CHAPTER 3
THE INDIAN MACHINE TOOL INDUSTRY:
STRUCTURE AND TECHNOLOGY STATUS

3.1 INTRODUCTION

The capital goods sector lies at the heart of the technology generation and diffusion process and thus plays a special role in technological change. All technological changes, whether of the product or process variety, require the development of modified or new machinery and equipment. Conversely, the diffusion of improved vintages of machinery facilitates the process of technological change in user firms. For this reason, policy planners in developing countries are paying special attention to technology management issues in the capital goods sector (Fransman, 1985).

Rosenberg (1976) has underscored the importance of the capital goods sector as:

"Historically, a major source of capital-saving innovation has been improvements in the efficiency of capital goods production. The important analytical point is that any cost reduction in the capital goods sector - whether it is immediately labor-saving or capital-saving in its factor-proportion bias - is a capital-saving innovation to the economy as a whole. Many of the major innovations in Western technology have emerged in the capital goods sector of the economy. But underdeveloped countries with little or no organized domestic capital goods sector simply have not had the opportunity to make capital-saving innovations because they have not had the capital goods industry necessary for them. Under these circumstances, such countries have typically imported their capital goods from abroad, but this has meant that they have not developed the technological base of skills, knowledge, facilities, and organization upon which further technical progress so largely depends".

The machine tool industry (MTI) is the lynchpin of modern industrialization and it occupies a most prominent position in the capital goods sector. It is often referred to as a "nodal" or "mother" industry as it supplies technology to other industries in the manufacturing sector. Technology improvements in and the diffusion of machine tools have enhanced productivity in the manufacturing industry since the Industrial Revolution (Carlsson, 1992, 1984). Given the strategic importance of the MTI, it has been accorded top priority by policy planners in several developing countries.
Before the Second World War developing countries almost totally depended on imports of machine tools. During the war and its aftermath countries such as India, Brazil and Argentina were forced to develop their own machine tool industries because their normal sources of supply were cut off. In the five decades following the war both consumption and production of machine tools in developing countries have grown considerably (Matthews, 1988). Some developing countries have even achieved virtual self-sufficiency in the production of universal machine tools. However, more sophisticated machine tools, i.e., automats, CNCs, precision tools, etc., are still being imported, even by the most advanced of the developing nations (Wogart et al., 1993).

Technological developments both in metal-cutting and in metal-forming have primarily led to increasing the productivity, efficiency and accuracy of manufacture. Undoubtedly, the most important advancement in machine tool technologies has been the application of computer numerical control, which has practically revolutionized metal-working during the past three decades. World trends in manufacturing technology point to an increasing integration of robots and the computer into the manufacturing process. Simultaneously with the development of CNCs and computer-integrated-manufacturing, a number of new metal-working technologies, especially the use of electrical methods, such as Electro-Discharge Machining, Electro-Chemical Machining and methods adopting Lasers and Electron-Beams are also gaining currency in the MT user industries.

The machine tool industries of the developed countries hold a leading position in world production and trade. During 1994, the thirteen member countries of the European Committee for Cooperation of the Machine Tool Industries (CECIMO) in Western Europe accounted for 41.1% of world machine tool production, followed by Pacific Rim countries including Japan (36.3%), North America (15.3%) and Eastern Europe (4.7%).
The rest of the world contributed to a mere 2.6% (Hallum, 1995). The total value of world machine tool production stood at US $ 29.0 billion during 1994.

The rankings provided by American Machinist (Hallum, 1995) for various machine tool producing countries are given below for the year 1994 (Table 3.1):

**Production of machine tools**

Japan occupies the top position followed by Germany, USA, China, Italy, Switzerland, Taiwan, UK, France and South Korea. India occupies the 20th position. More than 50% of the world machine tool production is shared by Japan, Germany and USA.

**Exports of machine tools**

Japan occupies the top position followed by Germany, Italy, Switzerland, USA, Taiwan, UK, Singapore, France and China. More than 50% of the world machine tool exports is shared by Japan, Germany and USA. India occupies a very low position with a meagre share of 0.1% of world exports.

**Import of machine tools**

USA occupies the top position followed by China, Germany, South Korea, and Singapore. India’s share of world imports is only 1.5%.

**Consumption of machine tools**

China occupies the top position followed by US, Japan, Germany, Italy, South Korea, UK, France and Taiwan. India occupies a very low position with a share of 1.2% of world consumption. More than 50% of world consumption of machine tools is shared by China, US, Japan and Germany.
Table 3.1 The World Machine Tool Industry
(Production, Exports, Imports and Consumption in the Year 1996)

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Country</th>
<th>Production</th>
<th>Exports</th>
<th>Imports</th>
<th>Consumption</th>
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<tr>
<td></td>
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<td>(Million US $)</td>
<td></td>
<td>(Million US $)</td>
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<tr>
<td>1</td>
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<td>6958.9</td>
<td>3739.2</td>
<td>370.8</td>
<td>3590.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(24.0)</td>
<td>(24.6)</td>
<td>(2.9)</td>
<td>(13.5)</td>
</tr>
<tr>
<td>2</td>
<td>Germany</td>
<td>5403.1</td>
<td>3636.4</td>
<td>1213.9</td>
<td>2980.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(18.6)</td>
<td>(23.9)</td>
<td>(9.6)</td>
<td>(11.2)</td>
</tr>
<tr>
<td>3</td>
<td>US</td>
<td>3223.0</td>
<td>1060.0</td>
<td>2188.0</td>
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<tr>
<td></td>
<td></td>
<td>(11.1)</td>
<td>(7.0)</td>
<td>(17.3)</td>
<td>(16.4)</td>
</tr>
<tr>
<td>4</td>
<td>Italy</td>
<td>2105.2</td>
<td>1370.7</td>
<td>577.0</td>
<td>1311.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7.2)</td>
<td>(9.0)</td>
<td>(4.6)</td>
<td>(4.9)</td>
</tr>
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<td>Switzerland</td>
<td>1359.6</td>
<td>1203.3</td>
<td>231.5</td>
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<td>(4.7)</td>
<td>(7.9)</td>
<td>(1.8)</td>
<td>(1.5)</td>
</tr>
<tr>
<td>6</td>
<td>China</td>
<td>2969.5</td>
<td>216.0</td>
<td>1940.0</td>
<td>4693.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10.2)</td>
<td>(1.4)</td>
<td>(15.3)</td>
<td>(17.7)</td>
</tr>
<tr>
<td>7</td>
<td>Taiwan</td>
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<td>687.9</td>
<td>441.4</td>
<td>827.2</td>
</tr>
<tr>
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<td>(3.7)</td>
<td>(4.5)</td>
<td>(3.5)</td>
<td>(3.1)</td>
</tr>
<tr>
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<td>UK</td>
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<td>488.7</td>
<td>543.0</td>
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<tr>
<td></td>
<td></td>
<td>(3.3)</td>
<td>(3.2)</td>
<td>(4.3)</td>
<td>(3.8)</td>
</tr>
<tr>
<td>9</td>
<td>S.Korea</td>
<td>587.1</td>
<td>111.0</td>
<td>709.0</td>
<td>1185.1</td>
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<td></td>
<td></td>
<td>(2.0)</td>
<td>(0.7)</td>
<td>(5.6)</td>
<td>(4.5)</td>
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<tr>
<td>10</td>
<td>France</td>
<td>618.3</td>
<td>300.3</td>
<td>636.0</td>
<td>954.0</td>
</tr>
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<td>(2.1)</td>
<td>(2.0)</td>
<td>(5.0)</td>
<td>(3.6)</td>
</tr>
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<td>11</td>
<td>Canada</td>
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<td>218.0</td>
<td>511.3</td>
<td>633.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.2)</td>
<td>(1.4)</td>
<td>(4.0)</td>
<td>(2.4)</td>
</tr>
<tr>
<td>12</td>
<td>Singapore</td>
<td>144.9</td>
<td>329.8</td>
<td>650.8</td>
<td>465.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.5)</td>
<td>(2.2)</td>
<td>(5.1)</td>
<td>(1.8)</td>
</tr>
<tr>
<td>13</td>
<td>Russia</td>
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<td>15.0</td>
<td>40.0</td>
<td>640.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.1)</td>
<td>(0.1)</td>
<td>(0.3)</td>
<td>(2.4)</td>
</tr>
<tr>
<td>14</td>
<td>Brazil</td>
<td>325.5</td>
<td>196.2</td>
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<td>220.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.1)</td>
<td>(1.3)</td>
<td>(0.7)</td>
<td>(0.8)</td>
</tr>
<tr>
<td>15</td>
<td>India</td>
<td>155.9</td>
<td>17.2</td>
<td>185.4</td>
<td>324.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.5)</td>
<td>(0.1)</td>
<td>(1.5)</td>
<td>(1.2)</td>
</tr>
</tbody>
</table>

Note:
1. All figures in million US $.
2. Figures in brackets denote the percentage share in the world.
3. Consumption = Production + Imports - Exports.
4. Machine tool producing countries are considered.

Source: American Machinist (May 1995)

3.2 THE INDIAN MACHINE TOOL INDUSTRY (IMTI): A Brief History

The earliest recorded production of machine tools in India was in 1890. Artisans from Punjab pioneered the manufacture of basic MTs such as cone pulley lathes and drilling machines. Till 1939 hardly 100 MTs were produced per annum, and these were made...
by factory owners exclusively for their own use. During the first world war, some engineering firms in North India took up manufacture of other types of MTs such as girder milling and shell turning lathes. Thereafter, it was in the 1930s that the production of MTs for non-military purposes began to make some impact. The outbreak of the second world war ushered in a new era in the history of the IMTI.

Between 1941 and 1943, a number of firms such as Mysore Kirloskar Ltd. (MK), Cooper Engineering, Investa, etc., obtained licenses for the production of MTs (Mehta, 1990). After the second world war, the IMTI collapsed because the structure and organization of the industry were not strong and specialized enough to compete with foreign machine tool firms. There was a general prejudice among consumers about indigenous MTs, as their standards, designs, quality, precision and performance were far inferior to those of imported MTs. The IMTI gained momentum only in the post independence period, after these initial setbacks (Patil, 1982).

After independence, Indian planners identified the need to develop a number of key industries within the public sector. Basic and key industries are generally capital- and skill-intensive, with long gestation and pay-off periods, and their profitability is relatively low. Owing to the poor response from the private sector to venture into setting up of capital goods industries, the Government of India started Hindustan Machine Tools Limited (HMT) in 1953, which commenced production in 1955.

In order to provide help to the IMTI, the Government of India, with a financial gift of Rs.6 million from the Government of Czechoslovakia, established the Central Manufacturing Technology Institute (CMTI, formerly Central Machine Tool Institute) at
Bangalore in 1965. The main objective of the institute is to render technical assistance to machine tool and other engineering industries.

The CMTI offers its expertise in the following areas (Janaki and Dasharathy, 1992):

- Design and development of machine tools;
- Development of tools and tooling;
- Solution to specific machining problems;
- Selection of production equipment;
- Technical information services and consultancy;
- Conducting training programs; etc.

The major users of machine tools in India include various organizations in the sectors such as Automobile, Auto-ancillary, Defence production, Railways, Power generation and Electricals, and Industrial machinery. The following Tables 3.2 and 3.3 provide the dependence of the IMTI on selected user sectors.

Table 3.2  **Indian Machine Tool Industry: Dependence on Select User Sectors**

<table>
<thead>
<tr>
<th>1% Growth in User Sector</th>
<th>% Growth in Machine Tool Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobiles</td>
<td>0.15%</td>
</tr>
<tr>
<td>Automotive Sector</td>
<td>0.34%</td>
</tr>
<tr>
<td>Textile Machinery</td>
<td>0.05%</td>
</tr>
</tbody>
</table>

Source: Janaki and Dasharathy (1992)
Table 3.3  The Growth of Indian Machine Tool Industry vis-à-vis Major Users

<table>
<thead>
<tr>
<th>Year</th>
<th>Machine Tools</th>
<th>Automobiles</th>
<th>Automotive Components</th>
<th>Textile Machinery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>1983</td>
<td>97.69</td>
<td>112.41</td>
<td>93.81</td>
<td>87.91</td>
</tr>
<tr>
<td>1984</td>
<td>101.55</td>
<td>134.76</td>
<td>97.27</td>
<td>92.85</td>
</tr>
<tr>
<td>1985</td>
<td>95.51</td>
<td>156.69</td>
<td>108.46</td>
<td>84.69</td>
</tr>
<tr>
<td>1986</td>
<td>100.10</td>
<td>201.38</td>
<td>119.37</td>
<td>84.92</td>
</tr>
<tr>
<td>1987</td>
<td>120.33</td>
<td>228.14</td>
<td>112.14</td>
<td>89.64</td>
</tr>
<tr>
<td>1988</td>
<td>119.11</td>
<td>247.17</td>
<td>124.86</td>
<td>98.74</td>
</tr>
<tr>
<td>1989</td>
<td>138.16</td>
<td>280.41</td>
<td>157.88</td>
<td>108.67</td>
</tr>
<tr>
<td>1990</td>
<td>157.01</td>
<td>298.48</td>
<td>166.21</td>
<td>134.85</td>
</tr>
<tr>
<td>1991</td>
<td>160.11</td>
<td>313.38</td>
<td>184.64</td>
<td>173.91</td>
</tr>
<tr>
<td>1992</td>
<td>150.66</td>
<td>278.48</td>
<td>206.06</td>
<td>130.69</td>
</tr>
</tbody>
</table>

Note: Based on price adjusted indices (1981-82 is the base year)
Source: Janaki and Dasharatly (1992)

There are about 325 companies in the public and private organized sectors in India which manufacture a wide range of machine tools. Along with its subsidiaries, HMT and other public sector units now contribute over 50% of the total output of machine tools in the country. It also leads by a big margin in the area of exports. Klockner Windsor Limited, Batliboi and Co., Mysore Kirloskar, Premier Automobiles and Voltas are the major machine tool manufacturing firms in the private sector. Apart from these, there are a large number of small scale units in the unorganized sector manufacturing machine tools in small workshops.

The following paragraphs discuss some important traits of the IMTI (NPC Report, 1992; Mehta, 1990):

* A small number of firms in the organized sector contribute bulk of the production whereas the small size units' contribution is less than 20% of the total output. This is contrary to the situation in the industrialized countries where several small size units account for a substantial part of the total production in the country. Moreover, these firms contribute a great deal to the latest technological innovations in the form of design and application engineering.
The IMTI leans heavily on the government even for its survival and shows little eagerness to attend to serious issues pertaining to research, design and innovation.

India’s export of MTs in relation to world trade is insignificant. Strong inclination to meet the high domestic demand, lack of marketing promotion facilities abroad and the inability of Indian firms to meet world standards are some of the main reasons attributed to this.

India had been almost self-reliant in machine tools in the 1970s. But, in recent years, it had to import nearly half of its requirement (in monetary terms). This clearly indicates that the IMTI has not kept itself tuned to the fast changing needs of user industries within the country and technological developments abroad. The Indian industry could not match the international competition by way of features and reliability of systems. Hence, not only did the IMTI lose its growing export market, but it became inevitable for the user industry to resort to import of machine tools. These issues point to the lack of adequate perspective planning and guidance of development efforts in the needed direction.

Most large firms, including HMT, still offer machine tools in the lowest range of the technology profile comprising conventional machine tools. This could be because most of these machine tools are installed in the small sector. Given the dependability of this category of demand, large firms are unwilling to vacate the low-tech segment of MT production. This results in an unwarranted situation wherein the giants of the IMTI such as HMT and MK are competing with tiny firms such as Parmar. The leading firms are yet to make substantial gains in the world MT production.

3.3 THE INDIAN MACHINE TOOL INDUSTRY: TECHNOLOGY STATUS

There are about 3000 different types of machine tools in existence. Each of these have many variations, each matching a particular user's requirements for performance in terms of size, precision, speed, level of automation, efficiency, etc. Machine tools can be grouped on the basis of technological complexity and size. This classification gives rise to six levels of technological development as given below (Mehta, 1990):

a. **First level**: Conventional machines or general purpose machines such as presses, lathes, milling, grinding, drilling and planing machines are at the lowest level.
b. *Second level*: Special purpose machines and automat{s} occupy this level.

c. *Third level*: This consists of standalone CNC machines such as CNC lathes, CNC automats, machining centres and grinding centres.

d. *Fourth level*: Flexible Manufacturing Cells (FMCs) come under this group.

e. *Fifth level*: Flexible Manufacturing Systems (FMSs) form this level.

f. *Sixth level*: Computer Integrated Manufacturing (CIM) systems and advanced FMS are at the highest level of technological development.

The IMTI basically operates with the first three levels of MT technology. While there is a plethora of organized and unorganized sector firms producing machine tools of the first level, second level machine tools are manufactured either by small technocrat entrepreneurs or by large firms. Several large firms entered into foreign technical collaborations for producing MTs belonging to the third level. The industry is yet to make inroads into the fourth and fifth levels, though HMT has produced some FMC prototypes. As of now, the sixth level comprising CIM systems is outside the purview of the IMTI (Mehta, 1990).

Several large and small MT firms entered the fray in the early eighties in an attempt to bridge the rapidly widening technological gap originating from increased CNC applications to machine tools in world markets. It has been observed that while several small firms such as ACE designers, Electropneumatic and NC Machines Ltd., have developed their own designs for CNC machines, large firms have generally depended on foreign technical collaborations.

The first major setback suffered by the IMTI was of its own making. In an inward-oriented policy framework and tariff-protected market, the industry failed to take adequate note of the revolutionary technological change, which had swept through the machine tool industries in the developed countries during the 60s and 70s. This was the
transition from the electromechanical drives and controls to a combination of electromechanical and hydraulic movements and digital electronic controls. Thus, while the NC/CNC era had already dawned and was becoming popular in the rest of the industrialized world, the IMTI remained mired in outdated technology. By the time the industry became aware of its technological backwardness in the late seventies, and attempted to reorient its technology strategies to the new paradigm, it was confronted by the inadequacy of indigenous component manufacturers who could not gear up to the needs of the new breed of MTs.

The industry is dependent on imports of several components of CNC machine tools, such as CNC systems, the AC spindle and servo drives, encoders and scales for Digital Readouts (DROs), curvic couplings, precision ball screws and ball bearings, sensing and feedback units. Further, there are problems in the area of high pressure oil seals, proximity switches, dependable voltage stabilizers and uninterrupted power supply systems. The environmental conditions in India necessitate the use of temperature/humidity control systems which are not built into the imported component technologies.

A Techno-Market Survey commissioned by the Government of India (TIFAC, 1991) identified the following technological options which need to be addressed by the IMTI:

a. Retrofitting of conventional MTs with CNC controls.

b. Development of CNC controls.

c. Development of systems and application software for controls.

d. Low cost CNC lathes.

e. SPMs fitted with programmable logic controllers and CNC systems.

f. CNC boring, drilling and milling machines.

g. CNC machining centres.
h. Development of critical accessories for CNC machines.

As the IMTI virtually stands at the crossroads of technological development, there should be complete coordination between the various concerned parties. It is imperative that the major machine tool manufacturers, end-user sectors including Automobiles, Railways, Textiles and Defence, the Ministries of Industry, Trade & Commerce, and Science & Technology, should make a concerted effort to infuse technological dynamism in the IMTI.

The protection regime in the country and the complete absence of competitiveness - from within the economy and from abroad, led to the complacent behavior of Indian firms in the earlier decades. With the economic liberalization currently in progress and the opening up of Indian markets to foreign firms, coupled with the major technological advances in CNC machines, FMS and CIM, the Indian share of world MT production and exports is likely to be eroded in the next decade.

3.4 ADVANCED MANUFACTURING TECHNOLOGIES IN INDIA

The diffusion of AMTs in newly industrialized nations has been less pronounced than in developed countries. The earliest FMS in India was installed at the Heavy Alloy Penetrator Project (HAPP) in Trichy. This system has intelligent CNC work centres, integrated with a tool management system and loading/unloading gantry, and is capable of uninterrupted operation for more than one shift. Automated Guided Vehicles (AGVs) and inspection through electronic gauges are the other notable features. The management is aiming at plant-wide integration by extending automation to other manufacturing organizations (SAC Report, 1991).

Bajaj Auto introduced partial flexible automation in its new factory at Aurangabad in 1985. Hindustan Cables Limited introduced an automatic storage and retrieval system
in its new manufacturing unit for making jelly-filled large-size cables for meeting the expansion plans of the Department of Telecommunications, Government of India.

Many others, including large and medium-size companies, introduced FMSs in parts, generally for expansion. By the turn of this century, India will have about 15 FMS installations.

In 1988, HMT executed its first FMS project in India, consisting of a battery of turning cells, conventional machines (for line balancing), automated guided vehicles, computer-aided inspections, and a central host computer for monitoring and control. A separate CIM division was formed in HMT. About 25 enquiries for FMS installations are under its active consideration. They have originated from a variety of sectors including defence, automobiles, railways, electrical, diesel engines, pumps and other related equipment, agricultural machinery, and technical universities.

The corporate R & D division of Bharat Heavy Electricals Limited (BHEL) initiated the indigenous development of an FMS by retrofitting the necessary electrical, mechanical, and electronic hardware on the existing MTs by developing the necessary software packages. This was done to develop the expertise of networking different CNC machines with a master computer, and to demonstrate the FMS concept to prospective users.

Robots and other material handling equipment are being developed at the Bhabha Atomic Research Centre (BARC), Bombay, for nuclear applications. The remote handling systems developed and deployed at various nuclear plants under the Department of Atomic Energy have freed the country from dependence on foreign suppliers.
Apart from the above exceptions, current manufacturing technology and practice in India is plagued by disappointing low levels of productivity, quality and reliability, and high input costs. The productivity of Indian firms is low in capital, energy and material use, and in labour (NPC Report, 1992). Productivity depends on several factors, of which technology is the most dominant. Unfortunately, Indian firms have not often absorbed and improved on the imported technology. According to government sources (SAC Report, 1991), the reasons for the dismal performance of the firms are:

* poorly defined goals and objectives of organizations,
* improper technology selection,
* indifference to changes in technology and market place,
* lip-service to in-house R&D, and
* protected markets.

Manufacturing industry in order to meet ever changing market requirement embarked on productivity improvement and cost reduction. Manufacturing organizations seek to maintain or gain a competitive edge in the market place by exploiting the advantages of advanced manufacturing technologies. Flexible manufacturing system (FMS) is one such advanced manufacturing technology which has emerged as a new class of automated manufacturing system with built in flexibility to respond to different manufacturing situations. FMS is capable of processing a wide variety of part types simultaneously in small - to - medium batches thereby retaining the efficiency of a high production transfer line and the flexibility of a job shop. Manufacturers have realized the importance of FMS because of ever changing market scenarios, increase in competition, and reduction in product life cycles, thus necessitating them to introduce new products with short lead times. The advantages of
FMS are high flexibility in terms of small effort and low lead times required to manufacture new products.

3.5 FLEXIBLE MANUFACTURING SYSTEM: AN OVERVIEW

In the 1960s NC machines reached a stage when they became reasonably reliable and productive. Computers and machine controllers were developed. By mid 1960s, the first Direct Numerical control (DNC) system had emerged in manufacturing. Since then the exploitation of computers in manufacturing led to not only its employment to link machines so that they effectively transform parts and data between them, but also joining them into one unified system, namely Computer Integrated manufacturing (CIM). The CIM consists of Computer aided design (CAD), Computed aided planning (CAP), Computer aided process planning (CAPP) and Computer aided process planning (CAPP) and Computer aided manufacturing (CAM). Further, the development of numerical control (NC) machines led to the installation of the earliest FMS during 1964, which was designed to manufacture the parts for aircraft at the Sundstrand Corporation. This was followed by the installation of FMSs in England during 1967, Japan in 1970, Germany in 1971, and erstwhile Czechoslovakia in 1974, and in India during 1989.

The introduction of NC control systems along with the development of machines, cutting tools, automated material handling (e.g. automated pallet and tool changing devices, automated guided vehicles (AGVs)), robots, etc., have made the FMS more effective and productive. One could realize the development in FMS, from the observation that the FMSs have undergone four generations of development of Caterpillar system during 1989.

FMS is an automated batch manufacturing system consisting of a set of numerically controlled machine tools that perform the operations required to manufacture parts.
The machine tools have automatic tool interchange capabilities and are connected by automatic material handling with changing environment. Two major components of an FMS are: FMS equipment and its Control System. FMS equipment is of two types - Primary and Secondary. The Primary equipment adds value to the piece parts being manufactured. Secondary equipment is used to support the primary equipment in achieving this goal. Primary equipment includes machine tools and processing centres. Secondary equipment includes support stations such as pallet/fixture, load/unload stations, tool commissioning/storage areas and support equipment such as material handling system for tooling and piece-parts. The FMS control system functions are performed by the host Computer. FMS control system must be able to handle problems in areas of production scheduling, process planning, real time process control and system monitoring.

The ever increasing customer demands on the manufacturing industry made it imperative to keep pace with the changing requirements. The increasing competitiveness among the manufactures made them to invest in system reliability, high productivity at reduced costs, and better process consistency (Chen and Adam 1991). Hence improved quality of product, reduced in-process inventory, reduced manufacturing lead times, high product variety, short delivery times, reduced labour costs, reduced bottlenecks and improved equipment utilization can be achieved through FMS.

Advantages of FMS

- Improved capital/equipment utilization
- Reduced work in progress and setup.
- Substantially reduced throughput times/lead times
- Reduced inventory and smaller batches
• Reduced manpower
• Ability to accommodate design changes readily
• Consistent quality
• Reduced risk as a result of specific product failure
• Concise management control
• Improved market image/credibility
• Reduced floor space requirements

Disadvantages of FMS

• High installation costs
• Uncertain production requirements
• Difficulty in defining a family of parts
• Fear of unknown (highly skilled)
• Mismatched vendor capabilities
• Vendor reluctance to supply customized software
• Software restrictions

The Conventional systems are built to process material, transport materials between work-stations (machines) and transform raw materials into final products or semi finished parts. The planning philosophy of conventional system is to take all decisions (including the operational decisions) at the pre-production level, assuming that once the production is started, everything on the shop floor will turn out to be exactly as expected. Those systems are typical in a manufacturing environment such as machine break down, blocking of work stations, tool wear, unexpected tool features, failure of control system etc. The production times are set to take care of the above factors by using the concept of efficiency.
Expediters are replaced by a supervisory computer in FMS. The manual communication and control as a whole are replaced by a centralized computer, the capability of which for collecting, retrieving communicating, controlling and utilizing on-line information, is far superior to commercial manufacturing systems, thereby making adaptive decisions that are just unimaginable compared with that of human expediters. Parallel to the visible material plans, there emerges in the FMS an invisible information flow. There is no information flow in conventional systems, but they do not have the ability to handle the information flow in bulk and continuously also fast.

The installation of a wide range of machine tools achieves flexible automation, which in turn increases both the productivity and labour savings. The loading and unloading of parts, and tools by industrial robots, in one solution which can lead to unmanned machining operations. This manufacturing cell has the flexibility to become an automatic factory through step by step installations leading to FMS.

The term “unmanned operation” is taken to mean the function of automatic machining with less man power in order to achieve high productivity and flexibility by using economic automation. The FMS is also capable of changing tools and parts, preferably unmanned, with communication and control under a centralized computer or main computer system. The part programs and further necessary data arrive and are fed back. Thus the unmanned operation can be achieved through FMS, though it is not an essential requirement for FMS operation. Both FMS and the unmanned operation improve productivity, but FMS provides the flexibility while the unmanned operations reduce labour costs.

Facilities of FMS

FMS contains some of the following facilities:
- CNC machine tools.
- Automatic storage and retrieval system (AS/ Rs).
- Automatic inspection stations.
- Tool crib room for storage, pre-setting, inspection and re-sharpening of tools.
- Other facilities include chip handling devices, on-line monitoring of equipment with the help of sensors and centralised and distributed computer system for integrating controlling all facilities of the system.
- Management information system for storage and retrieval of information related to system, production and decision making activities.
- Hierarchical computer system for communication and control between machines.

**Flexibility of FMS**

Flexibility is an important criterion in FMS as it determines the degree of variability, a system can have in operation. The various aspects of flexibility were discussed through a structural approach. Different flexibilities have been identified as follows:

(a) Machine flexibility

(b) Process flexibility

(c) Product flexibility

(d) Routing flexibility

(e) Volume flexibility

(f) Expansion flexibility

(g) Operation flexibility

(h) Production flexibility

The flexibility of manufacturing system can be expressed in terms of

(a) the ability of the systems demands to market fluctuations,

(b) the ability of the system to adapt to changes in production system e.g. new machinery.
(c) the ability of the system to adapt to changes in the product itself such as improvement in design.

The elements that contribute to the particular degree of flexibility can be grouped as:

i. Machine with automatic tool changing capabilities, automatic material handling system for movement of parts, tools, pallets and fixtures, etc

ii. Layout and storage areas for in-process inventory, and

iii. Management decisions and information systems and computer control.

Even though FMS offers many advantages over conventional manufacturing systems, their investment costs are very high. In order to realize the benefits, the FMS must be utilized at its optimum performance level. During the life time of the FMS, an organization undergoes many phases of decision making related to the system, caused by frequent changes in the business and economic environment.

3.6 IMPORTANCE OF JUSTIFICATION OF FMS

The problems relating to the economic justification of new manufacturing technologies have received increasing attention. Particularly flexible manufacturing systems have exposed some of the limitations of traditional methods of equipment justification. The justification problems can be broadly summarized under following categories (Meredith and Suresh, 1986).

High Capital Costs and Risks

High Capital Costs and the risk involved seem to be major deterrents to investing new manufacturing technologies. Almost all of the new technologies involve integration. The FMS brings to a simple cell the operations done at various work centers in the conventional factory, in which even material handling is automated and computer controlled. Thus, the Capital Costs turn out to be much higher and the payback period longer than conventional machine tools. The new technologies also pose higher risks
due to as yet unfamiliar technology, the control is mainly through software and the fact that they have wider implications.

Myopic Approaches to Equipment Justification
Most of the industries rely on the payback method in considering investment proposals. It ignores the reforms after these pay back period, and its emphasis on liquidity, etc. With respect to new technologies, the use of this method practically guarantees rejection. The main attraction of this method is its simplicity, and importantly, the fact that it is joint measure of risk and return.

Inappropriate Capital Budgeting Procedures
The capital Budgeting procedures for the new technologies are mere extensions of the procedures used for connected technologies. The procedures tend to (i) be a bottom-up processes for generating new equipment proposals. (ii) be subject to narrow levels of analysis as for conventional machines. (iii) Depend on traditional capital budgeting procedures for their evaluation, and (iv) virtually guarantee that the companies will either defer their purchase or, once purchased, apply them too narrowly. The emphasis on quick returns and short-term oriented reward system preclude the consideration of long, uncertain projects.

The Difficulty of Quantifying Indirect Benefits
With higher levels of integration, as in the FMS, indirect savings could amount to several times that of direct savings. The major benefits of FMS, are the throughputs time reductions, work-in-process inventory reductions and so on. Typically with inadequate tracking systems, may major savings areas have been excluded in the justification exercise, which also contribute to showing longer payback periods for the new technologies. Existing Capital Budgeting Procedures have also been seen to be
bottom-up, too quantitatively oriented, and tend to emphasize single valued such as
ROI, and do not favorably consider conjectures concerning strategic advantages.

**Prediction of Benefits over an Extended Time Period**

The complexities of new technologies not only pose problems for mean-term operating patterns, but also for predicating long-term performance and estimation of cash plans. These are augmented by the longer investment planning horizons required. Also, the cash flows are affected not only by market determined factors, but operating policies as well.

**Technological Uncertainties**

The rapid evolution of new technologies has created a sizeable knowledge gap among the both manufacturing and financial professionals. This has ‘wait and see’ attitude, favoring rejection of proposals.

**Inadequacies in Costing Methods**

Conventional cost accounting has its origins in mass production and classical job shop situations. In the job shop situation, a major focus of control is direct labor through elaborate time standards and work measurements. As the material proceeds from work center to work center, overhead allocations are typically made on the basis of direct labour. But in FMSs, the cell becomes the cost center, obviating the need for elaborate measurements within the cell from justification stand point. The difficulty of evaluating indirect benefits with the present inadequate accounting system poses the main problem.

**Differing Nature of Operations**

The new technologies introduce different methods of operation and control; in cellular manufacturing, as in GT and FMSs, the part family is the focus of interest as opposed
to the operation in the classical job shop. The operations are geared to taking advantage of component similarities and different operating philosophies based on economics of scope. Software in the primary means of control and simulation in a daily necessity. All these contributed to justification problem.

Analysis Still Based on Subsystems and Sub-optimization

Mathematical models based on operations research have been characterized by single valued criteria and tend to focus on narrow problem definitions. Also, engineering economy continues to be formula oriented and emphasizes such factors as cost of capital, tax rates, inflation rates and corresponding sensitivity analyses. There are by and large applicable for the traditional, stand alone technologies at the tactical level of decision making, but new tools are required for integrated systems, emphasizing multiple-criteria a decision making approaches, and capital budgeting procedures geared to system - wide analysis.

The Justification Framework

The technologies coming under the umbrella term of computer integrated manufacturing (CIM) can be grouped hierarchically, based on the level of system integration. For instance, stand alone technologies, machining centers, manufacturing cells, and FMSs can be represented as shown in Figure 3.1. Many managerial characteristics begin to unfold from this perspective, relating to financial justification, implementation of tech-
nology, production control, cost accounting and other aspects. The primary focus of interest is the implications of this hierarchical view for the justification of these technologies.

Fig. 3.1: A Hierarchical View