Performance Index of Frugal Manufacturing System

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Abstract
Frugal excellence is a coordinated response to today’s highly competitive environment. Frugal manufacturing philosophy asks for elimination of waste hidden in the manufacturing system by eliminating non value adding activities. Frugal manufacturing is a very successful strategy and can be applied to all type of organizations i.e. manufacturing or service organization etc. In this paper after giving a brief idea about frugal philosophy, different types of wastes, causes of wastes, a designed questionnaire for self test has been given along with evaluation criteria to identify the weakness and strength of an industry for successful implementation of frugal manufacturing strategy. It also gives a methodology for evaluation and improvement of performance index using the principle of continuous improvement. A case study of wastes elimination by computation of Frugal Manufacturing Index (FMI) has been discussed. Results obtained are quite encouraging. Idea presented in the paper will be useful for those who want to implement frugal manufacturing index in their organization.

Keywords: Wastes, FMI, Key Performance Areas, Sub-systems, Milestones.

Introduction
Markets all over the world are experiencing the change due to recent trends in industrial manufacturing. In view of these changes, old business models that worked well for several decades no longer work effectively. New systems of doing industrial business have evolved in recent decades such as frugal, lean, green, sustainable and agile manufacturing. Bringing down the cost of manufacturing by elimination of as many wastes as possible from the value stream has become a major long-term and short-term objective for all industries. The fundamental concept is to eliminate wastes and produce only the items needed at the required time and in the required quantities. Principles of Frugal are universal as they are broadly accepted during many manufacturing operations and have been applied successfully across many disciplines. A planned implementation of Frugal production system leads to improved quality, better cash flow, increased sales, better productivity, improved morale and higher profits. Many leading company have implemented frugal manufacturing programmes with increased efficiency, reduced costs, improve customer response time, and more [3]. As such many organizations are now a day’s interested to adopt frugal philosophy so that they are in a position to deliver high quality and cost effective products quickly [9].

The main aim of this research paper is to provide a tool kit for computation of performance index of frugal manufacturing system and a methodology to improve the performance index along with implementation programme.

Concept and Definition
Frugal is a combination of:

F ➔ FUNCTIONAL
R ➔ ROBUST
U ➔ USER-FRIENDLY
G ➔ GROWING
A ➔ AFFORDABLE

Frugal is a new way of thinking about manufacturing. It is more reliable and easy concept than any other. Frugal manufacturing has probably attracted more attention in a short time than any other manufacturing technique.
Frugal manufacturing thinking allows a company or organization to produce high quality products with reduced wastes. [2]

**Wastes in the Production System**

The ideal production system is one that permits manufacturing of just what is wanted, when it is needed and in the quantity that is required. Frugal Manufacturing is all about eliminating wastes from the production system and move towards this ideal state. The wastes commonly associated with the most of the manufacturing systems are shown in Fig.1.

Waste means useless, futile, any activity that does not add value and for which the customer is not prepared to pay for. Waste can be found everywhere in an organization or system. It is not possible to eliminate all non-value-adding activities from the organization but they are still defined as, waste. [1]

![Figure 1: Different types of Wastes](image)

Wastes that are commonly viewed as the cost of doing business create most of the day-to-day problems in traditional manufacturing. Things such as equipments downtime (due to long setup and changeover requirements, or because equipment repeatedly break down), large raw material, work-in-process, and finished goods inventory levels are usually seen, as standard operating inefficiencies companies feel obligated to pass on to the customer as the cost of doing business. These are hidden wastes. They are hidden because they are actually result of the production system itself and manufacturers are simply blind to them. Waste, can arise in industry because of over specification or under-specification. Wastes arise due to defective materials, machine breakdowns, long set ups, long lead times, unsuitable equipment, uneven schedules, unreliable suppliers, inefficient layouts, absenteeism, and rigid work rules etc.[2]

Waste inhibits speed and flexibility to dynamic customer requirements and expectations. Waste cost money or big money and impacts the quality of products and services, the quality of work force, the quality of processes, quality of customer service and even the quality of environment. Waste kill the business, customer trust, employee morale, market share, profit in short, everything you work for. The ultimate result is higher production cost and finally higher product cost or decrease in the value of product, causing loss in business.

Conceptually, the frugal effort is not merely eliminating spotted wastes, but also their invisible root causes, which in turn will lead to sustainable value-creation focused; effective and efficient. The waste elimination exercise should be to create a fully integrated manufacturing system characterized by the following:

- Only confirmed orders with shorter lead times.
- Change over times that are near to zero.
- Consistently producing defect free products.
- Work balancing to achieve high productivity.
- Reliable suppliers for JIT implementation.
- Robust logistics system to deal with flexibility in manufacturing.
- User-friendly IT system to integrate the entire value chain.
Mathematical Modeling for Computation of Frugal Manufacturing Index (FMI):
The frugal manufacturing index of a sub-system \( x \) is given as:

\[
(FMI)_x = \frac{1}{n_1} x \frac{1}{n_2} x \frac{1}{n_3} \sum_{x=1}^{n_1} \sum_{y=1}^{n_2} \sum_{z=1}^{n_3} w_{xyz} O_{xyz} \frac{O_{xyz}}{O_{xyz}}
\]

where,
- \( x \) = the Sub-system
- \( y \) = the Performance Area
- \( z \) = the Performance Objectives
- \( w \) = the Weightage factor

\( O_{xyz} \) = the Performance Value of FMI-\( z \) in PA-\( y \) in sub-system \( x \)

\( O_{xyz} \) = the Objectivated Output of FMI-\( z \) in PA-\( y \) in sub-system \( x \)

Cumulative Frugal Manufacturing Index (FMI) of the system:

\[
FMI(s) = \frac{\text{Total FMI of all Sub-systems}}{\text{Total number of Sub-systems}}
\]

Survey instrument design for data collection:

A typical industrial organization engaged in manufacturing and marketing (from raw material to finished goods) of engineering goods can be considered to operate as a system with different sub-systems and performance areas. The concept of improving productivity is the main area of interest for different manufacturing units. But in order to do so, one has to first determine the status of the concerned manufacturing unit with respect to productivity. To do that some kind of audit assessment is mandatory. The audit assessment tool will not only give an idea about the status of manufacturing units, but also will provide the direction to implementation programme. Table 1 gives different sub-systems/ performance areas along with number of performance objectives associated with each performance area for the case under consideration. For details refer appendix –A (table 6 to 15). Depending upon the size and nature of manufacturing industry, the number of sub-systems/ performance areas may vary.

| Sr. No. | Sub-systems | Performance Areas | Performance objectives |
|---------|-------------|-------------------|-----------------------|
| 1       | Production  | □ Manpower Utilization | 2 |
|         |             | □ Assets Utilization | 4 |
|         |             | □ Quantity of Production | 3 |
|         |             | □ Schedule Completion | 1 |
|         |             | □ Production Planning & Control | 5 |
| 2       | Marketing   | □ Sales | 6 |
|         |             | □ Market Research | 4 |
|         |             | □ Product Strategies | 6 |
|         |             | □ Sales Promotion and Publicity | 4 |
| 3       | Technology  | □ R&D/Innovation | 6 |
|         |             | □ Design and Development | 6 |
|         |             | □ Manufacturing Engineering | 3 |
| 4       | Financial (Accounting) | □ Costing | 9 |
|         |             | □ Accounts Receivable | 5 |
|         |             | □ Accounts Payable | 4 |
|         |             | □ Taxation | 3 |
|   |   |   |
|---|---|---|
| 5 | HRD |   |
|   | Industrial Relationship | 4 |
|   | Personnel Administration | 2 |
|   | Training and Development | 3 |
| 6 | Material |   |
|   | Purchase Management | 6 |
|   | Stores Management | 5 |
|   | Inventory Control | 3 |
| 7 | Goals and Values |   |
|   | Customer Satisfaction Level | 7 |
|   | Employee Satisfaction | 8 |
|   | Supplier Satisfaction | 2 |
|   | Investor Satisfaction | 2 |
|   | Social Goals | 3 |
| 8 | Safety |   |
|   | Vigilance of Safety | 3 |
|   | Loss | 1 |
|   | Time Consumption | 2 |
|   | Action Plan | 5 |
|   | Documentation | 2 |
| 9 | Customer Service |   |
|   | Recognition of customer problems | 3 |
|   | Management involvement | 4 |
|   | Cure of problems | 3 |
|   | Notify about vulnerable situation | 3 |
|   | Customer satisfaction | 4 |
| 10 | Inspection |   |
|   | Quality check | 4 |
|   | Documentation | 2 |
|   | Audit procedure | 5 |
|   | Accessibility | 2 |
| 11 | Inventory Management |   |
|   | Record of Inventories | 3 |
|   | Quality Measures | 1 |
|   | Controlling Procedure | 3 |

**Scoring System and Guidelines**

The rating of performance objective can be measured subjectively on 1-6 scale, refer table 2. Each performance objective of sub-system is designed for the responses from not adequately addressed to adequately addressed. When the response is at the rating scale from 1 to 3 i.e. not adequately addressed, it means effectiveness of practices is almost absent & these are the potential areas for improvements. When the response is at the rating scale from 4 to 6 i.e. adequately addressed, it means effectiveness of practices are followed so these areas are slightly covered from a study of effectively/productivity improvement. Accordingly the required actions may be suggested for productivity enhancement.

It will provide the assessor some kind of factual status regarding the efficiency and effectiveness of the manufacturing unit as far as frugal manufacturing concerned. The scaling of the performance area of a sub-system will help to measure the performance of the performance area, which is one of the requirements for assessing frugal manufacturing index (FMI).
A company engaged in manufacturing and marketing of engineering goods has been selected for implementation of the proposed model. The manufacturing and other working data were collected by using the designed survey instrument.

A production sub-system is the key constituent of operations that creates the value which is offered to the customer by an organization. Moreover for an organization to be responsive, it has to be backed up by the production system. Table 3 indicates (√) the responses received for production sub-system only. [10]

Table 2: Depicts responses of each question of Performance area of sub-system

| Performance area of a sub-system | Performance Objectives/Questions | Rating |
|---------------------------------|----------------------------------|--------|
|                                 |                                  | 1  2  3  4  5  6 |
|                                 |                                  |        |

Case Study

A company engaged in manufacturing and marketing of engineering goods has been selected for implementation of the proposed model. The manufacturing and other working data were collected by using the designed survey instrument.

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Table 3: Assessment of Production Sub-system

| Sr. No. | Performance Areas | Sr. No. | Performance Objective | Not Adequately Addressed | Adequately Addressed |
|---------|-------------------|---------|-----------------------|--------------------------|----------------------|
|         |                   |         |                       | 1  2  3  4  5  6         |                      |
| 1.      | Manpower utilization | 1.1    | Direct labour utilization=(Standard hours recovery/attendance hours) |                           |                      |
|         |                   | 1.2    | Are operators knowledgeable and capable of interpreting customers’ specifications? |                           |                      |
| 2.      | Assets Utilization | 2.1    | Is there evidence of setup reduction activities to reduce setup time and costs? |                           |                      |
|         |                   | 2.2    | Is there a documented setup procedure? |                           |                      |
|         |                   | 2.3    | Are all tools and drawings used in manufacturing process free of unofficial and handwritten changes? |                           |                      |
|         |                   | 2.4    | Is maximum tool life identified by the manufacturer and communicated to our operators? |                           |                      |
| 3.      | Quality of Production | 3.1 | Are obsolete engineering drawings and products specifications removed from all manufacturing operations immediately upon implementation of a new revision? |                           |                      |
|         |                   | 3.2    | Are regular reviews carried out for the purpose to enhance the process capability? |                           |                      |
|         |                   | 3.3    | Are problem solving techniques applied in a timely manner? |                           |                      |
| 4.      | Schedule Completion | 4.1    | Are process changes controlled, authorized, documented, dated and signed? |                           |                      |
| 5.      | Production, Planning & Control | 5.1 | Do we utilize a “pull versus push “technique to drive production (i.e. kanban or final assembly order processing)? |                           |                      |
|         |                   | 5.2    | Are manufacturing lots traceable throughout the production processes? |                           |                      |
5.3 Are process controls established at all critical points within the process as defined by either the customers or our process or design engineers? 

√

5.4 Do we have documented rework procedures i.e. consistent with that of either the customer or applicable industry standards?

√

5.5 Is there a written procedure for communication and distribution of specification and engineering changes?

√

5.6 Is there a written procedure for statistical process control?

√

Calculation of Frugal Manufacturing Index (FMI) For Production Sub-System:

\[
(FMI)_{11} = \frac{\frac{5}{6} + \frac{2}{6}}{6} = \frac{\frac{7}{6}}{6} = \frac{7}{36} = 0.250
\]

\[
(FMI)_{12} = \frac{\frac{5}{6} + \frac{4}{6} + \frac{3}{6}}{6} = \frac{\frac{12}{6}}{6} = \frac{12}{36} = 0.709
\]

\[
(FMI)_{13} = \frac{\frac{5}{6} + \frac{4}{6} + \frac{3}{6}}{6} = \frac{\frac{12}{6}}{6} = \frac{12}{36} = 0.723
\]

\[
(FMI)_{14} = \frac{\frac{5}{6} + \frac{2}{6}}{6} = \frac{\frac{7}{6}}{6} = \frac{7}{36} = 0.834
\]

\[
(FMI)_{15} = \frac{\frac{5}{6} + \frac{4}{6} + \frac{3}{6} + \frac{2}{6}}{6} = \frac{\frac{12}{6}}{6} = \frac{12}{36} = 0.612
\]

\[
(FMI)_{xy} = \sum w_{yuv} \frac{O_{yuv}}{O^*_{yuv}} = \frac{0.750 + 0.709 + 0.723 + 0.834 + 0.612}{5} = \frac{3.628}{5} = 0.7257
\]

So Frugal Manufacturing Index (FMI) for the production sub-system is = 0.7257.

Proceeding in the same way, the FMI, on the basis of various inputs, for other sub-systems can be computed. Table 4 indicates the values of various sub-systems.

Table 4: Computation of Frugal Manufacturing Index (FMI) of Various Sub-Systems

| Existing Mile-Stone | Over-production | Waiting | Transportation | Over-processing | Inventory | Rework | Human Potential | Faulty Design | Motion | Defects | Power and energy | FMI |
|---------------------|-----------------|---------|----------------|----------------|-----------|--------|----------------|--------------|--------|---------|-----------------|-----|
| **Customer service** | 0.0000          | 0.1405  | 0.0000         | 0.1405         | 0.0000    | 0.1410 | 0.0000         | 0.0000       | 0.0000 | 0.0000  | 0.0000          | 0.5780 |
| **Financial**       | 0.0615          | 0.0308  | 0.0000         | 0.0615         | 0.0000    | 0.0615 | 0.0000         | 0.0000       | 0.0000 | 0.0000  | 0.0615          | 0.6309 |
| **Goals & values**  | 0.0128          | 0.0128  | 0.0000         | 0.0256         | 0.0384    | 0.0384 | 0.0000         | 0.0128       | 0.0256 | 0.0000  | 0.0000          | 0.8336 |
| **HRD**             | 0.0000          | 0.1212  | 0.0000         | 0.0808         | 0.0000    | 0.1212 | 0.0000         | 0.0000       | 0.0808 | 0.0000  | 0.0000          | 0.5560 |
Inspection 0.0443 0.0295 0.0000 0.0443 0.0295 0.0000 0.0440 0.0443 0.0147 0.0443 0.0295 0.0000 0.0443 0.0295 0.0000 0.0440 0.0443 0.0147 0.0443 0.0295 0.0000
Marketing 0.0000 0.0266 0.0532 0.0000 0.0000 0.0530 0.0000 0.0798 0.0532 0.0266 0.0000 0.0266 0.0532 0.0000 0.0000 0.0530 0.0000 0.0798 0.0532 0.0266 0.0000
Material 0.0561 0.0374 0.0561 0.0374 0.0560 0.0000 0.0374 0.0374 0.0000 0.0374 0.0000 0.0561 0.0374 0.0560 0.0000 0.0374 0.0374 0.0000 0.0374 0.0000 0.0561
Production 0.0434 0.0000 0.0000 0.0434 0.0000 0.0144 0.0430 0.0434 0.0289 0.0289 0.0289 0.0430 0.0434 0.0289 0.0289 0.0289 0.0289 0.0289
Safety 0.0420 0.0000 0.0420 0.0630 0.0420 0.0000 0.0000 0.0000 0.0000 0.0000 0.0630 0.0420 0.0630 0.0420 0.0000 0.0000 0.0000 0.0000 0.0000 0.0630
Technology 0.0411 0.0000 0.0411 0.0411 0.0616 0.0616 0.0620 0.0411 0.0000 0.0000 0.0411 0.0616 0.0616 0.0620 0.0411 0.0000 0.0000 0.0000 0.0000 0.0616
Inventory Management 0.0695 0.0695 0.0000 0.0695 0.0695 0.0000 0.0000 0.0000 0.0000 0.0695 0.0695 7.3470

### Computation of Frugal Manufacturing Index for the system:

The value of frugal manufacturing index of the system is 7.3470.

### Implementation procedure for improvement of Frugal Manufacturing Index (FMI):

To improve the Frugal Manufacturing Index (FMI), the availability of technical and financial resources were reviewed and accordingly it was decided that the required improvement in frugal manufacturing index will be carried out in four stages and these stages are characterized as I, II, III & IV Milestone. Six months were allotted to each milestone for the implementation of suggested methods/processes in different sub-systems of manufacturing plant.[9]

### Computation of Frugal Manufacturing Index after I-Mile stone:

During the implementation of I-Mile stone, the wastes of Waiting, Over Processing and Human Potential have been reduced by 40, 30 and 20% respectively. In order to achieve the above target, the following points have been considered:

#### Waiting
- The activity which takes more time to set the process should be minimized by latest tool and techniques.
- Preventive maintenance system should be applied effectively.
- Standardize production tooling location system should be maintained by use of different standard techniques.
- Automated planning techniques should be implemented.
- Proper signal to indicate requirement of material by use of inventory tool like kanban.

#### Over-processing
- To utilize the methodology of design for productivity, assembly and maintainability so that over processing will be reduced as normal operating practice.
- To make proper planning and consumption for raw material by use of overall equipment effectiveness.

#### Human potential
- Optimum utilization of human capabilities by method study and to provide intensive bonus scheme towards the motivation of their work utility.
- Self-actualized of human action i.e., maturity, self-awareness and authenticity by self-identification.
- Identify the global talent.
- To enhance the basic skills of employee by providing proper training to meet the global environment.

Suggestion of I-Mile stone has implemented and the value of frugal manufacturing index is calculated by using the mathematical model and the improved value of FMI is 7.7628. The values of FMI of various sub-systems obtained after implementation of I-Milestone are tabulated in table-5.
Computation of FMI after II-Mile stone:
During II-Milestones the wastes of Over Production, Transportation, Inventory and Rework have been reduced by 30, 20, 20 and 10% respectively. In order to achieve the above target, the following points have been considered:

**Over-production**
- Proper application of problem solving techniques such as group discussion etc.
- Correct cost standard with respect to quality, operational and products matrix.

**Transportation**
- Excess material handling to be minimized.
- Value to be added with product.
- Good and proper facility layout.
- Better understanding of the flow process having small batch sizes and short lead times.

**Inventory**
- Waiting has to manage effectively.
- Inventory should be optimum by maintaining proper management otherwise it will add the cost.

**Rework**
- Use of standard tools and templates.
- Error in paper work or material should be minimized.
- Customer service (needs) should be treated at top priority.

Suggestions of II-Mile stone have implemented and the value of Frugal Manufacturing Index (FMI) is calculated by using the mathematical model and the improved value of FMI is 8.0141. The values of FMI of various sub-systems obtained after implementation of II-Milestone are tabulated in table-5.

Computation of Frugal Manufacturing Index after III-Mile stone:
During III-Milestone, the wastes such as Over production, Over processing, Motion, Defects, Faulty Design, Power & Energy and Rework are considered. These wastes have been reduced by 10, 10, 20, 15, 10.10 and 10% respectively. In order to achieve the above target, the following points have been considered:

**Over Production**
- Avoid unleveled scheduling.
- Balanced work load.
- Redundant inspections to be minimized.

**Over Processing**
- Product changes without process changes.
- True customer requirements to be well defined.
- Over processing to accommodate expected downtime has to be minimized.
- Communication at each level has to be proper.
- Redundant approvals have avoided.

**Faulty Design**
- Design of product should be proper in all respects.
- Problem associate with design should be completely removed by assuring the best performance.

**Rework**
- Proper process control.
- Better preventive maintenance.
- Proper training programme and work instructions.
- Proper product design.

**Motion**
- Elimination of unnecessary occupied areas.
- Optimized and ergonomics design of layouts.
- To increase the electronic data interchange capability.

**Defects**
- There should be adequate problem solving techniques.
Supplier of raw material should be reliable.
There should be complete compliances with customer requirement maintained and check regularly.

**Power and energy**
- Light and equipments should be tuned off when they are not in use.
- Make use of energy efficient equipments.
- Insulate rooms to minimize energy waste.
- Minimize the use of hot water as it cost much more than fresh available water.

Suggestion of III-Mile stone has implemented and the value of Frugal Manufacturing Index (FMI) is calculated by using the mathematical model and the improved value of FMI is 8.4943. The values of FMI of various sub-systems obtained after implementation of III-Milestone are tabulated in table-5.

**Computation of Frugal Manufacturing Index (FMI) after IV Mile-stone:**
During IV-Mile stone the wastes such as Over processing, Inventory, Rework, Human Potential & Power and Energy are considered. These wastes have been reduced by 20, 25, 20, 30, & 30% respectively. In order to achieve the above target, the following points have been considered:

**Over Processing**
- True customer requirements to be well defined.
- Over processing to accommodate expected downtime has to be minimized.
- Communication at each level has to be proper.
- Redundant approvals have avoided.

**Inventory**
- Waiting has to manage effectively.
- Inventory should be optimum by maintaining proper management otherwise it will add the cost.

**Rework**
- Proper process control.
- Better preventive maintenance.
- Proper training programme and work instructions.

**Human Potential**
- Optimum utilization of human capabilities by method study and to provide intensive bonus scheme towards the motivation of their work utility.
- Self-actualized of human action i.e., maturity, self-awareness and authenticity by self-identification.
- Identify the global talent.

**Power and energy**
- Light and equipments should be tuned off when they are not in use.
- Make use of energy efficient equipments.
- Insulate rooms to minimize energy waste.

Suggestions of IV-Mile stone have implemented and the value of Frugal Manufacturing Index (FMI) is calculated by using the mathematical model and the improved value of FMI is 8.8817. The values of FMI of various sub-systems obtained after implementation of IV-Milestone are tabulated in table 5.
### Table 5: Comparative Values of Improved FMI after Various Mile-Stones

| Sub-Systems            | Existing Mile-stone | Improved FMI after |   |
|------------------------|---------------------|-------------------|---|
|                        |                     | I-Mile stone      | II-Mile stone | III-Mile stone | IV-Mile stone |
| Customer service       | 0.5780              | 0.6624            | 0.6905        | 0.6905         | 0.7529        |
| Financial & Accounting | 0.6309              | 0.6617            | 0.7047        | 0.7250         | 0.7705        |
| Goals & values         | 0.8336              | 0.8464            | 0.8618        | 0.8927         | 0.9091        |
|                        | 0.5560              | 0.6367            | 0.6488        | 0.7397         | 0.7784        |
| Inspection             | 0.6756              | 0.7095            | 0.7257        | 0.7621         | 0.7900        |
| Marketing              | 0.6810              | 0.7182            | 0.7235        | 0.8113         | 0.8386        |
| Material               | 0.6074              | 0.6504            | 0.6859        | 0.7372         | 0.7720        |
| Production             | 0.7257              | 0.7473            | 0.7618        | 0.8073         | 0.8338        |
| Safety                 | 0.7480              | 0.7669            | 0.7963        | 0.8100         | 0.8416        |
| Technology             | 0.5888              | 0.6135            | 0.6443        | 0.6721         | 0.7309        |
| Inventory Management   | 0.7220              | 0.7498            | 0.7707        | 0.8464         | 0.8639        |
| **Total**              | **7.3470**          | **7.7628**        | **8.0141**    | **8.4943**     | **8.8817**    |

After implementation of suggested methodology, Frugal Manufacturing index (FMI) from existing value of 7.3470 becomes 7.7628 after I-mile stone and subsequently after II, III & IV Mile stones; it changed to 8.0141, 8.4943 and 8.8817 respectively.
Figure 2: Frugal Manufacturing Indices of various sub-systems obtained after different mile stones.
Conclusion
Frugal manufacturing method is an effective way to reduce all forms of non-value added activities in an organization for improved performance and enhance international competitiveness. It is obvious that there are strong benefits to be gained from implementing a frugal manufacturing culture. It is really important for the business and organization to identify and remove wastes in most effective, efficient and economical manner by using specific techniques such as frugal thinking. By reducing these wastes from manufacturing system, the productivity and hence profitability will be enhanced.

This paper highlights the types of wastes present in the system and their effect on the production activities. It is advisable to record the actual values of every item before implementation start. During implementation compare the progress achieved with the goals suggested. A survey instrument has been designed and developed having different key performance areas of sub-systems and each sub-system with different key performance objectives for collecting informations for an industry.

The Frugal Manufacturing Index, gives an idea of performance, of the system has been computed by using the mathematical model and data collected for an industry. Depending upon the value obtained the performance/productivity index of different sub-systems and implementation procedure has been decided.

Like most areas of technology, FMI is constantly evolving and based on the philosophy continuous improvement, FM is closely a “journey without end”.

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### Table-6: Performance Objectives of Performance Areas of Marketing Sub-system

| Sr. No. | Key Performance Areas | Sr. No. | Performance Objectives | Not Adequately Addressed | Adequately Addressed |
|---------|-----------------------|---------|------------------------|--------------------------|----------------------|
| 1.      | Sales                 | 1.1     | Whether money getting from total sales contented? | 1 2 3 4 5 6             |
|         |                       | 1.2     | Whether actual sales are meeting targeted sales?     |
|         |                       | 1.3     | Are sales expenses within limit?                     |
|         |                       | 1.4     | Are control measures available to curb sales expenses? |
|         |                       | 1.5     | Whether available market of our industry is ramified In different areas? |
|         |                       | 1.6     | Whether measures to acquire bigger market available or not? |
| 2       | Market research       | 2.1     | Do we have certain procedures to determine market demands? |
|         |                       | 2.2     | Do we have any policy to determine pricing trend?     |
|         |                       | 2.3     | Are our representatives and employees familiar with the customers’ industries? |
|         |                       | 2.4     | Is our business dependent on just one or two customers? |
| 3       | Product strategies    | 3.1     | Do we have planned procedure and relative platforms to introduce a new product in to market? |
|         |                       | 3.2     | Do we have a robust set for initial reviews of a new product? |
|         |                       | 3.3     | Do we have fixed standard and procedure to withdraw unsuccessful product from market? |
|         |                       | 3.4     | Does our strategic planning support our supplying products and services to all of the customers and industry segments we now serve? |
|         |                       | 3.5     | Do we dedicate resources and investment to serve our customer market? |
|         |                       | 3.6     | Have patents and royalties are awarded for products for technology we have developed? |
| 4       | Sales promotion and publicity | 4.1     | Whether we are capable enough to identify target area? |
|         |                       | 4.2     | Are promotional schemes are effective? |
|         |                       | 4.3     | Is product image well established or not? |
|         |                       | 4.4     | Are we active in industry trade groups, technical associations, or trade publications that support the industries? |
### Table-7: Performance Objectives of Performance Areas of Inventory Management

**SELF ASSESSMENT: INVENTORY MANAGEMENT SUB-SYSTEM**

| Sr. No. | Performance Areas          | Sr. No. | Performance Objectives                                                                 | Not Adequately Addressed | Adequately Addressed |
|---------|---------------------------|---------|----------------------------------------------------------------------------------------|--------------------------|---------------------|
| 1.      | Record of inventories     | 1.1     | Do we have written procedures to cover the storage, release, and handling of raw materials and inventory items? |                          |                     |
|         |                           | 1.2     | Do these procedures ensure that only approved materials are released and used in productions? |                          |                     |
|         |                           | 1.3     | Do we label or code materials to ensure proper identification while they are in storage or in process? |                          |                     |
| 2.      | Quality Measures          | 2.1     | Do we employ automated planning techniques to schedules and order raw materials and finished goods? |                          |                     |
| 3.      | Controlling procedures    | 3.1     | Do we have an effective inventory control procedure that maximizes the inventory turns? |                          |                     |
|         |                           | 3.2     | Does this procedure cover issues like shelf life and first-in-first-out (FIFO) methods to prevent deterioration of materials? |                          |                     |
|         |                           | 3.3     | Do our inventory control procedures effectively control surplus and obsolete inventories? |                          |                     |

### Table-8: Performance Objectives of Performance Areas of HRD

**SELF ASSESSMENT: HRD SUB-SYSTEM**

| Sr. No. | Performance Areas        | Sr. No. | Performance Objectives                                                                 | Not Adequately Addressed | Adequately Addressed |
|---------|--------------------------|---------|----------------------------------------------------------------------------------------|--------------------------|---------------------|
| 1.      | Industrial               | 1.1     | Index of useful hours (work stoppages) (total workman hours worked/ total workman hours (attendance)). |                          |                     |
|         |                          | 1.2     | Stability index (employees with 12 months service /employees enrolled 12 months ago). |                          |                     |
|         |                          | 1.3     | Skill conversation index (employees with over 12 months service / total employees) |                          |                     |
|         |                          | 1.4     | Employees turnover (nos. of employees at the end of year / no of employees at the beginning of year) |                          |                     |
| 2.      | Personnel administration | 2.1     | Recruitment costs index (employee recruited/ recruitment cost) |                          |                     |
|         |                          | 2.2     | Statutory compliance index (intangible scale) |                          |                     |

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3. Training and development

3.1 Trainee retaining index (trainees retained for min. one year after training / trainees recruited)

3.2 Training effectiveness index (intangible scale)

**Table-9: Performance Objectives of Key Performance Areas of Inspection Sub-system**

| Sr. No. | Key Performance Areas | Performance Objectives | Not Adequately Addressed | Adequately Addressed |
|---------|-----------------------|-------------------------|--------------------------|----------------------|
| 1       | Quality check         |                         |                          |                      |
| 1.1     |                       | Do we confirm incoming quality of materials through incoming inspection or via supplier material certifications? |                          |                      |
| 1.2     |                       | Is there a written procedure for statistical process control (SPC)? -Does it define reporting method? -Does it outline the frequency and timing? -Does it include the maintenance of statistically based control charts? |                          |                      |
| 1.3     |                       | Can we demonstrate that product-reliability, life-cycle costs have been confirmed? If so what statistical technique? |                          |                      |
| 2       | Documentation         |                         |                          |                      |
| 2.1     |                       | Are process and product specifications readily accessible to operators? |                          |                      |
| 2.2     |                       | Are calibration records and dates kept? |                          |                      |
| 3       | Audit procedure       |                         |                          |                      |
| 3.1     |                       | Are procedures in place to confirm the acceptability of product for release to the customer? |                          |                      |
| 3.2     |                       | Are all associated employees trained on the document controlled procedure? |                          |                      |
| 3.3     |                       | Are these procedures audited on a periodic basis to ensure compliance? |                          |                      |
| 4       | Accessibility         |                         |                          |                      |
| 4.1     |                       | Are process and inspection records accessible to the operators? |                          |                      |
| 4.2     |                       | Are process and product specifications readily assessable to operators? |                          |                      |

**Table-10: Performance Objectives of Key Performance Areas of Goals and Values**

| Sr. No. | Key Performance Areas | Performance Objectives | Not Adequately Addressed | Adequately Addressed |
|---------|-----------------------|-------------------------|--------------------------|----------------------|
| 1       | Customer satisfaction level |                         |                          |                      |
| 1.1     |                       | Can we demonstrate that our customer service function is clearly defined with a distinct organizational structure? |                          |                      |
| 1.2     |                       | Are the metrics we use to measure customer satisfaction accurate and complete? |                          |                      |
| 1.3 | Is our senior management actively involved in customer service? |
| 1.4 | Do we maintain a high level of customer service throughout our customer base? |
| 1.5 | Have customer satisfaction goals been established for our organization? |
| 1.6 | When customer satisfaction levels fall short of targeted or expected goals, does senior management direct corrective action efforts? |
| 1.7 | Do we have a mechanism for notifying customers of documentation problems? |
| 2.1 | Do we provide training and educational opportunities for all employees at every level within the organization? |
| 2.2 | Are we an equal opportunity employer? |
| 2.3 | Are employees involved actively in company decision making? |
| 2.4 | Does our senior management keep employees advised of financial and market conditions of the company frequently? |
| 2.5 | Do we maintain training records on each employee, illustrating the courses and educational opportunities afforded each employee? |
| 2.6 | Have all labour disputes been resolved either with or without outside intervention or mediation? |
| 2.7 | Does supplier support an active employee suggestion programme? |
| 2.8 | Are engineering and R&D personnel active in professional societies and continuing education? |
| 3.1 | Whether there is timely payments done to supplier? |
| 3.2 | Whether there is a positive image of company in the market? |
| 4.1 | Whether timely dividend is paid to investor or not? |
| 4.2 | Whether there is transparency in company share value operations? |
| 5.1 | Are these any schemes for community service available (like education, health)? |
| 5.2 | Whether there is active participation in community affairs and problems (like HIV, POLIO awareness programme, calamity etc)? |
| 5.3 | Whether industry operations are environmental friendly? |
### Table-11: Performance Objectives of Key Performance Areas of Safety

| Sr. No. | Key Performance Areas | Sr. No. | Performance Objectives | Not Adequately Addressed | Adequately Addressed |
|---------|-----------------------|---------|-------------------------|--------------------------|----------------------|
|         |                       | 1.1     | Time required to investigate the safety violations etc. | 1 2 3 4 5 6          |
|         |                       | 1.2     | Number of accidents caused by human errors/unsafe act.   |                          |
|         |                       | 1.3     | Number of violations corrected in allotted time period. |                          |
| 1.      | Vigilance of safety   | 2.1     | Production loss due to unsafe acts/accidents.            |                          |
| 2.      | Loss                  | 3.1     | Safety programmes conducted within specified/allocated time. |                          |
| 3.      | Time consumption      | 3.2     | Safety results/output result.                           |                          |
| 4.      | Action plan           | 4.1     | Are operators and maintenance personnel empowered to stop production operations? |                          |
|         |                       | 4.2     | Is there proper storage and control for hazardous materials used in a production process? |                          |
|         |                       | 4.3     | Is there a written procedure for electrostatic discharge protection when electrical components are used? |                          |
|         |                       | 4.4     | Are process controls established at all critical points within the process as defined by either the customers or our process or design engineers? |                          |
|         |                       | 4.5     | Is there a properly documented and enforced preventive maintenance system? |                          |
| 5.      | Documentation         | 5.1     | Is there an off-site storage location for key documents and backup copies? |                          |
|         |                       | 5.2     | Are all documents storage locations secure with controlled access? |                          |

### Table-12: Performance Objectives of Key Performance Areas of Material

| Sr. No. | Key Performance Areas | Sr. No. | Performance Objectives | Not Adequately Addressed | Adequately Addressed |
|---------|-----------------------|---------|-------------------------|--------------------------|----------------------|
|         |                       | 1.1     | Indents conversion index (Indents converted in time/indents received). | 1 2 3 4 5 6          |
|         |                       | 1.2     | Credit or turnover ratio credit/purchase) |                          |
|         |                       | 1.3     | Vendor index (Approved vendors / total vendors). |                          |
1. **Purchase management**
   - 1.4 Alternate source index (no of items with minimum to sources/total items).
   - 1.5 Timeliness index (purchase) (purchase in time/total purchase).
   - 1.6 Cost index (Total purchases/Operating cost).

2. **Stores Management**
   - 2.1 Receipt effectiveness index (materials receipt accountant in time/total material receipt (Nos.).)
   - 2.2 Issue effectiveness index (issue made in time/total issue indents received).
   - 2.3 Space usage index (area used in storage/area available).
   - 2.4 Good housekeeping (intangible).
   - 2.5 Cost index (value of stock/operating cost).

3. **Inventory control**
   - 3.1 Turnover ratio (value of material consumed/total stock).
   - 3.2 Non-moving inventory index (total stock/value of non-moving inventory).
   - 3.3 Stock out index (total issue indents received/nos. of stock outs).

### Table-13: Performance Objectives of Key Performance Areas of Technology

| Sr. No. | Key Performance Areas | Sr. No. | Performance Objectives | Not Adequately Addressed | Adequately Addressed |
|---------|-----------------------|---------|------------------------|--------------------------|---------------------|
| 1.1     | R&D/Innovation        | 1.1     | Is the scope of our R&D and product development activities sufficient for the industry we service? | 1 2 3 4 5 6 |
| 1.2     |                       | 1.2     | Are our R&D and new product development efforts focused on meeting the stated needs of our customers? | 1 2 3 4 5 6 |
| 1.3     |                       | 1.3     | Are procedures accommodated customer specifications during new product development? | 1 2 3 4 5 6 |
| 1.4     |                       | 1.4     | Any standard technique to maximize product reliability while reducing manufacturing and life cycle costs? | 1 2 3 4 5 6 |
| 1.5     |                       | 1.5     | Do we employ a policy for patents to encourage innovation? | 1 2 3 4 5 6 |
| 1.6     |                       | 1.6     | Does a long term technology plan exist to guide continued development of leading edge technologies? | 1 2 3 4 5 6 |
| 2.1     | Design & Development  | 2.1     | Do we employ concurrent or simultaneous engineering methodologies in the development of new product? | 1 2 3 4 5 6 |
2.2 Are design changes effectively controlled throughout the organization?

2.3 Are computer based designs tools used in the design of new products and processes?

2.4 Is computer simulation and modeling used to maximize the reliability and life cycle of new product?

2.5 Are key customers included as part of the design team?

2.6 Are key suppliers included as part of the design team?

3.1 Is a new product development process clearly defined and proceduralized?

3.2 Do our engineers in corporate internal manufacturing process capabilities into the design rules/criteria for new products?

3.3 Do new product/process development procedures define matrices to be employed to ensure compliance with design rules, cycle times, performance requirements, reliability requirements etc?

### Table-14: Performance Objectives of Performance Areas of Financial and Accounting sub-system

| Sr. No. | Key Performance Areas | Performance Objectives | Not Adequately Addressed | Adequately Addressed |
|---------|-----------------------|-------------------------|--------------------------|----------------------|
|         |                       |                         | 1 2 3                    | 4 5 6                |
| 1.1     | Costing               | Have we established cost standards against which operational metrics can be applied? |                         |                      |
| 1.2     |                       | Are cost standard compatible with all quality, operational and product metrics? |                         |                      |
| 1.3     |                       | Do our accounting functions interact frequently and supportively with our operational functions? |                         |                      |
| 1.4     |                       | Do we effectively control over time and other lead time- associated costs? |                         |                      |
| 1.5     |                       | Are we willing to share cost information with our customers for the product and services we provide? |                         |                      |
| 1.6     |                       | Do we include an internal interest rate or cost of capital figure in our cost accounting system? |                         |                      |
| 1.7     |                       | Can we demonstrate that our cost controls have been successful in reducing product and service cost during the prior 12-24months? |                         |                      |
2.1 Do we appropriately apply indirect and overhead cost?

2.2 Timeliness of transaction (invoice raised in time - (total invoicing value)).

2.3 Books of accounts - upkeep (intangible scale).

2.4 Expense control (sales/operational expense).

2.5 Is the percentage of goods and services sold to any one customer in excess of half the total goods and services sold to all customers?

3.1 Are our labour costs controlled effectively?

3.2 Timeliness of transactions (bills passed in time /total bills received).

3.3 Books of accounts upkeep (intangible scale).

3.4 Expense control (total purchases/operational expense).

4.1 Record keeping (intangible).

4.2 Dispute handling (transactions without disputes/ total transactions).

4.3 Expense control (value of production/operational expense).

Table-15: Performance Objectives of Key Performance Areas of Customer Service

| Sr. No. | Key Performance Areas | Sr. No. | Performance Objectives |
|---------|-----------------------|---------|-----------------------|
| 1.1 | Recognition of customer problems | 1 | Can we demonstrate that our customer service function is clearly defined with a distinct organizational structure? |
| 1.2 | Is a measurement system in place to effectively and consistently evaluate our customers satisfaction levels? |
| 1.3 | Are the metrics we use to measure customer satisfaction accurate and complete? |

| 2 | Adequately Addressed | Not Adequately Addressed |
|---|---------------------|-------------------------|
| 1 2 3 4 5 6 | | |
|   | Management involvement | 2.1 Is our senior management involved in customer service? | 2.2 Are both positive and negative trends in customer satisfaction reported directly to our senior management? | 2.3 When customer satisfaction levels fall short of targeted or expected goals, does senior management direct corrective action efforts? | 2.4 In the last six months has our senior executive personally spoken with employee or executive of our primary customers (i.e those that collectively comprise 80 % of our annual sales revenues)? |
|---|---|---|---|---|---|
|   | 3. Cure of problems | 3.1 Do we have and follow a documented procedure for handling customer complaints? | 3.2 Is the procedure followed by all customers service staff at all times? | 3.3 Are customer service start empowered to resolve customer complaints on the spot, without seeking management approval? |   |
|   | 4. Notify about vulnerable situation | 4.1 Is there a procedure to advise customers of potential delivery, quality or service problem in advance? | 4.2 Is there a procedure to advise customers of manufacturing of process changes in advance? |   | 4.3 Are all of our customers surveyed for approval of product changes before said changes are enacted? |
|   |   | 5. Customer satisfaction | 5.1 What has the trend been in our customer satisfaction over the last 3 – 5 years? | 5.2 Does our customer service consistently provide prompt (within 24 hours) resolution of customer complaints and/or requests for information? | 5.3 Are we flexible in both delivery schedules and order quantities? | 5.4 Do we provide field support when needed to resolve operational or installation problems? |