# Managing Flexibility in Manufacturing and Operations

## A Case Study in the Indian Context

O P Sharma

**Abstract**

The objective of this paper is to present the results and critical analysis of a case study conducted on Rail Coach Factory (RCF) Kapurthala, which is one of the largest engineering companies in India in the Government sector, engaged in manufacturing coaches for the railways. The electronics-enabled revolution has brought about rapid changes in not only the corporate and business world, but has also resulted in changing the social and cultural patterns globally. The manufacturing industry is no exception and has seen much advancement in manufacturing technology during the last few decades. The advent of Flexible Manufacturing Technology (FMT) is one such revolution. Although the diffusion of FMT is fairly substantial in Japan and other developed nations, especially in the USA, U.K., Germany, Sweden, Italy, and France; in India, the technology is in the nascent stage of take off. This study is a part of an exhaustive survey covering aspects related to the current and likely future state of adoption and operation of FMT in the Indian context. Various aspects covered in this study include the company profile, its FMT environment, the strategic factors contributing to the choice of FMT equipment, impacts of FMT on the technical and organizational systems of the company, and so on. A Situation-Actor-Process (SAP) analysis is carried out leading to the identification of learning issues and conclusions.

Keywords: Flexible Manufacturing Technology, Flexible Manufacturing Systems, Computerization, Automation, Production, Organization.

### 1. Introduction

Trends and thoughts in various disciplines, including management of manufacturing flexibility and technologies have undergone a metamorphosis, especially during the last few decades. Evolution of knowledge in management and production technologies is synonymous with that in the natural sciences and Sushil (1997) has described this phenomenon as characterized by *ever shifting paradigms*.

The transition paradigm of manufacturing systems from traditional to new has been compared with a family replacing their old car with a helicopter as their primary means of transport, and therefore, in order to benefit from the changeover, it is essential that the family not use the helicopter in the same way it used the family car (Hayes and Jaikumar, 1988; Shani et al., 1992).

A noticeable trend observed in several industries during the 1980s was that the strategic emphasis shifted from *cost* to *quality*, although the management system remained focussed on costs (Miller et al., 1989; Dixon, 1992). But as advancements in manufacturing technologies offer an increasing array of equipment choices, the questions that have become more relevant now are: How should a multi-product manufacturing organization design its production facilities, how many products should be assigned to each facility and what batch size or scheduling rules are appropriate? Benjaafar and Gupta (1998) have attempted quantitative models that can help

**O P Sharma**
Department of Mechanical Engineering
Delhi College of Engineering,
Delhi 110042

operations managers answer these questions.

Agility is a new paradigm in the context of manufacturing and according to Meade and Sarkis (1999), the manufacturing environment has undergone several transitions from being a craft industry to mass production, and now the newest paradigm, agility. Agile-based competition is destined to displace mass-production-based competition as the form of global commerce. In order to understand this new paradigm, the Agility Forum has introduced four dimensions of agility, which are: cooperating to enhance competitiveness, enriching the customer, mastering change and uncertainty, and leveraging the impact of people and information. The authors have discussed these four dimensions in detail.

The current business environment is becoming increasingly uncertain, unpredictable, complex and therefore more and more competitive, not only in India, but throughout the world. The rules of the game are changing much faster than one could imagine even about a decade ago and apart from Japan, several other Asian countries surging ahead on the path of economic progress are on the way to be taken notice of. However, much of these global upheavals are attendant upon rapid technological strides made during the last few decades, especially in the electronics-enabled sectors like information technology (IT), communications, and allied areas. These developments are altering not only the modes of business, but also the societal and cultural patterns in several nations, as their influence seems to be all-pervasive. The result is a perceptible paradigm shift in economic and business hues, such as from the conventional to the unconventional; from the nearly certain to the veritable uncertain; from the static to the dynamic; from the stochastic to the fuzzy; from the closed to the liberalized; from the protected to the open; from the local/regional to the global, and so on. But whereas economic prosperity and progress have been concomitant with this paradigm shift, its *management* has proved to be a daunting task as it has thrown several challenges to the industry, business leaders and managers.

The researchers and practitioners throughout the world realize that though there may be diverse and situation specific solutions to the problems posed by these challenges, *flexibility* has to be an essential feature of the tools to handle these changes. Sushil (2000), while deliberating upon the concept of systemic flexibility, has essentially stressed upon the multiplicity of connotations of flexibility in response to diversity of situations.

The manufacturing sector, which is (and is likely to remain) the core of any economic activity, is no exception and changes have taken place in this sector also, characterized by the concept and evolution of advancements in manufacturing technologies. The flexible manufacturing technology (FMT), incorporating the flexible manufacturing systems (FMSs) as its major constituents, is one of these. Other elements constituting the FMT are: computer numerical control (CNC) machine tools, robots, transfer mechanisms, automated guided vehicles (AGVs), automated storage and retrieval systems (ASRSs), computer-aided design and computer-aided manufacturing (CAD / CAM) systems, flexible manufacturing cells (FMCs), and general flexible manufacturing systems (GFMSs). When these physical elements of FMT are completely integrated using computers and different networks, they result in computer-integrated manufacturing (CIM) systems, which are considered to be quite complex and highly advanced manufacturing facilities. The state of diffusion and level of operations of the elements of these advanced manufacturing systems in various countries have been reported by different authors (Hill, 1985; Margirier, 1986; De Meyer et al, 1989; Ranta and Tchijov, 1990; Roller and Tombak, 1991; Carlsson, 1992; Upton, 1995; Sharma and Sharma, 1997). In India, the earliest recorded adoption of flexibility in manufacturing is credited to the Rail Coach Factory (RCF), at Kapurthala, Punjab, in 1987 and the first unit of FMS was installed at the Heavy Alloy Penetrator Project (HAPP) at Tiruchirappalli in South India, around 1989. A part of the supply and installation of equipment for this project was undertaken by the CIM Division of Hindustan Machine Tools Limited (HMT), a Government of India undertaking. However, both these units were set up by the Government of India, meaning, thereby, that Indian manufacturers in the private sector did not evince much interest in FMSs around this point of time. This was due not only to the high capital investment attendant on these systems, but also because they did not feel threatened. But after globalization of the Indian economy in 1991, a number of flexible manufacturing cells were set up by manufacturers in different parts of the country. The author has attempted to study the current and the likely future pattern and mode of diffusion of FMT in Indian industry (with a focus on the automobile and the engineering sectors) and the paper is a part of this exhaustive study. The research covered several aspects and employed the methodologies of the Empirical Study or the Questionnaire Method (to explore the current state and practices); the Delphi Methodology (to generate the likely future scenario); the System Dynamics (SD) Modelling (to construct a mathematical model to predict the future behavior of the static and dynamic systems involved); and the Case Studies (to explore in-depth the actual operating modes and experiences of the users of FMT in varying degrees, i.e., from those utilizing bare essentials to those incorporating fully operative FMSs in their manufacturing units). But here only a subpart of the case studies, which is only a part of this exhaustive study, is being presented.

According to Willenborg and Karbbendam (1987), the case studies method is appropriate for new and poorly structured problems like the introduction of advanced technologies. This is true of FMT also because flexibility is a relative term and there is need to understand just what the word *flexibility* means and does not mean (Hartley, 1984).

The focus of this exercise has been to find out:

- The difference between the situation before and after the introduction of FMT, wherever applicable.
- The extent to which FMT elements have been developed and used in India.
- The economic considerations and factors, which propelled the user organizations to go for FMT.
- The technical and functional performance and production characteristics of the installed equipment.
- What has been the impact of FMT environment of the user company on its technical, work and organizational systems?
- What are the strategic factors, and means and objectives leading to the choice of FMT equipment installed?
- Benefits actually realized after installation of flexible automated machining systems.

### *1.1 Methodology*

The method of gathering relevant information and details was to use a structured questionnaire-cum-information / data table supplemented by personal interviews wherever deemed necessary. Data was also collected from individuals, available records and reports. The situation-actor-process and learning-action-performance (SAP-LAP) paradigm (Sushil, 1997) was carried out and learning issues synthesized.

## 2. The Rail Coach Factory, Hussainpur, Kapurthala (Punjab)

Established during disturbed times in the northern state of Punjab, this factory is a classic example of a work culture conducive to adoption of FMT, making all the difference in successful operation of advanced manufacturing technology. Given below are the historical details.

### *2.1 Historical Background*

The decision to set up a rail coach factory at Kapurthala, in the northern Indian state of Punjab, was taken in August 1985. This was the result of an accord reached between the then (and now deceased) Prime Minister of India, Mr. Rajiv Gandhi and Sant Harcharan Singh Longowal (now deceased), a political leader of Punjab. This agreement was known as the Rajiv-Longowal accord. This was a timely step towards making good the shortfall and augmenting the coach manufacturing capacity of the Railway's other manufacturing units.

### *2.2 Objectives of Setting the Rail Coach Factory (RCF)*

The RCF was set up, not only with a clear mandate and free hand from the Government of India and with full political backup, but also with well-defined objectives as detailed below:

***Design Improvement:*** The RCF project was much more than just another manufacturing unit in the sense that it was envisaged as a comprehensive and well-programmed mission aimed at an overall improvement in the design of coaches. The emphasis was on the manufacture of lightweight passenger coaches with higher carrying capacity, enhanced safety and comfort, and capability to withstand the rigors of running at very high speeds.

***Technology Updating:*** Keeping abreast of the latest technological developments in India and abroad, including those in the manufacturing technology, with emphasis on in-built flexibility and agility.

***Productivity:*** Constant improvements in manpower productivity vis-a-vis the existing levels by innovative and progressive methods of managing human resources.

***Quality:*** Building and manufacturing quality and workmanship to the highest international standards.

***Manpower Development:*** Creation and development of an effective organization of personnel who take pride in their work and complement the management's efforts in meeting the goals and objectives.

***National Objectives:*** The RCF is committed to self-sufficiency, energy conservation, a pollution free environment and generation of direct and indirect employment.

### *2.3 Important Statistics and Salient Features*

The RCF is spread over a sprawling area of 1178 acres, out of which the township occupies 843 acres and the manufacturing facilities together with the technical training schools (TTS), extend over 335 acres. The foundation stone of the factory was laid on August 17, 1985 and production of coaches commenced on September 8, 1987. The first general second class (GS) coach rolled out on March 31, 1988 and the factory achieved its full capacity production of 1000 coaches per year in the year 1991-92. By June 1997, all the manufacturing units or workshops of RCF acquired ISO-9001 certification and the international environment standard; ISO-14001 was awarded in July 1999.

In 1995, the RCF signed a memorandum of understanding (MOU) with M/s Siemens Ltd. for manufacture of light rail vehicles and with M/s Temoinsa for modular coach interiors, which were needed for Mass Rapid Transit System (MRTS) for metropolitan cities, in 1995. This envisaged using the RCF manufacturing facilities at Kapurthala for producing these vehicles and did not involve any transfer of technology (TOT).

However, the RCF entered into its first supply and TOT contract with M/s Link Hoffman Busch (LHB) of Germany for design, manufacturing and assistance engineering to manufacture state-of-the-art coaches. M/s Fiat will supply bogies for these coaches. This contract, signed in 1998, is valid for 10 years.

***Major departments of RCF are***: Mechanical, Planning, Machinery and Plant, Design, Total Quality Management (TQM), Group for Application of Information Technology (GAIT), Electrical, Civil Engineering, Stores, Accounts, Personnel, Medical, Welfare of Scheduled Castes (SCs) and Scheduled Tribes (STs), Vigilance, Security, Sports and Public Relations and Publicity. Out of these, the first six contribute directly to manufacturing flexibility and a brief description of the relevant features is given in the ensuing sections.

The RCF complex, in addition to having a 100-bed hospital with all facilities is also housing three primary and two senior secondary schools, community facilities, including a beautiful golf course, playgrounds, and swimming pools. A brief discussion relating to the functional aspects of the first six departments will be helpful.

***The Mechanical Department:*** This department handles manufacturing and other production functions, fulfilling of ISO certification requirements, maintaining and enhancing quality and reliability of products, testing and trial run of coaches, process validation, interaction with user Railways, innovation and in-house training and after sales services.

***The Planning Department:*** The functions handled by this department are: materials planning, manpower planning, and process and production planning. Integration of IT elements into planning is also supported by this department.

***The Machinery and Plant Department:*** This division is entrusted with the task of procuring, commissioning and proving out, maintaining, modification and revalidation of the machinery and keeping the machinery and plant in good working condition within the rated capacity as per ISO specifications. As a consequence, availability of machinery and plant remains quite high.

***Department of Group for Application of Information Technology (GAIT):*** This department is the nodal agency for all activities involving the use of computers and computer integration at RCF. The state-of-the-art information technology (IT) infrastructure (i.e., hardware, software and application programs), was designed and executed by Hewlett-Packard (HP), the contract which was placed in February 1991 and the system became functional in July, 1992.

The hardware infrastructure of the GAIT can be divided into three main parts as described below:

***Computer Aided Design (CAD):*** The CAD facilities primarily consist of 20 workstations and 3 file servers integrated with 2 local area networks, called the Drafting LAN (local area network) and Design LAN. As a result of this integration, all facilities in the CAD hall can be accessed by all the workstations and therefore, are shareable. There is a special workstation exclusively for Finite Element Analysis (FEA) work. While others were talking about AutoCAD, the RCF acquired Uni-Graphics at the very beginning.

***The Main-frames:*** RCF has two mainframes of HP make, model HP 3000/955 each with 96 MB Random Access Memory (RAM) and a total of 13 GB of shared hard disk storage space and both run back to back, i.e., in case one fails, the other takes over the full load, although with reduced capabilities.

***PCs and Related Equipment:*** There are more than 300 terminals and 120 printers spread all over the administrative block and the workshops. Existing database applications are:

PINS, the Personnel Information System is designed to meet all requirements of the personnel department.

EASY, the Employee Accounting System handles all money related transactions of the staff.

EICS, the Employee Incentive Calculation System is a key element in implementing the incentive schemes.

TAMES, the Time office Attendance Maintenance System is used to collect and monitor attendance data of the employees.

FACT, the Financial Accounting System caters to all the information requirements of the accounts department.

STORMS, the Stores Management Systems monitor all activities of the stores.

PURSYS, the Purchase System covers all work starting from registration of demand to selection of vendors, tendering and placing of purchase orders.

PLANS, the Plant Maintenance System is used for managing preventive and breakdown maintenance.

JFQC, the Jigs and Fixtures Quality Control System was developed in-house to monitor jigs and fixtures.

HOSPITAL MANAGEMENT SYSTEM was developed in-house and it made issuance of registration slip to the patients easy and quick.

PMS, the Production Monitoring System is used for monitoring the coach production cycle time.

IDIOMS, the Integrated Design Office Management System was developed in-house to disseminate related information.

***The Design Department:*** This is one of the most important departments providing the RCF with its core competence. The department is responsible for design, redesign and modification of the products. Other activities of this division are: undertaking demonstrations, conducting trials, checking compatibility, conducting finite element method (FEM) analysis, and training the design engineers.

The FEM analysis is used for designing the coach, with an attempt to make it as light as possible. This is carried out on a computer by making a mesh. The prototype is then subjected to a squeeze-testing machine by applying a load of 100 tons. The actual strain produced is then measured by using strain gauges at pre-specified locations, which is then compared with the results of the FEM analysis.

***The Total Quality Management (TQM) Department:*** This department carries out both electrical and mechanical inspections. However, the quality management function is further bifurcated into two parts, the Quality Control Wing and the Quality Assurance Wing.

So far as the inspection of parts is concerned, this includes 100% and audit inspection of different parts of the coaches at several stages of production.

***Quality control wing:*** The Quality Control Wing primarily monitors the quality of products at various stages in shell, bogie, sheet metal, paint and furnishing shops.

***Quality Assurance Wing:*** This division is responsible for assuring quality of bought out items, developing new vendors and preparing a list of approved vendors for critical bought-out items and maintenance of ISO-9001 and other standards in various shops.

It may be mentioned here that the RCF is an excellent example of outsourcing because bulk purchase of critical items is done only from approved vendors, who, in turn, are encouraged to go in for ISO-9000 and other relevant certifications. Guidance and assistance in this effort are provided readily and free of cost.

Another aspect worth mentioning is the system of feedback from the 'customers', who in this case are chiefly the Zonal Railways. Staff from the customer cell visit the Zonal Railways on a regular basis to collect feedback on RCF coaches. Immediate corrective action, wherever required, is taken on the basis of these feedbacks.

It may also be mentioned that RCF Kapurthala has emerged as one of the largest and most modern rail coaches works in the world.

### *2.4 Technical Characteristics of the FMT Elements Installed*

Out of 200 machine tools, 95% are CNC machines, all of the best international quality, originally imported from various countries such as Germany, France, Switzerland, USA, UK, Sweden and Denmark. Since these machines are huge, the number of tools varies from one to a maximum of 60. But the number of pallets is an astronomical figure of 10,000. There are two types of pallets: the ISO-standard and in-house designed. Each component manufactured uses the ISO-standard as the basic pallet supplemented by the in-house developed for that special purpose. EOT cranes, fork lifters and dumper trucks are the chief means of conveyance used. Lifters and battery operated platform trucks are the other means of conveyance used. Loading is generally done by cranes and fork lifters, which number 28 and 40 respectively.

As on today, the RCF does not have any robot but negotiations for purchasing a trainer robot from various sources were in progress at the time this study was conducted. The RCF has one fully operative FMS, which is chiefly used for in-house and out-house training of operators and engineers. The software used is interactive, is developed in-house and the system is connected to two mainframes. Tool servicing and monitoring is carried out by the tool room, is computerized and is within an accuracy of 3 microns. Other major elements of FMT operational at RCF are described below:

***Flexible Manufacturing Facilities at RCF:*** The RCF excels by way of incorporating fully functional, state-of-the-art and most modern elements of FMT such as: Sheet Treatment Plant, CNC Cut-to-length Line, CNC Shearing Center, CNC Cold Roll Forming Machine, CNC Laser Profile Cutting Machine, CNC Underwater PLASMA Cutting Machine, CNC Press Brakes (100 to 1000 tonnes), Synergic Pulse and Programmable Automated Welding, 3-D Coordinate Measuring, and Material Handling through Automation and Palletization.

***Testing Facilities at RCF:*** Wide and extensive full fledged testing facilities existing at RCF comprise: Radiography Laboratory, Electronics Laboratory, Physical Laboratory, Paints Laboratory, Rubber Laboratory, Chemical Laboratory, Meteorology Laboratory, and Mechanical Laboratory.

### *2.5 Automation / Computerization of Some Production Functions*

Some of the production functions, such as routing and scheduling, transporting parts, monitoring tool wear etc., are often integrated into the FMT systems through the vehicles of computers and are automated, partly or fully. At the RCF, the situation is presented in Table 1 that shows the extent to which the shown production functions are automated or computerised.

Information on the corresponding costs has been non-available (n.a.) in some cases due to various reasons; for example, the first two functions are performed by the middle level managers and since it is part of their job, they are not being paid separately or extra for these functions, making it un-quantifiable in terms of money.

Another point to be noticed is that at the RCF, the *monitoring* and *management* functions of the stock and wear and tear of the tools are totally separated.

**Table 1: Automation/Computerization of Some Production Functions**

| Function | Automation | | Non-Automation | |
|---|---|---|---|---|
| | Extent | Cost in Rupees | Alternative Mode | Cost in Rupees |
| Management of Production | 5 | n.a. | 5 | n.a. |
| Management of Production Data | 10 | | | |
| Allocation of Parts to Different Machines | – – – – – – | Not relevant to the RCF | – – – – – – | – – – – – – |
| Transportation and Transferring Parts from the Conveyance Facility to Machines | 2.5 | 100 million (One time) | 7.5 | 5 Million p.a. |
| The stock and wear & tear of the tools | | | | |
| Monitoring | 10 | n.a. | | n.a. |
| Management | | | 10 | 2.5 Million p.a. |

Legend: 0=Not at all automated 10=100% (fully) automated.

**Table 2: Task Performance; FMT Vs Conventional Technology**

| Task | Performed by Whom | |
|---|---|---|
| | FMT | Conventional Tech. |
| • N.C. Machines Programming | Supervisors | |
| • C.N.C. Machines Programming and Minor Adjustments | Supervisors | |
| • Quality Control | Officers and Supervisors | |
| • Monitoring of Tool Stocks | Tool Room Engineers | |
| • Monitoring of Tool Wear | | Supervisors |
| • Loading / Unloading of Parts | Skilled Artisans | Artisans |
| • Setting up of Fixtures, Pallets | Supervisors and Artisans | Artisans |
| • Deburring and Tool Presetting | Senior Artisans | Artisans |
| • Coordinating and Planning | Officers | Supervisors |
| • Production Scheduling | Officers / Specialists | Officers |
| • Supervision of Operators | Supervisors | Artisans |
| • Responding to Un-anticipated Deviations from Normal Operations | Supervisors and Artisans | Artisans |
| • System Development | Senior Officers | Junior Officers |
| • Machine Servicing | Skilled Operators | Senior Artisans |
| • General Housekeeping | Skilled Operators | Artisans |

### *2.6 Performance of Tasks: FMT Versus Conventional Technology*

Difference in the required levels of skill of personnel performing tasks in the FMT and the conventional (say dedicated machinery) environment, is another characteristic of advanced manufacturing systems. Table 2 shows the level of persons performing various tasks in the FMT environment and the conventional technology environment at RCF.

It may be mentioned here that although the manufacturing facilities at RCF incorporate flexibility in very substantial measures, still many functions are performed through conventional technology. Another point meriting mention here is that an artisan is a qualified or trained worker whereas almost all the supervisors are diploma engineers, having sound knowledge and experience of electronics.

### *2.7 Production Characteristics of the Parts Processed on FMT Facilities*

FMT is not (and should not be considered to be the one) a panacea for all problems relating to the syndrome of *economies of scales versus the economies of scope*. There are some parts having some characteristics (for example: prismatic shaped or those requiring complex machining), which are best suited (and justified) for these advanced systems of manufacturing. Also, at least in the Indian context, coexistence of the conventional and the advanced manufacturing systems can only be expected. At RCF, we found that percentage, by volume, of the total annual production through FMT is 75, through conventional technology is 20

**Table 3: Production Characteristics of Parts Processed on the FMT Facilities**

| No. | Element | Minimum | Maximum | Max. / Min. = Coeff. Of diversity |
|---|---|---|---|---|
| 1. | No. of Different Part/Product Variants | 10 | 15 | 1.5 |
| 2. | Size of the Parts / Products (in $m^3$) | 270 (Approx.) | 400 (Approx.) | 1.5 (Approx.) |
| 3. | Batch Size | 1 | 30 | 30 |
| 4. | Production Time (in days) | 20 | 60 | 3 |
| 5. | Critical Components | 100 | 500 | 5 |

and through vendors is 5. Approximately 10 batches of air-conditioned (AC) Coaches and 20 batches of non-air conditioned (NAC) Coaches are produced per year. Other production characteristics are shown in Table 3.

## 3. Strategic Factors, Objectives and Means Contributing to the Choice of FMT Incorporated

Incorporating flexibility in manufacturing through the elements of FMT is a costly proposition and its veritable economic justification is still foxing the researchers. The paradox is that whereas *product* and *process* flexibilities can be best achieved through conventional machines of manufacturing, *production* (volume) flexibility and higher levels of *automation* can be best achieved through FMSs only. But these are not the only motivating parameters justifying the adoption of FMT. For example, to achieve the objectives of product variety, productivity and technological leadership etc., an organization makes certain strategies to fulfill these targets.

Table 4 lists the contribution of some (fifteen) identified means to achieve some major objectives by making certain strategies. The responses are on a ten-point scale and are shown in the squares of the matrix. A rating of zero denotes absolute minimum (0.0%) and ten denotes absolute maximum (100%) and any numeral in between denotes linearly varying rating. A negative sign denotes a negative contribution.

It may be seen from this Table that, at RCF, the strategic choice of creating world class facilities to meet the future export targets with the objective of globalization and acquiring flexibility for future need, has been the chief motivating factor leading to the choice of FMT incorporated.

Fast response to the markets through product variety was not a consideration at all because the market was captive and orders were almost always over-booked. Secondly, the RCF being purely a Government department, hiring and firing the labor at will is ruled out and the labor size flexibility is non-feasible at RCF.

The first reason explains the zero contribution of all the means to product variety, and the second reason explains the zero contribution of the tool of labor flexibility to all the objectives and strategies, as can be seen from the first column and seventh row of Table 4. In so far as the means are concerned, it may be seen from this table that the maximum *individual* contribution has been made by the experience in the field of CNC machines, followed very closely by improvements in the engineering aspects of the production process.

A comparative statement of the relative influence of all the objectives and their influence on the choice of FMT equipment listed in Table 4 is given in Table 5.

**Table 4: Strategic Factors, Objectives and Means Contributing to the Choice of Elements of FMT Installed**

| Strategies → / Objectives → / Means ↓ | Fast response to the markets / Product Variety | Maximizing Profits through Lower Unit Costs / Productivity | Acquiring the edge to beat Competitors / Technological Leadership | Acquiring flexibility for Future Needs / Survival & Growth | Creating world class facilities to meet export targets / Globalization | Total Score |
|---|---|---|---|---|---|---|
| 1. Enhancing Machine Utilization Time More Extensively | 0 | 9 | 5 | 6 | 9 | 29 |
| 2. Optimum Utilization During Partial Breakdown | 0 | 10 | 0 | 5 | 5 | 20 |
| 3. Making Machine Utilization More Intensive | 0 | 9 | 0 | 5 | 6 | 20 |
| 4. Making Machines more Versatile and Multifunctional | 0 | 9 | 6 | 7 | 8 | 30 |
| 5. Enhancing Product Quality | 0 | 0 | 8 | 8 | 10 | 26 |
| 6. Lowering Direct Labor Costs | 0 | 9 | 3 | 4 | 5 | 21 |
| 7. Making the Size of Labor Force Flexible* | 0 | 0 | 0 | 0 | 0 | 00 |
| 8. Making the Labor Force Multi-skilled and Multifunctional | 0 | 7 | 4 | 7 | 7 | 25 |
| 9. Better Sequencing and Scheduling of the Production Process | 0 | 6 | 4 | 6 | 3 | 19 |
| 10. Improvement in the Engg. Aspects of the Production Process | 0 | 8 | 8 | 8 | 8 | 32 |
| 11. Experience in the Field of CNC etc. | 0 | 10 | 9 | 9 | 10 | 38 |
| 12. Simultaneous Production of Various Parts / Products | 0 | -3 | 0 | 0 | 0 | -3 |
| 13. Smooth Launching of Newer Products | 0 | 0 | 6 | 6 | 7 | 19 |
| 14. Variation in the Batch Size | 0 | 6 | 0 | 0 | 0 | 06 |
| 15. Quickly Tuning to the input Variations | 0 | -2 | 8 | 8 | 8 | 22 |
| Total | 00 | 78 | 61 | 79 | 86 | 304 |

* Being a government department, this is fixed.

**Table 5: Objectives and their Influence on the Choice of FMT Elements Installed**

| Objective | % Relative Influence |
|---|---|
| Globalization | 28.28 |
| Enhancing Productivity | 26.65 |
| Survival and Growth | 25.98 |
| Technological Leadership | 20.96 |
| Product Variety | 00.00 |

## 4. Investment Cost of the FMT Equipment

Table 6 shows the latest available figures regarding investments made in major FMT equipment. The cost of developing vendors could not be quantified because initially, the vendors were given only the technical know-how. Now, in some of the very few cases, financial help is also arranged for prospective vendors.

**Table 6: Investment Cost of FMT Equipment**

| Element | Cost in Rs. (million) |
|---|---|
| CNC Machining Center and Stations | 1000 (all equipment) |
| Materials Handling Equipment | 100 |
| Tooling | 50 |
| Fixtures | 10 |
| Computer Hardware | 40 to 50 |
| Computer Software | 10 |
| Training of the Operators and Systems Managers | 2.5 (per annum) |
| Vendor Development | Not Quantifiable |

## 5. Benefits of FMT Actually Realized

It may be mentioned here that as RCF incorporated FMT since its very inception, the experienced benefits could be known only by

**Table 7: Benefits Actually Realized after Installation of FMT**

| Element | Percentage Change |
|---|---|
| 1. Reduction in Lead Time | 20 |
| 2. Improved Machine Utilization | 25 |
| 3. Reduction in Unit Costs | 10 |
| 4. Reduction in Direct Labor Hours | 30 |
| 5. Rapidity of Response to Market Changes | 10 |
| 6. Increase in Profits | 15 |
| 7. Improvement in Quality | 10 |
| 8. Improvement in Responsiveness | 10 |
| 9. Reduction in Inventory | 8 |
| 10. Improvement in Control | 5 |
| 11. Improvement in Discipline | 5 |
| 12. Reduction in Industrial Relations (e.g. Discussions regarding keeping pace with production, recruitments, layoffs etc. with labor unions) | Not Applicable. |
| 13. Reduction in Pay-back periods and Satisfactory Levels of Return on High Investment Required | Not applicable.. |
| 14. Reduction in the Number of Operations | 5 to 10 |
| 15. Reduction in 'door to door' and 'floor to floor' times | 5 |

comparing it with some similar factory, not incorporating FMT.

The Integral Coach Factory (ICF) at Chennai in Southern India, which was set up in 1956 by the Government of India, Ministry of Railways, and is therefore a sister concern of the RCF, has been taken as the basis for comparison. The ICF Chennai, employing 17,000 people as against the 7,500 employed at RCF, has its manufacturing facilities incorporating conventional technology. The production capacity of the ICF is lower than that of the RCF and so is the quality of the ICF coaches. Whereas the RCF exceeded its target capacity of 1000 coaches per year by producing 1098 coaches in 1993-94, the ICF has not been able to do so thus far.

Table 7 shows the benefits of incorporating FMT actually experienced at the RCF vis-a-vis the ICF.

It may be mentioned here that since the RCF is owned by the Government and its products are all used by the owner (Government of India) itself, it is a nonprofit organization. Hence, a 15% increase in profits as shown in Table 7 actually is the reduction in the cost of production. For the same reason, reduction in payback periods and satisfactory levels of return of high investment required is a non-issue at the RCF.

Also, since the RCF does not layoff and recruitments are not made by it, reduction in industrial relations is also rendered infructuous.

Another feature of the RCF is that after receiving orders, it makes broad production schedules for the entire year, broken into approximate monthly segments. Depending upon the exigencies, this production schedule is fine-tuned as and when required.

## 6. Impact of FMT on The Technical System

According to Willenborg and Krabbendams (1987), six features as given in Table 8 characterize the Technical System. Introduction of FMT alters these features, which in turn, sets in changes in the work and organizational structures.

Table 8 was not shown to the respondents of the company; only their responses were collected through interviews and questionnaires as shown in Appendix I.

The impact of FMT on the Technological System as actually experienced by the company was compared with the expected impact according to Table 8 and inferences drawn are shown in Table 9. The expected scores appearing in the first column of Table 9 have been reproduced from the CNC (third) Column of Table 8, since the plant is predominantly operating around this class of FMT. Actual scores show reported impacts.

The FMT environment at the RCF comprises chiefly of CNC machines and it incorporates a fully operational Automated Sheet Storage and Retrieval System (ASSRS). The capital tied up at

**Table 8: Features of the Technical System**

| Features | Conventional (Universal) | Special Purpose | CNC | FMS |
|---|---|---|---|---|
| Complexity | 1 | 1 | 3 | 4 |
| Level of Automation | 1 | 2 | 3 | 4 |
| Capital Intensity | 1 | 2 | 3 | 4 |
| Product Flexibility | 4 | 1 | 3 | 2 |
| Process Flexibility | 4 | 1 | 3 | 2 |
| Production Flexibility | 3 | 1 | 2 | 4 |

Legend: 1= Very Low, 2=Low, 3=High, 4=Very High.

**Table 9: Reported Impacts of FMT on the Technical System**

| Features | Expected Score | Actual Score | Experienced Level of Impact |
|---|---|---|---|
| Complexity | 3 | 2 to 3 | Low to High |
| Level of Automation | 3 | 2 | It is still Low |
| Capital Intensity | 3 | 4 | Very High |
| Product Flexibility | 3 | 3 | Change of design is relatively easy |
| Process Flexibility | 3 | 3 | Changing process plans is easy |
| Production Flexibility | 2 | 2 | Slightly demanding |

Legend: 1 = Very Low, 2 = Low, 3 = High, 4 = Very High

the RCF is to the tune of Rs. 4.5 billion. The operators are not allowed to alter, correct or modify the CNC programs, which is done only by qualified engineers. The relative ease in changing the product design is due, chiefly, to computer integration and CAD / CAM interfacing. Changing from one part type to another is slightly demanding although compared with the ICF, it is not very problematic due to the in-built flexibility.

Further, since the RCF evolved on the plank of manufacturing flexibility right in the beginning, not many changes have been felt in the technical system.

Other impacts of FMT on the technical system experienced at the RCF are given in the last column of Table 9, which is constructed on the pattern explained earlier.

## 7. Organizational Impacts of FMT

*Since the RCF was setup with the maximum possible manufacturing flexibility, more qualified engineering officers were put on the job vis-a-vis the ICF and this was the chief impact experienced.* Subsequently, when more elements of FMT were added, the experienced impacts of this change were almost negligible. Thus, the RCF amply exemplifies that it is easier (and better) to start a new plant with FMT initiation than to change over from conventional technology to FMT in an already existing production and organizational environment.

The prevailing organizational structure at the RCF is a judicious combination of capability based, networked, and hierarchical structures. It was also reported that vis-a-vis the ICF Chennai, relations with the labor union are comfortably better.

Other points of comparison between a conventional (in this case, ICF, Chennai) and the FMT work organization at RCF are given in Table 10. Significant deviations have been indicated by (*) and are explained here:

At the RCF, maintenance is slightly more critical than preventive maintenance because the machinery installed has almost no alternative roots. This is because standby is very costly. Therefore, breakdowns are un-affordable. This also explains the reversed order of critical areas (viz. mechanical, electrical and electronics). In fact, a separate department of electronics was created only in 1992 to cater to the needs of these aspects.

The communication network at RCF remains individual and low, notwithstanding the elements of FMT installed, primarily due to the reason that it is purely a Government run department. The same also explains why motivation is low and mainly wage oriented, and sense of pride in the organization is quite perceptible even amongst the lower staff.

Implementation of FMT at RCF did not entail any radical restructuring for the reason that it started with the incorporation of FMT at the very outset.

Again it may be mentioned that the RCF organogram is nearer to that of the one for conventional technology, with one difference that the number of unskilled labor is almost 10% of skilled artisans.

## 8. The Situation-Actor-Process (SAP) Analysis

### *The Situation*

- The Integral Coach Factory (ICF) at Chennai, a southern city in India, was established in 1956, to manufacture coaches for the Indian Railways. Before this, coaches for the Indian Railway were made of wood and were made in workshops.
- But this factory proved to be inadequate to meet the ever-growing demand for modern coaches by the Indian Railways and a need was felt to establish one more factory, preferably in the northern part of India.
- The then Prime Minister of India, (Late Mr. Rajiv Gandhi) and another political leader of the prosperous state of Punjab, Sant H. S. Longowal, reached an accord whereby it was decided to locate this factory in a remote and industrially backward part of this otherwise progressive state.
- It was the vision of Late Mr. Rajeev Gandhi to set up this factory on modern lines, incorporating the latest manufacturing technologies.
- The first G.M. of the proposed RCF, Mr. G.S. Kang (now retired) was given the mandate of setting up this factory in August 1985 with the target of starting actual production within two years. Full political and financial support with freedom of action was given to Mr. Kang, who, in turn, lived up to the expectations.
- Since this was a project involving massive investment by the Government of India, whose executive head is the Prime Minister of India, location had to be decided at a political level.
- Mr. Kang and his team visited several industrially advanced countries including USA, UK, France, Italy, Germany and Japan, to scout for the latest manufacturing equipment incorporating state-of-the-art technologies. This is an example of early entry of FMT into the Indian manufacturing industry, where the very conception, inception and functioning of the factory was totally based on elements of FMT.

### *The Actors*

- The then Prime Minister of India, Late Sh. Rajiv Gandhi and Late Sant Harcharan Singh Longowal, Sh. G.S. Kang, the first G.M. of Proposed RCF, Sh. J.S. Marwah, chief Mechanical Engineer, RCF, departmental heads, middle level executives, supporting staff, supervisors, workers (artisans), vendors, contractors, material suppliers, Punjab State Electricity Board (PSEB) for making power available, and the State Government of Punjab for making about 1178 acres of land available.

### *The Process*

- It was the vision of the then Prime Minister of India, to set world class manufacturing facilities at RCF Kapurthala, to manufacture rail coaches of world class quality at the cheapest possible prices. The founding G.M. was given this brief, who in turn selected and motivated his team of experienced and well qualified engineers of high caliber.
- A team of 5 to 6 officers was constituted for the purpose, which was sent to visit almost all the industrially developed nations making railway coaches. The countries visited were

**Table 10: Comparison Between Conventional and FMT Work Organizations**

| Features | The Work Organization | | |
|---|---|---|---|
| | As Expected in a Conventional Environment | As expected in an FMT Environment | Actual Response of the Company |
| 1. Level of Skills and Awareness Required by the Operators | Low | High | A little High skills with HIgh Awareness |
| 2. Level of Qualifications and Preparedness required by the managers | Moderate | High | About 10% Higher vis-à-vis the ICF |
| 3. Number of Operators Required | Moderate to large | Extremely Small | 20% less vis-à-vis the ICF |
| 4. Number of Specialists Required for Process Planning and Maintenance | Very small | Quite large | 30% more vis-à-vis the ICF |
| 5. Critical Components of Maintenance and Preventive Maintenance | Chiefly Mechanical | Electrical Electronics and Mechanical | Mechanical, Electronics and Electrical (*) |
| 6. Division of Labor | Job Specialization | Job Rotation | Job Specialization, Job Rotation in Non-critical areas |
| 7. Training | On the Job Trial and Error with Low Cost | Comprehensive Theory based with High Costs | Comprehensive and Formal with Low Costs |
| 8. Relations | Individual with Low Communication | Group with High Communication | Individual and Low (*) |
| 9. Culture | Lack of Motivation Wage Oriented | High Motivation Work Oriented | Low and Wage oriented (*) |
| 10. Problem Solving and Trouble Shooting | Low Capabilities (lack of skills and motivation) | High Capabilities and Specialists | Low to Higher Capabilities Required |
| 11. Software | Standard | Interactive | Interactive, Developed in-house |
| 12. Implementation | Smooth: Small Differences with Existing Division of Labor, Wages and Training | Radical Restructuring Required | Not Applicable (*) |

chiefly France, the UK, Switzerland, Germany, Sweden, USA, Canada and Japan. This team submitted its detailed report based on which the decision to buy which machinery and from which source was taken. The founding GM, Mr. G.S. Kang played a vital role at this stage, and it was decided to buy the best available in the world. He bypassed the Government of India's procedure to invite tenders and select the lowest bidders. Mr. Kang insisted on buying the best irrespective of the cost.

- For example, it was discovered that in the presses, the best variety was GWF of Germany. He decided to buy all the presses from this source. Mr. Kang reprimanded one of the officers, who recommended a press of Edward make based on the lowest bidding. It is worth noting that this press of Edward make is giving troubles to the RCF personnel even today. This exemplifies that excellence in manufacturing cannot be achieved with inferior machine tools; rather, even a single inferior machine tool tends to adversely effect the efficiency of the entire production system. This also illustrates that flexibility in the process of acquisition of elements of FMT is equally important.
- It may be added here that the actual placing of the orders for machinery was preceded by making specifications for the coaches to be manufactured and making a lay out of the plant and deciding on the parameters of the machinery. Other features of this process were that the team of machinery suppliers was helping in the installation and commissioning in early stages and that the team of engineers of RCF was associated actively during this process, which was also a learning phase for them.
- Of course, various teams of engineers from RCF were formally trained, well before the onset of the actual process of installation and commissioning by the suppliers, first in their own countries (e.g., Germany and Italy) and then in India. This training, which was a part of the contract, was theoretical as well as practical.
- As a result, the RCF team had only minor difficulties during this process of installation and commissioning like breakage during transportation and language problems. Not much difficulty was, however, experienced in the operation of machines.
- Integration with the computers, CAD / CAM, and information technology (IT) elements was done at a later stage (after about 2 years) by the RCF team; not much difficulties were faced, and the required training was done in India only.

## 9. The Learning Issues

- Under the present circumstances, the adoption of JIT system at the RCF appears to be difficult. Other means of reducing inventory should be explored. For example, the already existing network of vendors and suppliers could be trained and encouraged to supply materials at a short notice. ABC analysis and better control should also be attempted.
- Attempts should be made to always keep upgraded versions of computers in operation.
- Levels of automation should be raised wherever feasible and convenient. For example, the functions of transferring parts, management of the stock and wear of tools could be further automated.
- Attempts at multi-skilling of the artisans (operators) should be made earnestly.
- Attempts should be made at engaging more and more contractual labor to acquire some degree of labor size flexibility.
- There is an urgent need to cut down on the lead-time. For this purpose, vendors should be developed specifically to produce parts that can be manufactured simultaneously.

- Attempts should be made to demolish hierarchical barriers in order to cultivate group relation and high levels of communication. This can be achieved without much restructuring.
- Attempts must be made at raising the motivation level of the artisans (operators) and supervisors. This can be achieved through higher levels of communications and participative management.
- The FMT experience gained at RCF should be fully utilized by way of providing Consultancy to other governmental, public sector and private sector organizations. For example, the Indian Space Research Organization (ISRO) operating under the Ministry of Science and Technology, Defence Research and Development Organization (DRDO), and Ordinance Factories, both operating under the Ministry of Defence, Government of India, can interact closely in the area of advanced manufacturing technology.

## References


Benjaafar, Saifallah and Gupta, Diwakar (1998), Scope Versus Focus: Issues of Flexibility, Capacity and Number of Production Flexibilities, *IIE Transactions* 30(5): 413-425.

Carlson, B.(1992), Management of Flexible Manufacturing : An International Comparison, *OMEGA, International Journal of Management Science* 20(1): 11-22.

De Meyer, A., Nakane, J., Miller, J. and Ferdows, K. (1989), Flexibility: The Next Competitive Battle, The Manufacturing Future Survey, *Strategic Management Journal* 10: 135-144.

Dixon, J.R. (1992), Measuring Manufacturing Flexibility: An Empirical Investigation, *European Journal of Operational Research* 60(2): 131-143.

Hartley, J. (1984), *Flexible Automation in Japan*, IFS, pp. 191-216, Springer Verlag.

Hayes, R.H. and Jaikumar, R., (1988), Manufacturing's Crisis: New Technologies, Obsolete Organizations, *Harvard Business Review* 66: 77-85.

Hill, Malcolm, R. (1985), FMS Management – The Scope for Further Research, *International Journal of Operations and Production Management* 5(3): 05-20.

Margirier, Gilles, (1986), Flexible Automated Machining in France: Results of a Survey, *Journal of Manufacturing Systems* 6(4): 253-265.

Meade, L.M. and Sarkis, J. (1999), Analyzing Organizational Projects Alternatives for Agile Manufacturing Processes: An Analytical Network Approach, *International Journal of Production Research* 17(2): 241-261.

Miller, J.G., Amano, A., Demeyer, A., Ferdows, K., Roth, A. and Nakane, J. (1989), Closing the Competitive Gaps: The International Report of the Manufacturing Future Project, Boston University Manufacturing *Roundtable Research Report Series*.

Ranta, J. and Tchijov, I.(1990), Economics and Success Factors of FMS: The Conventional Explanation Revisited, *The International Journal of Flexible Manufacturing Systems* 2(2): 169-190.

Roller, L.H. and Tombak (1991), Strategic Aspects of Flexible Production Technologies: Theory and Evidence, *International Journal of Production Economics* 23: 197-204.

Shani (Rami), A.B., Grant, Robert. M., Krishnan, R., Thompson, Frick (1992), Advanced Manufacturing Systems and Organizational Choice: Sociotechnical Systems Approach, *California Management Review* 66(4): 91-111.

Sharma, O.P. and Sharma, P.B. (1997), Global Versus the Indian Industry's Competitive Edge with Flexible Manufacturing Technology, *Proceedings of the Portalnd International Conference on Management of Engineering and Technology (PICMET* July 27-31: 693-696, Portland, USA.

Sushil (1997), Flexible Systems Management: An Evolving Paradigm, *Systems Research and Behavioral Science* 14(4) 259-275.

Sushil (2000), Concept of Sytemic Felxibility, *Golbal Journal of Felxible Systems Management* 1(1): 77-80.

Upton, D.M., (1995), What Really makes Factories Flexible?, *Harvard Business Review* July-August: 74-84.

Willenborg, J.A.M and Krabbendam, J.J. (1987), Industrial Automation Requires Organizational Adaptations, Conference Paper, *International Journal of Production Research* 25(11): 1683-1691.