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Upgrade India's machine tool industry to build the Eurasian Land-Bridge

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In EIR*'s first issue of 1997, Lyndon H. LaRouche, Jr. broke new ground in economic analysis, with his article on "Machine-Tool Design: The Brains of Profit." He emphasized that "for any national economy taken as a unified whole, scientific and classical-artistic progress, combined, are the only source of sustainable profit, nothing else. The machine-tool sector illustrates the role of science in this. For the imperilled economy of the United States, and, of many other nations, today, the lesson told is a desperately urgent one, even if it appears to address only technological progress as such." This idea was expanded in LaRouche's Feb. 7, 1997* EIR *cover story, "Return to the Machine-Tool Principle."*

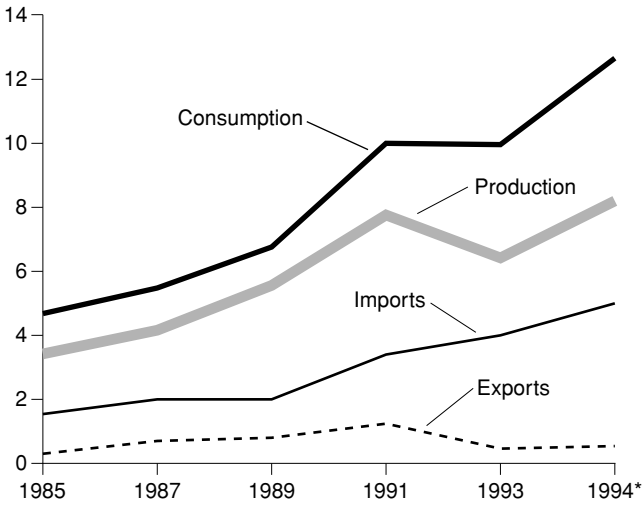
The following contribution, from EIR*'s New Delhi bureau, elaborates the current situation and future prospects of India's machine tool industry, as that nation struggles to join in the development program of the Eurasian Land-Bridge.*

After years of virtual stagnation, India's machine tool industry began a turnaround in 1994. Rates of growth showed a decided downtrend in the early 1990s, following two good growth years in 1989 and 1990, but picked up again visibly, registering a 26% growth in fiscal year 1994-95 (**Figure 1**).

India's machine tool industry is still a vastly underdeveloped sector, both from volume-output and technological standpoints. Production registered a marginal growth rate during the two-year period of 1992-93 and 1993-94. This setback to the sector, after a decades-long low-growth-rate cycle had been broken temporarily in 1989-90 and 1990-91, was due to a number of factors related to the health of the world economy.

First, following the collapse of the Comecon (former East bloc) countries, the attempted imposition of a new world order and "free market" economies on nations led to social and economic chaos. The Comecon countries, burdened with backward technologies, no effective financial institutions, and little trade expertise, were put under International Monetary Fund (IMF)-World Bank control, with the ostensible objective of macro-structural change. What followed was growth curtailment, reduction in capital formation, a squeeze on domestic industries, and looting of existing industries and infrastructure. This led to general despair among the population, forcing social chaos and economic bankruptcy in the early 1990s. India depended significantly on its trade with the Comecon countries, and so these difficulties were reflected in the growth of the machine tool industry in India as well.

FIGURE 1
Trends in India's machine tool industry
(billion rupees)



* Estimate.

Source: Indian Machine Tool Manufacturers Association.

What is relevant to note in the Indian context is that the setback to the machine tool sector caused by the collapse of the Comecon countries' economies, came about at a time when the Indian machine tool industry was beginning to break out of its cocoon after decades of slow growth and stagnation. This tentative upswing was brought about by the policy directives during the mid-1980s under the leadership of the late Prime Minister Rajiv Gandhi. The machine tool industry more than doubled in size between 1985 and 1992.

But then, in addition to the drop in exports to the Comecon countries, the Indian machine tool industry came under severe pressure from two other areas:

- Reduction in public expenditures to satisfy the IMF's

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Indian firms are upgrading the quality of domestically produced machine tools. By the turn of the century, computer numerically controlled machine tools are expected to comprise 70% of machine tool production.

requirement of reduced fiscal deficits, which resulted in a fall-off of government orders.

- A simultaneous growth in demand for high-tech and more productive equipment to meet the challenge posed by foreign industrial competitors, in the aftermath of the policy decision to liberalize India's tariffs and customs duties and globalize the Indian economy taken by the Rao government in 1991, which led to increased import of machine tools.

The capital goods industry was badly hit by the recession which set in shortly after the onset of liberalization in 1991. Within the capital goods sector, the machine tool industry, the mother industry for capital goods, was particularly affected. Production crashed from 7.5 billion rupees in 1992 (roughly $55 million in today's currencies) to 6.4 billion rupees in 1993—a decline of 18%—much more than any other industry (Figure 1).

Time for a new beginning

As policymaking discussions on the southern tier of the Eurasian Land-Bridge unfold in India and throughout the subcontinent, and the long-term inevitability of the project is comprehended in full among policymakers, the importance of strengthening the backbone of India's physical economy will also come into focus. The land-bridge will demand development of the physical-economic conditions which will lead to the production of high-tech and high-value products. Needless to say, the development of the machine tool industry is one of those conditions. Other necessary conditions are abundant power generation, and distribution of power throughout the subcontinent; development of high-skilled manpower, from a base which consists of 100% literacy; development of a domestic and commercial water distribution system throughout the subcontinent, which focuses on making optimal use of available water; upgrading and modernization of railroads, making the rail system a more efficient beast of burden; and, last but not least, spreading enhanced productivity in the agricultural sector from a handful of districts to the entire Ganges Valley through which the land-bridge will snake.

The urgency of working out plans to meet the requirements of the land-bridge, in terms of manpower, finance, and other inputs, is as important as laying out the high-speed railroads themselves and working out the logistical details with the nations involved directly in the land-bridge.

In evaluating India's machine tool industry, we have concentrated chiefly on the industry itself, an approach which is admittedly inadequate. The existing and planned infrastructure network, when put under a magnifying glass, will provide more insight into where the machine tool industry is heading. For instance, while India's basic metals and alloys research has many successes to show, the business environment and the all-pervasive bureaucratic system have done little to translate the research work into mass production processes. The environment, which includes a government-run, -dictated, and -controlled financial sector, has done perhaps more than anything else to harm the small machine tool manufacturers, while large machine tool manufacturing facilities have become overgrown and slothful—just as in South Korea—choking off the entrepreneurial spirit of a large number of competent and ambitious small manufacturers.

At the same time, India's abject failure in getting its power-production sector on a real growth path; its painful

slowness in putting in place a water distribution network which would help to hold water in reservoirs and underground aquifers, nature's bounty which comes annually in the monsoon; and its failure to provide primary education to almost 50% of children, are major roadblocks to developing a highly efficient and quantitatively adequate machine tool sector. The machine tool sector cannot function in a vacuum. The failure of the nuclear industry in India and the semi-success that the space industry has met so far, are signals that while high-technology can push the country forward, the back-up, the very basics of the infrastructure sector, if ignored, will turn the high-technology successes into failures.

According to many, the decidedly negative initial impact on the capital goods sector of the 1993 liberalization (which led to increased high-technology capital goods imports), over the longer term, far from harming the industry, has now actually strengthened its capacity to take advantage of the recovery which began in 1994-95. "The recession was a period of introspection of the industry. There was a conscious attempt to improve our quality in terms of better finish and packag-

Facing the competition

Following the introduction of a liberal free-trade economic policy in 1991, Indian machine tool manufacturers were confronted with the danger that demand would outstrip production. The other problem, manufacturers have begun to realize, is the tendency of Indian companies to make a wide range of products. To overcome the latter problem, manufacturers must concentrate on a few products and achieve economies of scale.

This is already happening. In 1994, only 54% of domestic consumption was met by domestic producers, up from 50% in 1993, but way below the pre-liberalization peak of 86%. Domestic manufacturers, however, do not see increased importation as a threat. Import of machine tools, indeed of any capital goods, would expand the market and ultimately help Indian machine tool makers. "The question is not about protection. It's about market size. I would prefer to have a small share of a large market rather than a large share of a small market," says Jamshyd Godrej, managing director of Godrej and Boyce.

Analysts claim that imports can only increase in the future, as duty rates comes down. The import tariff on computer numerically controlled (CNC) machines is 35%. Project imports carry a duty of 25%, while imports under the Export Promotion Capital Goods Scheme are at 15%. CNC controls and drives carry a tariff of 35%, while certain other components carry an import duty of 65%.

While industry will have to compete against imports, it is not in danger of losing control to foreign investors. This is perhaps due to technological development achieved by about a dozen companies. As a result, imports of cheap machine tools from East Asia are coming down. Certain Indian companies, such as ACE Designers, have benefitted immensely from technological development. Producing turning and machining tools, ACE has increased its production by 90% from 1992-93 to 1993-94 (100 million rupees to 180 million rupees).

Mysore Kirloskar Ltd. (MKL), a major victim of the worldwide economic recession at the end of the Cold War, has now become a believer in R&D. After visiting hundreds of plants abroad and analyzing the costs, MKL authorities have concluded that India is definitely competitive in large castings, precision-machined parts, subassemblies, carcasses, and so on.

Following this observation, MKL joined up with Colchester (U.K.), part of the well-known 600 Lathes Group, and jacked up its production facilities with lathes, CNC cylindrical grinding machines, and machining centers. As a result, MKL's turnover shot up from 380 million rupees in 1993-94 to 630 million rupees in 1994-95, and further on to 950 million rupees in 1995-96.

Another company, Batliboi and Co., previously known as a trading company, is making waves in India in the machine tool sector. Batliboi, which produces 400 to 450 milling, drilling, and turning machines annually, has gone a long way with technological development. Batliboi is now looking to form a joint venture with the Bridgeport Machines of the U.K. for enhanced production.

Another area of technology development which is going to have a major positive impact on Indian industry is retro-fitting conventional machine tools into CNC machines. Technofour is a leading player in this area. But, its role will be diminished significantly because big engineering outfits such as Godrej and Boyce, and Premier and TELCO (a Tata outfit), have large machine building divisions which will serve not only their in-house requirements but will also seek new markets.

The next step already taken by some Indian machine tool manufacturers is to create consortiums for market alliance and to provide solutions and specializations. A six-manufacturer consortium called Micromatic has been formed. In various memorandums presented by the manufacturers to the government, they do not call for increased tariffs or more protection. Instead, they are pleading for some sort of investment allowance for all those machine tool user industries that are going for CNC machines for the purpose of enhancing productivity in the industry.

ing," says Jamshyd Godrej, managing director of Godrej and Boyce.

The background

Indian machine tool production began in the 1930s. The total number of manufacturers before World War II was estimated to be close to 100. The ruling British forced manufacturers to produce defense equipment at the outbreak of war in Europe. The British government in India passed the Machine Tool Control Order in 1941, the main object of which was to regulate and channelize production for use in the defense industry. The cut-off of imports called for increased activity in the domestic machine tool sector, and machine tool production was significantly higher in 1941 because of this.

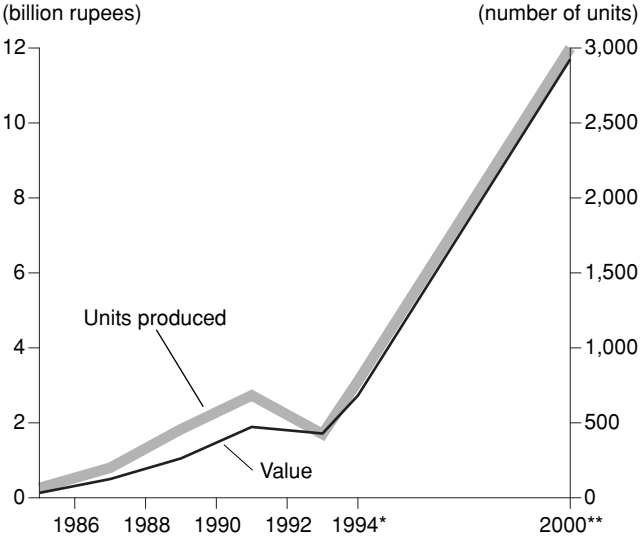
In the 1930s, however, India was importing most of the machinery needed to develop its industries. In 1933-34, the total import of machinery and millwork was valued at 1.277 million rupees, of which about half was accounted for by sugar and textile (cotton) machinery. All kinds of machinery and millwork figure in the imports, from earthmoving equipment to typewriters. This stopped during the war, but as soon as the war came to an end, imports were opened up and domestic manufacturers were confronted with competition from abroad. The number of domestic firms manufacturing machine tools dropped from 125 in 1941 to 45 in 1947, when British rule finally came to an end.

In 1948, soon after India achieved independence, the government of India reformulated the Industrial Resolution. It was decided that all the larger units in the category of "miscellaneous industry machinery," should be in the public sector, which meant that all larger and new machine tool facilities in the future would be under the public sector.

Among the highlights of the new policy was the setting up of Hindustan Machine Tools (HMT), in Bangalore, in a collaborative agreement with Oerlikon and Buerlhe (Switzerland). HMT started production in 1955; it was protected to the fullest extent, and all imports of machine tools were either restricted or banned. Subsequently, a number of agreements were signed with leading machine tool manufacturers in Japan, Europe, and the United States. By 1971, Indian manufacturers had increased production significantly, to the point where 70% of demand was met through domestic production. In 1961, the figure was 23%.

By the early 1970s, the Indian machine tool industry got into a rut. Functioning in a highly protected environment and in an economy which for decades never grew at a rate more than 3%, the machine tool industry adopted a low-growth syndrome. During the 1970s, there was a general slowdown in public investment and the demand for capital goods remained suppressed throughout the decade. Some argue that that decline in capacity utilization of the capital goods industries after the mid-1960s reflected some deep-seated problems, including the incompatibility of the structure of capacities with the evolving structure of demand. The bottom line, however, is that the feasibility of raising public investment was severely constrained by the lack of resources. Nonetheless, HMT, through some R&D efforts, started manufacturing numerically controlled/computer numerically controlled (NC/CNC) machine tools and other machine tools.

FIGURE 2
CNC machine tool production



* Estimate. ** Forecast.

Source: IMTMA.

In the early 1980s, with the stabilization of the Indian political scene, the government introduced a few liberalization measures. Large-scale imports of special-purpose machines and of CNC machine tools took place, which accounted for the increased share of imports, to the tune of 40% in 1988, in domestic consumption. Technological cooperation has helped Indian machine tool firms to introduce CNC machine tools, and if the present trend continues, the share of the CNC machine tools will be at least 70% of total production by the turn of the century (**Figure 2**).

During the end of the 1980s, the Indian machine tool industry got a boost (**Figure 3**) from a steady increase in exports to the Soviet Union. A new cooperation agreement signed in 1987 between the U.S.S.R. and India resulted in a steady growth of Indian exports (see **Figure 4** and **Table 1** for a look at India's comparative role in the worldwide production and trade of machine tools). On the import side, almost 25% of machine tools imported into India come from Japan. In the small-scale industry sector, Taiwanese and South Korean machine tools figure prominently in India's domestic consumption.

A new spurt in growth

The turnaround of the machine tool industry in 1993-

FIGURE 3
Indian machine tools data
(millions $)

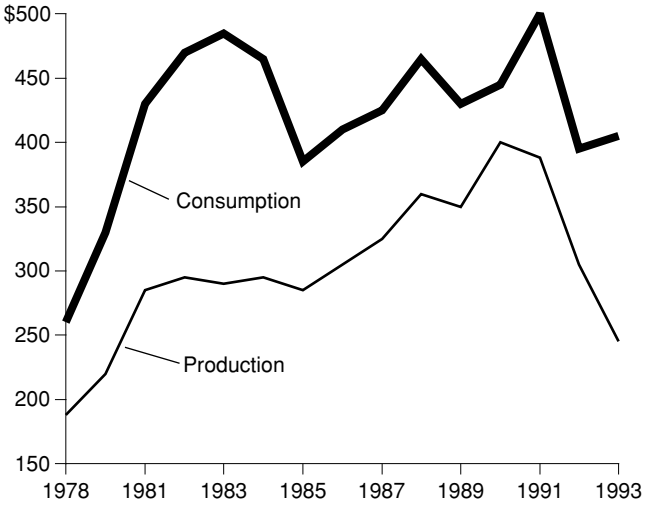


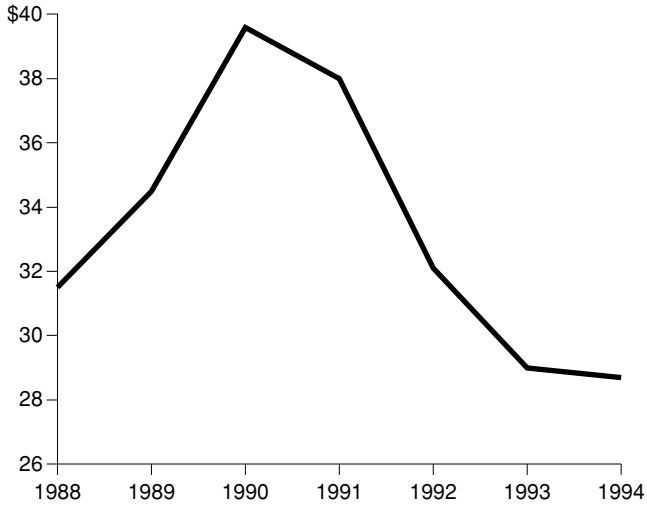
TABLE 1
Machine tool production and trade of selected countries
(millions $)

	Production			Trade	
Country	**Total**	**Cutting**	**Forming**	**Exports***	**Imports**
Japan	$6,959	$5,330	$1,629	$3,739	$ 371
Germany	5,403	3,469	1,934	3,636	1,214
United States	3,223	2,083	1,140	1,060	2,188
Italy	2,105	1,364	741	1,371	577
China	2,970	2,080	890	216	1,940
Taiwan	1,074	716	358	688	441
South Korea	587	489	98	111	709
France	618	459	159	300	636
Indonesia	13	7	6	1	518
India	156	143	13	17	185

* India's major export markets are the Commonwealth of Independent States, Singapore, Kenya, Algeria, United Kingdom, Saudi Arabia, United States, Malaysia, and United Arab Emirates.

Source: *American Machinist,* May 1995.

FIGURE 4
World machine tools production
(billions $)



94 is perhaps the most heartening development for Indian industry. The captains of industry are highly optimistic that the turnaround can be consolidated in the coming years, to make machine tools a major growth-oriented industry. Such optimism was clearly visible in the triennial machine tool manufacturers' jamboree, the Indian Machine Tools Exhibition (IMTEX), held in January 1995. There one could see the right blend of technology, quality, and cost-competitiveness of Indian machine tool manufacturers gearing up to meet the demand and requirements of machine tool users, especially in the automobile and auto component industries.

The machine tool industry which has emerged from the recession faces a situation entirely different from what prevailed in 1991. It now faces the emergence of the private sector (auto, for instance) as the major buyer of machine tools, increased competition from imports, and a major shift from conventional to computer-controlled machine tools.

There is a near unanimity among machine tool manufacturers that the advent of state-of-the-art automobiles, through joint ventures with some of the world's leading auto manufacturers, and the emergence of India as a global sourcing base for auto components, has opened up demand for flexible and cost-competitive manufacturing solutions.

The impact of changes due to the shift of buyers from the public sector to the private sector has been felt throughout the country (see **Figures 5** through **9** for consumption of selected machine tools). In the pre-liberalization days, 30% of the demand was from the government, particularly defense and railways. In the defense sector, projects such as the T-72 tank manufacture, modernization of the Ishapur Rifle Factory, and production of anti-aircraft guns were major sources of orders. There are still a few large projects in the pipeline. However, given the situation facing the railways, in which most of the capital expenditure involves conversion of track from narrow to broad gauge, orders for new machine tools have been reduced significantly. "The public sector now accounts for less

FIGURE 5
Machine tools consumption: standard drilling and broaching
(number of units)

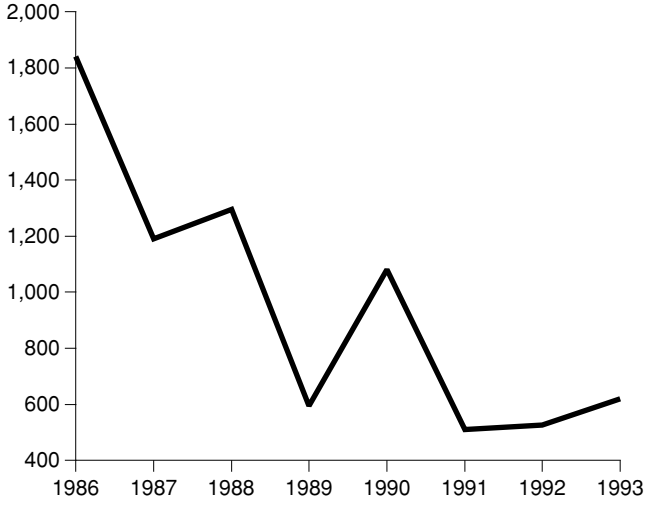


FIGURE 6
Machine tools consumption: standard gear cutting
(number of units)

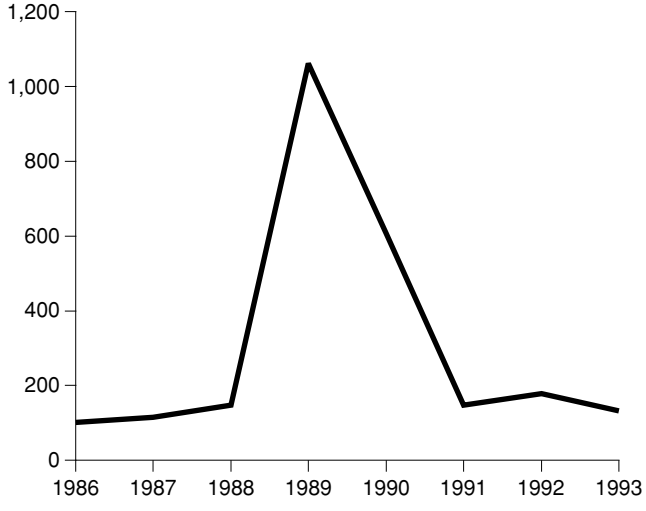


FIGURE 7
Machine tools consumption: CNC lathes and chuckers
(number of units)

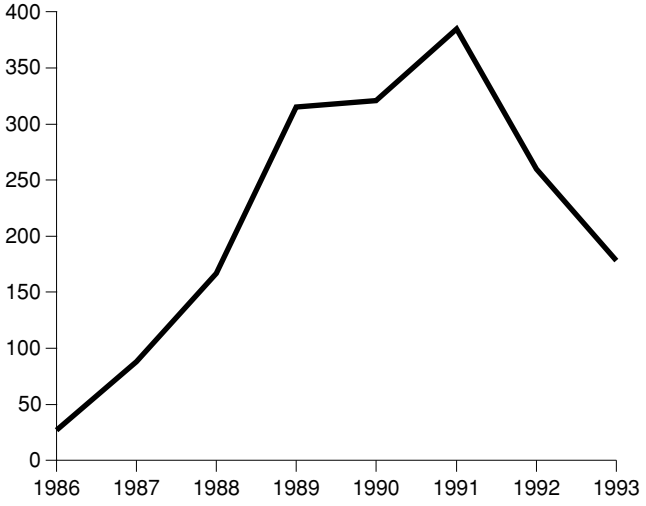
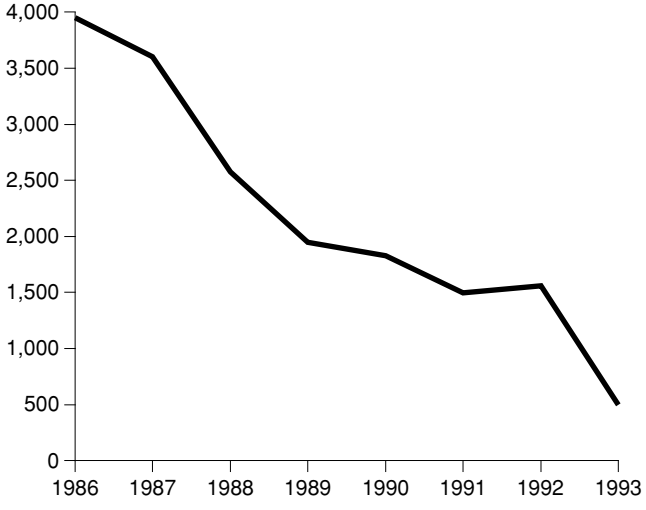


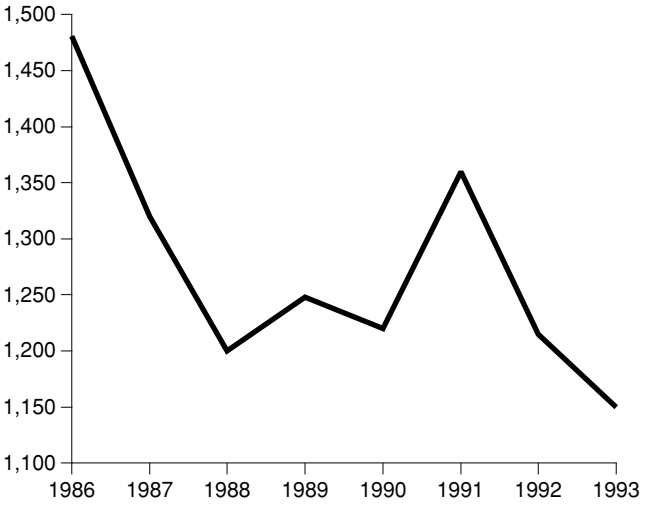
FIGURE 8
Machine tools consumption: standard lathes and automatic
(number of units)



than 10% of the whole demand," says Shailesh Sheth, president of the Indian Machine Tools Manufacturing Association. Companies such as Mysore Kirloskar, 30% of whose output used to go to the defense sector while another 30% was exported to Soviet Union and Germany, were major losers.

Although orders from the defense sector and the railways, and exports overall, have stagnated, the domestic order book situation is a lot more comfortable for a number of companies. Bharat Fritz Werner raised its turnover from 270 million rupees in 1993-94 to 350 million rupees in 1994-95. The Banga-

FIGURE 9
Machine tools consumption: milling and boring
(number of units)



lore-based Widia India Ltd., a subsidiary of Cincinnati Milacron, next year expects to top its turnover of 1.3 billion rupees in 1995.

From the technological standpoint, state-of-the-art passenger cars, two-wheelers, and commercial vehicles have introduced a whole new range of manufacturing processes. The emphasis is now more on enhancing productive machining systems which would reduce to a bare minimum the non-cutting time. These systems have to be capable of operating at high machining parameters, achieving specific process capability and increased automation in loading and unloading (resulting in substantial saving in time in each cycle of operation), flexibility to accommodate product-mix variations (resulting in emphasis on flexibile manufacturing cells in place of dedicated transfer lines), and with reliability and "high uptime" to support customer service.

In addition, the emerging requirements of metal-forming and plastics-processing technologies, to meet the needs of vehicle exterior and interior structural components, have introduced new machine tools and further improvement in operating systems. For instance, such requirements will call for a highly productive sheet metal processing industry, forging presses, plastic injection-molding machines, press toolings, dies, and molds.

With the emergence of new processing technologies, the machine tool industry in India is also shifting gears. Production of general purpose machine tools has declined from 16,000 per year in the mid-1980s to 9,000 in 1994, while production of CNC machines has risen from 16 in 1984 to 800 in 1994. However, it is also evident that such technological improvement in the machine tool sector will take some time to consolidate. Fanuc India, a joint venture between Fanuc of Japan, General Electric of the United States, and Voltas of India, which makes controls and drives for CNC machines, had to content itself by selling 500 units in 1995. In Japan, Fanuc produces 8,000 units per month.

The present mix

The Indian experience of more than five decades in machine tool technology, according to J.P. Malik, executive director of the Machine Tool Business Group, HMT, has made it resilient. It now offers a wide spectrum of machine tools, from conventional machines to flexible manufacturing systems in the metal cutting range, supplemented by metal forming machines and plastics processing machines. Over 350 manufacturers in the sector produce 10 billion rupees worth of machine tools, cutting tools, and other peripherals annually, Malik points out.

As in many countries, the Indian machine tool industry began with the manufacture of central lathes. Over the years, however, the industry grew to cover almost all the conventional technology machine tools and CNC machines. A wide range of metal forming presses, forging presses, and deep drawing presses, and sheet metal forming machinery, has been introduced to meet current needs.

One of the more satisfying features of the performance of the Indian machine tool industry in recent years has been the proportion of CNC machines produced compared to total turnover. In addition, the manufacturers have succeeded in developing their own design and widening and completing the range of CNC machines such as lathes, machining centers, and grinding machines.

Notable successes have also been achieved in making available in larger quantities such basic machine tools as work holding and tool holding equipment (mechanical clutches, hydraulic and pneumatic clutches, drill chucks, tapping attachments, and so on).

Improvements have been noticed in the modernization of production facilities by way of investment in critical mother-machines such as sideway-grinding, jig boring, and measuring and metrology equipment. Improvements in manufacturing systems through adoption of computerization to further the capability to service CNC machines, has also occurred in recent years.

The weaknesses

However, the Indian machine tool industry also exhibits some palpable weaknesses. Some of these weaknesses are not due to lack of vision, but perhaps more to inadequate funding and ineffective coordination. For instance, while the perspective plan for the industry is geared to creating the conditions so that the vital inputs required for manufacturing CNC machines are made available within the country, such items as

CNC controls, ball screws, axis drive motors, measuring scales, feedback elements, among others, continue to be imported because, except for a handful, most of these items have been ignored by manufacturers.

Since the machine tool industry has not grown at the rate it should have, the relative cost of production of Indian machine tools is very high compared to the corresponding freight-on-board prices of machine tools made abroad, such as those from South Korea and Taiwan.

In addition, the following shortcomings have been cited by the industry:

- The most often heard complaint is that the Indian machine tool industry has not made significant progress in absorbing and establishing technology for the manufacturers of high-precision machines such as jig borers, precision grinders, tool-room precision lathes, and so on.
- Except for the production of gear hobbers and gear-shaping machines, other gear-producing machines such as bevel gear generators, spiral bevel gear generators, and gear grinding machines have not been put into production.
- Development in the Indian foundry industry is also lagging behind international standards. The improvements required by way of accuracy in castings, reduction in machining allowances, and castings for high-precision machines are lagging considerably.
- There has been very little progress made in the production of heavy machine tools which are critical to key sectors such as power generation equipment, pressure vessel manufacturers, and marine engine production, among others.
- The Indian manufacturers have inadequate appreciation of changes in production systems such as cellular manufacture. They have yet to fully apprehend the underlying principles and the areas where adaptation and modification in machine tool designs are required.
- The reliability of Indian machine tools has been much lower than corresponding machines made abroad. The uptime of the CNC machines has been lower than for the imported machines.
- A large number of user industries have specific requirements of machine tools, and these are best met by focussing on specific products of the user industry and developing the corresponding machine tools needed. In such customization of machine tools, there exist visible gaps. Some of these items have been highlighted by experts from time to time.

This list is by no means exhaustive, in cataloguing the weaknesses in the still-to-be-developed machine tool industry. At a forum organized by the Confederation of Indian Industry (CII) last year, one of the participants, T.V. Mansukhani, pointed to a whole range of weaknesses, and outlined what the industry has to do in the future to overcome these weaknesses. A few of Mansukhani's suggestions hit the core of the problem. To begin with, he suggests:

- India's large and medium-sized machine tool builders should concentrate on the more complicated and special-purpose machines, and encourage smaller manufacturers to take on the manufacture of simpler products.
- It is important that machine tool manufacturers re-arrange their production facilities and move away from batch production to more flexible CNC manufacturing systems.
- Machine tool manufacturers must take action to improve the quality of castings which would help them to produce high-precision machine tools. Indian machine tool manufacturers are lagging behind in absorbing technology for castings and high-quality precision tools.

A similar view has been expressed by Malik elsewhere. He said that Indian machine tools are yet to attain international levels in terms of performance and reliability. He pointed out that the manufacturing philosophy requires a phase change. Manufacturers must abandon the present practice of in-house manufacture of all components and assembly. He says that through a series of interactions with machine tool builders

Flexible manufacturing cells and systems

Modern machine tools are not developed in isolation but are consciously designed as one element of a complete production system in the form of a production cell, which can be readily adapted to widely varying user needs. A survey conducted in 1995 among 35 leading companies from America, Japan, and Europe indicated a global trend toward modular production, necessitating further differentiation among Asian, American, and European zones.

Of the companies surveyed, 49% consider the modular method, based on simple, low-cost, stand-alone machine tools, the direction which will be taken in the immediate future. Some 38% favored modular production in the form of **flexible manufacturing cells (FMC),** with standard interfaces for additional modules. The remaining 13% see a future for integrated manufactures in the form of **flexible manufacturing systems (FMS)** with integral control and logistics.

There are, however, counter-arguments against a completely integrated system. The increased integration of a multiplicity of elements results in an exponential rise in the complexity of entire systems. The trend worldwide of buyers is that their purchase decisions are dominated by a very high up-time, on the order of 97-99%, for a machine or manufacturing cell, because down-times often add up to several times the amount invested in the machine itself in additional costs.

of international repute, Indian manufacturers have started to recognize the benefits of ancillarization in the areas of cost effectiveness and short delivery time.

Malik says that there is an effort afoot to enhance technology. Because manufacturing technology comprises machines, systems, and toolings, it requires cooperation between the machine tool industry and the suppliers of components—hydraulics, pneumatics, electronics, and cutting tool manufacturers. At the industry level, central R&D organizations, such as the Central Machine Tools Institute, are involved in associating all these agencies in the effort to upgrade technology.

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The general trend toward greater local autonomy and individual responsibility, including in the planning, control, and monitoring of individual manufacturing cells. Over 90% of those surveyed all over the world confirmed the increasing importance of computer integrated manufacturing (CIM) and intelligent manufacturing system (IMS). CIM systems will be necessarily simple, easily managed, and designed in accordance with worldwide compatibility standards. Initial moves toward IMS are already being made by some manufacturers, who monitor the condition of machines and tool wear by means of sensors. IMS will eventually lead to the automatic replacement of tools after certain limits have been exceeded.

Flexible manufacturing cells consist of at least two conventional and/or numerically controlled machine tools (NCMT) and include a material handling device such as a robot serving a number of machine tools standing in line or in a circle, or automatic pallet changers in conjunction with automatic transport between NCMTs.

Flexible manufacturing systems consist of several automated machine tools of the universal or special type and/or flexible manufacturing cells, and if necessary, automated workstations. They are interlinked by an automatic workpiece flow system in a way which enables the simultaneous machining of different workpieces which pass through the system along different routes.

In other words, FMC is based on a synchronization principle: At any given time, several machines are processing the workpiece.

FMS is based on a coordination principle: Each of the machines is processing the workpiece in sequence. The transfer between the different machines can be organized under two principles: flow shop, where the workpiece goes from one machine to another, as in a transfer line; and job shop, where it is then possible to combine in different manners the machine utilization.

How the FMS works

In most FMS installations, incoming raw workpieces arrive at a workstation where they are positioned into fixtures or pallets. When information is entered, the FMS-controlling computer takes charge, performing all the necessary operations to completion.

The controlling computer first sends a transporter to the load/unload station to retrieve a pallet. The loaded pallet then keeps moving in a loop until a machine becomes available to perform the first operation. When a position in the queue (in machine tool lingo, the shuttle) becomes available, the transporter stops and a transfer mechanism removes the pallet.

The controlling computer (called supervisor) determines whether all of the required machine tools are present in the packet and requests needed tools from either off-line tool storage or a tool crib/tool chain within the system. When all the required tools are loaded, the supervisor downloads the NC part program to the machine controller from the FMS computer.

When the set-up activities are completed, machining begins. The FMS monitors the tool during machining. If it breaks, a contingent procedure is invoked. Compensating corrections for any deviation are made during machining.

The finished, or machined part is moved to the shuttle to await a transporter, the pallet moves to the next operation, or else circulates in the system, or is unloaded at some intermediate storage location until the machine required for the next operation becomes available.