preventative maintenance is scheduled in a way which leads to</td>
</tr>
<tr>
<td>maintenance</td>
<td>equipment downtime.</td>
<td>maximized equipment uptime.</td>
</tr>
<tr>
<td>Occupational health and</td>
<td>The overall system presents an unhealthy organization through illness,</td>
<td>The organizations presents a healthy work environment.</td>
</tr>
<tr>
<td>safety org.</td>
<td>absenteeism and illness.</td>
<td></td>
</tr>
<tr>
<td>Capital equipment and</td>
<td>Not enough capital investment and tooling in order to create an</td>
<td>Enough capital and tooling is available in order to create an efficient</td>
</tr>
<tr>
<td>tooling</td>
<td>efficient system.</td>
<td>system.</td>
</tr>
<tr>
<td>Committed leadership</td>
<td>Leadership is not aware of the working level production system.</td>
<td>Leadership is committed and understands the working level production</td>
</tr>
<tr>
<td>Strategic Planning</td>
<td>There is no formal strategic planning system and the overall system is</td>
<td>There is a formal strategic planning process and decisions are made to</td>
</tr>
<tr>
<td></td>
<td>run day by day.</td>
<td>ensure long-term success.</td>
</tr>
</tbody>
</table>
FIGURE 1. CONTRIBUTION TO GDP GROWTH (1992-2000)

Contribution to GDP Growth (1992–2000)*

- 22% Manufacturing
- 22% Finance, Insurance and Real Estate
- 14% Retail Trade
- 14% Services
- 11% Wholesale Trade
- 10% Transportation and Public Utilities
- 2% Remainder of Economy
- 6% Software

*Percentage totals 101% due to rounding.

Source: NAM calculations from U.S. Commerce Department data
FIGURE 4. DEVELOPMENT ROAD MAP

STEP 1: Development of Pilot Version
First Draft by an engineer

STEP 2: Development of Pilot Version
Consulted expert in manufacturing

STEP 3: Testing of Pilot Version
Testing on a small North American manufacturer

STEP 4: Development of revised version
Additional instructions and detailed examples
FIGURE 5. MANUFACTURING DIAGRAM

Lean Manufacturing Enterprise

Production subsystem
- PUSH/PULL system
- Production Flow
- Work Rhythm
- Changeover techniques
- Supplier Delivery
- Material Handling
- Material Utilization
- Manufacturing Tech
- Standard operations

Total Quality Management
- Quality at the source
- Variance reduction
- Supplier Quality
- Customer Involvement
- Information and feedback

Human-at-Work subsystem
- Multi-functionality
- Problem Solving
- Empowerment
- Coordination
- Innovation/Creativity
- Physical working conditions (work environment)
- Physical working conditions (task content)

Support subsystem
- Cross-functional product design
- Layout
- Process Planning
- Production Leveling
- Inventory
- Total preventive maintenance
- Occ safety and health organization
- Capital equipment and tooling
- Committed leadership
- Strategic Planning
FIGURE 6. DEMAND & ENERGIZER DIAGRAM

**EXAMPLES**
- Money (profit, loss, etc)
- Material (raw material, parts, supplies etc.)
- Manpower (labor, etc)
- Time (time invested, time saved, time loss, etc)
- Energy (physical, mental, natural e.g. electrical etc)
- Risk (minimize risk, introduce risk, etc)

**DEMAND**

Consumption of resources or the input needed from the system

<table>
<thead>
<tr>
<th>EXAMPLES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Money</td>
<td>Business unit is losing money</td>
</tr>
<tr>
<td>Material</td>
<td>Wasting material due to high scrap rate</td>
</tr>
<tr>
<td>Manpower</td>
<td>Need to add manpower to inspect for poor quality</td>
</tr>
<tr>
<td>Time</td>
<td>Increases lead-time to customer</td>
</tr>
<tr>
<td>Energy</td>
<td>Consumes high amounts of energy</td>
</tr>
<tr>
<td>Risk</td>
<td>Increases risk to the business unit</td>
</tr>
</tbody>
</table>

**ENERGIZER**

Resources gained from the system

<table>
<thead>
<tr>
<th>EXAMPLES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Money</td>
<td>Business unit is profitable</td>
</tr>
<tr>
<td>Material</td>
<td>Efficiently utilizes all purchased materials</td>
</tr>
<tr>
<td>Manpower</td>
<td>Reduces manpower due to improvements</td>
</tr>
<tr>
<td>Time</td>
<td>Reduces lead-time to customer</td>
</tr>
<tr>
<td>Energy</td>
<td>Low amount of energy needed</td>
</tr>
<tr>
<td>Risk</td>
<td>Minimizes risks in the system</td>
</tr>
</tbody>
</table>
FIGURE 7. ELEMENT ASSESSMENT FLOWCHART

**DEMAND**
- Purely a demand would indicate that an element is only taking away from the system without adding value.
  - **EXAMPLES**
    - Communication could be evaluated as purely a demand if it is needed but no process currently exists to do so.

**ENERGIZER**
- Purely an energizer would indicate that an element is only taking adding value to the system with minimal resources.
  - **EXAMPLES**
    - Multi-functional workers could be evaluated as purely a demand if minimal training is necessary for the worker to perform many tasks in a variety of areas, therefore increasing system flexibility.

**BOTH DEMAND & ENERGIZER**
- Both DEMAND and ENERGIZER indicates there is a relationship between what resources are needed and what is gained from the system.
  - **EXAMPLES**
    - Manufacturing technology would be evaluated as a demand if it required heavy investments and also an energizer if the new equipment provided a competitive advantage by increasing productivity.

**NEITHER DEMAND nor ENERGIZER**
- Neither DEMAND and ENERGIZER indicates not
  - **EXAMPLES**
    - Changeover techniques would evaluate as neither if the system did not require any changeover processes.
FIGURE 8: PRESIDENT ENTERPRISE SUMMARY (CURRENT)

FIGURE 9: PRESIDENT PRODUCTION SUBSYSTEM (CURRENT)
FIGURE 10: PRESIDENT QUALITY SUBSYSTEM (CURRENT)

Customer involvement(4.0, 1.0)
Information and feedback(1.0, 1.0)
Quality at the source(1.0, 3.0)
Supplier quality management(1.0, 3.1)
Variance reduction(2.0, 2.0)

FIGURE 11: PRESIDENT HUMAN-AT-WORK SUBSYSTEM (CURRENT)

Communication(2.0, 3.0)
Coordination(1.0, 1.0)
Empowerment(1.0, 1.1)
Innovation/creativity(3.0, 1.0)
Multi-functionality(3.0, 4.0)
Problem solving(1.1, 1.0)
Task content(1.0, 3.0)
Work environment(4.0, 1.0)
FIGURE 12: PRESIDENT SUPPORT SUBSYSTEM (CURRENT)

FIGURE 13: VICE-PRESIDENT ENTERPRISE SUMMARY (CURRENT)
FIGURE 14: VICE-PRESIDENT PRODUCTION SUBSYSTEM (CURRENT)

FIGURE 15: VICE-PRESIDENT QUALITY SUBSYSTEM (CURRENT)
FIGURE 16: VICE-PRESIDENT HUMAN-AT-WORK SUBSYSTEM (CURRENT)

Communication (3.0, 1.0)
Coordination (4.0, 2.0)
Empowerment (4.0, 2.1)
Innovation/creativity (4.0, 1.0)
Multi-functionality (4.0, 3.0)
Problem solving (4.1, 2.0)
Task content (4.0, 3.1)
Work environment (4.1, 3.0)

FIGURE 17: VICE-PRESIDENT SUPPORT SUBSYSTEM (CURRENT)

Capital equipment and tooling (3.0, 2.0)
Committed leadership (4.0, 3.0)
Layout (4.0, 3.1)
Occupational safety and health (4.0, 2.0)
Process planning (5.0, 2.0)
Product design (4.0, 2.1)
Production levelling (5.0, 3.0)
Strategic planning (3.0, 3.0)
Total preventive maintenance (3.0, 3.1)
FIGURE 18: LINE MANAGER #1 ENTERPRISE SUMMARY (CURRENT)

FIGURE 19: LINE MANAGER #1 PRODUCTION SUBSYSTEM (CURRENT)
FIGURE 20: LINE MANAGER #1 QUALITY SUBSYSTEM (CURRENT)

FIGURE 21: LINE MANAGER #1 HUMAN-AT-WORK SUBSYSTEM (CURRENT)
FIGURE 22: LINE MANAGER #1 SUPPORT SUBSYSTEM (CURRENT)

FIGURE 23: LINE MANAGER #2 ENTERPRISE SUMMARY (CURRENT)
FIGURE 26: LINE MANAGER #2 HUMAN-AT-WORK SUBSYSTEM (CURRENT)

FIGURE 27: LINE MANAGER #2 SUPPORT SUBSYSTEM (CURRENT)
FIGURE 30: PRESIDENT QUALITY SUBSYSTEM (FUTURE TARGET CONDITION)

FIGURE 31: PRESIDENT HUMAN-AT-WORK SUBSYSTEM (FUTURE TARGET CONDITION)
FIGURE 35: VICE-PRESIDENT QUALITY SUBSYSTEM (FUTURE TARGET CONDITION)

FIGURE 36: VICE-PRESIDENT HUMAN-AT-WORK SUBSYSTEM (FUTURE TARGET CONDITION)
FIGURE 37: VICE-PRESIDENT SUPPORT SUBSYSTEM (FUTURE TARGET CONDITION)

FIGURE 38: LINE MANAGER #1 ENTERPRISE SUMMARY (FUTURE TARGET CONDITION)
FIGURE 39: LINE MANAGER #1 PRODUCTION SUBSYSTEM (FUTURE TARGET CONDITION)