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Contents

Strategy Paper on Galvanizing Machine Tools Industry in India through Technology Development

HARBHAJAN SINGH AND SANJAY CHAVRE

Machine tools play a vital role in countering technolgy denial as well as develop equipments for strategic sectors. A strong machine tool industry is essential to realise ambitions in manufacturing growth; provide gainful employment, provide sustained manufacturing competitiveness and ensure national security. This paper provides SWOT analysis of the machine tool industry in India. Besides, the demand under XII plan and technology gaps are also discussed in the paper.

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1. Industry Overview

Strategic Industry: The machine tool industry is a strategic industry which plays a vital role in the economic growth through its multiplier effect as high as 1:100. It determines the manufacturing competitiveness in important sectors such as automobiles, consumer goods and others. Machine tools play a vital role in countering technology denial as well as develop equipments for strategic sectors such as defence, aerospace and nuclear. A strong machine tool industry is essential to realize ambitions in manufacturing growth, provide gainful employment, provide sustained manufacturing competitiveness and ensure national security.

Early Era: The start of organized sector of the Indian machine tool industry took place in early years of the Second World War. Due to non-availability of imported machine tools, few British-owned general engineering firms took up their manufacturing in India. This followed the start of centrally planned economy as reflected in a series of Five-year Plans. This process of planned economy resulted in the second phase of Machine Tool Manufacturing with start of Public Sector Investment in Machine Tools (HMT Ltd, 1953; HEC: 1958). These two initial phases of development of the Indian machine tool industry saw the production of general purpose machine tools, most of which were produced under technical assistance from foreign collaborators (Oerlikon, Louden, Ward, Herbert, Jones & Shipman, etc.).

Middle Era: The sixties marked the third phase of machine tool industry, typified by rapid growth in production and horizontal expansion in various types of machine tools such as multi-spindle automats, gear-cutting machines, SPMs, broaching machines, presses, etc. The fourth phase beginning mid-eighties saw the advent of the Japanese machine tool-makers through licensing arrangements (Mori-Seiki, Mitsubishi, Hitachi-Seiki, NachiFuji-Koshi, Murata, etc.).

Current Era: The fifth and current phase began in early nineties after the new policies of Open Market Economy were introduced, which saw advent of technocrats. The market share of companies owned by technocrats steadily increased due to in-house design capability, entrepreneurial spirit, greater technology friendliness, operational flexibility and lean managements. As a result, import of technology is declined. This also resulted in the shrinking market share of big companies and public sector giants. Thus, the Indian machine tool industry has come a long way in the last decade since liberalization and economic reforms were ushered in.

Profile of the Sector: Data on market size, production, exports, imports, etc.

The industry figures of market size, production, exports, imports, import content, employment, investment intentions and FDI are as given below.

Market size indicates the total demand of machine tools in India. This demand is met through domestic production and imports. A small portion of domestic production is exported.

The significant feature of domestic production is its import content, that is, even to make a machine tool in India, Indian companies import some critical components and sub-assemblies. These are fitted into their products, which are then sold in the domestic market and some time exported. It may also be mentioned that the production remained stagnant between 1991 and 2002. The year 2003 onwards, the rate of growth in production increased slightly. The production declined as a general pattern till 2014, since when some recovery is seen.

The challenges before Indian machine tools sector is its increasing dependence on imports—on two counts. Firstly, direct import of machine tools. Already in the last few years, the import of finished machine tools is about 55–60 percent of the total demands. The domestic production is already declining in percentage of total demand. This is because the demand of high technology machine tools is increasing over a time. The Indian companies are not able to keep pace with the technology advancements elsewhere.

Secondly, the import content in the domestic product is also increasing, again on account of technology advancement.

The impacts are losing share of manufacturing and consequently income and employment. Perhaps on long terms more disastrous results are on account of strategic nature of the machine tools industry.

The same trend is reflected in the overall manufacturing sector. Some other underlining reasons are low unit size, costs of doing business, governance issues, taxation and FDI regime favouring imports, totally liberal trade policies, exposure of still developing sectors to global competition even in FTAs and skill scarcity. The Government of India has recently come out with a reactive manufacturing policy.

Direct employment in manufacture of machine tools sectors is low; however, its cascading effect is five times. This is due to the fact that every machine tool made creates further employment opportunity—direct, secondary and tertiary.

The Industrial Licensing and FDI policies for the sector were liberalized in 1991 reforms. Still very few new

	2004–05	2005–06	2006–07	2007–08	2008–09	2009–10	2010–11	CAGR
Market Size (Rs Cr)	3,403	4,877	7,162	8,698	8,319	7,245	10,236	16%
Production (Rs Cr)	1,634	2,028	2,579	2,853	2,138	2,484	3,624	12%
Import (Rs Cr)	1,821	2,899	4,656	5,992	6,271	4,842	7,245	20%
Export (Rs Cr)	52	50	73	147	90	81	91	13%
Import content in domestic production (%)	30% in standard machine tool (medium technology) 40% in high-technology machine tools							
Employment (No. of people)			30,000					
Investment Intentions (Rs Cr)	NA	NA	173	20	228	675	957	(Total) 2,053
FDI (Rs Cr)	NA	NA	170	226	206	640	53	(Total) 1,295

Source: Report by the Working Group on 'Capital Goods and Engineering Sector' set up by the Planning Commission for preparing 12th FYP.

interments are planned as reflected in the trends of Investment Intentions data. The FDI is also marginal. The FDI during last five years was at Rs 1,300 crore (approx.). It was mainly for service centres/representative offices for imported machine tools and not for core manufacturing technologies. The FDI failed to spur the sector with technology and management practices, as in some other sectors like telecom services, automobiles, etc. This brings out then issues of present policy set not servicing the industry growth needs.

Year	Production	Import	Consumption	% Share of Indigenous Manufacturers in Total Indian Consumption
2010–11	3,623	6,703	10,191	36%
2011–12	4,299	7,645	11,764	37%
2012–13	3,885	7,598	11,269	33%
2013–14	3,481	4,672	7,906	44%
2014–15	4,230	5,318	9,267	46%
2014–15 *[First Half]*	2,075	2,482	4,421	47%
2015–16 *[First Half]*	2,179	2,681	4,717	46%

Source: IMTMA.

Major Indian Manufacturers:

1. M/s Ace Designers Ltd, Bangalore
2. M/s Ace Manufacturing Systems Ltd, Bangalore
3. M/s Bharat Fritz Werner Ltd, Bangalore
4. M/s Electronica Machine Tools Ltd, Hyderabad
5. M/s HMT Machine Tools Ltd, Bangalore
6. M/s ISGEC, Yamuna Nagar
7. M/s Jyoti CNC Automation Pvt. Ltd, Rajkot
8. M/s Kennametal India Ltd, Pune
9. M/s Lakshmi Machine Works Ltd, Coimbatore
10. M/s Lokesh Machines Ltd, Hyderabad
11. M/s TAL Manufacturing Solutions Ltd, Pune
12. M/s Áskar Micron
13. M/s Champkraft Machine Tools
14. M/s Batliboi Ltd
15. M/s Electropneumatics & Hydraulics (India) Ltd
16. M/s Galaxy Machine
17. M/s GedeeWeiler Pvt. Ltd
18. M/s Hind Hydraulics & Engineers Ltd
19. M/s Hindustan Hydraulics Pvt. Ltd
20. M/s Macpower Machine Tools
21. M/s Marshal Machine Tools
22. M/s Micromatic Grinding Technologies Ltd
23. M/s Motor Industries Company Ltd
24. M/s Parishudh Machines Pvt. Ltd
25. M/s PMT Machine Tool Automatics Ltd
26. M/s Singhal Power Presses
27. M/s Premier Ltd

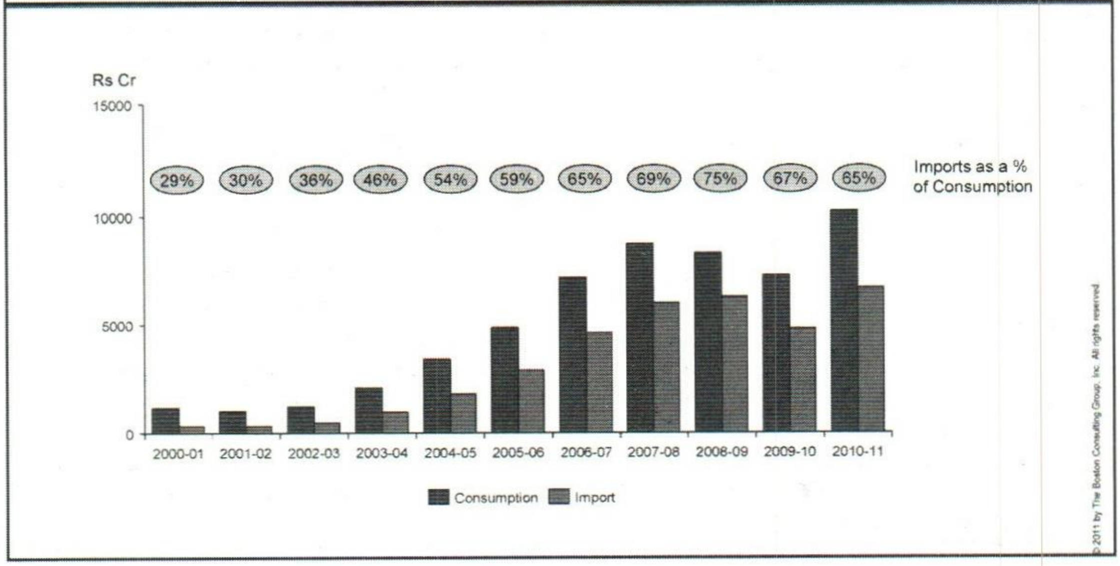
Major Machine Tools Manufactured In India:

- Non-CNC general purpose machines
- Standard CNC machines
- Gear cutting, grinding, broaching machines
- Medium-sized machines
- Electro Discharge Machine (EDM), Wire EDM
- Special Purpose Machines (SPMs)
- Medium-size machines
- Presses, press brakes
- Pipe bending

Import Dependency: Indian manufacturers are mostly in SMEs sector. They need to increase production volumes in order to survive in global markets. They should also upgrade products and processes in terms of technology and quality in order to remain competitive at both local and global markets. Domestic players have been losing local market in favour of imports.

Additionally, there is an import content of 30 percent in standard equipment and 40 percent in high-tech equipment. Thus, the machine tool industry faced the dilemma of whether to remain as finished product supplier and face competition from large volume of global players or become sub-suppliers of components and/or sub-systems. The latent potential of this sector and its inherent strengths lent credence to the belief that the Indian

Share of imports has grown over time for Machine tools



Source: Report by the Working Group on 'Capital Goods and Engineering Sector' set up by the Planning Commission for preparing 12th FYP.

machine tool industry can become a significant global player and carve a niche for itself in the high technology sunrise segment of CNC machine tools.

SWOT Analysis:

Strength:

1. Skilled manpower.
2. Economic low-volume production.
3. Technical base in diverse fields.
4. Availability of basic raw materials.
5. Wide range of products at industry level.
6. Rising class of technical entrepreneurs.
7. Component manufacuring capabilities (foundry castings).
8. Strong and visible industry association (IMTMA), supportive central government, Central Manufacturing Technology Institute (CMTI).

Weakness:

1. Technology gaps and weak in technological innovation/R&D.
2. Lack of vision and focus on core competencies.
3. Low volume.
4. Inverted duty structures.
5. Liberal policy—tilt towards imports.
6. Insignificant export.
7. FDI—oriented towards domestic markets based on assembly, technical/service centre.
8. Poor image—both internal and external.
9. Poor infrastructure.
10. Poor workmanship/lack of skilled manpower/poor pay packages in R&D/technical development/ manufacturing.
11. No support in public procurement, lack of offset and contract development policies.
12. High cost of capital/doing business and governance issues.

Opportunity:

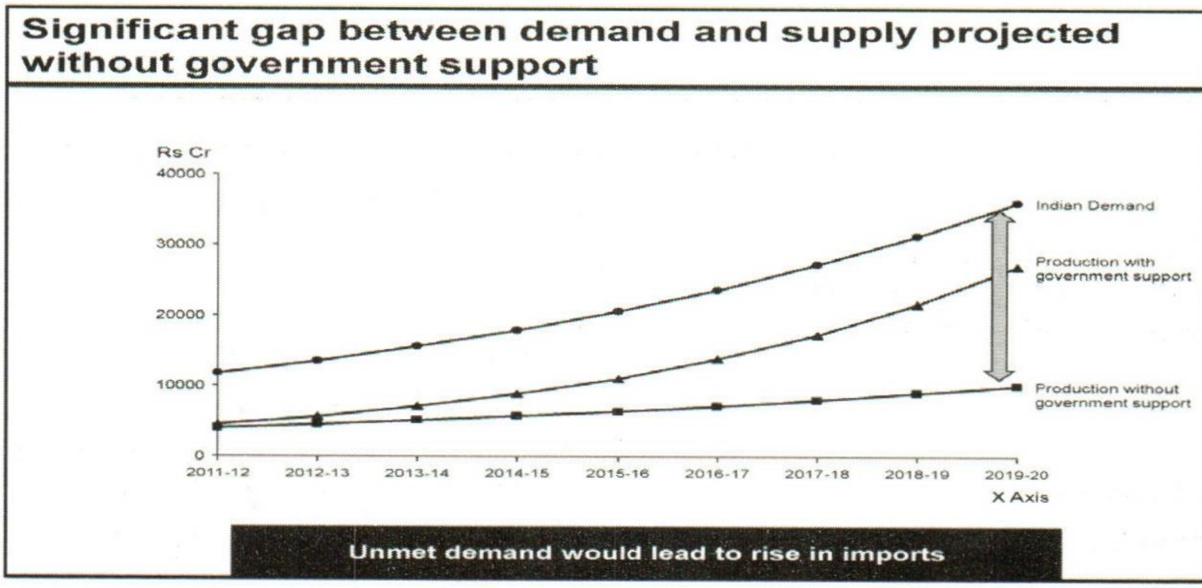
1. India presents one of the most growing market.
2. 'Product Development Centre' for technology generation and National Manufacturing Policy on the anvil.

3. The PSUs to be promoted for import substitution.
4. Strategic alliances/JVs, acquisition of technology firms abroad.
5. Low cost and wide manufacturing base.
6. Government sensitivity towards strategic nature of the industry.
7. Public procurement policy draft—5 percent price preference to public sector in government purchases.

Threat:

1. Competition from international players manufacturing/supplying in India.
2. Emerging new machine tool manufacturing countries—China, the Province of Taiwan and the Republic of Korea.
3. Non-tariff barriers/adverse FTAs.
4. High cost of distribution (in export markets).
5. 'Direct' marketing by foreign machine tool manufacturers in India through their own selling set ups.
6. Rise of 'Regional' distributors selling on 'Stock and Sale' basis, on behalf of foreign manufacturers.

Alarm Bells: The machine tools industry in India is currently not attracting investment in the manufacturing of machine tools and needs support. Without an impetus towards technology development and capacity creation, a huge demand supply gap greater than Rs 30,000 crore is expected to develop in the sector.



Source: Report by the Working Group on 'Capital Goods and Engineering Sector' set up by the Planning Commission for preparing 12th FYP.

12th Plan Projections:

Recently a Working Group on Capital Goods & Engg. Sector was set up for preparation of XII FYP and according to it the projected target with government support is as under.

	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17	CAGR
Market Size (Rs Cr)	11,771	13,537	15,568	17,903	20,588	23,678	15%
Production (Rs Cr)	4,530	5,663	7,078	8,848	11,060	13,824	25%
Import (Rs Cr)	7,355	8,016	8,668	9,277	9,806	10,201	6.7%
Export (Rs Cr)	114	142	178	222	278	347	25%
Employment (No. of people)	80,000						

The 12th FYP plan data by IMTMA is

Year	Production	Import	Consumption	% Share of Indigenous Manufacturers in Total Indian Consumption
2010–11	3,623	6,703	10,191	36%
2011–12	4,299	7,645	11,764	37%
2012–13	3,885	7598	11,269	33%
2013–14	3,481	4,672	7,906	44%
2014–15	4,230	5,318	9,267	46%
2014–15 *[First Half]*	2,075	2,482	4,421	47%
2015–16 *[First Half]*	2,179	2,681	4,717	46%

Source: IMTMA.

One of the key objectives for the 12th FYP is increase manufacturing sector growth to ~ 2–4 percent more than GDP growth to make it the engine of growth for the economy and increase its share to ~ 25 percent of overall GDP by 2025. Since the manufacturing sector is expected to grow at 14 percent, the Capital Goods Sector must grow at 17–19 percent at least. This means that the Machine Tools Sector must also maintain similar growth rate. Indian Machine Tools Manufacturers Association has projected a growth rate of 25 percent with government support.

Without Government support, the domestic production may grow at 11th FYP CAGR of 12 percent to Rs 6,387 crore. The import content in the domestic production is estimated to increase to 75 percent to 85 percent. This will make Indian production to be assemblies' supply.

The import of finished machine tools is also expected to grow at 11th FYP CAGR of 20 percent if not more. This means that end plan imports of finished machine tools will be Rs 18,028 crore.

This, again means that the end 12th FYP demand of Rs 24,415 crore (without taking into account exports, re-engineering and in house production) will consist of total imports of Rs 22,700 crore. Hardly any domestic value addition, this scene must be reversed in the national interest.

With government support as proposed in the 12th FYP Working Group

Target size and growth rate

Demand is projected to grow at an average CAGR of 15 percent over the 12th Plan period (2012 to 2017). Production is projected to grow at 25 percent CAGR over the same period with government support.

Target export and import levels

Exports are projected to grow at 25 percent CAGR during the next five year plan, whereas imports are estimated to grow at a CAGR of 6.7 percent with government support.

Target employment levels

The industry has targeted to directly employ an additional 50,000 persons in machine tools and related industries by 2016–17 with government support.

Policy and scheme (worth Rs 6,500 crore) support are proposed in the 12th FYP.

2. Current Levels of Technology Development

Although India is one of the larger consumers of machine tools, the indigenous machine tool industry holds only around 30 percent of market share. This is due to the fact that user industries depend on imports for several types of advanced machine tools. Even though industry has good design and manufacturing competence for a wide range of products, the product range and the technologies manufactured in India have a substantial gap with the present levels abroad.

Mix of Technological Capabilities: The Indian machine tool industry has a mix of technological capabilities. At present, the products manufactured by the industry are entirely of indigenous development, pointing to a good strength in product design and development, mainly for the standard products in manual and CNC machines besides metal forming presses. It is also able to design and build low and medium technology special purpose machines for certain specific end users. A hidden strength of the industry is its ability to design, engineer and manufacture a range of special purpose machines (SPMs) by SMEs. Examples are SPMs for cylinder boring, valve seat finishing, conrod boring, etc., for auto components, multi-station index machines for defence production, assembly, testing and measuring stations for auto, defence and other industries.

Technology Gaps: But the industry has large technology gaps in certain areas like grinding, gear cutting, high precision machine tools, multi-axes and multi-function machines, large/heavy duty machines and metal forming machines. These are required for the strategic/defence sectors like aero-space, defence production, power/energy sectors, etc., affecting national security.

Use of IT, development of new materials and critical components: Also of importance are software tools for design, analysis and simulation, and the development of new materials for machine tool construction. For all of these the industry is dependent on imports at present, a situation that should be reversed over time. A range of attachments, accessories, sub-systems and parts also need to be developed. Particular mention may be made of the need to develop indigenous manufacture of critical mechanical and electronic elements that are the *heart* of CNC machine tools, for which the industry is entirely dependent on imports. The industry is also subject to technology denials on these elements as well as for the higher technology machine tools. This is a potentially serious weakness which must be overcome.

The user industries expect the latest technologies to produce high quality end products at competitive prices. This has made it imperative for the machine tool industry to take an inventory of present technologies and those it should develop within a five-year time horizon. These are summarized in the table below.

Existing Technology	Technologies Required
• Non-CNC general purpose machines	Metal cutting machine tools:
• Standard CNC machines	• Multi-axes, Multi-tasking machines
• Gear cutting, grinding	• High-precision machines
• Medium-sized machines	• Large machines (boring milling, turning)
• EDM, Wire EDM	• Gear cutting and finishing machines
• SPMs	• Grinding technology and machines
• Medium-size machines	• Electrical and micro machining
• Presses, Press Brakes	Metal forming machines:
• Pipe Bending	• Higher press automation and transfer systems
• Hydroforming (limited)	• Servo presses
• Servo presses (limited)	• Sheet working machines (including laser, waterjet heads)
• Rolling, Bending	• Hydroforming
• Measuring, metrology and gaging	• Fine blanking
• Drives and controllers (limited)	• Forging machines
	• Flow forming
	Special technologies:
	• Explosive forming
	• Electromagnetic forming, etc.
	• Cutting tool technologies
	• Robotics and automation
	• Alternative materials (epoxy granite, etc.)
	• Thermally stable welded structures
	• Hydrostatic spindles, guideways
	• Motorized and high frequency spindles
	• Smart machines with embedded sensors
	• Critical components development:
	o Anti-friction linear guideways
	o Ball screws
	o Precision spindle and ball screw support bearings
	o CNC controls
	o Spindle/axes servo motors with controllers
	o Feedback measurement systems

Source: IMTMA.

3. Key Issues and Challenges

◊ **Technology Denial**: It is well known that certain advanced manufacturing technologies like Japan and Germany are not allowing export of high technology Machine Tools to India on the basis that these are *dual use* technologies. The refusal is based on the IAEA guidelines on the levels of precision and control capability of the machines. The denials were usually applied to certain *entities* in India engaged in the defence, aerospace and nuclear manufacturing activities, and also applied to other manufacturers supplying to these establishments. What is not so well known is that these guidelines have been applied against Indian machine tool companies. The CNC controls with more than three axes simultaneous interpolation are denied to machine tool companies, even if they are not intended for use on strategic sector supplies. Several cases of precision machine tools being denied to Indian machine tool companies are on record (which have affected the production of hi-tech machine tools). These instances bring out the vital importance of developing these competencies within the country and reduce dependence on foreign machines. A large investment is needed for technology development.

◊ **Lack of capacity creation through expansion and new units**: While there have been new investments in machine tool units in the last ten years, these are not on a scale required to meet rapidly increasing domestic demand, or make India a significant global player.

◊ **High interest rate makes industry non-competitive**: The prevailing interest rates of 14 percent and more makes the industry non-competitive due to the long gestation period and high capital investment required to set up units.

◊ **Reducing/zero duty imports under FTAs/PTAs**: During recent years a number of FTAs/PTAs have been signed with foreign countries whereby the import duty on machine tools imported from these countries is gradually reduced to zero. This places domestic producers at a disadvantage due to high input costs, high interest rate and the incidence of 7.5 percent custom duty on imported parts. This in fact leads to a situation of inverted duty structure detrimental to the competitiveness of domestic manufacturers. Also, despite stipulations of local value addition in the partner countries to qualify under FTA/PTA, there is likelihood of machines manufactured in other countries being diverted via these countries to take advantage of the lower duty. Free import does not encourage transfer of technology and local manufacturing/value addition. This stunts the growth and development of the industry.

◊ **Fragmented nature of the industry**: Given the fragmented nature of the industry, the SMEs find it difficult to invest money in technology because of limited availability of funds to these industries.

◊ **Shortage of skilled manpower**

o increasing pool of available resources

o increasing quality of resources

o rationalizing labour policy

◊ **Infrastructure issues**

o power and water supply

o infrastructure for transportation and logistics

◊ **High cost of capital**

o corpus fund for modernization/expansion/ upgradation of units

4. Lessons from China

In giving a new thrust to the machine tool industry along several fronts, the strategy adopted by the Chinese government may be of great interest. These are summarized as below:

◊ China has declared the internal development of precision CNC machine tools as one of the country's strategic needs and targets over the next fifteen years.

◊ Chinese government document has stated that China should reduce its reliance on imported CNC machine tools by developing its own machine tools and computer control systems.

◊ Chinese government has identified types of machine tools that it plans to build domestically over the next five years.

◊ China follows a carefully crafted strategy while attracting foreign investment, which is designed to ensure eventual technology transfer. Selective acquisition of foreign machine tool companies is adopted by the Chinese companies to get advanced technology and markets at one stroke.

Localization leading to technology transfer

China introduced procurement law to favour domestic products over imported ones

"Article 10 The government shall procure domestic goods, construction and services, except in one of the following situations:

(1) where the goods, construction or services needed are not available within the territory of the People's Republic of China or, though available, cannot be acquired on reasonable commercial terms;

(2) where the items to be procured are for use abroad; and

(3) where otherwise provided for by other laws and administrative regulations."

<Chinese Government Procurement Law 2002>

Government procurement policies spell out the preference for domestic goods

Control over purchase of imported products

- Special procedures and approvals required if government departments or projects are to purchase imported products

Preference for indigenous innovation products

- Domestic innovation will be valued more than that developed overseas, in the eyes of the Government
- Local companies would get preferential treatment in tenders

Despite recent tightening in the procurement process, uncertain outlook remains

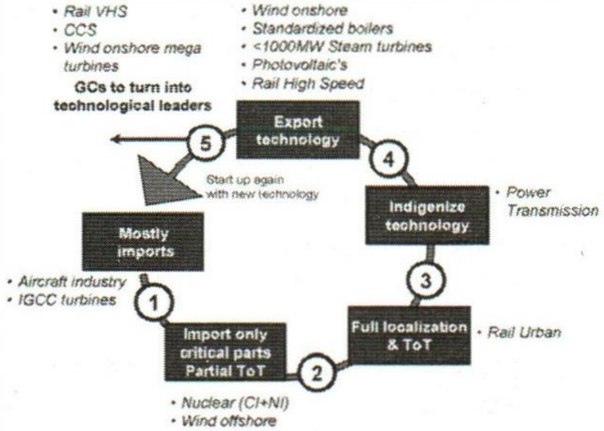
- China is seeking to join the Government Procurement Agreement (GPA) under the WTO framework
- On-going negotiation and battling between China and other WTO member countries

Source: The US-China Business Council, China Procurement Law, literal research

1 Localization leading to technology transfer

After localization in China, all surveyed industries saw systematic transfer of technology

Systematic indigenization of technology after importation of critical parts



Source: Press resaearch, BCG analysis

Varying but shortening timing between critical parts' importation and Chinese exports

Industry	Technology transferred	3	5
Coal Power	Supercritical steam boiler	1995	2003
Coal Power	<1000MW steam turbines	1995 *JV Westinghouse -SEC*	2003 *SEC to South-East Asia*
Wind Onshore	1,5MW turbine	2005 *Sinovel: ToT from Führländer*	2009 *Export in the USA*
T&D Power	Power switchgears GIS • ToTs in conventional & HVDC • UHV mostly own design	1990's	2009 *Brazil*
Rail High Speed	High Powered electric locomotives – 8 axles, 9600 kW	2005 *CNR: ToT from Alstom*	2010 *Export to Belarus*
Rail High Speed	Electric Multiple Units Velaro ICE-3	2005 *CSR: ToT from Siemens*	2010 *Export to Thailand*

5. Actions Required and Direction Ahead

5.1 Increasing Local Value-addition

The growing demand of machine tools should be leveraged so that access to Indian market for foreign firms should be linked to improving depth of Indian manufacturing and furthering technology absorption in India. Following levers should be employed to increase value-addition:

◊ Regulatory mechanism to stipulate 30 percent minimum local value addition for large value imports of machine tools along with transfer of technology to an Indian company via JV/JWA

◊ Tax holidays for wholly owned subsidiaries, JVs and overseas companies setting up production base in India with a Phased Manufacturing Program leading to 75 percent local content over three years

◊ Higher depreciation after first year at 25 percent on machinery manufactured with 75 percent local value addition in India.

◊ Minimum of 30 percent local content as a PQ criterion for PSU/government buyers

◊ Preference to JV/JWA bids over foreign companies against total import offers on government tenders

◊ Graded import duty structure in line with the reduction in import content. Higher import duty on products with higher import content should be mandated.

5.2 Establishing Centres of Product Development (CPDs)

The objective of this initiative is generation of technologies which are 'feeder technologies' for all the equipment manufacturing segments.

The CPDs would be similar to Fraunhofer Institutions of Germany. Each CPD has a *specific technology competence* which could help industries across manufacturing sectors. It would service technology and product development requirements of industries which deploy technologies and strengths which are core competences of the particular CPD. The CPDs, Academia and Industries form an operational cluster. The CPDs will have design, manufacture, assembly and testing infrastructure along with requisite laboratory infrastructure manned by system development engineers and scientists. They will be capable to develop technologies, subsystems, total systems, etc., and even may demonstrate limited series production themes to bring the products to a level of commercialization.

The following technologies need to be developed as 'foundation technology resources' through 'Centers for Product Development' (CPDs):

1. New material adaption technologies
2. Metal working technologies—metal machining, deposition, welding technologies including surface coating technologies
3. Metal casting
4. Tools and tooling, dies and moulds, etc.
5. Robotics and automation
6. Measurement technologies—sensors, inspection aides/systems, scales, etc.
7. Electrical drives and controls, kinematics
8. Embedded electronics and Computer Numerical Control (CNC)
9. Tribology, lubricants, bearings and guideway-related technologies
10. Information and Communication Technology (ICT) and Simulation Technologies—man–machine interface technologies

These technologies need to be developed with an organized effort and they would be facilitating machine tools development across the sectors.

S. No.	Name of Centre for Product Development (CPD)
(i)	CPD - New material adaptation technologies and products
(ii)	CPD - Metal working/shaping technologies, tools, tooling and dies and moulds
(iii)	CPD - Electronics and controls technologies and products
(iv)	CPD - Drives and controls technologies and products
(v)	CPD - High fidelity measurement technologies and products
(vi)	CPD - Robotics, material handling and automation technologies and products
(vii)	CPD - Tribology, lubricants, bearings and guideway related technologies
(viii)	CPD - ICT and simulation technologies – man machine interface technologies

The following Centres of Product Development (CPDs) would then help in providing the sectors with the basic technologies.

5.3 PSUs/ Private Sector as Base for Technology Development

◊ The PSUs and some private companies play a vital role. Though, they are required to concentrate on developing and deploying *niche*, high-tech and distinguishable products, total manufacturing solutions with advanced technologies above the normal *milieu* that cannot be sourced from international domain due to strategic reasons.

◊ The PSUs will be leading the technology generation and ownership aspects. It is proposed that PSUs and some leading private sector companies should interact with academia and R&D institutions like DRDO labs, labs, etc. This is needed for development of advanced technology machines.

◊ It is also proposed to facilitate a possible *co-creation- tie up* between PSUs like HMT/HEC and BHEL/Railways/Defence, etc. The end-users and solution providers are brought together as value addition partners in a strategic and business tie up both in respect of scale of operations and in developing new technologies and advanced machine tools.

◊ It is also proposed to support HMT and HEC to transform them to be national/global champions. This effort is required to be supplemented with providing simultaneous support to few private sector Indian companies. This will bring advance technology development for the strategic necessity of the country.

5.4 Cluster Development

◊ Clusters along with Common Facility Centres are proposed to equip with modern facilities of plant and machineries including advanced testing equipments and Computer Aided Design (CAD) systems to enhance productivity, achieving the desired quality and Industrial Cluster Parks (ICPs) with high growth potential requiring assistance for upgradation of infrastructure to world class standards. Both of these facilities will contribute substantially in enhancement of competitiveness in the machine tool industry. An illustrative list of common plant and machinery for CFCs and infrastructure for ICPs are given below.

◊ Common Facility Centres (CFCs)

- Building for common facilities
- Plant and Machinery
  - Modern Foundry
  - Heat Treatment Facility
  - Product Development
  - Equipment for Testing Laboratories
  - CNC Lathe Machines for Critical Machining
  - General and Specific Machine Shops
  - Special Purpose Fabrication/Forging and Welding Facility
  - Common Production Processes
  - Centre of Excellence
  - Technical Information Centre including IP related activities
  - Other Need-based Common Facilities

◊ Sector-specific Industrial Cluster Parks (ICPs)

◊ Physical Infrastructure

- Administrative Building
- Road
- Water Supply and Storm Water Drainage
- Common Captive Power Generating Units
- Transmission and Distribution Infrastructure
- Common Fuel/Gas Supply System
- Common Effluent Treatment Plant
- Solid Waste Management Facilities

5.5 Acquisition of Technology

◊ Provide incentives for acquisition of advanced technologies which are required for strengthening country's technological capabilities from the long term point of view. The incentive could be among others, in the form of allowable deductions under Income Tax Act, custom duties exemption and also specific subsidization.

◊ Priority treatment be given in respect of a strategic manufacturing sector such as machine tools to provide a dedicated fund for acquiring technology for their tier-2 suppliers.

◊ *Creation of a* Technology Acquisition Fund for use by the machine tools manufacturers.

◊ A regular mapping and institutionalization of the Technology Acquisition/Development process is an essentiality.

5.6 *Inter-ministerial Coordination to Develop Technology Roadmap*

◊ There is need to have inter-ministerial coordination to provide an assured demand to domestic players to enable capacity creation and utilization and technology development. The importance of such coordination can be illustrated with following three examples.

- NTPC: NTPC has current capacity of 34,000 MW and around 15,000 MW under construction. This capacity is projected to grow to 75,000 MW up to 2017 and 128,000 MW up to 2032. This amounts to consolidated demand of Rs 1,43,000 Cr over the next five-year period. If this demand could be consolidated and used as an incentive to promote technological development through say BHEL, it could create huge benefits for the level of technology development in the country. Coal India's annual value of purchase of mining equipment is over $2 billion every year. It is the largest buyer of mining equipment in India. A concerted effort to develop technology for the equipments that would be required by Coal India over the next five years would promote investments in technology in machine tools industry.
- Ministry of Defence & Ministry of Railways: Ordnance factories and various units under the Ministry of Defence and Railways, respectively, have large demand of machine tools which are generally met through imports. Action has been initiated with the said ministries to develop the technology and to meet the requirements by the local machine tool industry.
- SAIL: Rs 200,000 crore worth of plant and machinery would be required in the coming 7–10 years in order to meet the projected steel production capacity. Players like HEC, HMT and private companies could work in coordination with SAIL to draw out a technology roadmap for the metallurgical machinery and machine tools industry.

5.7 *Machine Tool Technology Development Fund*

◊ Technology Development Fund required to be set up for modernization, expansion and upgradation of the SMEs and other companies. The fund can also be used for design development, product development, energy efficiency, green technology development, productivity development, training and such other knowledge development activities.

◊ It is proposed to support Capital Goods Sector including machine tools-related development under DHI through an SPV.

6. Conclusion

In India, time has arrived to recognize the strategic and economic importance of the machine tools industry. India must learn from the experiences of China, Germany, Japan, Taiwan and other countries. These countries understood the cascading impact of the machine tools sector in the growth of their economies. They developed synchronized policies, institutional framework, purchase preference programmes, imports tied to technology transfer for domestic manufacturing and other support measures. The financing support for R&D and technology development was increased manifold. The result was significant growth in domestic production and employment as well as exports. Technology development of machine tools sector in these countries resulted in long-term benefit in increasing global competitiveness of domestic manufacturing industry.

The focus is on generation of technology competence through the proposed product development centres. India has also announced a new *manufacturing policy* recently. This policy will allow eight new manufacturing investment zones to be created and also existing industry clusters to be upgraded. Delhi Mumbai Industrial Corridor, SEZs and cluster development programmes also present fresh opportunities for the machine tools sector. Strategic policy, institutional and funding support proposed in this article is timely and will go a long way in improving global competitiveness of Indian machine tools sector. This will also have a positive impact on manufacturing industries of the country.

> *Technology is ruled by two types of people : those who manage what they do not understand, and those who understand what they do not manage.*
>
> ***—Mike Trout***

Machine Layout Design through Particle Swarm Optimization in Indian Industry

G. S. DANGAYACH, HIMANSHU BHATT, SUMIT GUPTA AND M. L. MEENA

The article aims at assigning the machines of the crankshaft line of an automotive company to the related optimum locations within the floor plan along with determining the number of components that the machines should produce per day, ultimately minimizing the total material handling cost involved. Particle Swarm Optimization (PSO), a meta-heuristic technique, is employed to solve a mathematical model concerning the machine layout problem, modelled as Quadratic Assignment Problem (QAP). A coding is done for basic and modified PSO technique in Matrix Laboratory (MATLAB) environment and the program on running resulted in a cost savings of 19.3 percent and 20.6 percent, respectively, per day per line. The proposed values of distances, frequency and material handling cost are compared with the existing values of the same. Furthermore, the execution time and the quality of solution were observed to be altering with change in particle size and number of iterations.

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1. Introduction

The optimum location of facilities/machines is one of the most critical issues that must be resolved in early steps of the manufacturing system design (Chwif et al., 1998). Material handling cost is an indirect cost and every company wishes to reduce this as it constitutes a major part of the total production cost in a facility. According to Tompkins et al. (1996), it has been estimated that between 15 percent and 70 percent of the total manufacturing operating disbursal can be assigned to material handling, and an effectual facility layout can lower down these costs by at least l0–30 percent. Layout affects the material handling cost, time and throughput, and consequently affects the overall productivity and efficiency of the plant (Morad). Poor layout would bear results of having more parts spending longer time moving from one machine to another, that is, waiting, and thus results in increased high material handling costs (Morad). Carefully planning the layout within a plant or facility can have substantial long-term benefits for the company's manufacturing and distribution activities. Therefore, the layout problem in manufacturing systems is of major importance.

Machine layout problem concerns with the physical arrangement of a given number of machines within a provided configuration (Reddy et al., 2012). The machine arrangement determines how long or far the materials have to travel and thereby the material handling cost. Machines that handle materials subsequently after each other can be placed close to each other to reduce this cost. This is easy if all the materials are processed on the machines in a given fixed order, but if the order in which the machines have to deal the materials is complicated then it's a hard problem to solve.

According to Reddy et al. (2012), the facility layout focuses on the organization of a company's physical facilities to promote the efficient and effective use of resources, such as, equipment, material, people and energy (Reddy et al., 2012).

According to Reddy et al. (2012), some common objective functions through which optimality of Facility Layout Problems (FLP) can be measured are minimization of material handling cost, frequency of handling, overall production time and increase in effective and economical usage of space along with maintaining flexibility in arrangement and operations, providing a safe and efficient construction, etc.

Machine layout problems are generally classified as single-row machine, multi-row equal area, multi-row unequal area facility and multi-objective FLP (Reddy et al., 2012).

Various formulations have been addressed in the literature. The QAP was proposed by Koopmans and Beckman for the first time. Sanhi and Gonzales showed its Non-deterministic Polynomial time (NP) completeness. A large number of techniques have been extensively proposed and they can be roughly divided into optimum methods or suboptimum methods.

Some authors have attempted to solve this problem using search tree techniques, like Branch and Bound. Beam-Search (BS) and some derived techniques like FBS, DCBS were also proposed for the same whereas others have been proposed methods based on graph theory. Hierarchical approaches also have been explored well. Due to the reason of computational unfeasibility of many formulations, various heuristics methods have been developed. These heuristics methods may be categorized into two groups: constructive methods and iterative improvement methods.

There are fundamentally three types of approaches that are appropriate to create best layout of any workplace or department to organize the departments or machines. They are conventional approaches that include the use of diagrams, charts, graphs, etc. Quantitative approach that incorporates techniques from the operations research in addition to mathematical techniques (Morad). Quantitative approach divides itself into Quadratic Assignment and Integer Programming Formulation and further Integer Programming splits into Branch and Bound Algorithms, Cutting Plane Algorithms and Dynamic Programming (DP) techniques.

Several heuristic tools have evolved in the past decades that facilitate solving optimization problems that were previously difficult or impossible to solve. These tools include evolutionary computation, Simulated Annealing (SA), Tabu Search (TS), particle swarm, etc. New heuristic tools have been combined among themselves and with knowledge elements, as well as with more traditional approaches such as statistical analysis, to solve difficult problems. Solutions with these tools have two main advantages: (a) development time is much shorter than traditional approaches and (b) the systems are very strong, being relatively insensitive to noisy and/or missing data.

Natural evolution is a hypothetical population-based optimization process. Simulating this process on a computer results in stochastic optimization techniques that can often outperform classic methods of optimization when applied to difficult real-world problems. In recent times, some attention has been focused on a special class of search methods called extended neighbourhood search. This may be considered as generic heuristics methods (they may be applied to many optimization problems). The great merit of these methods is to prevent being caught in local optima by some of the times accepting moves that worsen the objective function (Chwif et al., 1998).

There are a few methods or meta-heuristics available to solve the problem of machine layout. They include Integer Programming, Ant Colony Optimization, SA, Genetic Algorithm (GA), PSO, etc. (Kwang and Mohamed, 2008).

2. Literature Review

The purpose of the literature review is to give light to the various dimensions over which machine layout problems are spread. The review was done to know how machine layout problems are dealt with and the work being done so far in this context. The application of PSO methodology over machine layout problems and the efficacy of the method in finding out an optimum solution is also an important issue to be explored.

2.1 Machine/Facility Layout Design

Kusaik Andrew and S. Heragu Sunderesh (1987) surveyed the FLP. Different formulations and algorithms for solving the problem were introduced. Sunderesh Heragu (1990) presented a mathematical model for the machine layout problem and was successfully solved by SA algorithm. Gen Mitsuo et al. (1995) formulated a fussy multi-row machine layout problem where the clearance between any two adjacent machines was given as a fuzzy set. To maximize the minimum grade of satisfaction over machines and meanwhile to minimize the total travel cost among machines was the objective function considered. The GA approach was used for the problem solving and, subsequently, computer simulations were used for the demonstration of the performance of proposed algorithm.

Chwif et al. (1998) presented FLP solution in the continual plane, which was based on SA and the approach may be applied either in General Facility Layout Problems (GFLP) considering facilities areas, shapes and orientations or in Machine Layout Problems (MLP) considering machine's pick-up and drop-off points. Chin Ho Ying and L. Modie Colin (1998) dealt with the machine layout problem within an automated manufacturing system with a linear single-row flow path. A two-phase layout procedure that combines flow-line analysis with SA was nominated.

Bock Stefan and Hoberg Kai (2007) preamble an integrated approach that enables a more detailed layout planning through simultaneously evaluating machine arrangement and transportation paths. Introduction of a new mathematical layout model and development of several improvement procedures was drawn. An analysis of the computational experiments showed that more elaborate heuristics using variable neighbourhoods can generate promising layout configurations.

2.2 Layout and Particle Swarm Optimization

Hassan et al. (2004) examine the claim that PSO has the same effectiveness (finding the true global optimal solution) as the GA but with better computational efficiency (less function evaluations) by enforcing statistical analysis and formal hypothesis testing. Paul et al. (2006) proposed a new approach, that is, PSO to deduce better solutions for unequal area facility layouts including inner walls and passages to minimize material flow between facilities simultaneously satisfying the constraints of areas, aspect ratios of the facilities and inner structure walls and passages and thus the FLP was mathematically formulated. The proposed algorithm grounded on the PSO in this article was implemented with C++ language. A comparison with existing algorithms (GA and improved GA, that is, Islier's algorithm) was executed for eight facilities to evaluate the proposed algorithm's efficiency and the results revealed that the proposed algorithm is superior to the existing ones. Kumar et al. (2008) proposed a PSO algorithm for obtaining the optimal solution of unidirectional loop layout design problems whose objective is the determination of the ordering of machines around a loop to minimize the total number of loop traversals for a family of parts or, in other words, minimize the total traffic congestion in a FMS environment. The proposed method is validated with benchmark problems, that is, via Differential Evolution Algorithm and GA. It is seen that the PSO algorithm is relatively efficient in finding good-quality solutions for the layout problems with less percentage solution effort.

Rezazadeh et al. (2009–10) extended an ameliorated version of the Discrete Particle Swarm Optimization (DPSO) algorithm proposed by Liao and Tseng (2007) to solve the Dynamic Facility Layout Problem (DFLP). A computational study was executed with the existing heuristic algorithms, including the DP, GA, SA, Hybrid Ant System (HAS) and Hybrid Simulated Annealing (SA-EG), hybrid genetic algorithms (NLGA and CONGA). These algorithms were applied to the forty-eight test problems and the results showed that the DPSO is very effective in dealing with the DFLP. The extended DPSO also has very good computational efficiency when the problem size increases. Pandian (2007) addressed the unidirectional Loop Layout Design Problem (LLDP) using a modern meta-heuristic, that is, PSO algorithm. The results produced by this heuristics are consistently ameliorated than earlier popular methods.

Y. T. Teo. and S. G. Ponnambalam (2008) proposed a hybrid meta-heuristic by linking ACO and PSO to solve the single-row layout problem leads to a better representation of a realistic case. It was found that the proposed ACO/PSO performs better over the heuristics. It was also noticed that the proposed heuristics could provide best solution for larger problems than smaller ones. Samarghandi et al. (2009) explored PSO algorithm to solve the SRFLP. The computational results verify the efficiency of the algorithm in finding good quality and near-optimum solutions in a very short time compared to the other heuristics available.

Hamed Samarghandi and F. F. Jahantigh (2011) modelled the natural uncertainty in material handling costs with fuzzy theory for the dynamic FLP. A Fuzzy Particle Swarm Optimisation (FPSO) algorithm was proposed to solve the problem. A number of ranking criteria from the literature in order to prove the performance of the developed algorithm were implemented. Computational results reflect the efficiency and effectiveness of the proposed mechanisms. Yong-Qian Zheng and Kui-Xue Ding (2012) described the orientation of the facilities, the intra-cell and inter-cell layout simultaneously in the model. Due to the complexity of the model, an improved PSO algorithm (modified by adopting the crossover operator used in GA) was introduced. A simulation experiment proves the validity of the proposed method. C. T. Hardin and J. S. Usher (2005) proposed a method that divides a facility into a swarm of intelligent tiles and devises a set of simple rules for tile behaviour. Using these simple rules, the tiles self-organize and a solution to the layout problems is evolved. Improved results compared to CRAFT are provided by this method, which is one of the primary methods for facility layout in use today.

Literature review deduced that the machine/FLPs are modelled as QAP model subjected to the linear constraints with the objective of minimization of the total cost involved in transporting material between machines. In majority of the problems, various meta-heuristics including GA, SA, TS, Ant Bee (ABC), PSO, etc., are observed to be very helpful in optimizing the model. A PSO is found to perform better in terms of computational efficiency, efficient in finding good quality solutions with less percentage solution effort, robustness and simplicity in implementation in comparison to other meta-heuristics. In almost all of the mathematical models for layout problem, distance was the prime design variable, whereas frequency and unit material handling cost was assumed to be constant. So, work can be done regarding treating the frequency and unit material handling cost as design/decision variables and give a new direction to layout optimization problems.

3. Problem Description

Due to the improper design of the machine layout of the crankshaft assembly line (straight line), the case company pays a little more on material handling that they should pay actually resulting in poor flow and storage. In the single-row machine layout, some machines are too close to each other and some are very far from each other resulting in inappropriate storage of material (between the machines and final storage). A lot of inconvenience is to be faced by the maintenance workers during the maintenance of machines due to less clearance between some of the machines. Safety hazard issues also arise sometimes due to this clearance gap between two adjacent machines. Also, they do not have sufficient space for the storage of the final assemblies of the crankshaft, due to which the final assemblies remain unallocated scattered in different corners. The present total travel distance (length wise) of the machines in the line is 132.334 feet. Distance available for the line in the company (measured) is 152 feet. This 152 feet needs to be utilized for two purposes, for assembly (machine) line and storage of assembled parts keeping the width of a single line (23.67 feet) same. The management desires to have the assembly line in around 117 feet and rest 35 feet space should be allotted to the final assembly storage. Present distance for storage is 11.166, which is insufficient. Now to get an estimate of the space or distance occupied by the machines present in the line, adding the total travel distance with half width of the first and the last machine (that is, SFC and assembly press). Space occupied by the machines in the line = 132.334 + 0.5*(7.83 + 9) = 132.334 + 8.5 = 140.834 feet. So, the estimate of the proposed targeted value of the travel distance between the machines of the line is 108 feet.

3.1 Material Flow and Analysis

The machines (dye glow, washing machine and assembly press) serve two lines of crankshaft assembly simultaneously, that is, the crankshaft component after being processed at the IDG machines of the Line 1 and Line 2 moves to the dye glow machine and then further to other subsequent machines. The distances between the machines are not set according to any rule or standards but are improper and not well designed, due to which high material handling cost is incurred. Also, the placement of machines like dye glow, washing machine and assembly press is not worth as the distance between different IDG machines to the dye glow is significantly different. The assembly line is set up at a greater length due to poor distance management between machines as a result of which storage of final assemblies is not managed well.

Figure 1 represents the current and proposed machine layout of the crankshaft assembly line representing two similar lines, that is, Line 1 (right hand side) and Line 2 (left hand side), producing crankshaft model *W* and model *X*, respectively. The LH and RH represent the machines assigned for making the LH and RH part of a crankshaft, respectively. The LH and RH parts along with the connecting rod comprise an assembled part of a finished crankshaft assembly.

The proposed layout comprises of the rearranged machines along with new limits of *machine to machine gap* distances. The purpose of the mathematical modelling and optimization through PSO is to find an optimum machine to machine distance and frequency of production/movement (decision variables) between the machines so as to minimize the total material handling cost of the line. The proposed machine layout ensures better and smooth

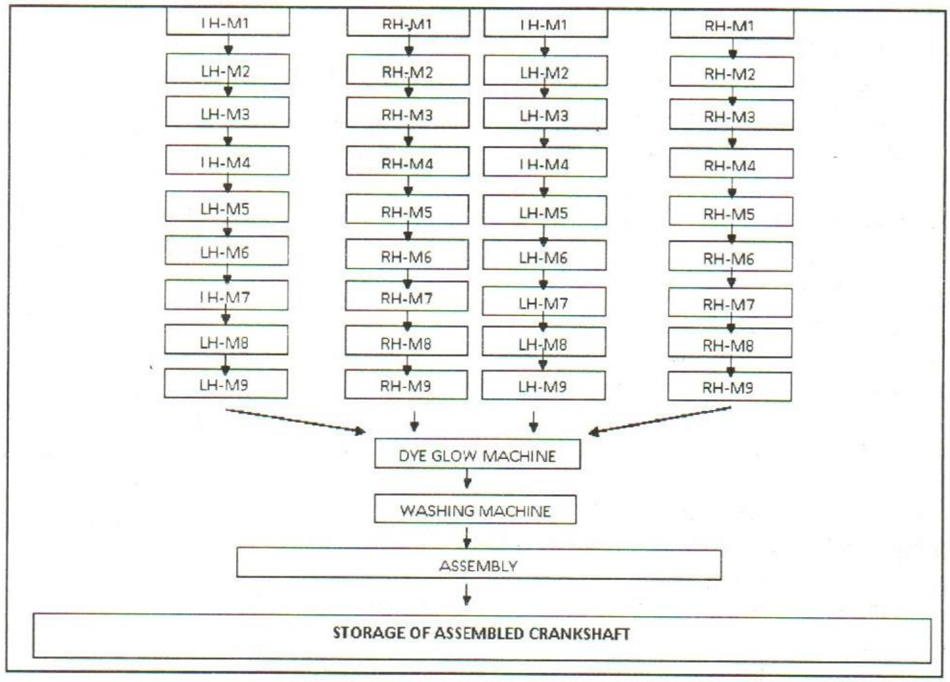

Figure 1: Proposed Machine Layout of the Assembly Line

flow of material along with decreased travel path and on the basis on which the constraints and mathematical model is designed.

3.2 Goals of the Study

1. Improving machine layout and thus reduce material handling cost resulting in reduction of congestion and disruptions and achieve smooth material flow between machines in the line.
2. Optimize the distances between machines and production/day for the minimum material handling cost.
3. Providing standard clearance between machines keeping the safety and maintenance considerations into mind.
4. Space allocation for storage.

3.3 Assumptions

1. Required machinery and material handling systems have been selected initially.
2. It is assumed that the demand has been fulfilled.
3. Machines are square or rectangular in shape.
4. The width of the line is assumed to be constant, that is, area is directly proportional to the length of the line.
5. Frequency and distance between machines are the variable where as the unit material handling cost is assumed to be constant throughout the analysis.
6. The machine's pick up and drop off points (loading/ unloading points) are assumed to be at the centre of the machines.

3.4 Determining Unit Cost of Material Flow

For analysis, the unit cost of material flow is required. But this cannot be generated directly, so this cost is calculated indirectly as below.

So the total production or manufacturing cost of a tonne component is calculated to as Rs 2,27,250 and material handling cost is 20 to 30 percent of the total manufacturing cost per tonne. As we are dealing with the material flow in a straight line without many disruptions, so for analysis we take 20 percent of the manufacturing cost, then material handling cost comes out to be Rs 45,450 per tonne.

Unit material handling cost = material handling cost/ total distance travelled by the material (Rs/tonne/ft) = 45,450/ {(250 + 100) + (144 + 300) + (144 + 300)}

= 45,450/1,238

= Rs 36.71 /tonne/ft

The unit material handling cost of Rs 36.71 is calculated for one tonne material for one foot distance travelled. The unit material handling cost is considered to be constant in future analysis.

3.5 Estimation of Existing Material Handling Cost Incurred in the Assembly Line

The total material handling cost per day per line for the existing assembly line can be calculated by

Total material handling cost across the whole assembly line (between machines)

$= \sum_{i=1}^{n} \sum_{j=1}^{n} fij * dij * cij$

Where *n* is the number of machines.

$i = 1, 2 \ldots n$ and $j = 1, 2 \ldots n$ are the indices for machines.

Condition, $j = i + 1$ as the component move machine to machine sequentially without skipping any machine in between.

C_{ij} is the material handling cost for a unit material for a unit distance between machines *i* and *j*.

f_{ij} is the material flow from machine *i* to *j* in tonne.

d_{ij} is the rectilinear distance between centres of machines *i* and *j* in feet. The distances shown below in Table 1 are the average values of the five readings of distances taken in order to minimize *parallax* error.

Putting the values in the expression for material handling cost in Table 1 for different machines individually:

Each row of Table 1 gives the value for material handling cost incurred in moving the respective amount of material through one machine to another. So summing up all the individual costs until the production of a finished crankshaft assembly, we get the total material handling cost of a crankshaft assembly line per day, that is, *Rs 17,731.62*.

The main objective of this article is to minimize this material handling cost by machine layout design.

4. Solution to the Mathematical Model

This problem can be formulated as an optimization task in which the best facility layout is sorted by optimizing some measure of performance, such as, material handling costs, subjected to some constraints or restrictions (Zhang Byoung-Tak and Kim Jung-Jib, 2000).

It requires building an objective, collecting as much factual data as possible required accordingly, analysing the data thoroughly, applying the known laws and principles, and formulating a solution. In collecting the data deliberate attention should be given to the effect of handling on the product, the present method, and cost factors too.

The problem can be formulated as an optimization task in which the best facility layout is assayed by optimizing some measure of performance, such as,

Table 1: LH Line-Material Handling Cost Analysis/Day and Total Material Handling Cost of the Line

S. No.	Machine(From–to)	f_{ij}	d_{ij}	C_{ij}	Material Handling Cost $f_{ij}. d_{ij}. C_{ij}$
1.	1–2	3.674	9	36.71	1,213.85
2.	2–3	3.669	10.167	36.71	1,369.38
3.	3–4	3.667	9.67	36.71	1,301.73
4.	4–5	3.663	9.75	36.71	1,311.07
5.	5–6	3.660	9	36.71	1,209.22
6.	6–7	3.656	6.67	36.71	895.19
7.	7–8	3.654	12.167	36.71	1,632.06
8.	8–9	3.652	11.33	36.71	1,518.95
9.	9–10	3.636	9.91	36.71	1,322.76
10.	10–11	3.634	21	36.71	2,801.48
11.	11–12	3.632	23.67	36.71	3,155.93
Total material handling cost					**Rs 17,731.62**

material handling costs that are subjected to some constraints (Zhang Byoung-Tak and Kim Jung-Jib, 2000).

In practice, the FLP is often solved by intuition, using the artistic and spatial skills of the human designer; however, when there are quantitative considerations associated with the layout problem, the human is at a disadvantage as compared to the computer.

The decision variables for our machine layout problem are centre to centre distance between machines (d_i) and frequency of material moved from one machine to another (f_i). Once the decision variables are defined, we define our objective function, that is, goal. So, our goal here is to reduce/optimize the material handling cost by designing an optimized machine layout for the assembly line.

4.1 Mathematical Formulation of the Problem

M(X) = MHC = Material handling cost

$MHC = \Sigma F_{i,i+1} * D_{i,i+1} * C_{i,i+1}$

Minimize $M(X) = \Sigma F_{i,i+1} * D_{i,i+1} * C_{i,i+1}$

$C_{i,i+1} = 36.71$ = Constant

As calculated above and is assumed to be constant over the entire analysis.

So the function becomes

Minimize $M(X) = 36.71 \Sigma F_{i,i+1} * D_{i,i+1}$

Subjected to

Distance constraints:

$9.876 < D_{1,2} \leq 10.860$,	$10.376 < D_{2,3} \leq 10.704$,
$10.294 < D_{3,4} \leq 10.622$,	$9.044 < D_{4,5} \leq 9.372$,
$7.626 \leq D_{5,6}$dH 7.954,	$6.947 < D_{6,7} \leq 7.275$,
$8.204 < D_{7,8} \leq 8.860$,	$9.204 < D_{8,9} \leq 9.860$,
$9.282 < D_{9,10} \leq 10.267$,	$11.602 < D_{10,11} \leq 11.930$,
$12.602 < D_{11,12} \leq 12.930$;	

Frequency constraints:

$3.669 \leq F_{1,2} \leq 3.674$,	$3.667 \leq F_{2,3} \leq 3.669$,
$3.663 \leq F_{3,4} \leq 3.667$,	$3.660 \leq F_{4,5} \leq 3.663$,
$3.656 \leq F_{5,6} \leq 3.660$,	$3.654 \leq F_{6,7} \leq 3.656$,
$3.652 \leq F_{7,8} \leq 3.654$,	$3.636 \leq F_{8,9} \leq 3.652$,
$3.634 \leq F_{9,10} \leq 3.636$,	$3.632 \leq F_{10,11} \leq 3.634$,
$3.630 \leq F_{11,12} \leq 3.632$.	

and $\Sigma d_{i,i+1} = 108$ for i = 1-11

4.2 Machine to Machine Distance

The clearance between the machines needs to be accounted in the loop layout design and the aspect helps in selecting the best layout (Kumar et al., 2008).

In real manufacturing departments, every machine has its own clearance gap that varies from machine to machine. Providing sufficient clearance is must between each machine for storage of parts, movement of operator, for ease of maintenance, safe operation, etc. Hence, gap between the machines has to be taken into consideration while designing the layout (Kumar et al., 2008).

It is a compulsion to save some distance between neighbouring machines for the sake of safe operation of machines, the movement of personnel, the storage of work-in-process (WIP) and a lot of other purposes. One assumption is that each machine has its own minimum required safe distance to be kept far from other machines (Ying and Colin, 1998).

The total clearance between the machines alters according to the ordering of machines. The minimum total clearance given by a layout is selected as the best layout as it minimizes the overall travelling distance of components (Kumar et al., 2008).

Overlapping of the departments/machines should be prevented and unused gaps between the departments/ machines should also be reduced (Jolai Fariborz et al., 2011).

4.3 Formation of Distance Constraints

4.3.1 Travel Distance Calculation

A major issue in machine layout design is how to generate the correct travel distance of a component. Two popular well-explored distances calculation methods are the Euclidean distance method and the rectilinear distance method. For both, the distance from a point i to another point $i + 1$ is the same as the distance from $i + 1$ to i. However, in real practice, the travel distance from i to $i + 1$ is not necessarily same as the travel distance from $i + 1$ to i. Also, Euclidean and rectilinear distances are not always necessarily equal to the actual travel distance. The travel distance of any movement is calculated as the length of flow path segment travelled by that movement, which is the actual travel distance (Ying and Colin, 1998).

So, in order to determine the machine to machine centre or travel distances, the dimensions (width, along which the workers work into the machines) of all the machines are taken, subsequently taking lower and upper clearance limits for each and every machine depending upon the machine type, machine work, machine cycle time (for material storage in case, if the cycle time of the machine is considerably less than the cycle time of previous machine in the line), number of parts machine can process at a time, safety and maintenance considerations, etc. Figure 2 gives a clear picture of the travel and clearance distances between machines.

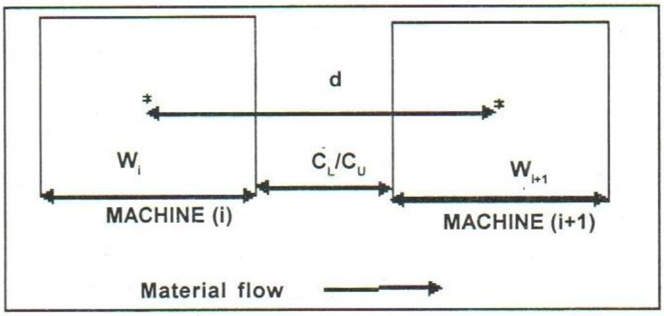

Figure 2: Distance Between Two Adjacent Machines

According to rule prescribed under Sub-section (1) of Section 38 (Rajasthan factory rules, 1992) the value of clearances or the gaps between machines should be at least 2.952 feet (90 cm) wide. But for the case company, the minimum gap/clearance should be at least 2.296 feet (70 cm) as per the management of the company. So, 2.296 feet would be the least value for lower clearance C_L and it may increase as per the requirement in space or machine type, etc. The maximum value for the upper clearance C_U is 4.625 feet. Hence, the values of C would fluctuate between 2.296 and 4.625 feet.

Table 2: Existing and Proposed Clearance Distances between Different Machines

S. No.	Actual Clearance	Lower Clearance (C_L)	Upper Clearance (C_U)
1–2	1.42	2.296	3.280
2–3	2.087	2.296	2.624
3–4	1.672	2.296	2.624
4–5	3.002	2.296	2.624
5–6	3.67	2.296	2.624
6–7	2.675	2.952	3.280
7–8	6.587	2.624	3.280
8–9	4.75	2.624	3.280
9–10	3.58	2.952	3.937
10–11	13.335	3.937	4.265
11–12	15.005	3.937	4.265
TOTAL	57.783	30.506	36.083

Table 3: The Minimum and Maximum Value of Travel Distance for All Pairs of Machines

S. No.	Machines	Centre to Centre Distance in Feet (at present)	Clearance Range between Machines	Minimum Distance between Machines $\{(W_i + W_{i+1}/2) + C_L\}$	Maximum Distance between Machines $\{(W_i + W_{i+1}/2) + C_U\}$
1.	SFC-RT	9	2.296–3.280	9.876	10.860
2.	RT-FT	10.167	2.296–2.624	10.376	10.704
3.	FT-VMC	9.67	2.296–2.624	10.294	10.622
4.	VMC-DAM	9.75	2.296–2.624	9.044	9.372
5.	DAM-TR	9	2.296–2.624	7.626	7.954
6.	TR-IH	6.67	2.952–3.280	6.947	7.275
7.	IH-ODG	12.167	2.624–3.280	8.204	8.860
8.	ODG-IDG	11.33	2.624–3.280	9.204	9.860
9.	IDG-DYE GLOW	9.91	2.952–3.937	9.282	10.267
10.	DYE GLOW-WASHING MACHINE	21	3.937–4.625	11.602	11.930
11.	WASHING MACHINE-ASSEMBLY	23.67	3.937–4.265	12.602	12.930
	TOTAL	132.334	30.506–36.083	105.057	110.634

Table 2 shows the existing and proposed clearance distances between different machines of the line. The new proposed clearance distances comprises of the lower as well as the upper limit, so as to have an optimum value of clearance while the machine layout design problem is optimized.

After the lower and upper limits of clearance have been decided, the machine to machine travel distance for all the machines present in the line are calculated.

$$d_{Min} = 0.5^* (W_i + W_{i+1}) + C_L$$

$$d_{Max} = 0.5^* (W_i + W_{i+1}) + C_U$$

Table 3 shows the minimum and maximum value of travel distance for all pairs of machines.

So, now the distance constraints can be established for all the machines in the line. The travel distance between any two machines will lie within the range of its minimum to maximum travel distance range as calculated in Table 3.

4.4 Formation of Frequency Constraints

Frequency in material handling cost is basically the amount of material moved from one station (machine/department) to the next station. But,

Amount of material/product produced = Amount of material/product moved;

so, the amount of movement directly depends upon the production and the movement tells about how frequent the material is moving from one machine to another. Hence, amount of product produced counts for the frequency constraints.

The frequency constraints between one machines to the next machine is generated by taking the minimum and maximum production/line/day in tonne. The lower range of frequency is calculated by the minimum production and the upper range is similarly calculated by taking the maximum production per line per day. The difference between the lower and upper limits is a measure of average rejection observed per line per day.

The minimum frequency of the preceding machine is taken as the maximum frequency of the successor machine, so as to keep into consideration that the successor machine production does not exceed the production of the preceding machine. This could occur because some of the successor machines have a greater cycle time than the preceding machines.

Table 4 gives an idea about the maximum and minimum production/line/day in number of components as well as in tonne.

Table 4: The Maximum and Minimum Production/Line/Day in Number of Components/Tonne

S. No.	Machines	Max. Production/ Line/Day in Number of Components	Min. Production/ Line/Day in Number of Components
1.	SFC	1,670 (3.674)	1,668 (3.669)
2.	RT	1,668 (3.669)	1,667 (3.667)
3.	FT	1,667 (3.667)	1,665 (3.663)
4.	VMC	1,665 (3.663)	1,664 (3.660)
5.	DAM	1,664 (3.660)	1,662 (3.656)
6.	TR	1,662 (3.656)	1,661 (3.654)
7.	IH	1,661 (3.654)	1,660 (3.652)
8.	ODG	1,660 (3.652)	1,653 (3.636)
9.	IDG	1,653 (3.636)	1,652 (3.634)
10.	DYE GLOW	1,652 (3.634)	1,651 (3.632)
11.	WASHING MACHINE	1,651 (3.632)	1,650 (3.630)
12.	ASSEMBLY	1,650 (3.630)	1,650 (3.630)

Hence, the frequency constraints are formed as per shown in Table 5.

Table 5: Frequency Constraints Formation

S. No.	Machines	Production/Line/ Day Range or Frequency Constraints in Tonne
1.	SFC-RT	$3.669 < F_{1,2} < 3.674$
2.	RT-FT	$3.667 < F_{2,3} < 3.669$
3.	FT-VMC	$3.663 < F_{3,4} < 3.667$
4.	VMC-DAM	$3.660 < F_{4,5} < 3.663$
5.	DAM-TR	$3.656 < F_{5,6} < 3.660$
6.	TR-IH	$3.654 < F_{6,7} < 3.656$
7.	IH-ODG	$3.652 < F_{7,8} < 3.654$
8.	ODG-IDG	$3.636 < F_{8,9} < 3.652$
9.	IDG-DYE GLOW	$3.634 < F_{9,10} < 3.636$
10.	WASHING MACHINE	$3.632 < F_{10,11} < 3.634$
11.	WASHING MACHINE- ASSEMBLY	$3.630\ F_{11,12} < 3.632$

5. Research Methodology

The PSO technique was developed by Eberhart and Kennedy in 1995 is a swarm intelligence method that roughly models the social behaviour of swarms (Paul et al., 2006). The PSO is an evolutionary computation technique inspired by social behaviour of bird flocking or fish schooling. Similar to other non-traditional techniques, PSO is a population-based optimization technique. The system initialized with a population of random solutions (particles), searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions called particles are flown through the problem space by following the current optimum particles. The PSO discusses a type of biological social system, where the collective behaviour of simple individuals interacting with their environment and each other is focused (Kumar et al., 2008).

The PSO is characterized by its simplicity and straightforward applicability, and it has proved to be efficient on a plethora of problems in science and engineering. Several studies have been recently performed with PSO on multi objective optimization problems, and new variants of the method, which are more suitable for such problems, have been developed (Paul et al., 2006).

5.1 Analysis and Implementation

The problem was formulated for Line 1 as per the given conditions to generate a mathematical model. Going through the literature it was found that machine or FLPs are formulated as QAP. Objective function along with the subjected constraints was formed where the objective function was a quadratic function comprising of the material handling cost for all the machines where ever the material moves for the whole line whereas the connected constraints are linear in nature.

After the mathematical model is generated, then the issue of solving/optimizing it comes into play. The model is hence solved by PSO methodology. Here, the PSO optimizes distance *d* and frequency *f* and separately according to its mechanics and then their product along with the unit material handling cost is optimized, that is, material handling cost of the line.

5.2 Algorithm in Machine Layout Design

It follows the following algorithm:

1. The swarm is initialized by taking *N* number of particles which would comprise of *N* corresponding sets of random values of decision variables such as *d* and *f*. Each particle will have its different data sets of values of *d* and *f* at the initial step. There would be eleven values for each *d* and *f*, respectively.

2. The fitness function is determined for every particle after the random allocation of values of *d* and *f* to the particles. The fitness function out here is the material handling cost of the assembly line. Less is the value of material handling cost, the more fit the function is. Also, the value of pbest (locally best or minimum values of material handling cost from various material handling costs found for every particle) is found for every particle.

3. For every individual particle, compare the particle's fitness value (material handling cost) with its pbest (previously found best value or minimum material handling cost found so far). If the current value of Material Handling Cost (MHC) is less than the pbest value, then set this value and the current particle's position, x_i, as p_i.

4. From *N* numbers of particles identify the particle which has the best fitness value (minimum MHC) and the value of its fitness function is identified as gbest (global best or minimum MHC within the whole domain or among all of the particles) and its position as p_g.

5. As PSO is driven by updating the velocity of the particles and hence changing the position (distances and frequencies), so now we update or change the velocities of all the particles using equation:

$$v_i(t) = v_i(t\text{-}l) + C_1(xpbest_i - x_i[t]) + C_2(xgbest - x_i[t]);$$

And in case inertial weight is used, we can use the following equation:

$$v_i(t) = w(j) * v_i(t - 1) + C_1(xpbest - x_i[t]) + C_2(xgbest - x_i(t)$$

Then update the position of the particles according to the expression given below:

$$x_i(t) = x_i(t - 1) + v_i(t)$$

The position is represented by distance in case of distance optimization and by frequency in case frequency optimization.

6. Repeat the steps 2–5 until a stopping criterion is met out (for example, maximum number of iterations or a sufficiently good fitness value). So the distances and frequency (position) keeps on changing until the optimized global position has reached, that is, minimum material handling cost is achieved.

6. Mathematical Model Optimization

Here we have optimized the machine layout model or MHC through two methodologies. One is the basic PSO method and another one is the modified PSO.

6.1 Optimization through Basic PSO

For the mathematical model of the machine layout design minimizing the MHC in a line of crankshaft assembly, we optimized or solved it with the help of a latest meta-heuristic that gives the best optimum results for any sort of objective function and the related constraints. The meta-heuristic used here is basic PSO. A basic PSO programming code was written in MATLAB software. The MATLAB used is version R2010a.

6.1.1 Specification and Algorithm

The PSO used here is a basic PSO technique which follows the following features:

Number of particles taken for moving into the hyperspace (N) = 20;

Value of positive acceleration constants (C1 and C2) = 1;

Number of iterations = 100;

Figure 3 shows the flowchart showing approach of the PSO technique.

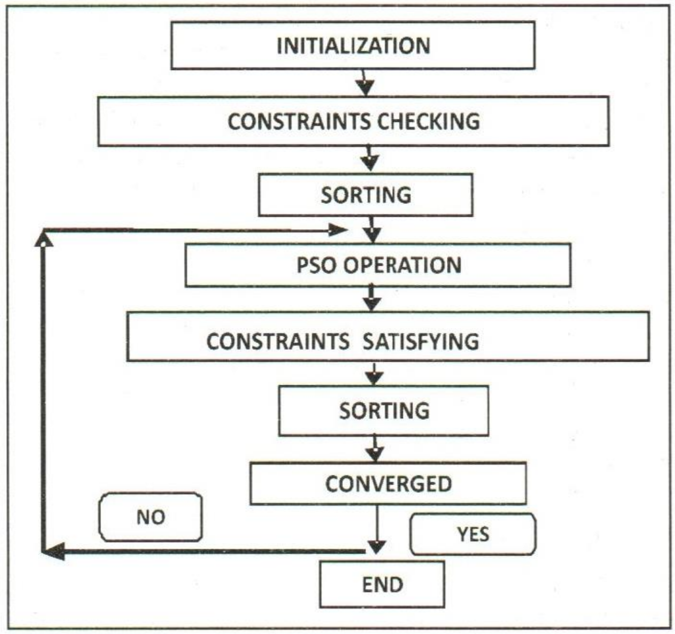

Figure 3: Flowchart Showing Approach of the PSO Technique

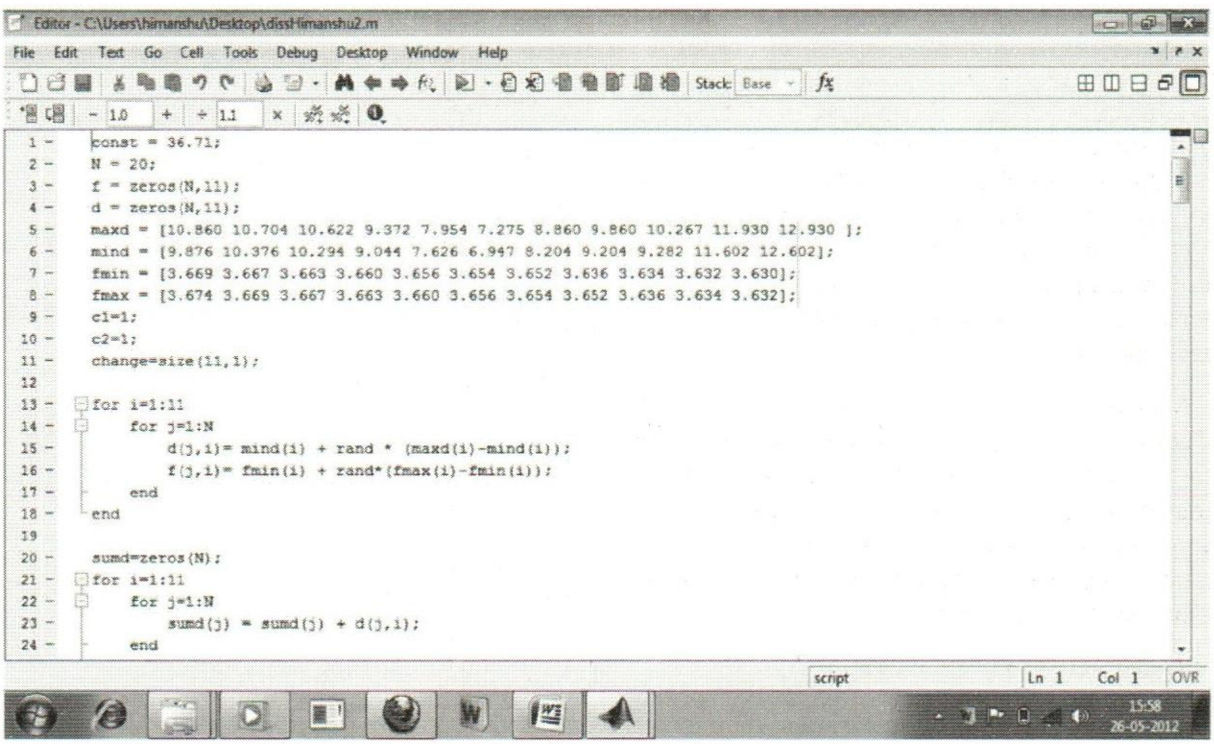

Figure 4: Preview of Basic PSO MATLAB Code

6.1.2 Basic PSO Coding in MATLAB

Figure 4 shows a preview of the basic PSO MATLAB code (refer to appendix).

6.1.3 Optimum MHC

The program was run with the help of the green button shown above Figure 4 to get the optimized values of MHC and the corresponding distances and frequencies. The

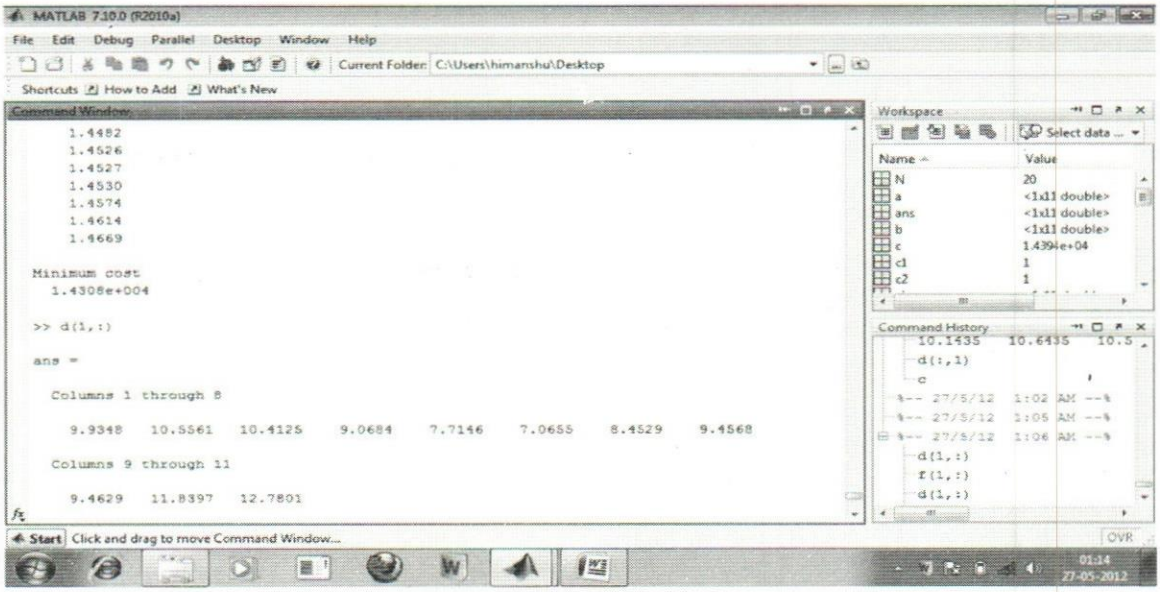

Figure 5: Command Window of MATLAB Showing the Minimum Material Handling Cost

program was run various numbers of times. Figure 5 shows the command window of MATLAB showing the minimum MHC within 100 runs.

The minimum cost of the line/day came out to be Rs 14,308 (1.4308e + 004) in the execution time of 0.4168. So, our minimum MHC is Rs 14,308.

6.1.4 Optimum Distance and Frequency

Seeking for the values of *d* and *f* for this corresponding MHC, the following values of *d* and *f* were found as shown in Figure 6 (command window). These are the eleven values of each *d* and *f* representing distance and frequencies of each pair of machines (from machine to machine).

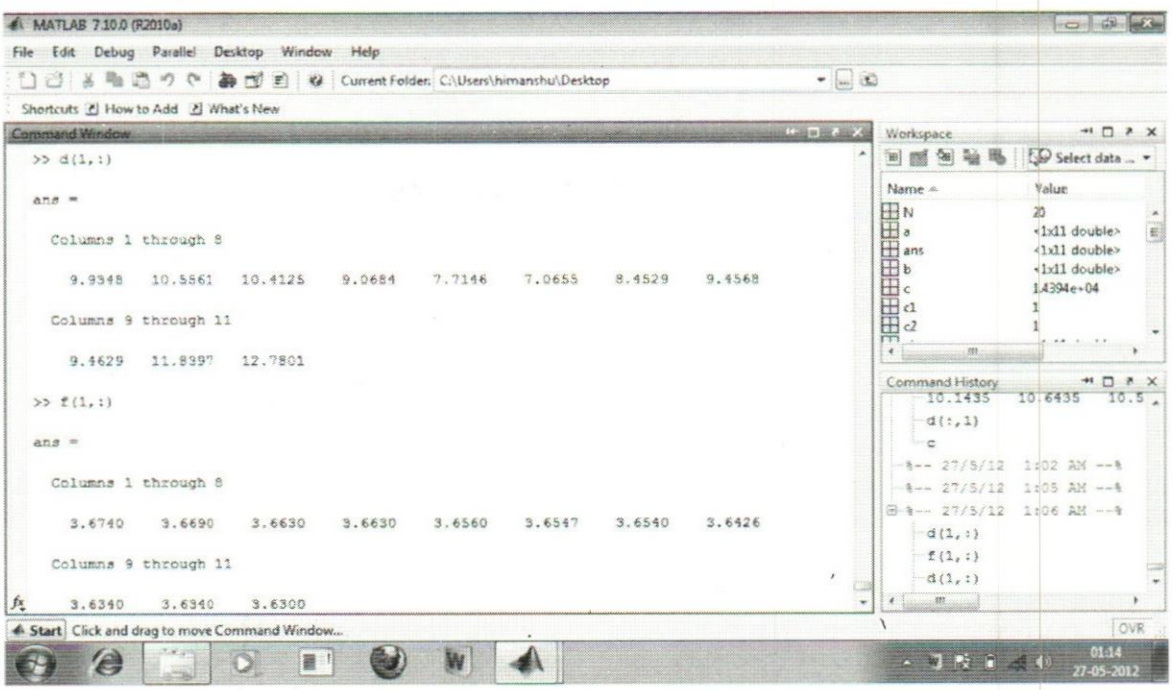

Figure 6: MATLAB Command Window Showing Optimum Values of *d* and *f*

6.2 Optimization through Modified PSO

The meta-heuristic used here is modified PSO. The specifications as well as the algorithm remains the same in this case as per the basic PSO but the PSO programming code is a little modified by including a term called *inertial weight* in the program. The PSO used here is a modified PSO technique which follows the same features and algorithm as taken in the basic PSO, except here we introduced a factor called inertial weight (*w*). The value of *w* is taken from 0.3 to 0.9.

6.2.1 Modified PSO Coding in MATLAB

Figure 7 shows a preview of the modified MATLAB code (refer to appendix).

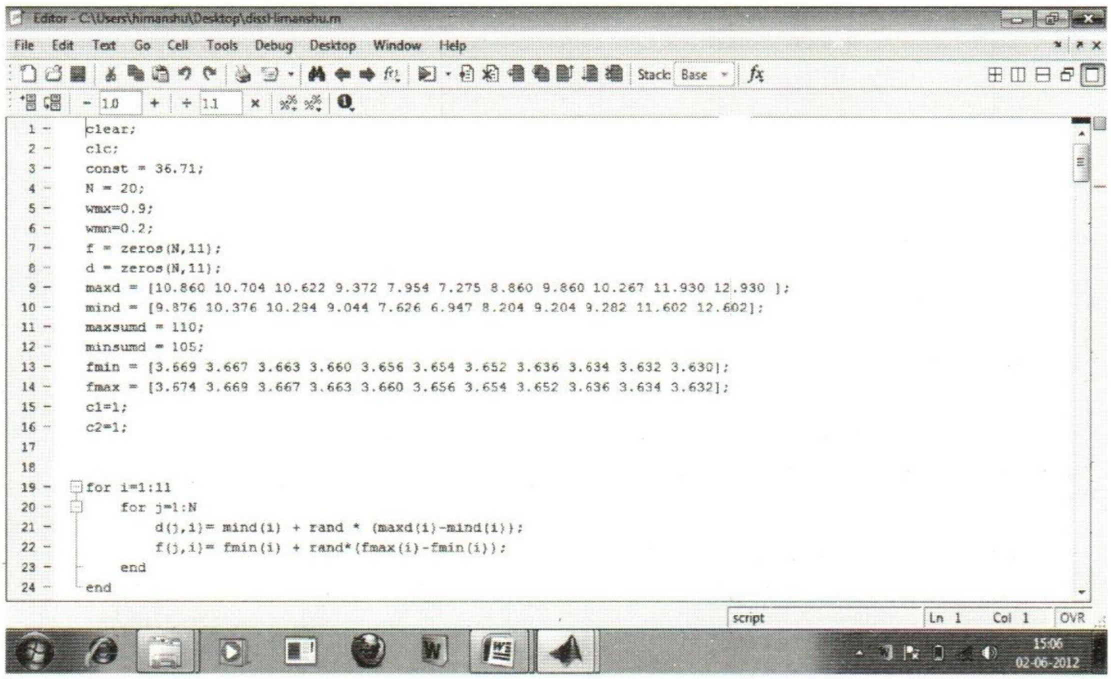

Figure 7: Preview of the Modified MATLAB Code

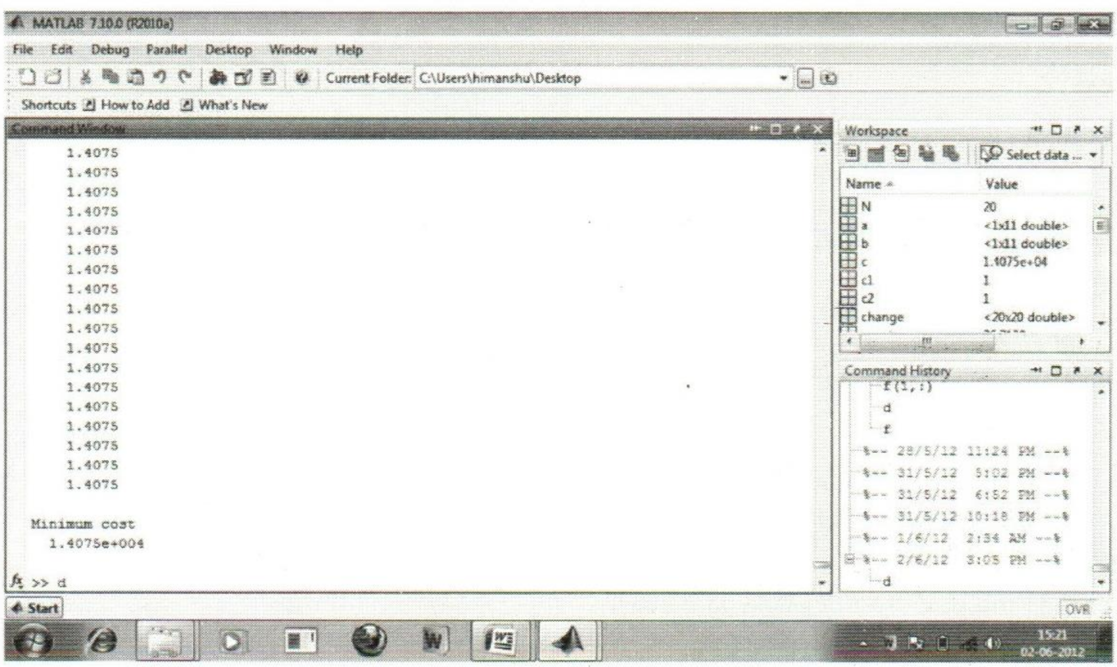

Figure 8: Command Window of (Modified PSO) MATLAB Showing the Minimum Material Handling Cost

6.2.2 Optimum Modified MHC

The modified program was run again to get the better optimized values of MHC and the corresponding distances and frequencies. The program was run various numbers of times and this time also variation in the values was observed.

Figure 8 shows the command window of MATLAB showing the minimum MHC within 100 runs. The minimum cost came out to be Rs 14,075 (1.4075e + 004) in the execution time of 0.4344 seconds. Hence, the minimum cost per line/day in this case equals to Rs 14,075.

6.2.3 Optimum Modified Distance and Frequency

Seeking for the values of *d* and *f* for this corresponding MHC, the following values of *d* and *f* were found as shown in Figure 9 (command window). These are the eleven values of each *d* and *f* representing distance and frequencies of each pair of machines (from machine to machine).

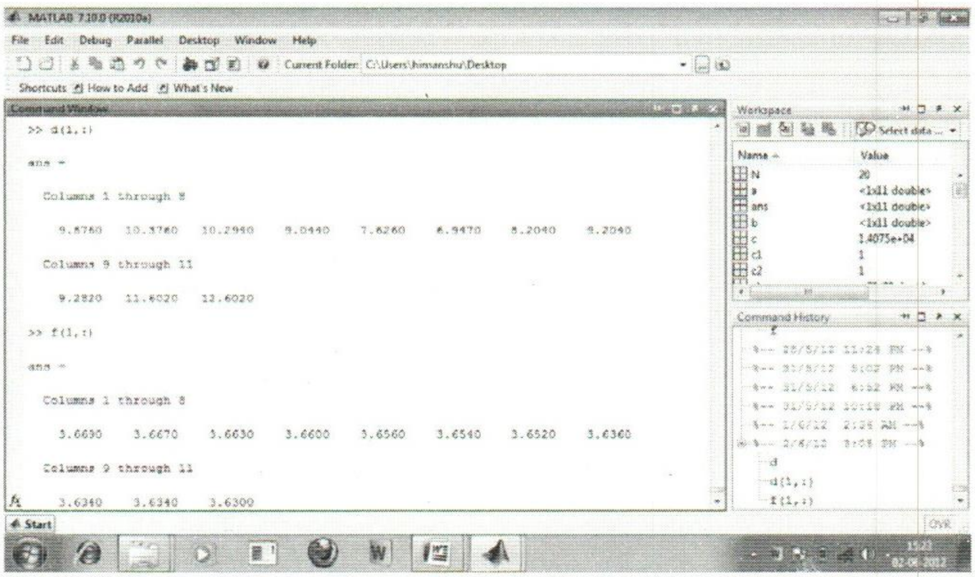

Figure 9: MATLAB Command Window Showing Modified Optimum Values of *d* and *f*

7. Results and Discussion

7.1 Basic PSO

After the PSO program written in MATLAB was run, the optimum results were generated for machine to machine distance in the line, frequency of movement of the product and hence the MHC separately for all the machines in the line. The proposed total distance over which the line was to be set up is justified. And finally, the total material handling cost of the line is minimized for the proposed machine layout or machine placement.

7.1.1 Distance Optimization

Table 6 shows the earlier (existing) and proposed (optimized) machine to machine distance values for all the machines of the line in feet.

Adding up all the proposed machine to machine distances, we get 106.7433 feet. It means that the line would occupy 106.7433 + 0.5*(7.83+9) ≈ 117 feet.

Table 6: Existing and Proposed (Optimized) Machine to Machine Distances

S. No.	Machine (From–To)	Existing Distance	Optimized Distance
1	SFC-RT	9	9.934
2	RT-FT	10.167	10.556
3	FT-VMC	9.67	10.412
4	VMC-DAM	9.75	9.068
5	DAM-TR	9	7.714
6	TR-IH	6.67	7.065
7	IH-ODG	12.167	8.452
8	ODG-IDG	11.33	9.456
9	IDG-DYE GLOW	9.91	9.462
10	DYE GLOW-WASHING MACHINE	21	11.839
11	WASHING MACHINE-ASSEMBLY	23.67	12.780
	TOTAL	**132.334**	**106.7433**

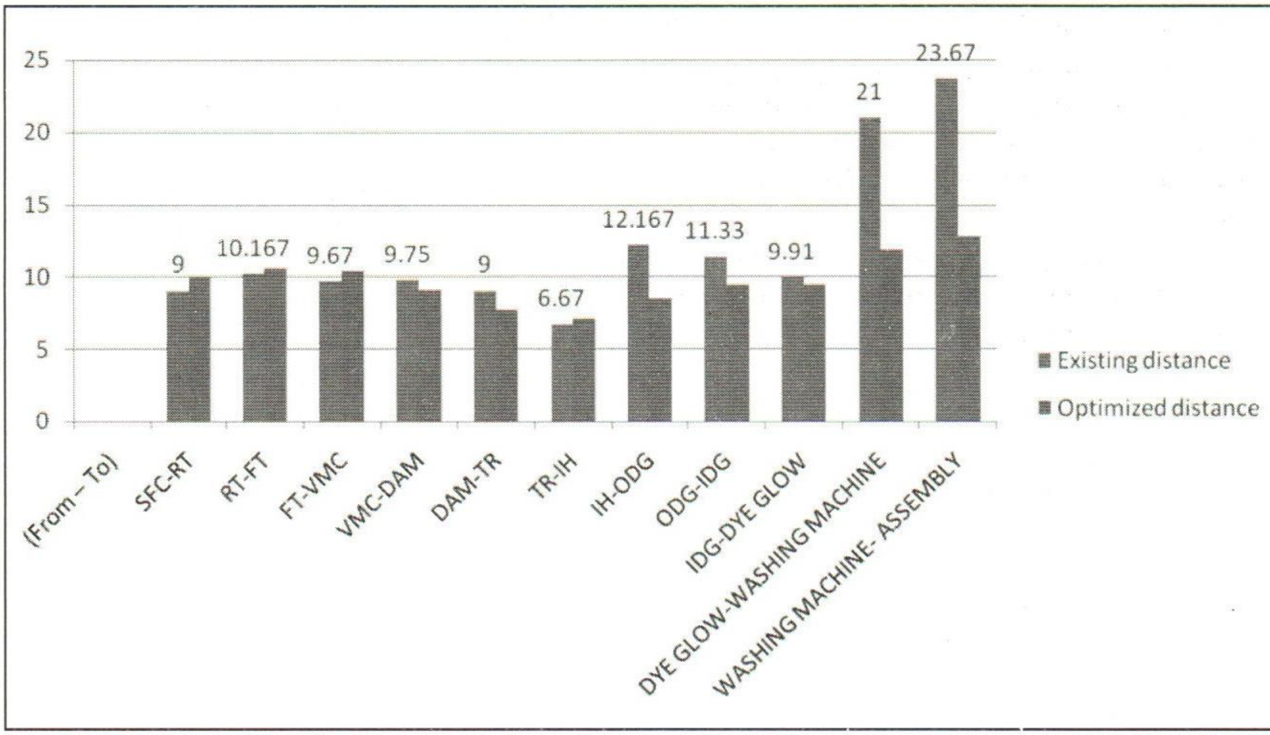

Figure 10: Statistical Comparison of the Existing and the Proposed (Optimized) Distances

The management desired to have the assembly line in around 117 feet and rest 35 feet space for storage of the final assembly storage. Hence *objective of space allocation* of crankshaft assembly components is accomplished.

Figure 10 is a chart showing the statistical comparison of the existing and the proposed (optimized) distances for all pair of machines separately. The proposed machine to machine distances are obtained as a result of suitable clearance gap, maintenance, safety hazards and material storage considerations. Some machines in the line are placed closer to each other as a result of which gap between the machines is less than sufficient whereas some machines are placed very far from their adjacent machines making the gap quite large which is unnecessary. For the SFC-RT, RT-FT, FT-VMC and TR-IH pair of machines the existing distances are less than the proposed values of distances. While for the rest pair of machines, the existing distance is greater than the proposed optimized distances as shown in Table 6 and statistically in Figure 10. *These proposed distance values contribute towards minimizing the material handling cost of the assembly line.*

7.1.2 Frequency/Production Optimization

Table 7 shows the earlier and proposed (optimized) frequency of movement or amount of production for all the machines of the line per day in tonne.

Table 7: Earlier and Proposed (Optimized) Frequency of Movement or Amount of Production for All the Machines Per Day

S. No.	Machine (From–To)	Existing Production/ Frequency	Optimized Production/ Frequency
1	SFC-RT	1,670 (3.6740)	3.6740
2	RT-FT	1,668 (3.6690)	3.6690
3	FT-VMC	1,667 (3.6670)	3.6630
4	VMC-DAM	1,665 (3.6630)	3.6630
5	DAM-TR	1,664 (3.6600)	3.6560
6	TR-IH	1,662 (3.6560)	3.6547
7	IH-ODG	1,661 (3.6540)	3.6540
8	ODG-IDG	1,660 (3.6520)	3.6426
9	IDG-DYE GLOW	1,653 (3.6360)	3.6340
10	DYE GLOW-WASHING MACHINE	1,652 (3.6340)	3.6340
11	WASHING MACHINE-ASSEMBLY	1,651 (3.6320)	3.6300

Figure 11 is a chart showing the statistical comparison of the existing and the proposed frequency of movement or amount of production in tonne between/for all pair of machines separately per day. The blue rectangular blocks represent the existing frequency whereas the red blocks represent the proposed frequencies. The proposed

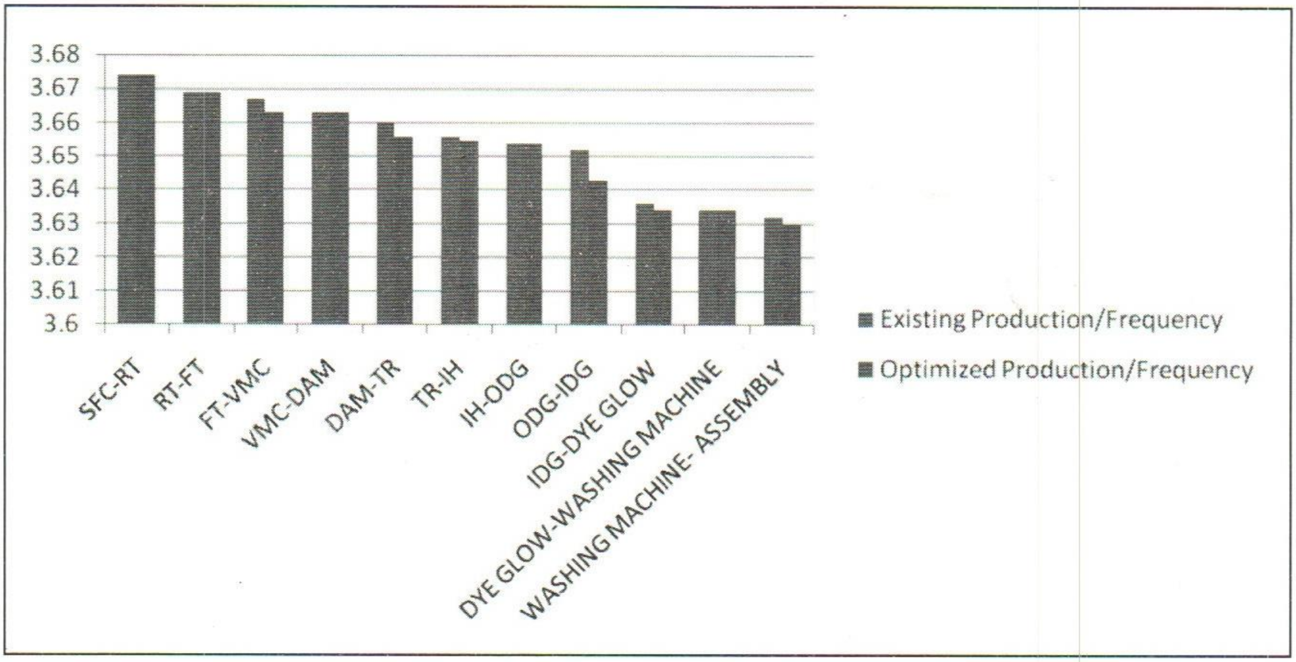

Figure 11: Statistical Comparison of the Existing and the Proposed Frequency of Movement

frequencies are obtained as a result of the maximum and minimum number of components produced by the adjacent machines and number of rejection considerations. If the frequency of the successor machine exceeds the frequency of the preceding machine, then it violates the results and hence the optimization. This is because of the reason that each crankshaft assembly is processed from the first machine and then passing on to the next subsequent machines. So the frequencies can be equal at most but the proposed frequency can never be greater than the existing frequencies. For the SFC-RT, RT-FT, VMC-DAM, IH-ODG and DYE GLOW-WASHING MACHINE pair of machines the existing frequencies are less equal to the proposed frequencies whereas for the rest pair of machines the proposed frequencies are found to be less than the existing ones as shown in the table and statistically in the figure. *These proposed values of frequency contribute towards minimizing the material handling cost of the assembly line.*

7.1.3 Material Handling Cost Optimization

Table 8 shows the earlier and proposed (optimized) material handling cost in moving the material from one machine to the next machine for all the machines of the line/day in rupees.

Figure 12 is a chart showing the statistical comparison of the existing and the proposed MHC in rupees between/for all pair of machines separately incurred per day. The blue rectangular blocks represent the existing MHCs whereas the red blocks represent the proposed MHCs. The MHC's are obtained as a result of the product of distance, frequency and unit material handling cost between machines. For the SFC-RT, RT-FT, FT-VMC and TR-IH pair of machines the existing MHCs are less than

Table 8: Earlier and Proposed (Optimized) Material Handling

S. No.	Machine (From–To)	Existing (Old) MHC	Proposed Optimized MHC
1.	SFC-RT	1,213.85	1,339.9317
2.	RT-FT	1,369.38	1,421.7905
3.	FT-VMC	1,301.73	1,400.1557
4.	VMC-DAM	1,311.07	1,219.4162
5.	DAM-TR	1,209.22	1,035.3901
6.	TR-IH	895.19	947.93601
7.	IH-ODG	1,632.06	1,133.8580
8.	ODG-IDG	1,518.95	1,264.5619
9.	IDG-DYE GLOW	1,322.76	1,262.3901
10.	DYE GLOW-WASHING MACHINE	2,801.48	1,579.4650
11.	WASHING MACHINE-ASSEMBLY	3,155.93	1,703.0416
	TOTAL	Rs 17,731.62	Rs 14,308

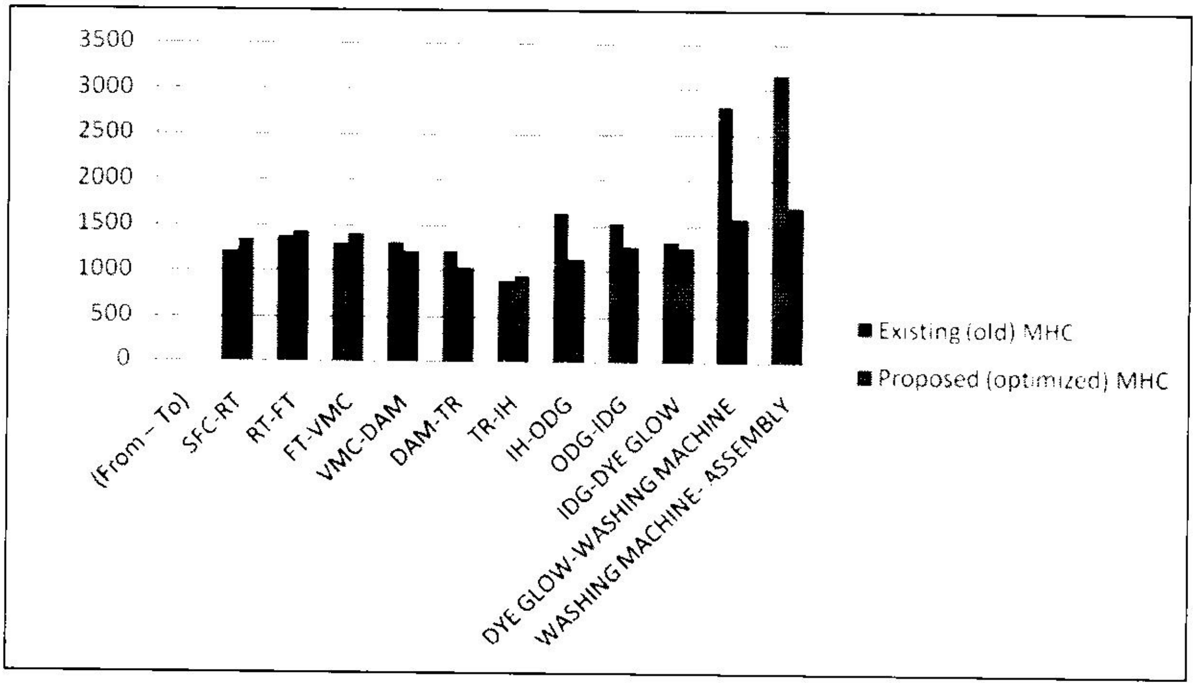

Figure 12: The Statistical Comparison of the Existing and the Proposed Material Handling Costs

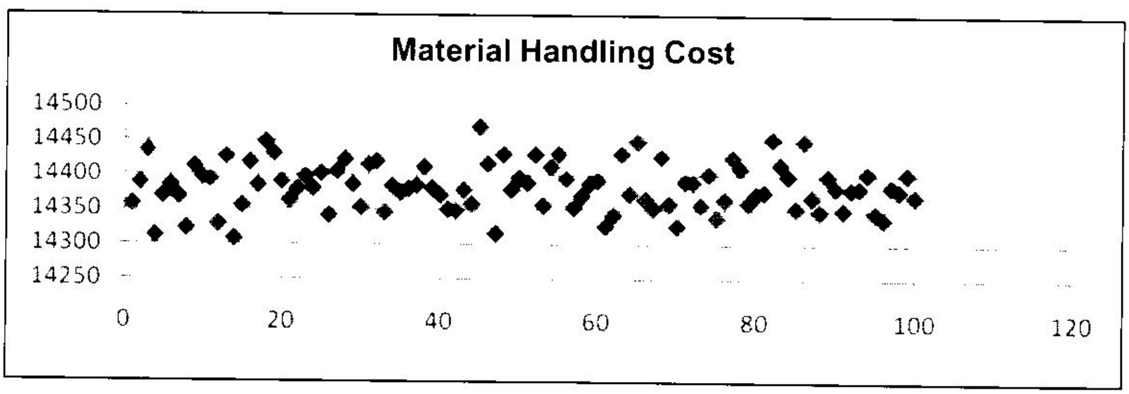

Figure 13: Scatter Plot Diagram Showing Variation in Material Handling Cost

the proposed MHCs whereas for the rest pair of machines the proposed MHCs are found to be less than the existing ones as shown in the table and statistically in the figure. The reduction in material handling cost for the rest pair of the machines can be either due to the reduction in distance or frequencies. *These proposed individual values of all the MHCs contribute towards minimizing the total Material handling cost of the assembly line.*

7.1.4 Variation in MHC

After the program was run 100 times, a variation in the value of material handling cost was observed. Every time the program gives a different value of MHC and hence of *d* and *f* too. This is due to the value of random number used in the PSO techniques, that is, Rand and Rand whose value varies from 0 to 1. This is also due to the particle size, number of iterations and constraints of the model. So, running the program up to 100 times various values of MHC were found between the ranges of Rs 14,308 to Rs 14,471. Figure 13 shows a scatter plot showing the variation in material handling cost along with the number of the program runs.

7.2 Modified PSO Results for MHS

Similarly, running the modified program up to 100 times various values of MHC/line/day were found between the ranges of Rs 14,075 to Rs 14,165. The minimum cost was executed by PSO in 0.4344 seconds. Figure 14 shows a scatter plot showing the variation in material handling cost along with the number of the program runs.

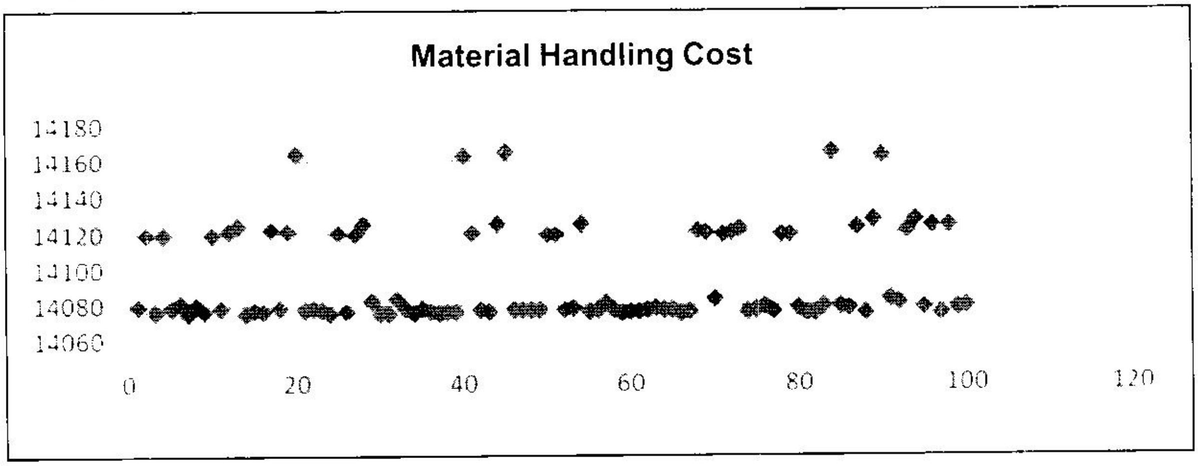

Figure 14: Scatter Plot Diagram Showing Variation in Material Handling Cost

7.3 Results

For basic PSO, we can see the comparison between the existing and proposed values of decision variables of the mathematical model, that is, *d* and *f* and the objective function or goal, that is, MHC. The existing cost in the crankshaft assembly line per day is Rs 17,731.62 whereas the optimized (proposed) cost comes out to be Rs 14,308.

Savings = 17,731.62 - 14,308 = Rs 3,423.62, which comprises of 19.3 percent of the total existing cost.

For modified PSO, observing and analysing the existing and modified proposed values of the MHC. The existing material handling cost in the crankshaft assembly line per day is Rs 17,731.62 whereas the modified optimized (proposed) cost comes out to be Rs 14,075.

Savings = 17,731.62 - 14,075 = Rs 3,656.62, which comprises of 20.6 percent of the total existing cost.

8. Conclusions

A PSO coding is done on MATLAB environment version R2010a and the program was run for optimization of the machine layout problem model. The existing material handling cost/line is successfully reduced, using the basic PSO methodology and modified PSO methodology resulting in cost savings of 19.3 percent and 20.6 percent, respectively, per day per line. Implementation of modified PSO technique includes a variable called inertial weight is observed to improve the quality of the solution. The execution time was found to be increased with increase in the particles size (*N*) and number of iterations and also the quality of solution was increased. The optimization also results in a proposed machine layout with proper distances between machines and smooth flow (congestion free) within the line as well as maintains the production of the line equal to the demand of the product. The result (optimized centre to centre distance between machines) gives the exact location (position) of the machines in the line leading to minimize the material handling cost. Also, we get the information regarding the number of components that machines within the line should produce per day in order to minimize the MHC of the line and meet out the demand.

The problem of space allocation for the storage of assembled components is also solved immaculately. The proposed machine layout of the assembly line rearranges and repositions the machines distance wise so as to fit in the line in around 117 feet as a result of which 35 feet of the distance is saved and utilized for storage of assembled crankshaft components.

9. Future Scope

1. Working on frequency of movement and unit material handling cost and their related constraints to make the layout problem more realistic.
2. Working on the parameters of PSO like particle size (*N*), number of iteration, inertial weight so as to get better optimized results.
3. Hybridizing meta-heuristics methods to receive better results.
4. Rearranging the machines for the present case as well so as to get better results.

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There is no single development, in either technology or management technique, which by itself promises even one order of magnitude improvement with a decade in productivity in reliability, in simplicity.

—Fraderick P. Brooks Jr.

Plant Layout Optimization Using CRAFT and ALDEP Methodology

VIVEK DESHPANDE, NITISH D. PATIL, VILAS BAVISKAR AND JAIVESH GANDHI

Facility layout design is the field of selecting the most effective arrangement of physical facilities to allow the greater efficiency in the combination of resources to produce a product. The facility planning plays a vital role in manufacturing process because in achieving an efficient process flow it reduces the total cost of manufacturing activity and provides optimum space to give maximum output with minimum effort at the floor area. The manufacturing facility needs to be responsive to the frequent changes in demand while minimizing material handling (Deshpande and Chopade, 2005). By keeping material moving faster, manufacturing time is also reduced. The objective of the facility planning is to achieve the lower work—in process, inventory, lower material handling and production cost (Patil, Deshpande and Gandhi, 2015). The different method or techniques are employed to design the facility layout. The most widely used techniques for facility layout design is Systematic Layout Planning (SLP) by Muther. Nowadays computer programs are used to assist the layout planner in generating alternate layout. In this article, a computerized layout algorithm (improvement type), that is, Computerized Relative Allocation of Facilities Technique (CRAFT) technique is presented for improving existing layout. Further, authors have proposed the new plant layout using Automated Layout Design Program (ALDEP) technique. The improvement given by ALDEP over CRAFT technique was found to reduce annual material handling cost by 23 percent. Travel chart is also used here in CRAFT technique. All these aspects are explained in this article with the help of a case study.

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1. Introduction and Problem Identification

The facility layout design is the basic problem in any manufacturing environment, which influences the work efficiency, that is, productivity of the whole organization. Facility layout deals with allocation of the various facilities within the department. We do use facility layout design at different phases. Say, for example, selection of plant site among many or developing the layout (that is, arranging different departments within the selected layout) or after identifying a department within a plant how to arrange the machines. These are nothing but plant layout design problems which are encountered at different phases of the survival of the plant. The objective of the facility layout is to reduce WIP, optimum space utilization and improve the flow process of production system.

The case study is based on RMG alloy steel industry in Bharuch. It deals with rolling mill making RCS bar. In the existing plant, material handling consume lots of effort. Also, time taken for material handling is more. This increases the cost of Material Handling (MH). The layout should be designed to transfer material with low outlay of time and with minimum effort, thereby lessening the Manufacturing Lead Time (MLT), inventory and cost of indirect labour. Computerized layout algorithm can be used to give improved layout. Few widely used computer programs are construction type algorithm (CORELAP, ALDEP) and improvement algorithm (CRAFT), etc. In this article, we discuss about CRAFT technique for improving existing layout (Drira, A., Pierreval, H., & Hajri-Gabouj, S., 2007). It resulted in substantial improvement. Also, ALDEP technique is used to propose optimum layout based on the adjacency score and proper material flow.

2. Literature Survey

There are different methods and techniques for solving the facility layout problems such as SLP (Shah, N.D.;

Shahin, 2011; Sutari, 2014; Tak and Yadav, 2012). CRAFT, ALDEP, CORELAP (Alex, Lokesh and Ravikumar, 2010), M-CRAFT, BLOCK PLAN, MIP, MULPTIPLE, etc. Based on above literature survey (Patil et al., 2015) it has been found that the comparative study of facility layout problem using both CRAFT and ALDEP techniques has not been done.

3. Methodology Adopted

For improving the existing layout, CRAFT method is used. It is used as an improvement algorithm (Paneerselvam, 1999). It starts with an initial layout and improves the layout by interchanging the department's pair-wise so that the transportation cost is minimized. CRAFT first evaluates (Agarwal, 1997) a given layout and then considers what the effect will be if the departments under consideration are interchanged. If making pair-wise exchange can make improvement, the exchange producing the greatest improvement is made. The process continues until no improvement can be made by pair wise exchange.

3.1 Input Requirement

i. Initial layout shows in the size of the department arrange.

ii. Flow matrix giving the number of unit loads moving between all departments over a given period of time.

iii. Cost matrix giving the cost per unit distance of movement between all departments.

iv. Space requirement for each department.

3.2 Algorithm by which the Programmed Operates is as Follows

i. CRAFT interchanges a pair of departments which have either a common border or the same area requirement.

ii. Calculate the distance between departments, the distance being taken as centroid to centroid rectilinear distances between the departments.

iii. Calculate the reduction in total movement cost result in from the interchanged of all possible pairs of department.

iv. Interchanged the two departments which provides the greatest saving in total movement cost.

3.3 Assumptions

i. Centroid of each department or area should have taken on absolute coordinate X (0,0).

ii. Inter departmental MH of workers to be considered.

iii. Working days per month: 26

iv. Working hours per day: 8

v. Working hours per month = 26 * 8 = 208 Hr or 74,800 sec/month

3.4 Cost Data for Existing Layout

The overhead crane used to transport material from one place to another place, respectively. On the other hand, human works also appointed to transport the most of material that utilized human operator level 1 (operator 1) with an average salary Rs 16,000 per month.

The method starts from first calculating the cost between Dept 1 (Store) to Dept 2 (WHFFURNACE). The overhead magnet crane used whose weight is 20 tonne. Magnetic gripper is used to attach to the bloom. The bloom weight is 2 tonne and 30 HP motor is used in the crane which consume 65 unit per hours and 1 worker is working with it whose salary is Rs 16,000 per month. The time taken to move from Dept 1 to Dept 2 is 0.05 Hour (3 minutes).

i. Working days per month: 26

ii. Working hours per day: 8

iii. Working hours per month = 26 * 8 = 208 Hr or 74,800 sec/month

iv. Unit = KW * running hours = 65 * 0.05 = 3.25

v. 1 Unit cost = Rs 8

vi. 3.25 Unit costs = 3.25 * 8 = Rs 26

vii. Crane driver salary (for 0.05 hr) = 16,000/208 * 0.05 = Rs 3.846

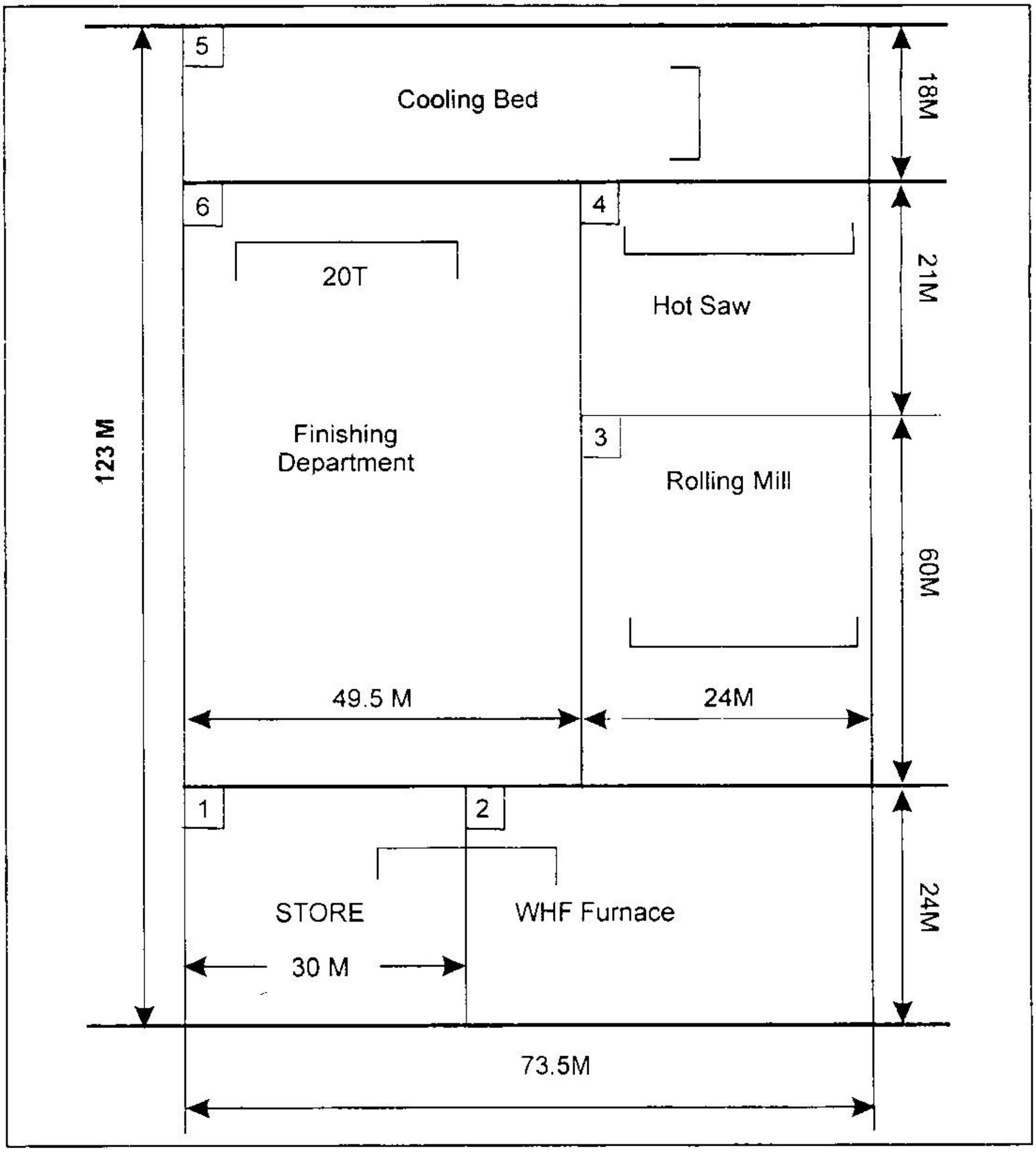
viii. Workers salary (208 Hr/month) = Rs 6,000

ix. Worker salary (for 0.05 hr) = 60000/208 * 0.05 = Rs 1.442

x. Total transportation cost between Department 1 and 2 = C_{12} = vi + vii + ix = 26 + 3.846 + 1.442 = Rs 31.28

3.5 Existing Layout

Refer to Figure 1 for Existing layout and Table 1 for Layout details.



1-STORE, 2-WHF FURNACE, 3-ROLLING MILL, 4-HOT SAW CUTTING, 5-COOLING BED, 6 FINISH NG

Figure 1. Existing Layout

Table 1: Description of Existing Layout with Coordinates

Departments	X	Y	Description
1	15	12	Store
2	51.8	12	WHF furnace
3	61.5	54	Rolling mill
4	61.5	95	Hot saw cutting
5	36.8	114	Cooling bed
6	24.8	65	Finishing

3.6 CRAFT Method

Total cost of initial layout is calculated as, Total cost = $F_{ij} * D_{ij} * C_{ij}$

Where,

F_{ij} is the flow from department *i* to the dept *j*

D_{ij} is the distance from dept *i* to the dept *j*

C_{ij} is the cost/unit distance of travel/trip

Tables 2 to 5 indicates distance matrix, flow matrix, cost matrix and total cost matrix, respectively.

Table 2: Distance Matrix (D_{ij}) for Existing Layout

S. No.	From\To	Store	WHF Furnace	Rolling Mill	Hot Saw	Cooling Bed	Finishing
1	Store	-	36.75	88.5	129	123.75	62.25
2	WHF Furnace	36.75	-	51.75	92.25	117	79.5
3	Rolling Mill	88.5	51.75	-	40.5	84.75	47.25
4	Hot Saw Cutting	129	92.25	40.5	-	44.25	66.75
5	Cooling Bed	123.75	117	84.75	44.25	-	61.5
6	Finishing	62.25	79.5	47.25	66.75	61.5	

Table 3: Flow Matrix (F_{ij}) for Existing Layout

S. No.	From\To	Store	WHF Furnace	Rolling Mill	Hot Saw	Cooling Bed	Finishing
1	Store	0	1	0	0	0	0
2	WHF Furnace	0	0	1	0	0	0
3	Rolling Mill	0	0	0	1	0	0
4	Hot Saw Cutting	0	0	0	0	1	0
5	Cooling Bed	0	0	0	0	0	1
6	Finishing	0	0	0	0	0	0

Table 4: Cost Matrix (C_{ij}) for Existing Layout

S. No.	From\To	Store	WHF Furnace	Rolling Mill	Hot Saw	Cooling Bed	Finishing
1	Store	0	31.28	72.70	125.14	137.66	168.94
2	WHF Furnace	0	0	41.29	93.42	108.83	131.79
3	Rolling Mill	0	0	0	52.18	62.514	93.80
4	Hot Saw Cutting	0	0	0	0	10.38	41.67
5	Cooling Bed	0	0	0	0	0	31.28
6	Finishing	0	0	0	0	0	0

Table 5: Total Cost Matrix (TC_{ij}) for Existing Layout

S. No.	From\To	Store	WHF Furnace	Rolling Mill	Hot Saw	Cooling Bed	Finishing
1	Store	0	1149.54	0	0	0	0
2	WHF Furnace	0	0	2137.11	0	0	0
3	Rolling Mill	0	0	0	2113.53	0	0
4	Hot Saw Cutting	0	0	0	0	459.67	0
5	Cooling Bed	0	0	0	0	0	1923.72
6	Finshing	0	0	0	0	0	0
7	Column Total	0	1149.54	2137.11	2113.53	459.67	1923.27
8	Total Cost of MH	Rs 7783.57/Hr * 208 Hr* 12 Months = 194,26,368 Rs/year					

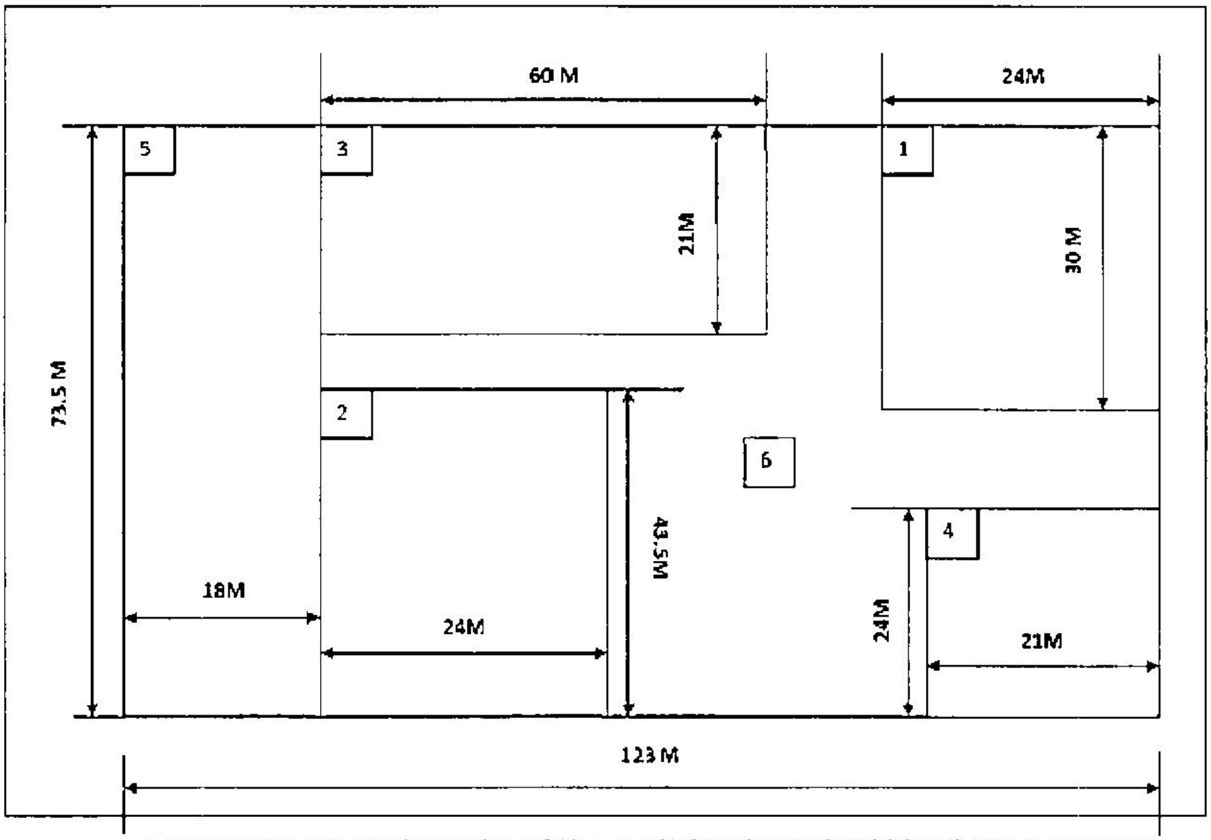
Total Annual Cost of MH for the existing layout = Rs 1, 94, 26, 368

The pairwise interchange is done based common border rule as per the CRAFT technique. For each interchanged, all three associated matrices, that is, distance matrix, cost matrix and flow matrix is calculated. After implementation of the CRAFT algorithm we get the following solution. Refer to Figure 2 for improved layout using CRAFT technique.

Total Annual MH Cost for improved layout = Rs 7,775/ Hr * 208 Hr * 12 Months = Rs 1,94,06,400/-

Hence the total saving in MH cost per annum = Rs 19,968/- (0.1027 percent only).

This improvement is very less and hence we are interested in proposing new layout with the help of ALDEP methodology.



1) STORE, 2) WHF FURNACE, 3) ROLLING MILL, 4) HOT SAW CUTTING, 5) COOLING BED, 6) FINISHING

Figure 2: Improved Layout using CRAFT technique

4. ALDEP Methodology for Proposing New Layout

ALDEP is a construction layout. ALDEP does not need any initial layout. ALDEP (Francies and White, 1999; Meller and Gau, 1996) constructs a layout when there is none. It requires the area of each departments and the relationship between these departments based on Activity Relationship chart (REL chart) and sweep width. Let us first discuss its procedure.

4.1 Department selection

i. Randomly selects the first department.

ii. Out of those departments select the one which has *A* relationship with the first one from REL chart or (*E*, *I*, etc., minimum level of importance is determined by user).

iii. Select randomly the second department.

iv. If no such department exists, it selects the second one completely randomly.

v. The selection procedure is repeated until all departments are selected (always search for the department having relationship last one placed in the layout, not all).

4.2 Department Placement and Sweep Pattern

i. Starts from upper left corner and extends it downward.

ii. Sweep width is determine by user.

iii. If minimum requirements met, it prints out the layout and the score is given.

iv. The layout with highest score (closeness rating) is selected as solution.

4.3 Activity Relationship Chart (REL Chart)

A relationship diagram that provides a visual means to determine the intensity of flow between processes. Activity relationship diagram shows the relationship of every department, office, or service area with every other department and area. In order to establish this relationship, we use closeness code to "WEIGH" the decision. Refer to Figure 3 for REL chart.

Rating	Definition
A	ABSOLUTE NECESSARY
E	ESPECIALY
I	IMPORTANT
O	ORDINARY CLOSENESS
U	UN-IMPORTANT
X	UNDESIRABLE

Rating	Definition
1	FLOW OF MATERIAL
2	AS PER PROCESS
3	NEED

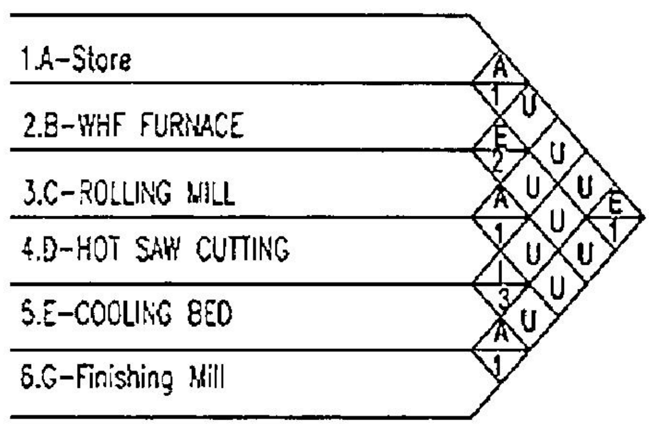


Figure 3: REL Chart

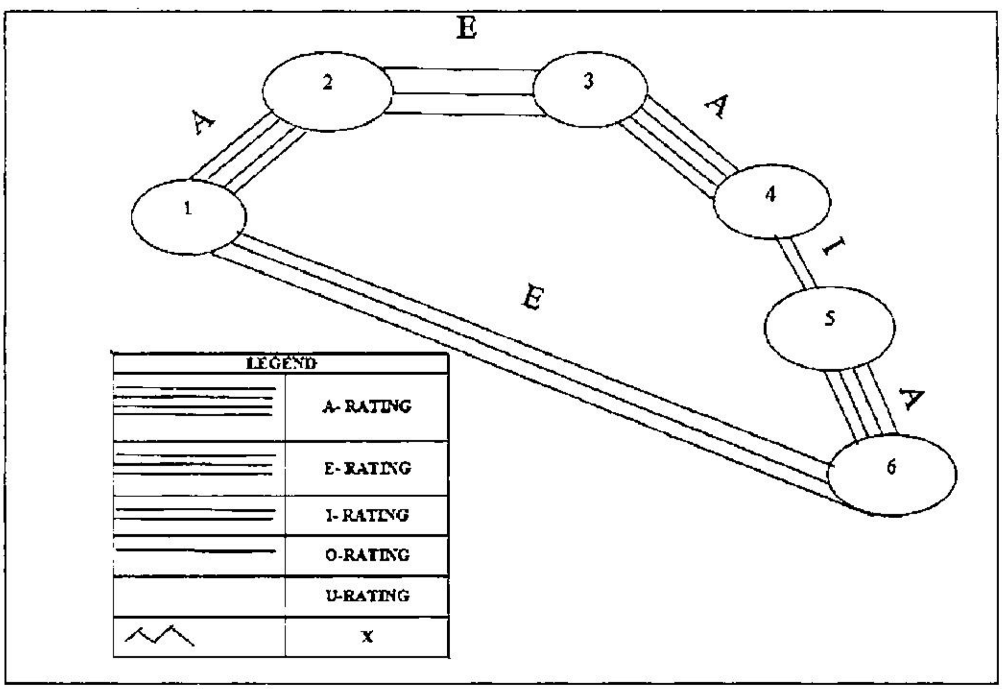


Figure 4: Activity Relationship Diagram

Assignment of the Closeness Ratio is Subjective Rule of Thumb

1 Very few *A* and *X* relationship should be assigned (no more than 5 percent of closeness rating to be an *A* and *X*).

2. No more than 10 percent should be an *E*.

3. No more than 15 percent to be an *I*.

4. No more than 20 percent to be *O*.

5. Which mean that about 50 percent of the relationship should be *U*.

Based on REL chart, Activity relation diagram is made as shown in Figure 4. Based on this, relationship process diagram is made as shown in Table 6 and Space Relationship is shown in Table 7.

Table 6: Relationship Process Diagram

Dept. No.	Dept. Relationship						Summary					TCR
	1	2	3	4	5	6	A	E	I	O	U	
1		A	U	U	U	E	1	1	0	0	3	7
2	A		E	U	U	U	1	1	0	0	3	7
3	U	E		A	U	U	1	1	0	0	3	7
4	U	U	A		I	U	1	0	1	0	3	6
5	U	U	U	I		A	1	0	1	0	3	6
6	E	U	U	U	A		1	1	0	0	3	7

Table 7: Space Relationship

Dept. No.	Name	Area (M^2)	No. of Unit Square
1	Store	720	8
2	WHF	1,044	12
3	RM	1,440	18
4	HC	504	6
5	CB	1,323	16
6	Finishing	4,009.5	48

ASSUME:

- TCR (Total Closeness Rating) A = 4, E = 3, I = 2, O = 1, U = 0
- 1 grid = 84 M^2
- Sweep width = 4

4.4 ALDEP Solution

Iteration 1: Refer to Figure 5 for layout modification by Iteration 1 of ALDEP method.

Iteration 5: Refer to Figure 6 for layout modification by Iteration 5 of ALDEP method.

Iteration 6: Refer to Figure 7 for layout modification by Iteration 6 of ALDEP method.

As per above analysis it is found that among all the iterations of ALDEP, Iteration-1 offers best solution. The sequence for this is mentioned in Table 8. This iteration is selected compared to other iterations due to reason that it is not affecting the flow of the process. Otherwise the cost of MH will increase. Construction algorithm ALDEP gives new layout and this proposed layout is again evaluated by CRAFT technique to find out the annual cost of MH. The final layout is given in Figure 8.

4.5 Evaluation of ALDEP Solution by CRAFT for finding out annual MH Cost:

Refer Table 9 for details of proposed layout. Refer to Tables 10 and 11 for distance matrix and total cost matrix of proposed layout.

Total Annual Cost of MH for the proposed layout (ALDEP) = Rs 1, 49, 51, 040/-

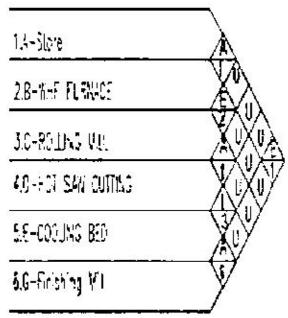
Total saving in MH cost per annum by ALDEP over CRAFT =

(MH Cost for existing layout - MH Cost for proposed layout)/(MH Cost for existing layout)

= (1,94,26,368 – 1,49,51,040) * 100/(1,94,26,368)
= (44,75,328*100)/(1,94,26,368) = 23 percent

	1	2	3	4	5	6	7	8	9	10	11	12
1	F	F	F	F	H	H	R	R	R	R	R	R
2	F	F	F	F	H	H	H	H	R	R	R	R
3	F	F	F	F	C	C	C	C	R	R	R	R
4	F	F	F	F	C	C	C	C	R	R	R	R
5	F	F	F	F	C	C	C	C	W	W	W	W
6	F	F	F	F	C	C	C	C	W	W	W	W
7	F	F	F	F	F	F	F	F	W	W	W	W
8	F	F	F	F	F	F	F	F	S	S	S	S
9	F	F	F	F	F	F	F	F	S	S	S	S

Adjacent dept.	RATING	VALUE
(F,H)	U——0	0
(F,C)	A——4^3	64
(R,H)	A——4^3	64
(R,C)	U——0	0
(W,C)	U——0	0
(W,S)	A——4^3	64
(R,W)	E——4^2	16
(W,F)	U——0	0
(F,S)	E—— 4^2	16
TOTAL SCORE		224



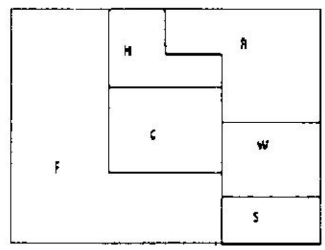
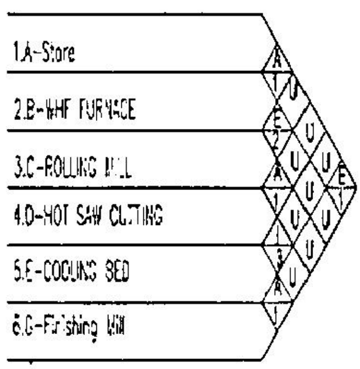


Figure 5: Layout for Iteration 1 by ALDEP Method



Adjacent dept.	RATING	VALUE
(F,R)	U——	0
(F,W)	U——	0
(F,S)	E—— 4^2	16
(F,C)	A——4^3	64
(S,C)	U——0	
(S,H)	U——0	
(W,H)	U——0	
(W,R)	E——4^2	16
(R,H)	A——4^3	64
TOTAL SCORE		160

	1	2	3	4	5	6	7	8	9	10	11	12
1	F	F	F	F	R	R	R	R	R	R	R	R
2	F	F	F	F	W	W	W	W	R	R	R	R
3	F	F	F	F	W	W	W	W	R	R	R	R
4	F	F	F	F	W	W	W	W	R	R	R	R
5	F	F	F	F	S	S	S	S	H	H	R	R
6	F	F	F	F	S	S	S	S	H	H	H	H
7	F	F	F	F	F	F	F	F	C	C	C	C
8	F	F	F	F	F	F	F	F	C	C	C	C
9	F	F	F	F	F	F	F	F	C	C	C	C

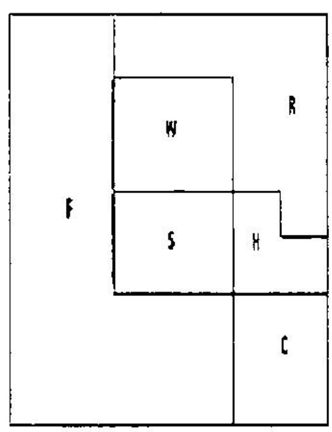


Figure 6: Layout for Iteration 5 by ALDEP Method

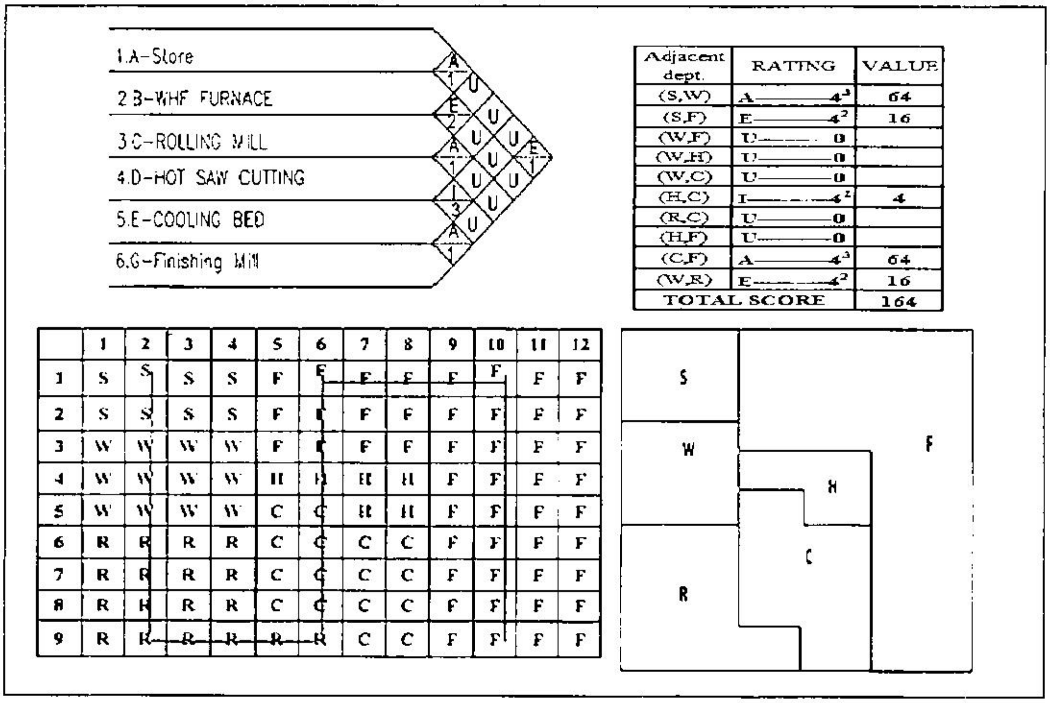


Figure 7: Layout for Iteration 6 by ALDEP Method

Table 8: Different Possible Solutions by ALDEP

Sr. No.	Sequence	Adjacency score	Possibility
1	F-C-H-R-W-S	224	Better solution for process flow
2	W-S-F-R-H-C	228	Rank is high but process flow not followed
3	C-F-S-W-R-H	224	process flow not followed
4	S-W-R-H-C-F	224	process flow not followed
5	F-S-W-R-H-C	224	process flow not followed
6	S-W-R-C-H-F	164	Not possible
7	S-W-F-R-H-C	212	process flow not followed
8	W-R-H-C-S-F	164	Not possible
9	W-S-C-F-R-H	208	process flow not followed
10	R-H-C-W-S-F	212	Process flow not followed
11	R-H-C-S-W-F	228	Rank is high but process flow not followed
12	R-W-H-C-S-F	164	Not possible
13	H-R-C-W-S-F	224	process flow not followed
14	H-C-F-R-W-S	164	Not possible
15	H-R-W-S-C-F	224	Process flow not followed
16	C-S-W-R-H-F	212	Process flow not followed
17	C-H-R-F-S-W	228	Rank is high but process flow does not followed
18	F-W-S-C-R-H	224	process not followed

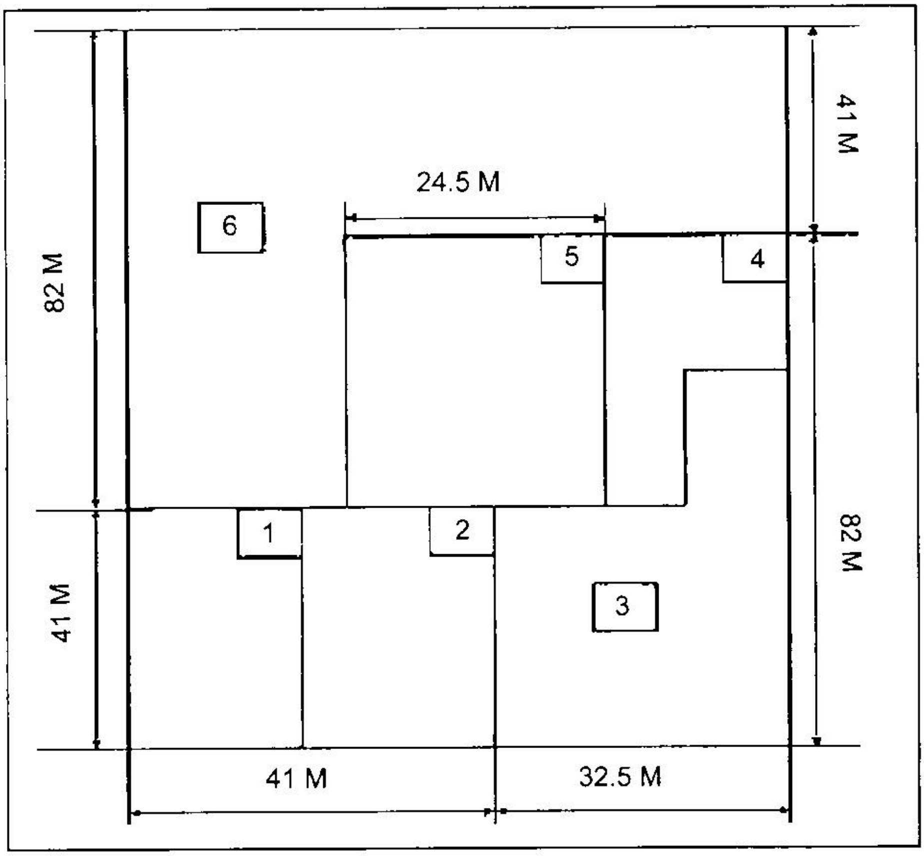


Figure 8: Proposed Final Layout by ALDEP Method

Table 9: Centroid Distance between Departments

Dept. No.	X	Y
1	8.25	20.5
2	28.75	20.5
3	58.48	24.056
4	63.86	65.056
5	40.75	61.5
6	30.62	92.25

Table 10: Distance Matrix (D_{ij}) for Proposed Layout

S. No.	From\To	Store	WHF Furnace	Rolling Mill	Hot Saw	Cooling Bed	Finishing
1	Store	0	20.5	0	0	0	0
2	WHF Furnace	0	0	33.286	0	0	0
3	Rolling Mill	0	0	0	46.36	0	0
4	Hot Saw Cutting	0	0	0	0	26.66	0
5	Cooling Bed	0	0	0	0	0	40.88
6	Finishing	0	0	0	0	0	0

Table 11: Total Cost Matrix (TC_{ij}) for Proposed Layout

S. No.	From\To	Store	WHF Furnace	Rolling Mill	Hot Saw	Cooling Bed	Finishing
1	Store	0	641.24	0	0	0	0
2	WHF Furnace	0	0	1374.60	0	0	0
3	Rolling Mill	0	0	0	2419.34	0	0
4	Hot Saw Cutting	0	0	0	0	276.9	0
5	Cooling Bed	0	0	0	0	0	1278.72
6	Finishing	0	0	0	0	0	0
7	Column Total	0	641.24	1374.6	2419.3	276.9	1278.72
8	Total Cost of MH	Rs 5990/Hr * 208 Hr* 12 Months = 1,49,51,040 Rs/year					

5. Result and Conclusion

The CRAFT technique shows an improvement of only 0.10 percent in MH cost for the existing layout. The proposed layout by ALDEP technique indicates the improvement (that is, saving) in MH cost by 23 percent. This improvement of 23 percent, that is, Rs 44.75 lacs is a great savings per annum. This indicates usefulness of ALDEP methodology. It does mean that if the layout would have been developed at the inception it would have resulted in a profit of Rs 44.75 lacs/year till date. Further benefits were:

- Increased productivity
- Low cost of product
- Reduction in efforts by production workers

In this article, an attempt has been made to indicate the usefulness of ALDEP method in developing the optimum layout.

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Technological Progress has merely provided us with more efficient means for going backwards.

—Aldous Huxley

Technology Innovation in Indian MSMEs: A Case Study Using SWOT and SAP–LAP Analysis

DAVINDER SINGH, J. S. KHAMBA AND TARUN NANDA

In India, 95 percent of the industrial units are in small-scale sector, with 40 percent addition in the manufacturing sector and 6.29 percent contribution to the Indian Gross Domestic Product. So it becomes necessary for organizations to adopt new technologies or upgrade existing setup to meet continuously changing global market and fulfil customer needs. The case study of ABC industry highlights the problems and possibilities of innovative behaviour in Micro, Small and Medium Enterprises (MSMEs). Strength, Opportunity, Weakness and Threats (SWOT) Analysis is one of the techniques to undertake a more structural analysis to formulate the best strategy. Also, a Situation Actor Process (SAP)–Learning Action Performance (LAP) Model has been applied to analyse the case study of ABC. The situation represents the present scenario of the organization. Actors are the participants, influencing the situation to evolve different business processes. Based on SAP, various learning issues have been analysed, which lead to suitable action followed by impact of SAP on the performance of the supply chain of the organization.

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1. Introduction

1.1 General

Indian economy has also brought a host of opportunities for the industrial sector, particularly the MSME segment. While MSMEs have responded to competition reasonably satisfactorily, there is scope for increasing their export potential, domestic market share and developing them as serious players in the global value chain. The socio-economic policies adopted by India since the Industries (Development and Regulation) Act, 1951, have laid stress on MSMEs as a means to improve the country's economic conditions (Garg and Walia, 2012; MSME Annual Report, 2012-13).

Economic development is a process of economic transition involving the structural transformation of an economy through industrialization and income per head. Economic growth, on the other hand, contributes to the prosperity of the economy and is desirable because it enables the economy to consume and contribute to more goods and services by increasing investment, increase in labour force, efficient use of inputs to expand output and technological progressiveness. Any nation that experiences economic development and growth will benefit from improvement in the living standards especially if the government can assist in growth by implementing complementary and growth-enhancing monetary and fiscal policies. The MSME sector is considered very important in many economies because they provide job, pay taxes, are innovative and very instrumental in country's participation in the global market. The MSME activity and economic growth are important because of the relatively large share of the MSME sector in most developing nations and the substantial international resources from sources like the World Bank group that have been channeled into the MSME sector of these nations (Beck and Kunt, 2004; Hussain et al., 2011; James et al., 2014).

Many researchers have observed that MSMEs enhance competition and entrepreneurship, therefore, they suggest that direct government support can boost economic growth and development. Also, MSMEs growth boost employment more than large firm because they are labour intensive and make better use of scarce resources with very small amount of capital. Developing countries should be interested in MSMEs because they account for a large share of firms and development in these countries (Hallberg, 2000; Baral, 2013). The MSMEs are not only important because they are a source of employment but also because they are a source of efficiency, growth and economic decentralization (Yong, 1994).

1.2 Importance of MSMEs

The 11 million MSME units, which make up the Indian MSME sector, produce over 8,000 products. The MSMEs constitute over 90 percent of total enterprises in most of the economies and are credited with generating high rates of employment and account for a major share of industrial production and exports. The MSME sector also plays a significant role in the development of entrepreneurial skills and forms a substantial portion of the country's export earnings. In this globalized environment, the government of India has felt that there is a need to enhance the global competitiveness of the MSMEs by simplifying systems and procedures, easy access to capital and taking the MSMEs in the global value chain by increasing their productivity (Rai, 2009; Kumar and Sardar, 2011).

The importance of MSMEs is well understood by national economies. World over, half to two-thirds of all businesses are MSMEs and in many regions this proportion is much higher. The MSMEs are capable of creating jobs with least amount of capital and in dispersed locations which makes MSMEs attractive to policymakers. The importance of MSMEs in India became crucial in rural areas because it promoted economic growth. In fact, MSMEs can be the factor through which productivity is increased and income generation for household local community is improved.

1.3 Technology Innovation

The MSMEs have been considered one of the *driving forces* of modern economies due to their multifaceted contributions in terms of technological development, employment generation, export promotion, etc., of these, the ability of MSMEs to develop assumes significance because innovation lends competitive edge to firms, industries and, ultimately, economies. Therefore, technological development has the potential to spur growth of individual enterprises at the micro level and aggregate industries and economies at the macro level (Subrahmanya et al., 2010; Srivastaw and Sadhukhan, 2013).

Technological development is a key factor in a firm's competitiveness. Technological development is unavoidable for firms which want to develop and maintain a competitive advantage and/or gain entry in to new markets (Becheikh et al., 2006). Among firms of different sizes, MSMEs are generally more flexible, adapt themselves better and are better placed to develop and implement new ideas. The flexibility of MSMEs, their simple organizational structure, their low risk and receptivity are the essential features facilitating them to be innovative (Harrison and Watson, 1998). Therefore, MSMEs across industries have the unrealized innovation potential (Chaminade and Vang, 2006).

1.4 Need of Technology Innovation

Modernization, technological and quality development have assumed great significance in the present day's context. With the inflow of latest technology reducing the cost of production and the increasing competition from within and outside, the small-scale sector will have to attach more importance and pay attention to the areas of technology innovation and modernization. However, due to lack of information on the areas of technology innovation, entrepreneurs who have plans for technical development are not to go ahead (Laranja, 2009).

In order to enable MSMEs tide-over the problems of technological backwardness and enhance their access to new technologies, it is imperative to offer them a conducive environment, which in the present context of globalization calls for an approach with knowledge playing a predominant role. There is a need to understand and assess the real needs of the MSMEs and accordingly devise approaches that ensure their sustainable growth. The need today is also to leverage or modern technologies to harness human capabilities through the process of increased communication, cooperation and linkages, both within the enterprise as well as across enterprises and knowledge-producing organizations.

2. Case Study of ABC Company

A case study on ABC Company is given to illustrate the essential implication of technological innovation in Indian MSMEs to improve manufacturing performance. The case study illustration is given in SWOT and SAP-LAP framework.

2.1 Quality Policy

They are pioneer in this line of manufacturing quality products and their products command country-wide market due to best quality. The quality of every part fitted in the machine is thoroughly checked by experienced and qualified technicians. The complete manufactured machine is individually checked and passed after a successful trial. The ABC Company shall achieve total customer satisfaction by providing quality products on continuous improvement basis, under reasonable cost and within agreed time frame.

2.2 Management

- All the resources required to meet the customer's requirements are made available.
- All the facilities and manpower have been provided accordingly.
- The production process is well established based upon many years of experience.
- The standards of acceptability have been well defined in the form of inspection and test plan for all stages.

2.3 Objective

Their objective is to be a lean organization that drives revenue through greater exports and higher value added products and profits through sustained cost reduction. They try to increase revenues and decrease costs through even greater emphasis on technologies and by leveraging their strengths in design and technology to considerably compress development time. The company emphasizes on three key themes that form the cornerstone of the company's growth strategy: they strictly adhere to the delivery schedule given by customers. They try to reduce the breakdown time. They would try to reduce in-process rejections, rework and wastages at all stages. These quality objectives are measurable, that is, they can measure the reduction in rejections, rework, wastage, breakdown time, unplanned down time, optimum utilization of the available resources and timely delivery to the customers.

The products manufactured by ABC and milestones achieved are summarized in the Tables 1 and 2, respectively.

Table 1: Products Manufactured and their Features

S. No.	Product	Features
1.	Self-Centring Chucks	• High tensile • Wear resistant cast iron alloyed with nickel, chrome and manganese
2.	Independent Chucks	• Manufactured specially for heavy duty and rigid gripping • Non-self-centring action of jaws allows highly controlled centering
3.	Special Purposes Chucks	• Manual self-centring power • Automatic indexing chuck with hydraulic clamping and indexing
4.	Rotary Table	• Dynamic performance • Higher acceleration/deceleration • Higher RPM • Zero backlash • Preloaded axial radial roller bearing • Direct measurement for precision positioning
5.	Ring Turning Chucks	• Ground working surfaces ensure sustained accuracy • Reasonable space for tool clearance is provided to do face turning
6.	Wood Working Chucks	• Safety jaw accessory mounting jaws • Comprehensive range of jaw set available • Available in a range of thread options
7.	Back Plates & Face Plates	• Comfortable without being bulky • Easily attaches to shoulder pads • Add protection for back from impacts from behind • Vented energy blocks disperse the impact of the force over a wide area

Table 2: Milestones of ABC

1995	• Incorporated as manufacturing unit in small machine tools. • First product manufactured in 1995.
1997	• Sales and production departments were established. • Raw material brought from different states.
1999	• Expanded their range of products by addition of manual lathe chucks. • Digital inspection equipments were installed.
2002	• Launches official website. • Started importing raw material from China. • Milling machine purchased.
2004	• Started their business in international market. • Tie up with Central Tool Room (CTR), Ludhiana, for inspecting raw materials.
2006	• Got ISO certification. • Established quality control department.
2008	• Installed CNC turning centres to improve machinability. • Dealer network is enlarged in order to provide quick delivery to customers. • Employee Provident Fund (EPF) started for all permanent employees and workers.
2010	• Adopted and formulated R&D policy for better utilization of research function. • Continuously installing CNC machines of different types for improving production and machinability.
2013	• Exhibited in EMO HANNOVER. • Started exporting products to Italy and Malaysia.

2.4 SWOT Analysis of ABC

- **Strengths**

- An ISO 9001:2008 certified company.
- Organization has loyal employees.
- Desire to succeed.
- Situated in industrial area.
- Organization has consistent track record.
- Owner's management.
- Flexibility in management.
- Strong relationship with customers.
- Adjacent to tourism city.
- Cost effective and competitive price of product.
- High level of top management commitment.
- Family environment.
- Credibility in quality.
- Strong leadership.
- Less overhead.
- Organization has vision in line to customer satisfaction in all aspects.
- Closeness to market.

- **Weaknesses**

- Conflicts of role and responsibilities.
- High absenteeism.
- Entrepreneur not multi-skilled for different functions of industry.
- Qualification background of employees not good enough.
- Lack of quality consciousness in workers.
- High dependency on individual.
- R&D is outsourced.
- Lack of quality control.
- Scale of production.
- Lack of service after sales.

- Dependency on local suppliers for part assemblies.
- Dependency on local manual labour.
- Lack of visibility in corporate world.
- Lack of professional input.
- Traditional outlook of industry.
- Hiring of employees is reference based and subjective.
- Low productivity whereas high input costs.
- Lack of advertisement opportunity.
- Cost induced on training of employees is very less.
- Career planning is of very small level.
- Lack of financial strategy.
- Bureaucratic hurdles for finance procuring.
- Inadequate information of market trends.
- Employee's reward scheme is not well structured and perfect.
- Financing problems.
- Small-scale production skills not helping enough to promote technical innovation.
- CAD facilities not available in factory premises.
- OEM drawings not available, design depends upon skills only.
- Extreme competition.
- Delivery delays are often.
- Hurdles of law and policies influence the growth of industry.
- Lack of government subsidies for technology upgradation.
- Poor technology base.
- High cost and unreliable power supply affecting industrial performance.
- Lack of infrastructure.
- Lack of skilled workers.
- Marketing and distribution problems.
- Gradual withdrawal of reservation policy.
- Entrepreneurial myth or e-myth.
- Mindset problem.
- Lack of extensive sales and service network.
- Customer complaint handling not effective.
- Limited interaction with third party R&D.
- Sharing of common issues among other industries is very limited.
- Specific innovation approaches not followed for technology upgradation.
- Absence of technology support from large-scale industries.
- More prone to global fluctuations.
- Social welfare areas neglected.

- **Opportunity**

- Increasing competition in small-scale industry.
- Government support is admissible.
- Product reservation by government.
- New technology and product can be introduced.
- Internal competition.
- Scope of on-job trainings for workmen and employees.
- Exposure to foreign markets.
- Flow of foreign investment and technology.
- Emerging areas of business.
- Less government intervention.
- Employment generation.
- Increased output of skilled manpower by technical institutes.
- Trade fare and international exhibitions.
- Increasing competition between banks.
- Improving upon market network to get into new market.
- Better performance by the MSMEs.
- Better customer satisfaction.
- Growing number of financial institutes to resolve finance issues.
- Short- and long-term capital.
- Export contribution.
- Grabbing of outsourcing created by MNCs.
- Inexhaustible source of innovation.
- Removal of regional disparity.
- Better industrial relations.

- **Threats**

- Bad economy.
- Payment delays.
- Order cancellation by party.
- Inadequate attention to R&D.
- Corporate linkage with steady in-flow.

- Lack of technology superiority.
- New cost, taxes and compliances.
- Logistic freight charges undetermined.
- Bank super conscious against Nonperforming Assets (NPA) for approving loans, etc.
- High alloy surcharge set by government for raw materials
- Lack of honest working.
- Hidden costs which are untraceable.
- Present structure of Labor Law does not encourage MSME.
- Loan interest rates for plant and machinery is high.
- Wrong commitments.
- Complicated documentation procedure.
- Corruption.
- Stiff competition due to changing norms of WTO and arrival of MNCs.
- Hidden employment.
- Lack of supervision.
- Reduced profit margins.
- Outflow of wealth.
- Political interference.
- Wide technology gap with developed industries.
- Mismatch of education base and professional requirements.

2.5 SAP Analysis of ABC

✣ Situation

- The ABC Company has variety of product range. Nine products are manufactured and assembled at the location.
- A small group of dedicated team is focused on manufacturing the products for its different customers.
- Industry is having traditional outlook, layout and working as set by the first owner. No big change in these is made by follower entrepreneur.
- Production capacity is increased over the last few years.
- Very few workmen are permanent and remaining are on contract wage basis. Small increments are offered to them.
- Lack of skilled workers, lack of infrastructure, usage of poor technology and issues created by local agencies are making the industry weak.
- Policies are not effectively working to produce employment trust in small-scale industry.
- There is lack of support and cooperation between research organization to promote technology and remove barriers.
- Cleanliness and other environment-related activities are considered lightly. This affects the morale of working of all.
- Little support is gained from government agencies.
- Fuel and power tariff are high comparing to other states.
- Finance is the major problem for industry. Public sector enterprises tend to block major funds of the industry.
- It is difficult for management to provide job security and career development opportunity to employees as compared by large-scale industries.
- There is absence of modernization of innovation for technology development.
- Industry setup is in industrial area where it can avail its basic requirement any time.
- Production numbers are low and R&D is also outsourced which is affecting its turnover.

✣ Actor

Management of ABC, manager of the industry, supervisor of the industry, suppliers of the industry, work force of the industry are the *actors*.

✣ Process

- Plant has its special inbuilt mechanism to convert the raw material into useful product. Each product is accompanied with is process sheet-cum-drawings.
- Production is limited to conventional techniques. Non-conventional machining processes are not yet installed.
- All raw material testing is carried out at local testing laboratories at Mohali.
- Suppliers are connected to industry by means of telephone, fax and email. Main raw material used in industry is GI sheets, electric motors, electric control switches and gears, ducting grills, fan belts. The

manufactured units are transported through tempos to nearest road or rail transport carrier for delivery to the customers.

2.6 LAP Synthesis at ABC

- Small-scale industry has various challenges before it To withstand with these challenges, industries have to put a lot in R&D, technology infrastructure and marketing.
- Industry needs to prove itself and made recognition as small-scale industries has specific advantages like flexibility, concentration and strong internal communication.
- Engineering standard, managerial policies and quality control have to be more successful with its current resources.
- Industry need to break old barriers of working, acquire and deploy new technology.
- A highly effective strategy for small-scale organizations is to develop a market niche. This involves developing a product which, by virtue of its own features, is able to defend itself against any competitor in the sector, whatever their size. Personalizing the product and addition of appropriate options is all part of this strategy.
- Technical trainings and work experience of workmen gives industry a prompting edge. Industry needs to promote these for their workmen and staff.
- Multi-skill enhancement in workmen always helps to reduce errors of working and initiate problem solving exposure among the team.
- Small-scale organizations prefer external recruitment of experienced staff rather than training the staff internally. Training in such organizations is usually ad hoc and underlines poor attitude towards learning.
- Small firms often rely on their own experiential know-how, and train up their own operative and intermediate level skills. Small units generally remain insular and autonomous and fail to recognize the underlying or latent skill deficiencies.
- It is critical to match employees to projects not only on the basis of their experience but also in terms of where their interests lie. Employees are most creative when they are about their work and are stretching their skills. So provide them opportunity to deeply engage themselves into their work and make real progress.
- Documented working of whole processes should be made effective to produce quality product. Separate inspection department be incorporated.
- Finance scheme should be easy and effectively approachable to entrepreneur to get maximum benefit out of these.
- Efficient usages of fund acquired from financing agencies is very much important than just to grab the liquidity only.
- Government should provide appropriate information and help to make the small-scale industry on its feet. It should also help to acquire new techniques which are non-hazardous, eco-friendly, economical and environment friendly.
- Government needs to regulate the equality among all states regarding policies, concessions and offers to enhance growth of industries.
- Provision of *study visits* for entrepreneurs to various technically advanced units both in India and developed countries, along with technical experts in the trade, to create awareness of prevailing technologies and manufacturing techniques.

3. Conclusion

The SMEs play an essential role in sustaining a developing nation's survival and growth. The aim of this article was to investigate the extent to which the SWOT factors have been attained in MSMEs with particular reference to the selected company. The SAP–LAP Analysis presents the situation of technology innovation in Indian MSMEs. It also helps in identifying technology gaps in adoption of innovation strategies. The synthesis of SAP leads to LAP, which bridges the gap of technology development by suggesting improvement actions on the gaps of innovation or the learning from the present situation, actors and processes. The main threats observed are competition from large and multinational businesses, financial stringency and technological obsolescence. In spite of the various lacunas, it is felt that with the existing technology and manpower, MSMEs can do miracle by adopting technological innovation.

The analysis and implications of technological innovations studied with reference to the small firm indicate that if small firms have to survive and grow, they need not always resort to technological innovations. Even incremental innovations can contribute to their competitiveness. The most important advantage of these firms is their ability to provide what the market demands.

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> *Science and technology revolutionize our lives, but memory, tradition and myth frame our response.*
>
> ***—Arthur M. Schlesinger***

Focus

Standardizing the Processing Parameters to Obtain Mozzarella Cheese from Partially Homogenized Milk

ATANU JANA, AKSHAY MAHAGAONKAR, HIRAL MODHA AND K. D. APARNAHTI

Homogenization of cheese milk is beneficial with regard to appearance (whiteness), increased cheese yield and reduced fat leakage (upon baking) of mozzarella cheese (pizza type). However, homogenization treatment exerts adverse effect on curd formation and few functional properties of cheese. Partial homogenization (homogenization of cream and mixing it with untreated skim milk) is reported to exert lesser adverse effect on cheese curd properties than does complete homogenization. Though productivity of cheese is enhanced by homogenization, some of its end-use functionality is impaired. Hence, it was decided to study the impact of partial homogenization (25 + 10 [P_1] and 50 + 10 kg/cm^2 [P_2] pressure, 60°C) of milk (3.0 percent fat) on the modification required in mozzarella cheese making process in order to obtain satisfactory quality mozzarella cheese suitable for its end usage. Based on the findings, it was recommended to incorporate $CaCl_2$ @ 0.01 percent to partially homogenized cheese milk, cook the cheese curd to higher temperature (44°C vs 35°C for control), adopt higher whey acidity at draining (that is, 0.45 percent and 0.49 percent Lactic Acid (LA) when adopting P_1 and P_2 pressure, respectively) and using milder plasticizing conditions (that is, 95°C mould water and keeping contact period of 3–4 min. and 2–3 min. for pressures P_1 and P_2, respectively, vs 99–100°C/ 4–5 min. for control). Use of such modified process helped in obtaining mozzarella cheese conforming to legal standards and with enhanced milk solids recovery leading to improved cheese yield.

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1. Introduction

Homogenization is one physical pre-treatment that has proved beneficial when applied to milk as well as for certain milk products including cheese (especially soft cheeses). However, there are some detrimental effects of milk homogenization on the properties of cheese curd characteristics, reflecting on the functionality of cheese during its end-use application. Complete homogenization (homogenizing the standardized cheese milk) of milk has been found to increase the whiteness of mozzarella cheese and enhance the cheese yield; partial detrimental effects have been noted for shredability, stretch and meltability of cheese (Breene et al., 1964, p. 1173; Jana and Upadhyay, 1992b, p. 256; Jana and Upadhyay, 2003, p. 16). Achieving an increase in cheese yield at the same time complying with legal compositional standard is a significant way to accomplish productivity. Such increased cheese productivity (that is, cheese yield) is due to increased recovery of milk solids in the resultant cheese system. Partial homogenization (that is, homogenization of low-fat cream and recombining it with unhomogenized skim milk to obtain standardized cheese milk) is one alternative method of homogenization wherein the benefits accrued out of such treatment are availed, while the detrimental effect on cheese functionality is minimized (Rudan et al., 1998, p. 2065; Rudan et al., 1999, p. 661). However, any change in the pre-treatment (that is, homogenization) to cheese milk leads to modification in the cheese manufacturing process (owing to increased interaction of fat and protein, leading to softer cheese curd and increased moisture content) in order to obtain cheese of desired quality. Hence, it was decided to standardize the manufacturing protocol for mozzarella cheese making from partially homogenized milk in order to achieve higher productivity (more output of cheese per unit quantity of milk used) and with reasonable end-use functionality. Jana and Upadhyay (1992b, p. 256) had standardized the method of preparing mozzarella cheese from homogenized (complete homogenization) standardized (4.5 percent fat) buffalo milk. The modifications that were suggested in the manufacturing protocol when preparing cheese from homogenized milk (as against unhomogenized milk) were: (a) addition of 0.01 percent calcium chloride ($CaCl_2$) to cheese milk, (b) adopting higher cooking temperature (that is, 42.5°C vs 40°C for control cheese), (c) adopting higher whey acidity at draining (that is, 0.43 and 0.45 percent LA when using 25.0 and 50.0 kg/cm^2 pressure, respectively, vs 0.41 percent LA for control), and (d) employing moulding water temperature of 87–90°C/2–3 min. and 87–90°C/1–2 min. for milk homogenized at 25 and 50 kg/cm^2 pressure, respectively, vs 99–100°C/2–3 min. for control (that is, from unhomogenized milk).

2. Materials and Methods

2.1 Materials: Lactic acid as 90 percent extra pure as well as calcium chloride, dihydrate (extra pure grade) was procured from M/s. Merck, Mumbai. Tata brand vacuum evaporated salt manufactured by M/s. Tata Chemicals Ltd, Mumbai, was obtained from local market.

2.2 Equipments: An open discharge power-driven mechanical cream separator of M/s. Sarvoday Engineering, Ahmedabad, having a capacity of 550 lit. of milk/h was used to separate the cream and skim milk. A two-stage homogenizer of M/s. Goma Engineering Pvt. Ltd, Mumbai, was used to homogenize the standardized cheese milk or the standardized cream as per need.

***2.3 Compositional analysis*:** Cheese milk was analysed for fat (BIS, 1977), protein (Jayaraman, 1981, p. 75) and TS content (Milk Industry Foundation [MIF], 1959, p. 283). The mozzarella cheese was analysed for salt and pH (Patel et al., 1986), TS (MIF, 1959, p. 283), fat (BIS, 1979), protein (Jayaraman, 1981, p. 75) and ash (BIS, 1961) content.

2.4 Preparation of cheese: Mozzarella cheese was prepared on a laboratory scale from 10 kg mixed milk (cow and buffalo) for each treatment. Mozzarella cheese was manufactured following the method standardized by Jana and Upadhyay (1992b, p. 256) for homogenized milk (3.0 percent milk fat), adopting direct acidification technique using 20.0 percent solution of LA. Control mozzarella cheese was made from unhomogenized standardized cheese milk (3.0 percent milk fat) following the direct acidification method of Patel et al. (1986, p. 394).

Partial homogenization involved adjusting the fat content of separated cream (40 percent fat) to 25 percent fat using skim milk, homogenizing (two stage) the diluted cream (25 percent fat) at 25 + 10 kg/cm^2 pressure (P_1) and 50 + 10 kg/cm^2 pressure (P_2) and 60°C and then mixing the homogenized cream with unhomogenized skim milk to obtain standardized (3.0 percent fat) cheese milk. The parameters studied to obtain satisfactory quality mozzarella cheese from partially homogenized milk were: (a) addition of calcium chloride to cheese milk, (b) optimizing the cooking temperature, (c) optimizing the whey acidity at draining and (d) optimizing the conditions of moulding water required for plasticizing the cheese curd.

2.5 Stretch test for cheese curd: At the desired whey acidity at draining, a fixed quantity of cheese curd (15 g) was collected in a glass beaker containing water at 90°C (curd: water, 1: 2.5 w/v). The curd was allowed to lay immersed in such water for 2–3 minutes, the water drained and the curd kneaded in beaker using a long glass rod. The plasticized cheese mass was withdrawn from the glass rod and stretched manually. Greater length of stretched strand indicated higher stretchability than the ones exhibiting lower length of stretch.

2.6 Statistical analysis: The statistical analysis of the data was carried out using Completely Randomized Design (Steel and Torrie, 1980, p. 137).

3. Vat Performance

The cheese making procedure (vat performance) based on unhomogenized milk, completely homogenized milk (that is, homogenization of standardized milk at P_1 pressure only—referred to as CH) and from partially homogenized (P_1 and P_2 pressures) milk (referred to as PH) is depicted in Table 1. Some noteworthy points associated with the use of homogenized milk (complete or partial) for cheese making were: (a) softer curd formed after renneting; (b) more tendency of curd to shatter during stirring while cooking, especially so in case of CH milk curd; (c) requirement of higher whey acidity at draining, higher homogenization pressure led to requirement of still higher whey acidity at draining; and (d) reduced losses of fat in whey and moulding water.

Homogenization affected the protein structure and caused the casein micelles and whey proteins to become associated with the fat globule membrane (Michalski et al., 2002, p. 2451). The interactions between fat and proteins led to lower curd firmness during rennet coagulation, curd shattering during cutting and improper curd matting (Tunick et al., 1993, p. 3621). Increased shattering of cheese curd has been reported for low-fat

Table 1: Milk Composition, Manufacturing Aspects of Mozzarella Cheese from Unhomogenized and Homogenized Milks, Recovery of Milk Solids and Cheese Yield

Particulars	Unit	Treatment				C.D. (0.05)
		Unhomogenized	Completely Homogenized*	Partial Homogenization* P1	P2	
Particulars of milk[§]						
Mixed milk	Kg	10.00	10.00	10.00	10.00	
Milk fat	%	3.03	3.05	3.03	3.00	
Protein	%	3.09	3.05	3.15	3.12	
Total solids	%	11.50	11.52	11.60	11.68	
Acidity	% LA	0.128	0.126	0.126	0.128	
Acidification with lactic acid**						
Temperature of milk during acidification	°C	15	15	15	15	
Amount of acid used per 10.0 kg milk (v/w)	Ml	280	310	300	320	
Milk acidity at renneting	% LA	0.495	0.522	0.513	0.522	
Addition of calcium chloride						
Rate of addition (w/w)	%	0.005	0.015	0.01	0.01	
Coagulation of milk using Fromase rennet						
Rate of addition	g/100 kg milk	4.25	4.25	4.25	4.25	
Temperature of milk during renneting	°C	15	15	15	15	
Time taking for setting	min.	25.0	25.0–30.0	25.0–30.0	25.0–30.0	
Cutting of curd						
Size of cut curd	cm^3	1.00	1.00	1.00	1.00	
Cooking of cheese curd						
Start of cooking after renneting	min.	45	45	45	45	
Initial & final temperature	°C	35 & 42.5	35 & 44	35 & 44	35 & 44	
Period of cooking	min.	40	40	40	40	
Whey acidity at draining	% LA	0.42	0.46	0.45	0.49	
Salting of cheese curd						
Rate of addition of salt	% w/w of curd	2.75	2.75	2.75	2.75	
Plasticizing and moulding						
Temperature of moulding water	°C	99-100	90	95	95	
Time of contact	min.	3–4	1–2	3–4	2–3	
Quantity of moulding water	Water:curd	2.5:1	2.5:1	2.5:1	2.5:1	
Particulars of cheese						
Yield	Kg cheese/ 100 Kg milk	10.20[a]	11.24[b]	11.05[b]	11.18[b]	0.27
Fat recovery	%	83.49[a]	89.88[b]	86.10[c]	86.83[c]	1.07
Protein recovery	%	77.14[a]	78.99[b]	80.10[c]	79.08[b]	0.87
TS recovery	%	45.29[a]	47.25[c]	46.28[b]	46.24[a]	0.96

Flash pasteurization at 72°C/no holding. * 25% fat cream was homogenized, ** Lactic acid 20 percent solution (w/v). P_1 – 25 + 10 kg/cm². P_2 – 50 + 10 kg/cm² # Homogenized at P. pressure. LA – Lactic acid. CD (0.05) – Critical difference at 5 percent level of significance mozzarella cheese made from milk homogenized at low pressure (Tunick et al., 1993, p. 3621; Rudan et al., 1998, p. 2065). In cheese making, it was observed that use of partial homogenization by treating 25 percent fat cream prevented the curd shattering that was associated with completely homogenized milk.

Addition of calcium salt to cheese milk: Homogenization of milk in cheese making leads to a weaker coagulum (Vaitkus et al., 1979, p. 30; Emmons et al., 1980, p. 15; Jana and Upadhyay, 1992a, p. 72). To overcome this, addition of calcium chloride ($CaCl_2$ @ 0.01–0.02 percent) to the homogenized milk prior to renneting has been recommended (Lapshina et al., 1978, p. 33; Jana and Upadhyay, 1992b, p. 256). Thus, with a view to increase the curd tension of the renneted homogenized milk curd to a level nearer to that of control milk, $CaCl_2$ at a level of 0.01 and 0.015 percent (w/w) was added to the homogenized milk lots (PH and CH milks), respectively. Unhomogenized milk was also added with small quantum (that is, 0.005 percent) of calcium salt, since mixed milk (cow plus buffalo) was used; cow milk yields a softer curd than use of buffalo milk. Incorporation of such calcium salt facilitated the handling of the curd during cheese manufacture, reducing the losses of milk solids in whey as well as in moulding water.

Based on the preliminary trials, it was decided to use 0.01 percent $CaCl_2$ for cheese made from partially homogenized milk at P_1 and P_2 pressures. Addition of higher amount of $CaCl_2$ (that is, 0.02 percent) led to a curdy meltdown during baking of pizza containing such cheese as a topping.

Effect of cooking temperature on the cheese curd characteristics: Homogenization of milk or cream leads to a greater entrapment of moisture in the weaker curd structure formed. This leads to resultant cheese curd having much higher moisture content that does not conform to the legal requirements. Food Safety and Standards Act (FSSA) (2006, p. 293) specifies maximum moisture of 54 percent in pizza cheese (a variant of mozzarella cheese); shred quality and shelf life of cheese is also adversely affected. Hence, it was necessary to cook the curd at a temperature higher than conventionally used (that is, 40°C for unhomogenized). In preliminary trials, three cooking temperature were tried out, viz., 40°C, 42°C and 44°C. The cheese curd attained moisture content within the limits (that is, less than 54.0 percent) laid down by FSSA and exhibited desired curd stretching properties only when the cooking temperature was kept at 44°C, resulting in more or less firm curd that was amenable to shredding during pizza applications. The cheese curd quality at the time of plasticizing is described in Table 2, based on which the cooking temperature of 44°C was finally selected.

Table 2: Effect of Cooking Temperature on the Cheese Curd Characteristics Obtained from Partially Homogenized Milk

Cooking Temperature	Cheese Curd Quality
40°C	Too moist curd; cheese had moisture content exceeding 54.0%, the maximum specified by FSSA for pizza cheese
42°C	Moist curd; cheese could barely meet the requirements for moisture as per FSSA, could not be shred with ease for pizza applications
44°C	Firm curd enabling moisture content within limit (maximum 54.0%) specified for pizza cheese, amenable to shred for pizza applications

Jana and Upadhyay (1992b, p. 681) restricted the cooking temperature to 2.5°C (that is, 42.5°C) higher than conventionally (that is, 40°C) used to avoid inhibition of the starter culture used in mozzarella cheese manufacture. In our case, since direct acidification method was employed, there was no obstacle in raising the cooking temperature to 44°C.

Optimizing the whey acidity at draining: The whey acidity at draining has a profound influence on the cheese characteristics through control of partitioning of minerals between cheese curd and whey curd; such a parameter influences the cheese pH also. The desired pH of mozzarella cheese made by direct acidification method is in the range 5.2–5.4 (Jana and Upadhyay, 1991, p. 167). Any influence on cheese curd characteristics has a bearing on the end use of cheese (that is, shred, melt, fat leakage, stretch) during pizza applications.

The draining acidity was decided on the basis of stretch test, which indicated that the curd drained at the specific whey acidity could be plasticized satisfactorily. The draining acidities of whey were required to be kept higher for cheeses made from partially homogenized milk as compared to control (that is, 0.42 percent LA); the cream homogenized at higher pressure (that is, P_2) was required to be drained at higher whey acidity (0.49 percent LA) than the one homogenized at lower pressure (that is, P_1) (that is, 0.45 percent LA) (Table 3). The basis for selecting such specific whey acidity at draining is shown in Table 3.

The requirement of higher draining acidity for homogenized milk lots might be due to the higher retention of moisture in the curd, which needs to be expelled out up to certain extent (by the end of cooking) so that stretching property develops in the cheese curd. Moreover, it might be that homogenized milk curd requires higher acidity for formation of mono-calcium paracaseinate, which when

Table 3: Influence of Whey Acidity at Draining on the Cheese Curd Characteristics from Partially Homogenized Milks

Homogenization Pressure	Whey Acidity at Draining(% LA)	Effect on Curd Characteristics
P_1 - 25.0 + 10.0 kg/cm^2	0.40 0.42	No stretch Slight tendency to stretch
	0.45	Optimum stretch
P_2 - 50.0 + 10.0 kg/cm^2	0.45 0.47	No stretch Slight tendency to stretch
	0.49	Optimum stretch
Unhomogenized	0.42	Optimum stretch

formed provides the stretch property to the curd. Such effect of draining whey acidity on kachkaval cheese curd has been reported (Djordjevic, 1962, p. 490).

Optimizing the plasticizing conditions for mozzarella cheese curd: The plasticizing treatment involved use of hot moulding water at a specific temperature and keeping that moulding water in contact with the cheese curd for some period of time, before the moulding water is drained and subsequently the cheese curd is plasticized using mechanical action. Such plasticizing treatment (for cheese curd at desired pH) had a profound influence on the losses of milk solids in the moulding water and also determined the body and texture (through shrinkage of casein matrix releasing some water) of the resultant mozzarella cheese. Since higher whey acidity at draining was required for the partially homogenized milk cheese, suitable for the curd to be stretched, such curd would have lower mineral content than the curd drained at lower acidity (that is, from unhomogenized milk). Plasticizing the cheese curd having lower mineral content with hot moulding water tended to soften (as a plastic mass) the cheese mass to a greater degree as compared to that obtained from unhomogenized milk.

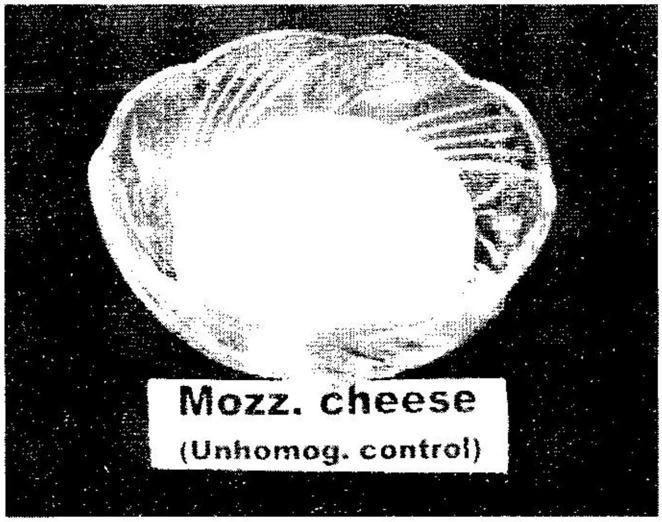
Hence, it was necessary to optimize the plasticizing conditions (that is, moulding water temperature and its contact period with the cheese curd) in the manufacture of mozzarella cheese. It was revealed from experimental trials that the cheese curd obtained from partially homogenized milk employing P_1 and P_2 pressures required moulding water temperature of just 95°C (Table 4) as against 99–100°C for control (from unhomogenized milk). Lower temperature than this did not permit the curd to fuse with each other to the extent desired for plasticizing.

Table 4: Effect of Moulding Water Temperature on Mozzarella Cheese Curd Characteristics from Homogenized Milk

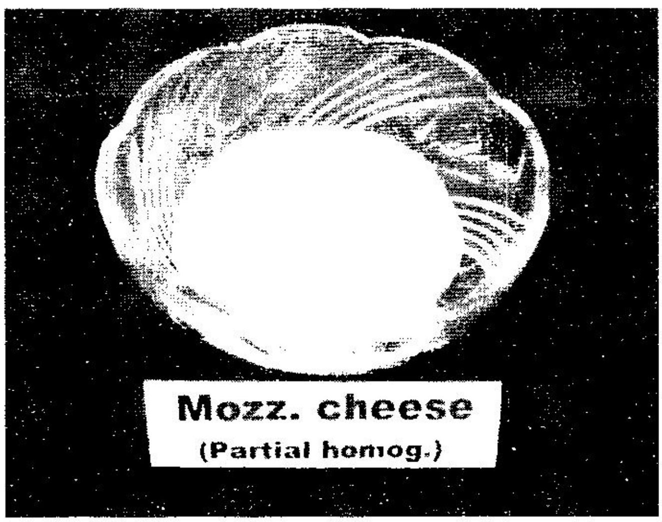
Temperature of Moulding Water	Property of Cheese Curd at Plasticizing
Pressure P_1	
85°C	No matting of cheese curd
90°C	Slight matting of curd, but did not stretch adequately
95°C	Proper matting of curd, curd stretched properly and became elastic
Pressure P_2	
85°C	No matting of cheese curd
90°C	Slight matting of curd, but did not stretch adequately
95°C	Proper matting of curd, curd stretched properly and became elastic
Unhomogenized milk 99–100°C	Proper matting of curd, curd stretched properly and became elastic

P_1 – 25 + 10 kg/cm^2 pressure, P_2 – 50 + 10 kg/cm^2 pressure

(A)



(B)



(C)

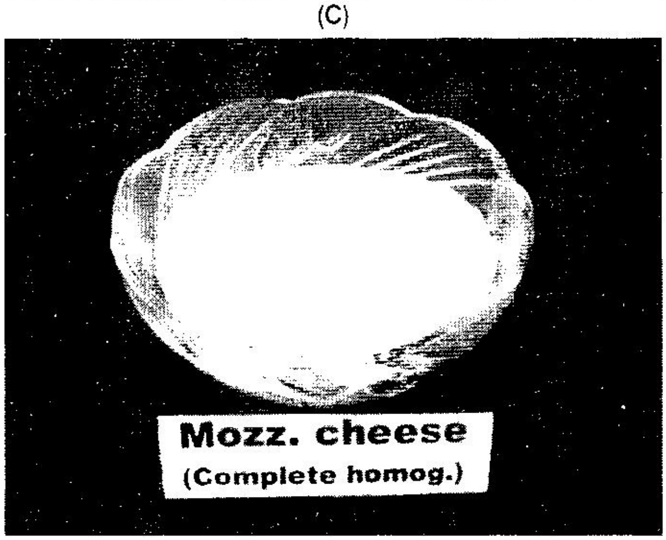


Figure 1 Mozzarella Cheese Obtained from Unhomogenized (A), Partially Homogenized (B) and Completely Homogenized (C) Milks

Temperatures greater than 95°C led to greater softening of the cheese mass, not allowing the cheese to retain their shape (ball form) upon cooling

Likewise, the time required for plasticizing the cheese curd at the aforementioned moulding water temperature (that is, 95°C) was 3–4 min. and 2–3 min. respectively for curd obtained from cream homogenized at P_1 and P_2 pressures. Keeping contact period greater than such specified period had detrimental effect on milk solids losses and body and texture of cheese mass. Figure 1 shows the photographs of Mozzarella cheese made from unhomogenized milk, partially homogenized milk and completely homogenized milk, depicted as Figure 1A, 1B and 1C, respectively.

Our findings with regard to use of milder plasticizing conditions (that is, lower temperature of moulding water and lower contact period with cheese curd) are in consonance with the findings of Jana and Upadhyay (1992b, p. 681) for mozzarella cheese made from completely homogenized buffalo milk.

4. Milk Solids Recovery and Cheese Yield

A significant ($P < 0.05$) improvement in the fat and protein recovery of mozzarella cheese was noticed when employing partial homogenization as compared to control cheese made from unhomogenized milk (Table 1). Homogenization of cream led to adsorption of protein (casein) on to the increased fat globule surface (Michalski et al., 2002, p. 2451), which brought about interaction between protein and lipid in cheese structure. Such association of protein with lipids makes their entrapment in cheese structure more efficiently. Such an increase in the recovery of fat and protein as a result of milk/cream homogenization has also been reported by other workers (Quarne et al., 1968, p. 527; Rudan et al., 1999, p. 661; Jana and Upadhyay, 2003, p. 16). The rate of increase in cheese yield over control cheese was 8.3 percent and 9.6 percent when adopting partial homogenization at P_1 and P_2 pressures, respectively. Complete homogenization of milk yielded increase in cheese yield by 10.2 percent when compared to yield of control cheese (Table 1). This would mean that when preparing 1,020 kg of mozzarella cheese, use of 893 kg less of milk would be required if completely homogenized milk was utilized; likewise, 769.2 kg and 876.6 kg less of milk would be required when partially homogenized milk treated at P_1 and P_2 pressures was used for cheese making, respectively. There would be saving of Rs 23,076 compared to use of control milk (price of 3.0 percent fat milk was assumed to be Rs 30 per kg) when using partially homogenized (P_1 pressure) milk for producing 1,020 kg mozzarella cheese.

5. Composition of Mozzarella Cheese

Both control as well as homogenized (partial) milk cheese conformed to the requirements laid down by FSSA for mozzarella cheese (pizza type), viz., maximum of 54.0 percent moisture and minimum of 35 percent Fat on Dry Matter (FDM). Homogenized (partial) milk cheese had significantly ($P < 0.05$) greater moisture and FDM content as compared to control (unhomogenized milk) mozzarella cheese. However, the former had significantly ($P < 0.05$) lower fat, protein (at constant moisture), salt and ash compared to control cheese (Table 5). The pH of both cheese tended to be at par with each other (Table 5). Such findings are in agreement with the findings of Jana and Upadhyay (2003, p. 16) for mozzarella cheese made from completely homogenized milk.

Table 5: Composition of Mozzarella Cheeses Made from Unhomogenized and Partially Homogenized Milks

Constituents	Mozzarella Cheese Made from Partially		CD(0.05)
	Unhomogenized Milk	Homogenized* Milk	
Moisture %	48.94[a]	50.52[b]	1.26
Fat, %	24.83[a]	24.34[b]	0.35
Fat on dry matter,%	48.63[a]	49.20[b]	0.55
Protein at constant (50%) moisture, %	22.89[a]	22.52[b]	0.32
Salt	0.98[a]	0.90[b]	0.06
Ash	1.56[a]	1.48[b]	0.03
pH	5.55[a]	5.50[a]	NS

* Homogenization of 25 percent fat cream at P_1 pressure; cheese milk for both was standardized to 3.0 percent fat.

Conclusions

Based on the experiments carried out in standardizing the processing parameters for mozzarella cheese making from partially homogenized milk, it is recommended to adopt the following optimized conditions: (a) calcium chloride be added at the rate of 0.01 percent by weight of cheese milk vs 0.005 percent $CaCl_2$ for control cheese milk, (b) the cheese curd should be cooked to a higher temperature (that is, 44°C in 40 minutes vs 35°C for control), (c) adopting whey draining acidity at 0.45 and 0.49 percent LA, respectively, when adopting P_1 and P_2 pressures compared to 0.42 percent LA for control, (d) employing moulding water treatment of 95°C/3–4 min. and 95°C for 2–3 min., respectively, when adopting P_1 and P_2 pressures, respectively, as compared to 99–100°C/3–4 min., for control cheese curd. Employing partial homogenization of cheese milk helped in obtaining mozzarella cheese (pizza type) conforming to legal requirement with attendant improvement in the recovery of fat and protein in cheese, culminating in increased cheese yield; an increase in yield of 8.3–9.6 percent was noted when adopting partial homogenization (based on pressure) and 10.2 percent increase in yield when adopting complete homogenization.

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Our technological powers increase, but the side effects and potential hazards also esclate.

—Alvin Toffler

Analysis of Growth of Exports and Geographic Concentration of Automobile Industry in India

JIMMY CORTON GADDAM

This article studies the export and output relationship of automobile industry besides focusing on geographic concentration of automobile industry exports from India to other countries. This work revealed that there is a significant impact of automobile industry output on its exports. The analysis of geographic concentration of automobile industry exports from India to other countries has revealed that there is an improvement of automobile industry exports to other countries.

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1. Introduction

The supply chain of automotive industry in India is very similar to the supply chain of the automotive industry in Europe and America. The orders of the industry arise from the bottom of the supply chain, that is, from the consumers and goes through the automakers and climb up until the third tier suppliers. However, the products, as channeled in every traditional automotive industry, flow from the top of the supply chain to reach the consumers. Automakers in India are the key to the supply chain and are responsible for the products and innovation in the industry.

The description and the role of each of the contributors to the supply chain are discussed below.

Third Tier Suppliers: These companies provide basic products like rubber, glass, steel, plastic and aluminium to the second tier suppliers.

Second Tier Suppliers: These companies design vehicle systems or bodies for First Tier Suppliers and OEMs. They work on designs provided by the first tier suppliers or OEMs. They also provide engineering resources for detailed designs. Some of their services may include welding, fabrication, shearing, bending, etc.

First Tier Suppliers: These companies provide major systems directly to assemblers. These companies have global coverage, in order to follow their customers to various locations around the world. They design and innovate in order to provide *black-box* solutions for the requirements of their customers. Black-box solutions are solutions created by suppliers using their own technology to meet the performance and interface requirements set by assemblers.

First tier suppliers are responsible not only for the assembly of parts into complete units like dashboard, breaks-axel-suspension, seats or cockpit but also for the management of second tier suppliers.

India's automobile exports have grown consistently, with United Kingdom being India's largest export market followed by Italy, Germany, the Netherlands and South Africa. According to *New York Times*, India's strong engineering base and expertise in the manufacturing of low-cost, fuel-efficient cars has resulted in the expansion of manufacturing facilities of several automobile companies like Hyundai Motors, Nissan, Toyota, Volkswagen and Suzuki.

In 2008, Hyundai Motors alone exported 2,40,000 cars made in India. Nissan Motors plans to export 2,50,000 vehicles manufactured in its India plant by 2011. Similarly, General Motors announced its plans to export about 50,000 cars manufactured in India by 2011.

In September 2009, Ford Motors announced its plans to setup a plant in India with an annual capacity of 2,50,000 cars. The cars will be manufactured both for the Indian market and for export. The company said that the plant was a part of its plan to make India the hub for its global production business. Fiat Motors also announced that it would source auto components from India.

In recent years, India has emerged as a leading center for the manufacture of small cars. Hyundai, the biggest exporter from the country, now ships more than 2,50,000 cars annually from India. Apart from shipments to its parent Suzuki, Maruti Suzuki also manufactures small cars for Nissan, which sells them in Europe. Nissan will also export small cars from its new Indian assembly line. Tata Motors exports its passenger vehicles to Asian and African markets, and is in preparation to launch electric vehicles in Europe in 2010. The firm is also planning to launch an electric version of its low-cost car Nano in Europe and the US. Mahindra & Mahindra is preparing to introduce its pickup trucks and small SUV models in the US market.

The automobile industry since the nineties has led to robust growth of the auto component sector in the country. In tandem with the industry trends, the Indian component sector has shown great advances in recent years in terms of growth, spread, absorption of new technologies and flexibility. Indian auto component industry has seen major growth with the arrival of world vehicle manufacturers from Japan, Korea, the US and Europe. Today, India is emerging as one of the key auto components centre in Asia and is expected to play a significant role in the global automotive supply chain in the near future. The auto component industry is also expected to drive the growth of the engineering sector in view of its strong downstream and upstream linkages with many other segments of the engineering sector like raw materials, capital goods, intermediate products, etc. Auto component industry supports industries like automobiles, machine tools, steel, aluminium, rubber, plastics, electrical, electronics, forgings and machining. India has also emerged as an outsourcing hub for auto parts for international companies such as Ford, General Motors, Daimler Chrysler, Fiat, Volkswagen and Toyota.

2. Reviews of Earlier Studies

R. N. Agarwal (1988) attempted to explain the objective of the study to pinpoint the main causes of the sickness of the industry and then to suggest remedial measures. It appears to us prima facie that the industry is caught in the vicious circle of small size of the market, for its products and near absence of innovations in technology over the three decades. The industry has not developed its own vehicles and the export demand for its vehicles is negligible. Broadly we may classify the causes of sickness under the following heads.

1. Technology and cost structure
2. Government policies
3. Certain other economic factors

Sharipad Bhat Sharipad and Prof. T. V. Setharaman (1995) in their work attempted to explain the main objective of this work to evaluate the effects of technology transfer on the export performance and the determinants of the export intensity of the automobile industry. The empirical literature on technology transfer and export performance shows that no clear cut conclusion can be drawn regarding the relationship between the two.

This article has been divided into six sections. Section 2 presents the analytical background to the issue of technological transfer and export performance in the developing countries. Section 3 describes the methodology and hypothesis to be tested. Section 4 deals with data sources and definitions of the variables. The results and discussions are dealt with in Section 5. The last section summarizes the main findings.

This article also highlights some of the determinants besides technology imports, which are thought to be vital to analysis of the export performance of the automobile firms, such as, size (S), capital intensity (CI), profit (P), foreign share (FE), number of technical agreements (NTI).

P. K. Chugan (1995) in his work attempted to explain an investigation of the factors related to foreign technology vis-à-vis their role in determining the firm's development, adaptation and absorption (DAA) capabilities reveals that while the number of foreign collaboration agreements (FCA) and foreign equity do influence DAA capabilities, the impact is limited, for other technology transfer-related factors restrict the firm's freedom to operate in a manner it deems fit. A comparative analysis of FCA and non-FCA units indicates that inspite of weaker R&D base, the non-FCA units spend more on R&D in relative terms and develop/ adapt larger number of products than the former.

Rajaram Das Gupta (1986) attempted to estimate demand for different categories of commercial vehicles up to the end of this decade (that is, 1990). The author contends that the official demand forecasts are exaggerated because the assumptions about growth of traffic on which they are based are unrealistic. In the light of demand projection the author argues that the current policies of licensing a number of new units is likely to result in under utilization of capacity and consequent loss of economics of scale.

R. N. Agarwal (2001a) in his study has taken the data from fifty-eight large public sector enterprises (CPSE) manufacturing producing goods as well as data from industry groups provided by the Department of Public Enterprises, Ministry of Industries, Government of India for the period 1990–91 to 1998–99. The fifty-eight firms cover more than 90 percent share by sales or gross assets for the entire CPSE.

The objective of the study is to analyse the technological change, technical efficiency and total productivity growth of CPSE, industry group wise and firm wise. The results show that the public sector enterprises have not experienced a significant technological change during the 1990s. Results also suggest that a majority of the firms have low levels of technical efficiency and that the efficiency has not improved significantly over time.

R. N. Agarwal (2001b) examined the impact of globalization on technical efficiency and export intensity of firms. Technical efficiency of medium and large engineering firms (public limited companies) in the post reform period (1992–95) is measured by a deterministic frontier production function based on a cross-section of a firm level data supplied by the Reserve Bank of India. It is hypothesized that technical efficiency and export intensity of firms influence each other. A simultaneous equation model consisting of two equations is specified and estimated by the 2SLS method. It is revealed that the competitive pressure generated by liberalization of economic policies and globalization through the import of technology, foreign direct investment and exports has helped in improving the technical efficiency of firms.

K. B. Akhilesh, K. N. Krishnaswamy and T. R. Mohan Madan (1994), in their study, have taken a step in that direction through a multi-variate analysis of data gathered from eighty-nine manufacturing firms in India. The study found that factors internal to the firm are more critical and the organizational and managerial factors are different for different stages.

This article was conducted to identify the managerial, organizational and environmental variables influencing adoption, adaptation and motivation in manufacturing firms. The data was obtained from a field study; two hundred and thirty firms in capital goods sector located across India were contacted of which eighty-three responded.

Pulapre Balakrishnan, K. Pushpangadan, and M. Babu Suresh (2000) in their investigation of the trend in productivity growth since 1988–89 by using panel data comprising firm level information drawn from groups within manufacturing industry which have experienced the most significant tariff reduction. The sample of 2,300 firms and 11,009 observations, spanning the period 1988–89 to 1997–98 is very likely the largest assembled for the purpose thus far. The writer finds no evidence of acceleration in productivity growth since the onset of reforms in 1981–92. The result is evaluated in relation to the changes till date in the policy regime in the Indian economy.

3. Methodology

In this article the analysis of export output relationship and geographic concentration of automobile industry exports are analysed.

The analysis in this article is under the following heads:

I. Export–Output Relationship

II. Geographic Concentration of Automobile Industry Exports

3.1 Export–Output Relationship

The relationship between automobile goods exports and automobile goods output is observed by applying ordinary least squares (OLS) regression method. It is based on the assumption that output influences exports. Here we also included the dummy variable to know the policy changes after liberalization..The relationship gives the extent picture of export–output relationship in the Indian automobile sector growth and also it can be observed export sector role in this industry.

$$E_{e(t)} = b_0 + b_1 E_{O(t-1)} + b_2 D$$

Where,

$E_{e(t)}$ is the value of automobile industry exports in year t,

$E_{O(t-1)}$ is the value of automobile industry output in year $t-1$,

D is the dummy variable,

b_0 is constant, and

b_1, b_2 are co-efficient of $E_{O(t-1)}$ and dummy variables.

Here exports variable is dependent variable and output variable is independent variable.

3.2 Geographic Concentration of Automobile Industry Exports

The technique most commonly used to estimate concentration in trade is Gini-Hirschman concentration index. Geographical concentration is the concentration involved in distribution of exports among the selected twenty-three countries. However, in this study the treatment of the concept of concentration index is slightly different from other economists who had used in cross country investigations. Since the study concentrates on automobile industry goods and these values are part of total exports and can be defined in partial form as

$$G_e = 100\sqrt{\sum_{r=1}^{P}(X_r/X_E)^2}$$

Where G_e = Co-efficient of geographic concentration of automobile industry exports for a country.

X_r = India's exports of automobile industry goods to r^{th} country.

X_E = Total value of automobile industry exports from India in a particular year.

G_e is used to analyse the India's exports to r^{th} country.

The minimum value to these concentration indexes is estimated from the following formula:

Min. Index Value = 100/($\sqrt{}$No. of Observations)

Here, the Minimum Index Value indicates the zero or no concentration geographically. That means the exports are geographically diversified. Geographic concentration index compared with this minimum index value. The higher G_e than the minimum index value indicates more concentration vis-à-vis.

4. Empirical Results

4.1. Export–Output Relationship

The relationship between automobile industry exports and automobile industry output is observed by applying ordinary least squares regression method. It is based on the assumption that there is no or negative impact of output on exports. To know the policy changes after liberalization, the dummy variable is included in regression model.

The Results:

$E_{e(t)} = b_0 + b_1 E_{o(t-1)} + b_2 D$
(exports) (output) (dummy)

$E_{e(t)} = -1360.44 + 0.158\, E_{o(t-1)} - 1120.301D$

S.E. (955.035) (0.020) (1323.263)

t-values (-1.424) (7.983) (-0.847)

R^2 = 0.828, adj. R^2 = 0.809

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.910	0.828	0.809	2167.43851

A Predictors: (Constant), DUMMY, OUTPUT

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	428327475.464	2	214163737.732	45.588	.000
	Residual	89258004.221	19	4697789.696		
	Total	517585479.685	21			

a Predictors: (Constant), DUMMY, OUTPUT
b Dependent Variable: EXPORTS

Coefficients

Table 1: Regression Coefficient of Automobile Industry Output on Exports

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-1360.440	955.035		-1.424	0.171
	OUTPUT	0.158	0.020	0.970	7.983	0.000
	DUMMY	-1120.301	1323.263	-0.103	-0.847	0.408

a Dependent Variable: EXPORTS

The detailed methodology of this section is provided in the beginning of this article. The second hypothesis of this study is tested here.

The relationship between automobile industry output and automobile industry exports is observed in the following Table 1, taking the automobile industry exports as a function of automobile industry output. Here, exports is a dependent variable, output and dummy are independent variables.

Table 1: Automobile Industry Export and Output Values at Constant Prices (Base 2003–04 prices)

	Automobile Exports		Automobile output	
Year	Current prices (Rs Cr.)	Constant prices (Rs Cr.)	Current prices (Rs Cr.)	Constant prices (Rs Cr.)
1985–86	187.09	786.09	3751.22	15895
1986–87	201.49	1325.59	4337.33	17211.63
1987–88	253.12	1422.02	4614.81	17546.81
1988–89	362.99	1770.68	6116.26	20455.72
1989–90	526.18	1580.12	7861.82	25037.64
1990–91	718.74	2164.88	9384.38	28096.95
1991–92	1223.76	2826.24	8759.62	26384.40
1992–93	1545.74	2961.19	11608.74	33358.45
1993–94	1856.6	3425.46	13190.07	35940.25
1994–95	2421.66	3976.45	19017.78	45936.67
1995–96	3093.8	4573.41	30641.23	63047.80
1996–97	3438.92	4653.48	33483.16	61212.36
1997–98	3452.99	4795.82	32617.59	58245.70
1998–99	3204.8	4021.08	31075.13	46105.53
1999–00	3510.72	4106.11	43423.65	60988.27
2000–01	4531.38	5407.38	41944.09	60091.82
2001–02	4869.07	6063.6	42366.82	56791.98
2002–03	6455.44	7055.13	57356.96	67162.72
2003–04	8988.12	8988.12	70243.88	70243.88
2004–05	12713.94	11017.28	143458.8	137808.60
2005–06	19139.3	16585.18	120728.9	102923.20
2006–07	22398.2	20548.81	140843.8	104406.10

Source: Current prices data is taken from Hand Book of Statistics, Center for Monitoring Indian Economy
Others estimated.

The results from regression in Table 1 revealed that automobile industry output has significant impact on exports and dummy (policy impact) show no significant impact on automobile industry exports.

Export–Output relationship: Regression output on exports

The R^2 value is 0.828 or 82.8 percent indicating that the model is a good fit. The high significance *p*-value of the variable output indicates that the growth of automobile industry output has a significant impact on the automobile industry exports. As a result, the assumed null hypothesis that there is no or negative impact of output of automobile industry on exports of automobile industry can be rejected. On the other hand, the low significant *p*-value of dummy variable reveals that there is no impact of reforms on the automobile industry exports.

4.2. Geographic Concentration of Automobile Industry Exports

India has made links in automobile industry exports with all the regions of the world. The trade most of the times involved concentration, that is, more goods flew to one particular region or country in the region. To measure this concentration in trade, geographic concentration index technique is used. The most commonly used technique to estimate the concentration in trade is Gini-Harschman Concentration Index. However, in this article the treatment of the concept of concentration index is slightly different from other economists who had used in cross-country investigations. Since the article concentrates on automobile industry, due to lack of India's competitiveness to export automobile industry goods to more countries, this article has taken the data in this section from the year 1991–92.

Apart from geographic concentration index, this article computes the minimum index value and coefficient of variation on time using the regression analysis. The minimum index value indicates the *zero* or no concentration country wise. It means the exports are country-wise diversified. Geographic concentration index is compared with this minimum index value. The higher G_e than the minimum index value indicates more concentration vis-à-vis. The coefficient of variation on time shows the changes/ fluctuations in this concentration index. The automobile industry exports for twenty-three countries are included in this article. (The selected countries can be seen at the the end of the article.)

From Table 2 over the period 1991–92 to 2006–07, the degree of geographic concentration country-wise has slightly increased with fluctuations. If we look at the year-wise changes, the concentration value has been steadily increasing till 1996–97 with small fluctuations. The same trend can also be observed even after the year 1996–97 to 2006–07.

The geographic concentration index value stood far from minimum value, which indicates the *zero* level of concentration. The minimum value of geographic concentration for this article with number of automobile industry exports to countries from India is 20.85. In the study period the concentration value started with 60.56 and ended with 69.22 which are almost three times above from the minimum concentration value.

The same is supported by the following trend analysis of the time series of index G_e over the period under consideration. The regression model is used for this. Here, the model is explained.

Table 2: Geographic Concentration Index for Countries

Year	Concentration Index	Index Min value is Base
Min Value	20.85	100
1991–92	60.56	290.46
1992–93	65.13	312.37
1993–94	68.18	327
1994–95	66.83	320.53
1995–96	66.58	319.33
1996–97	71.91	344.89
1997–98	65.04	311.94
1998–99	74.23	356.02
1999–2000	69.57	333.67
2000–01	71.14	341.2
2001–02	71.44	342.64
2002–03	67.1	321.82
2003–04	71.67	343.74
2004–05	70.61	338.66
2005–06	76.15	365.23
2006–07	69.22	331.99
Max Value	100	479.62

Source: Computed based on Hand Book of Statistics and Center for Monitoring Indian Economy data.

Regression Analysis for Geographic Concentration Index:

The model is

$G_{ei} = b_0 + b_1 t$
$G_{ei} = 64.605 + 0.527t$
$R^2 = 0.421$ (42.1%)
G_{e} = concentration index
b_0 = constant
b_1 = coefficient of time

Table 2: Regression Equation Model for Concentration Index

Predictor	Coefficient	SE Coefficient	t	Sig. (*p-value*)
Constant	64.605	1.596	40.467	0.000
Time	0.527	0.165	3.192	0.007

Time is significant in this model.

The results from Table 2 shows that the positive sign in coefficient of the time variable indicates increase in geographic concentration of automobile industry exports. But at the same time the value of time coefficient is very less. The reason is East European countries emerged as a big market for Indian automobile industry whose share has declined after the disintegration of erstwhile Soviet Union. However, this shortfall has been compensated by large exports to develop and new developing markets in the world.

5. Major Findings

1. During the study period the relationship between output and export indicates that the output has significant impact on exports. The high significant *p*-value as well as the positive value of the coefficient of the variable output indicates that the automobile industry output has a positive and significant impact on the growth of the automobile industry exports.

2. The geographic concentration index of the automobile industry minimum value is 20.85 which are taken as 100 for construction of the index. In the year 1991–92 the concentration index 290.46 and has increased to 331.99 in the year 2006–07 indicating that the automobile industry exports to these countries has increased during the study period. These results indicate that the Indian automobile industry sales are increasing in these countries.

6 Conclusions

This article concludes that the relationship between output and export indicates that the output has significant impact on exports. The geographic concentration index of the automobile industry indicates that the automobile industry exports to the countries under the study has increased during the study period. The results indicate that the Indian automobile industry sales are increasing in these countries.

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> *It has become appallingly obvious that our technology has exceeded our humanity.*
>
> ***—Albert Einstein***

TABLES

Table: Automobile Industry Exports to Selected Twenty-three Countries (Current Prices) from Centre for Monitoring Indian Economy. (in Rs lakhs)

Year	Australia	Bangladesh	Belgium	Egypt	France	Germany	Greece	Italy
1991–92	709	2,444	198	2,443	2,224	3,266	1,800	12,052
1992–93	1,264	3,230	548	3,008	2,802	4,367	1,900	11,591
1993–94	1.996	6.608	501	8,276	6,443	5,734	2,100	4,596
1994–95	3,659	16,996	1,582	4,053	5,733	7,408	1,950	3,563
1995–96	4,861	28,955	1,525	4,692	4,799	11,477	3,260	8,682
1996–97	5.523	23,650	2,781	4,365	5,160	10.572	2.810	12,850
1997–98	3.513	12,348	2,706	4,826	6,821	13,615	1,110	18,553
1998–99	4.890	10,520	2,260	8,230	5,860	16,950	19,790	14,480
1999–2000	3.080	17.520	4.460	6.620	8,110	11.930	3.120	14,650
2000–01	4,540	27,730	4,440	6,240	9,190	16,760	1,270	24,120
2001–02	3,760	37,270	1,700	7,070	12,510	22,180	910	22,900
2002–03	4.260	27.720	3,460	9,490	14,300	24.500	4,770	28,760
2003–04	4.350	40,830	14,850	9,060	21,080	31,140	9,400	47,190
2004–05	6,960	26,070	11,230	9,340	49,220	48,130	9,620	70,000
2005–06	9.180	35,450	15,950	19,810	1,11,350	34,160	10,560	90.240
2006–07	15.920	41,750	15,060	33,150	55.780	67.920	21.280	1,11,630

Table Automobile Industry Exports to Selected Countries (Current Prices) from Centre for Monitoring Indian Economy. (In Rs lakhs)

Year	Malaysia	Mexico	Netherlands	Nepal	Nigeria	Singapore	Spain	Saudi Arabia
1991–92	3,461	3,300	1,148	3,795	4,225	2,555	191	758
1992–93	3,194	3,375	2,043	4,708	8,431	4,382	344	899
1993–94	4,040	3.325	6,970	7,325	6,109	4.434	2,282	1,048
1994–95	5,367	2,693	11,990	9,407	3,839	4,093	3,750	1,081
1995–96	3,561	1,123	12,029	7,668	5,291	4,560	10,002	3,859
1996–97	10.231	1,184	15,060	8,545	8,390	8,872	12,664	870
1997–98	11,773	1,462	12,314	8,201	15,002	4,842	9,668	2,134
1998–99	2,010	3,296	12,760	7,700	8,310	1,020	12,290	1,340
1999–2000	3.440	4.760	23,270	12,630	8,940	4,130	9,010	1,980
2000–01	6.600	11,020	11,350	7,120	17,950	4,900	9,780	2,610
2001–02	7.630	20,800	7,560	22,900	24,150	5,560	10,410	2,200
2002–03	7.890	23,420	27.280	22,070	15,480	4.970	2,370	3,140
2003–04	9.150	12,460	29,340	27,250	21,060	13,240	17,350	7,560
2004–05	9,810	45,880	22,950	29,160	13,590	68,300	18,510	14,350
2005–06	49.380	46,870	42,360	25,020	13.830	2,14,880	26,030	15,980
2006–07	8.200	52,260	21,170	26,370	14.940	1,61,650	34,190	21,330

Table: Automobile Industry Exports to Selected Countries (Current Prices) from Centre for Monitoring Indian Economy. (In Rs lakhs)

Year	South Africa	Sri Lanka	Tanzania	Turkey	UAE	UK	USA
1991–92	10	10,400	3,444	1,197	3,606	4,501	6,383
1992–93	11	12,858	6,128	2,004	6,484	7,651	9,450
1993–94	257	17,035	5,384	4,530	5,147	9,496	12,945
1994–95	1,383	26,384	5,697	302	6,207	13,735	20,976
1995–96	4,083	24,970	6,964	2,074	8,226	14,663	28,653
1996–97	6,169	19,280	3,848	3,129	10,086	16,737	54,503
1997–98	9,034	20,400	2,562	2,050	8,417	18,706	34,526
1998–99	4,661	30,440	3,260	4,140	10,090	22,660	30,933
1999–2000	3,400	27,910	2,940	6,420	9,270	20,350	36,285
2000–01	6,740	36,210	3,740	10,480	10,000	27,990	61,587
2001–02	7,480	23,630	3,940	1,680	16,370	25,940	59,318
2002–03	12,470	50,830	3,800	3,830	17,420	27,530	93,373
2003–04	11,120	69,250	7,570	12,010	36,440	90,350	1,02,126
2004–05	36,830	1,03,100	7,770	20,470	48,100	82,650	1,45,741
2005–06	1,31,650	1,41,310	10,150	38,390	1,22,110	68,960	1,83,912
2006–07	1,97,660	1,63,490	12,610	55,880	84,670	81,950	2,51,448

Feature

Economic Analysis of Rural Out-Migration and Its Determinants in Resources-Poor Region of Tamil Nadu

M.THILAGAVATHI, T. ALAGUMANI AND M. UMA GOWRI

The present article made an attempt to assess the value loss in agriculture due to soil alkalinity and to article the influence of affected lands on migration of rural sample households in resource-poor regions of Tamil Nadu. The article was based on the cross-section data from 240 numbers of farm households (160 affected and 80 non-affected) from the resource poor districts (Tuticorin and Ramanathapuram) of Tamil Nadu. The data collection was made through personal interview method and the determinants of migration were examined through probit model. The article resulted that among the major crops the value loss was very high in paddy and coarse cereals followed by pulse crops. To supplement the income loss from agriculture earning members are moving out in seeking employment opportunities at various distant places. Non-farm sources are the major income sources (57.00 percent and 46 percent of total income) followed by on farm income in the sample rural households. The earning members fails in the age group of 20 to 40 years, had education up to secondary level, migrated to nearby areas and short-distance places for seeking employment. The family size, age and education level of potential earners group in the rural families, land quality and wage differentials were the potential factors which determine the probability of migration participation in the rural households.

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1. Introduction

Over the years, degradation of land and water added to the dimensions of uncertainty in agriculture production, employment, environment and economic development. Land degradation is disinvestment in the stock of land if more value than replaced (by nature or man) is extracted from it (UNSO, 1994). Historical evidences show that these problems lead to abandonment of land in the long term. In the short and medium terms, there is adverse productivity impact and also displacement of labour from agriculture (Joshi, 1994). In rural areas of developing economies, the environments are the fundamental source of livelihood.

Exogenous shocks to the environment such as flooding, drought (or), the gradual degradation of natural resources associated with population pressure and human activities could lead to an impoverishment of rural areas and force people to move and seek better employment opportunities elsewhere. Majority of household members are moving outside for earning to supplement crop income under resource degraded situation (Chopra and Gulati, 1998 and 2001) since migration is the survival instinct that drives humans to seek better prospects elsewhere also revealed by the recent worldwide estimates. Traditional economic theory acknowledges the role of expected earning gaps as the primary determination of migration arguing that higher expected earnings in the region of destination would induce people to migrate.

The new economics of migration views the migration decision as part of a household's risk-diversification strategy whereby a household gain from remittances could compensate for market failures in the regions from where they have migrated. Hence, degradation of natural resources as a major cause of migration has been recognized. The estimated land degradation area in India was about 170.5 million hectares (Saxena and Pofali, 1999), of which salinization occurs in 10.1 million hectares. In Tamil Nadu, about 2.9 lakh hectare area under problem soil (Agrostat, 2000). The natural resource degradation led to agriculture less dependent, abandoning agriculture and resulted in rural–urban migration.

It is evinced through several studies that the probable reason for the reduced output could be due to the changes in land quality deterioration caused by the increasing salt content in soil (Joshi, 1987 and 1994; Datta et al., 2004). The income loss in agricultural activities (Datta et al., 2004) due to degradation of natural resources could lead to an impoverishment of rural areas and force people to move outside and seek better employment opportunities elsewhere (Pingali, 1997). It was observed that the output from agriculture is substantially lower in affected farms when compared to that of the non-affected farms. In this context, the present article makes an attempt to assess the value loss in agriculture due to alkalinity in soils and to study the influence of affected lands on migration of rural sample households.

2. Review of Literature

The economic development is always contingent upon environmental sustainability. In 1985, the United Nations Environment Programme (UNEP) introduced the concept of environmental refugees, defined as 'those people who had been forced to leave their traditional habitat, temporarily or permanently because of a marked environmental disruption that jeopardized their existence and seriously affected the quality of their life'. Recent worldwide estimates of environmental refugees reveal that an increasing number of people are being displaced due to environmental changes in the Southern Hemisphere. The estimates suggest the need to explore how environmental changes influence migration decision and the resulting economic implications for both southern and northern regions. Traditional economic theory acknowledges the role of expected earning gaps as the primary determination of migration, arguing that higher expected earnings in the region of destination would induce people to migrate. Earning gaps are traditionally explained by differential in income at employment opportunities. *The new economics of migration* views the migration decision as part of a household risk-diversification strategy from where they have migrated. Accordingly, Joshi (1994) found that the problem soils lead to abandonment of land in the long term. In the short and medium terms, there is adverse productivity impact. At the regional level, the problem soil created problem, the consequences of which had been (a) displacement of labour from agriculture, (b) widening of income disparities and (c) adverse effect on the sustainability of secondary and tertiary sectors. Chopra and Gulati (1998) revealed that the depletion of natural resources and environmental degradation have resulted in reduction of farm productivity and shortage of employment in agriculture, which resulted in the reduction of farm income, restricted choice of crops, low income and land abandonment. The studies by Reddy (2003) and Rao (1994) identified the main drivers of migration as the worsening situation of dryland agriculture created by drought, crop failure, soil quality changes and poor terms of trade in Andhra Pradesh. Pingali (1997) observed that the watershed degradation had imposed negative externalities on low land productivity in Philippines, especially in terms of sediment flow affecting irrigation infrastructure. He found that higher degradation had correlation with higher out migration, unemployment, higher age dependency ratio and school dropouts and higher infant mortality rate. Goldsmith et al. (2004) identified that agriculture production factor have a significant impact on rural–urban migration. The result revealed that the greater urban per capita earnings compared to rural per capita earnings (wage differentials) plus degrading economic conditions in the rural sector play key roles in motivating rural out migration. Yashwant (1962) found that migration was the result of pull factor like availability of adequate land and water resources, better living conditions and employment opportunity at destination areas. The small cultivators and agricultural labours from the resource-poor area were moving to those places in seeking better opportunities. Bogue (1977) in his migration studies tried to break down migration motives into various categories, which were further structured by De Jung and Fawcett (1981) stressing different aspects of the general framework, namely, economic (wages, vacancies, unemployment), social (social mobility, social status), environmental (residential satisfaction) factors, etc.

3. Survey Design and Methodology

The study area (Ramanathapuram and Thoothukudi districts) experiences a hot tropical climate with a minimum of 18 degree Celsius to a maximum of 41 degree Celsius temperature. These districts in general are considered to be drought prone as the mean annual rainfall ranges between 600 and 800 mm. In addition, the nature of rocks (Archacan [precambian] age and quartzites tuffaceous kankar) worsens the soil quality and water bodies. Extensive geophysical and hydro-geological investigations revealed that the quality of ground water varies from alkaline, though potable to high saline and sodic water types in the district. Hence, the rain-fed agriculture is predominant in these districts. To fulfil the objective of the study, the income, employment and migration details were collected from 240 numbers of farm households (160 affected and 80 non-affected) from the Tuticorin and Ramanathapuram districts of Tamil Nadu. These districts are categorized as rain-fed districts with the major soil group of vertisols having sub-soil group of Typic Chromusters. Major area of this soil group was affected through soil alkalinity. The data collection was made through personal interview method.

Three-stage purposive sampling method was followed in the selection of district, taluks and villages. Information from department of agriculture, statistical department was used for selection of taluk and villages in each district. The basic criteria's like cropping area under vertisols, area under problem soils, soils with high soil pH (> 8.5) were used for the selection of sample area and sample population. The field survey was undertaken during the year 2004–05. The survey aimed at collecting wholesome information about the farm households which include the socio-economic details of households, cropping pattern, irrigation sources, severity of problem soils, cost of cultivation and income, employment, consumption and migration particulars of farm households.

3.1 Methodology

Migration is a pre-emptive move. It is the survival instinct that drives humans to seek better prospects elsewhere. The majority of household members are moving outside for earning to supplement crop income. This might be due to poor land quality and absence of better opportunities with in villages. It was observed that the presence of migrants (at least one of its member) in most of the sample households and not seen in few among the selected sample households. Hence, the predictions will lie in the 0, 1 interval for all the factors (x). The requirement of such a process is that it translate the values of the attributes x which may range in value over the entire real line to a probability which ranges in value from 0 to 1. This transformation to maintain the property that the changes in factors (x) included in the model associated with increases (or decreases) in the dependent variable for all values of x responsible for the migration. It is essential to know that the changes in migration participation with respect to changes in the factors (x) responsible for that. It refers the associationship between dependent and independent variable. It needs some transformation to maintain the property that increase in x are associated with increases (or decreases) in the dependent variable for all values of x. These requirements suggest the use of the cumulative probability function. Hence, to capture the household decision on migration participation, probit model (McFadden, 1978) selected to identify the factors that are responsible for migration participation. The probit (probability) model is associated with the cumulative normal probability function. In this model, the decision to participate in migration or not depends upon a theoretical continuous index M_i which is determined by an explanatory variables included in the model. The index M_i was expressed as $M_i = \alpha + \beta x_i$ - where x_i was the 1, 2 ..... i^{th} explanatory variable.

The observations on M_i are either one or otherwise (that is, 1, 0). M_i represents the probability of participation of individual i for the each sample households. Each individual households had some critical cut off value (M_i^*) which translates the underlying index (M_i) into a migration decision specifically the households decides to participate in migration.

if $M_i > M_i^*$ or otherwise if $M_i \leq M_i^*$

This probit model assumes that M_i^* is a normally distributed random variable. So the probability to get participation in migration that M_i^* is less than or equal to M_i can be computed from the cumulative normal probability function. The estimated value of the index M_i can be obtained through the inverse of the cumulative normal function, that is,

$$M_i = \alpha + \beta x_i$$

The probability resulting from the probit model as an estimate of the conditional probability that an each household decide to get participate or migration or not (Pindyck and Rubinfield, 1991). Hence, to estimate the probability of migration participation by sample households, the following model is used.

The empirical model used to study the factors determines household migration decision is as follows.

$$M_i = \beta_1 + \beta_2 X_i + U_i$$

Where, U_i was the stochastic disturbance term.

The specified model for the study is,

M_i = f (FAZ, WDF, LQS, EDN, AGE, DPN, TFZ)

M_i = Probability of participation in migration among households. Thus the dependent variable is taking 1 = if migrants are present and zero otherwise.

FAZ = Total family size in numbers

WDF = Differences in wage rate in rupees

LQS = Land quality scores (Poor = 1, Average = 2, Good = 3)

EDN = Educational level of the migrants (number of years in schooling)

AGE = Age of migrants in years

DPN = Number of dependents in family

TFZ = Total farm size in hectares

These variables are included in the model with the assumption that if the total family size increases in resource-degraded areas migration participation also increases to meet the basic necessities of their family. It was hypothesized that the poor land quality induces more people to outside in seeking job opportunities elsewhere. In this article it is hypothesized that the family size has positive relationship in migration participation. Then through the literature it came to be understood that the presence of young age group family members, education and wage differences (Bogue, 1977; Perloff; 1991; Rao, 2001; Goldsmith et al., 2004) between farm and non-farm sector act as a pulling factor for migrants from the rural to urban areas. Hence, it is hypothesized that these factors have strong positive influence in the probability of migration participation of rural households. Also, it was assumed that if the number of dependents in the family, that is, small kids (less than one year) and aged persons (more than 60 years) and total farm size increases it has negative influence in migration participation since they need more care and maintenance.

4. Empirical Findings

It could be observed from the results of the socio-economic profile of sample households (Table 1) that the earner–dependant ratio of the farm family's, that is, 1.36:1 and 1.43:1 in affected and non-affected farm categories implied that the sample farm families were having the dependants at equal proportion with the minimum increase in earners ratio. It indicates that the dependents (that is, aged and children) needs higher consumption expenses towards their additional care and health expenses which are also concluded through the size of adult consumption unit size at 4.95 in affected and 5.08 in non-affected farm categories indicates the need of increased level of income to maintain the household necessities. It was identified through field research that most of the earners group in agriculture was aged one. Of the total earners, 40.93 percent and 46.20 percent were involved in agriculture (aged group), both in affected and non-affected farm categories. It was indicated that only less than 50 percent of earners are involving in agricultural activities which contributes lesser income share of the total income.

Also, it was observed that most of these agricultural activities are carried out by the adult family members with the age group of above 45 years having better farming experience of more than 20 years which would instil capabilities in them to assess the quality of soil and to take the measures for its proper maintenance implied that the farmers in both (affected and non-affected) farm categories. Then both in affected and non-affected farm categories more than 50 percent of sample farmers had education up to secondary level which empowers them to take decision-making on seeking employment opportunities elsewhere to support their livelihood. This is the similar results with Destaw Berham et al. (2003). He found that education had a positive relationship in non-farm activity participation.

The crop cultivation was taken up by the farmers only from 58 and 62 percent of the total farm size in affected and non-affected farm categories because of the prevailing problems in agriculture like labour scarcity and higher cost of production as well as non-remunerative prices for agricultural product. Paddy, coarse cereals, pulses, chillies and cotton are the major crops grown by the sample households in the study area. Since the study area is located in arid climate more than 65 percent of crop cultivation is under rain-fed cultivation which is also generating lower income to the growers. To supplement the income from agriculture the sample farms in study area are possessed with the animal units size of 1.36 in affected and 1.22 in non-affected farm categories which indicates that livestock (cattle, sheep and poultry) maintenance is one of the important component which augments the level of income of farm families through generating employment opportunities since the agriculture provides employment only for the period of six to the period of six to eight months.

Paddy and chillies were the major crops grown both in irrigated and rain-fed situation in the study area. Also sorghum, bajra and pulses were grown under rain-fed condition. Among the other crops, cotton was grown in wetlands followed by paddy crop. In sample farms, millets (sorghum and bajra) took major share of 26.72 and

Table 1: Socio-Economic Profile of Sample Households (in numbers)

S. No.	Particulars	Affected	Non-affected
1.	Average size of family	5.4	5.52
2	Number of workers	3.14 (57.41)	3.25 (58.88)
3.	Number of dependents	2.30 (42.59)	2.28 (41.30)
4.	Number of farm workers	2.21 (40.93)	2.55 (46.20)
5.	Earner–dependant ratio	1.36:1	1.43:1
6.	**Age**		
	< 35 years	13 (8.13)	1.0 (1.25)
	36–45 years	48 (30.00)	20 (25.0)
	46–60 years	70 (43.75)	46 (57.50)
	> 60 years	29 (18.12)	13 (16.25)
7.	**Education**		
	Illiterate	4 (25.63)	20 (25.00)
	Primary	36 (22.50)	27 (33.75)
	Secondary	73 (45.63)	29 (36.25)
	Collegiate	5 (3.13)	0 (0.0)
8	Average size of farm (in hectares)	2.18	1.54
9.	Area under cultivation	1.264 (58.09)	0.956 (62.13)
10.	Standard animal units in farm households	1.36	1.22

(Numbers in parenthesis indicate percentage to total)

*Affected indicates that the sample farms with problem (alkaline) soil with pH > 8.5.

** Non-affected indicates that the sample farms with neutral soils with pH < 8.0, that is, up to 7.00.

24.16 percent followed by paddy accounted for 22.90 and 24.07 percent in the affected and non-affected farms. Among the commercial crops, chillies occupied major portion with 21.37 and 23.15 percent. It was indicated from Table 2 that the yield damage (value terms) was very high in paddy accounting for 74 percent followed by sorghum with 59 percent in sample farms as propounded by Joshi (1987 and1994) and Datta et.al. (2004) that the yield loss was high in paddy. Next to cereals, the yield loss was very high in pulse crops and it accounted for 63 percent in green gram and 70 percent in black gram due to alkalinity problems in soils.

Because of the resource poor and resource-degraded nature, employment opportunities in agriculture was minimal in the study area. It paves way for seeking better employment opportunities in off-farm and non-farm activities to supplement agricultural income as found by Yeshwant (1962) and Rao (1994). Non-farm sources were predominant in the affected category (52.58 percent) whereas in non-affected sample farms this was only 36.86 percent and on-farm employment constituted 54.10 percent. Off-farm activities constituted only 7.58 and 9.04 percent of the total employment in these categories of farms (Table 3).

Table 2: Area Under Crops and Value Difference from Crops in Sample Households

(Rs/hectare)

Particulars	Area under crops (in ha.)			Gross Margin			Value difference	
	Affected	Non-affected	All farms	Affected	Non-affected	All farms	In Rs	In percentages
Paddy	0.30	0.26	0.28	2,737	10,558	6,648	7,821	74
Sorghum	0 21	0.11	0.16	2,034	4,607	3,320	2,573	59
Bajra	0 14	0.13	0.13	2,897	5,158	4,028	2,261	28
Greengram	0 15	0.17	0.16	4,672	12,484	8,578	7,812	63
Blackgram	0 05	0.05	0.05	2,091	6,996	4,543	4,905	70
Chillies	0 28	0.25	0.27	6.341	13,602	9,972	7,261	36
Cotton	0.10 0.22	0.10 0.00	0.10 0.04	5.343	14,125	9,734	8,782	31
Area under crops	1.45	1.083	1.267					
Cropping intensity	115	113	114					

Table 3: Employment and Income from Different Sources Per Household Per Annum

S. No.	Particulars	Affected	Non-affected
	Employment (in man-days)		
	On farm		
1.	Crop production	139 (22.15)	216 (36.86)
2.	Livestock	111 (17.69)	101 (17.24)
	Total	250 (39.84)	317 (54.10)
	Off farm	47.6 (7.58)	53 (9.04)
	Non-farm	330 (52.58)	216 (36.86)
	Casual Jobs	231 (70.00)	139 (64.35)
	Permanent jobs	99 (30.00)	77 (35.65)
	Total Employment per Household (in man days)	628	586
	Average Earners	3.17	3.25
	Per Earner Employment Days	198	180
	Earnings (Rs in thousands)		
	On-farm	23.94 (35.23)	29.14 (47.61)
	Crop Production	16.70 (24.58)	22.54 (36.82)
	Livestock	7.24 (10.65)	6.60 (10.79)
	Off-farm Income	3.11 (4.58)	3.45 (6.76)
	Non-farm	39.90 (58.72)	27.49 (45.63)
a)	Casual Jobs	27.09 (39.87)	15.61 (25.91)
b)	Permanent Jobs	12.81 (18.85)	11.88 (19.72)
	Total family Income	66.95 (100.00)	60.08 (100.00)

(Numbers in parenthesis indicate percentage to total.)

*Off-farm income defined as the income that includes wages received for agricultural work from other farms, hiring out of farm equipments and bullock power.

*Non-farm income defined as the income received from trade, pension, savings and other services other than agriculture received by all members of the family working in different categories.

As far as rural non-farm employment activities are concerned, infrastructure development construction work and roadwork provided substantial amount of employment to the farm households. In our study area, Prosoplis Juliflora was grown widely. Charcoal production was the major economic activity in both study areas. From the Ramanathapuram district, large number of household members migrated to many places including other states like Kerala, Karnataka and Andhra Pradesh seeking jobs in coir industries (coconut) and to work at harbour. But, the situation was different in Thoothukudi district, endowed with small-scale industries like fire and match works, textile mills, chemical industries and industries of salt corporation of Tamil Nadu and private firms (salt pans), etc. More number of earning members from sample households got employment in these industries. The survey also revealed that the family members got employment opportunities at Chennai, Salem, Coimbatore and Tiruppur through friends and relatives in unorganized sectors on contract basis. The affected farm family members also engaged themselves more in non-farm activities, which seemed to be a better proposition as revealed by better income realized by them through such diversified activities.

Also it was noted from the table that in affected farm households the crop production contributed 24.60 percent of total household income whereas it was 36.82 percent in non-affected farm households (Table 3) indicated that the share of the crop income was lesser than the income from other sources as propounded by Singh et al. (2003). But in sample farm families, the proportion of non-farm income to total household income was higher in affected farm categories, that is, 58.72 percent. But it was relatively less in non-affected farm categories on an account of 45.63 percent since their dependency was more on agriculture they have lesser time to allocate for other activities. The inference could be that the average income in different size groups of farms in the affected category was relatively higher than that of non-affected category, where non-farm income constituted major part of total income, which would mean non-farm occupation paid better for all sample farms in the study area.

Impact of Land Degradation (Alkaline Soils) on Migration Participation

From Table 4 it could be observed that both in the affected and non-affected farm categories, 91.88 and 92.57 percent

Table 4: Details of Migrants among Farm Households (Numbers)

S. No.	Particulars	Affected	Non-affected	Total Farm Households
1	Migrants Families	147 (91.88)	74 (92.50)	221 (92.08)
	Non-migrants (families) Total Families	13 (8.12) 160 (100.00)	6 (7.50) 80 (100.00)	19 (7.92) 240 (100.00)
2.	**Age** Upto 20 years	26 (11.46)	8 (7.4)	34 (10.15)
	21–40	157 (69.16)	76 (70.37)	233 (69.55)
	>40	44 (19.38)	24 (22.22)	68 (20.30)
3	**Education**			
	Illiterate	21(9.26)	3 (2.77)	15(4.48)
	Primary	27 (11.89)	1 (0.93)	28 (8.36)
	Secondary	117 (51.54)	86 (79.63)	208 (62.09)
	+ 2 and above	62(27.31)	18 (16.67)	84(25.07)
4.	**Distance of migration** Up to 20 km	73 (32.16)	49 (45.37)	122 (36.42)
	21–100	65 (28.63)	33 (30.56)	98 (29.25)
	100–300	33 (14.54)	7 (6.48)	40 (11.94)
	> 300	56 (24.67)	19 (17.59)	75 (22.39)
5.	Average Migrants per Family	1.42	1.35	1.38
6.	Percentage of Migrants to Total Family Members	26.3	24.0	25.2

(Numbers in parenthesis indicate percentage to total.)

of the households had migrants in their family. On an average, 26.30 percent and 24.00 percent of the family members including dependents were migrants from the affected and non-affected categories sample households It could also be noticed that the major proportion of migrants of the selected farm households lying between the age group 20 and 40 years. It was 69.16 and 70.37 percent for the affected and non-affected farm categories. This result was coincided with the major findings of Rogers and Castro (1981) and Rossi (1955). They postulated that young adults had the highest propensities to migrate. This would clearly indicate the preference of the most productive category of the working population to opt for non-farm employment to supplement farm income.

An analysis of the education level of migrants of the sample households revealed that 51.54 and 79.63 percent of migrants from affected and non-affected farm categories had education up to secondary level followed by 27.31 and 25.07 percent with education above secondary level. The analysis further revealed that 32.16 percent and 45.37 percent of the migrants were found to migrate to nearby areas followed by short distance migrants accounting for 28.63 and 30.56 percent in the affected and non-affected farm categories, respectively. It could also be seen that 48.39 percent and 26.67 percent of migrants of large holdings in the affected and non-affected categories moved to faraway places seeking jobs because of their better educational qualification to supplement the income loss from agriculture as found by Destaw Berham et al. (2003).

Determinants of Migration Participation among Sample Households

The prevalence of the distress situations (arid climate, problem soil occurrence, etc.) in study area would force mostly the family labour to participate in various activities for their livelihood at various places. They were seeking better employment at distant places. The results of the analysis (probit model) indicated the same. In affected farm categories, the variables, namely, wage differences (0.146) and education level of migrants (0.016) had positive and strong significant association with migration participation which implied that the higher wage rate in non-farm activities and better education level act as a pulling factor to attract the younger productive working group people from the study area since the rain-fed agriculture provides employment opportunities for them only few months. The average age of migrants (-0.139) had significant association but the relationship was negative which indicates that if the age increases the level of migration participation decreases in turn it reveals that the young and middle age group of family members from

Table 5: Determinants of Migration Participation (Probit Estimates) among Sample Households

Variables	Co-efficient	Asymptotic *t* value
Constant	6 9782	2.565 (0.010)
Family Size (numbers)	0 084	1.634* (0.102)
Wage Differences (Rupees)	0.1466	2.690*** (0.006)
Soil Quality (if affected = 1 Non-affected = 0)	0.098	1.817* (0.069)
Education (Years)	0.016	3.026*** (0.002)
Average Age of Migrants (Years)	-0.139	-2.776*** (0.007)
Dependents (Numbers)	-0.187	-0.384NS (0.701)
Total Farm Size (Hectares)	-0.171	-1.569* (0.104)
R^2	0.51	

(Numbers in parentheses indicate estimated *p* values) *** p < 0.01, ** p < 0.05, * p < 0.10.

sample households are migrated to other places. Family size and soil quality had a marginal influence on the migration participation of family members in sample farms. But this study revealed that the proportion of income earned from non-farm activities was very high in affected sample farms and the migrants of the affected farm family moving to faraway places to earn better income to support their families which indicated that the nature of poor quality of soils reduces opportunities in agriculture for the affected farm family members than non-affected category. It was observed that most of the migrants from non-affected sample farms are moving to nearby places only in seeking employment opportunities because they had better opportunities in agriculture. Total area owned also have marginal influence on migration participation in sample farms but it is negative which is inferred that the level of migration participation was low if the farm size increases. Hence, it could be inferred that in the study area prevalence of young age group members in family, wage differences between farm and non-farm work, education level and quality of soil were strong push factors.

5. Conclusion

In this article we have attempted to examine the value loss in agriculture (in terms of income loss) due to alkalinity problem in soils and to assess the influence of affected lands on migration participation in rural sample households of resource-degraded areas of Tamil Nadu. This study seems to be very important to bring out the major economic determinants of migration participation of rural households both in affected and non-affected farm households of resource poor area. Our analysis on value loss from agriculture due to land degradation (alkaline soils impact) indicated that the yield loss (value terms) was very high in paddy and coarse cereals followed by pulse crops than chillies and cotton. In the sample households, non-farm income sources provides major portion of (330 and 216 man days) employment, that is, 53 and 37 percent followed by on-farm activities, which provide employment for 250 and 317 man days, that is, 40.00 percent and 54.00 percent in the affected and non-affected categories. Of the various income sources, non-farm income constituted major portion (57.00 percent and 46 percent) of the total income followed by income (24.58 percent and 36.82 percent) from crop production, both in the affected and non-affected farms. To supplement the income loss from agriculture, earning members are involved in various other activities through migration. Both in affected and non-affected farm categories, 91.88 and 92.57 percent of sample farm families had migrants in their family. On an average, 26.30 percent and 24.00 percent of the family members including dependents were migrants from the affected and non-affected categories of sample households falls in the age group of 20 to 40 years and had education up to secondary level. The proportion of income earned from non-farm activities was very high in affected sample farms and the migrants of the affected farm family moving to faraway places to earn better income to support their families which indicated that the nature of poor quality of soils reduces opportunities in agriculture for the affected farm family members than non-affected category. But most of the migrants from non-affected sample farms are moving to nearby places only in seeking employment opportunities because they had better opportunities in agriculture. The variables such as, wage differences, age of migrants and education level, soil quality and family size act as major determinants for the migration in the sample farms. By which this study emphasized that the prevalence of limited employment opportunities locally and the wage differences between farm and non-farm activities were the major reasons for migration. The nature of soil quality, family size, age and education level of potential earners group in the rural families were the potential factors which determine the probability of migration participation in the rural households. Hence, it is necessary to promote the agro-industrial and other industrial activities of different scales in the rural areas along with the implementation of soil quality improvement programme facilitates to absorb the migrant working force in the resource degraded areas.

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Any sufficiently advanced technology is indistinguishable from magic.

—Arthur C. Clarke

Feature

Fruits and Vegetables Processing in India: Science, Technology and Skill Development Policy Issues

MOHAMMAD RAIS, JYOTI KUSHWAHA AND ADITYA ROHAN

Post-harvest management of fruits and vegetables (F&V) is of great importance in India. India, the second largest producer of fruits and vegetables in world, is having several lacunas in a field otherwise having great potential. This article addresses F&V processing issues in science, technology and skill development, analyses the policy development in the sector and suggests appropriate policy reforms. Opening up of Indian economy post 1991 and its impact on F&V sector, latest policies on Foreign Direct Investment (FDI), food marketing and retail, recent food safety and standard legislation, etc., were studied. Both factor productivity and technical efficiency declined in the decade following liberalization but picked up in the last decade. Technical progress is still quite low and does not contribute much to the productivity growth. Inadequate installed power capacity and low per capita income have been found to be few factors responsible for low number of food processing industries in certain states like West Bengal, Madhya Pradesh and Bihar in spite of substantial production of F&V. Policy recommendations in relation to food safety and hygiene, infrastructure, marketing, technological upgradation, skill development incentives are suggested.

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1. Introduction

Indian traditional agriculture approach and F&V sector in specific does not provide due emphasis to post-harvest management; rather, the focus is on increasing the produce. Value addition of F&V produce is estimated at 7 percent while processing is at meagre 2 percent as compared to 70 to 80 percent processing in other developing countries such as Malaysia, Brazil and Thailand. A target specified for 2011 by expert committee of Government of India (headed by Shankerlal Guru, 2001) that value addition and processing in F&V needs to be raised to 35 and 10 percent, respectively, has not been achieved. Capacity utilization of F&V processing industry was observed to be around 30 percent pre Liberalization Privatization Globalization (LPG) reform era and it could register meagre 15 percent growth in following the decade (1991–2001). Market links are weak and both producer and consumers are losing on the front of fair price. Government has been analysing these issues and working on them in the past with various degree of success achieved on different fronts.

In post-Independence India, the first noteworthy development in the sector was experienced post green revolution, which was focused mainly on staple food like wheat, rice, maize, etc., but the various benefits related to technology, institutions, policies, etc., were absorbed by F&V sector too. Regarding post-harvest policies, another major development which enabled this sector for trade in a transparent, competing and challenging environment was opening up of Indian economy post LPG reforms of 1991. Recent phase of economic reform post global economic crisis of 2008 also gave a boost to the sector by attracting FDI in retail, abolishing restrictive trade practices, etc. Most important among recent government initiatives for the strengthening the F&V sector is announcement of Second Phase of Green Revolution-Shift to Horticulture, which was announced in the Union Budget (2014–15) speech by the finance minister. This will be a technology-driven phase of green revolution with emphasis on higher productivity and a protein revolution.

2. Methodology

The required data was collected from relevant literature and secondary data available on food processing sector was analysed. The data sources are National Sample Survey Organisation (NSSO), Economic Survey (2014–15), Draft Report of Working Group Food Processing Industries for 12th Five Year Plan, Indian Institute of Vegetable Research, Vegetable Statistics, Technical Bulletin Number 51 (2013), Planning Commission, Association for Social and Economic Transformation-Estimation Loss of Horticulture Produce Due to Non-availability of Post-harvest and Food Processing Facilities in Bihar and UP (2003), Annual Survey of Industries (ASI) reports of the year 2012–13, Ministry of Food Processing Industry (MoFPI) strategic plan and others. The NSSO data belong to 59th and 70th rounds. The other reports which were consulted are Emerson Climate Technologies (2013), The Food Wastage & Cold Storage Developing Realistic Solutions Infrastructure Relationship in India (2013). PHD Chamber of Commerce and Industry-India Farm to Fork (2014). Two professional data providers Indiastat and Center for Monitoring Indian Economy (CMIE) were also utilized.

3. F&V Sector—Presence of India on the World Map

India is one of the largest producers of fruits and vegetables in the world and has been consistently ranked as one of the top producers in the world, only behind China. The production of fruits in India has increased from 46,000 tonnes in 2003 to 82,632 tonnes in 2011, while in vegetables the production has increased from 79,000

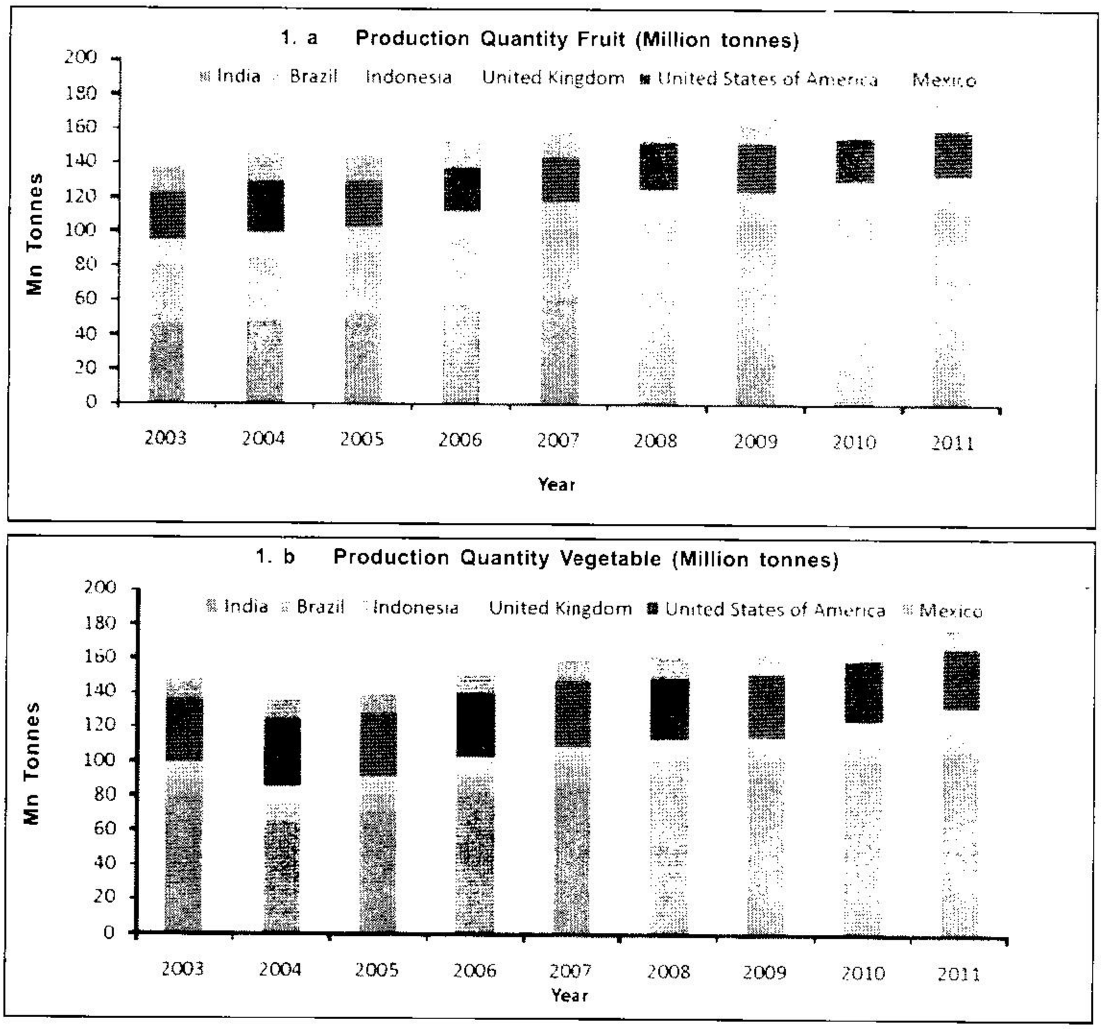
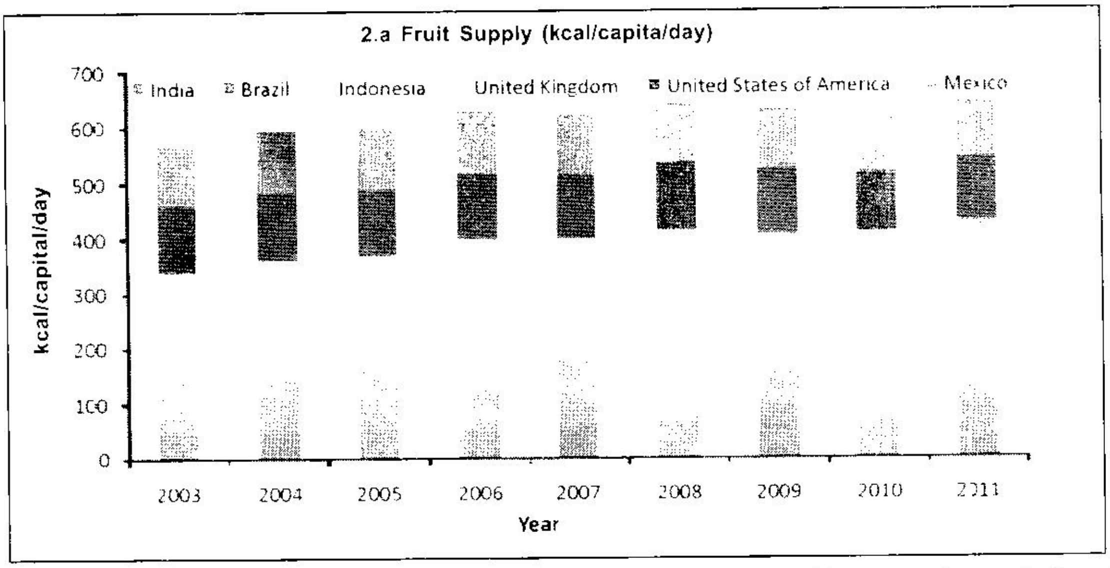


Figure 1: Production Quantity Fruits (1.a) and Vegetables (1.b) Status in Selected Countries



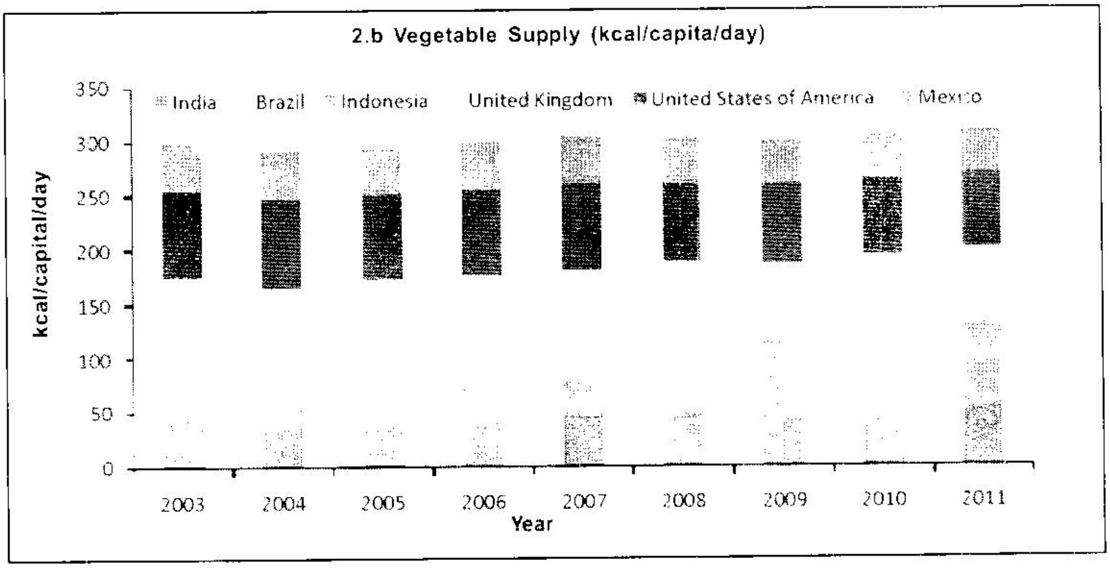


Figure 2: Fruit (2.a) and Vegetable (2.b) Supply (kcal/capita/day) Status in Selected Countries

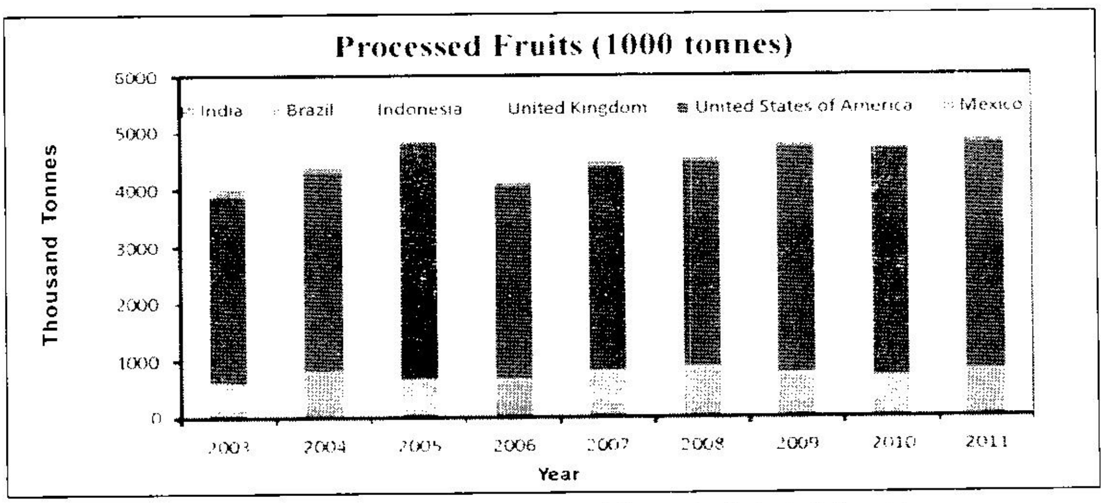
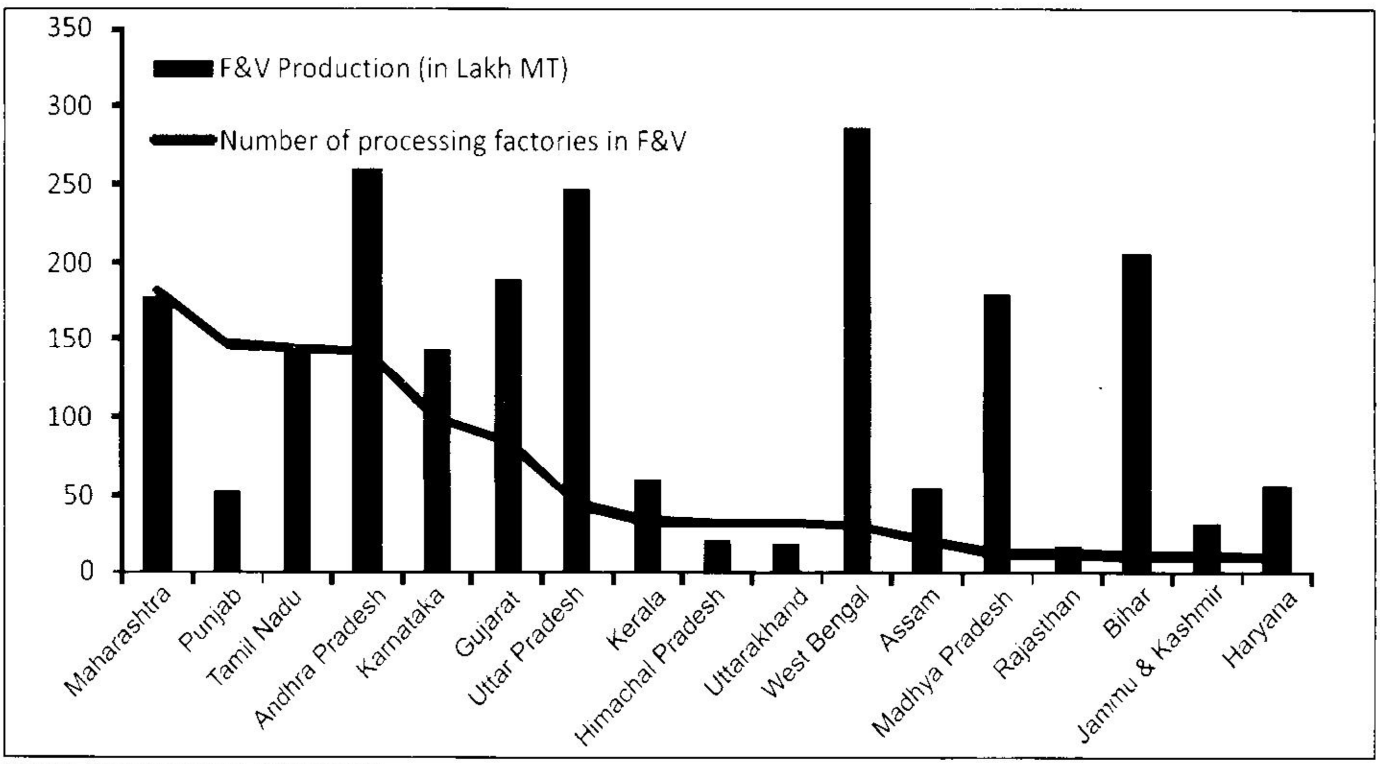


Figure 3: Processed Fruits (1000 tonnes) Status in Selected Countries

tonnes in 2003 to 1,21,000 tonnes in 2011. In general, the production of fruits and vegetables has almost doubled in the years from 2003 to 2011. India has been the top producer of almost all fruits and vegetables like mango, banana, orange, papaya, onions, chilli, tomatoes, cauliflower, etc. India itself accounts for 12.6 percent and 14.0 percent of the total world production of fruits and vegetables, respectively. Out of total production, more than 75 percent is consumed in fresh form and wastage accounts for around 20 percent. In comparison to production, India's ranking in F&V processing is very poor in comparison to other countries. Only 2 percent of vegetable production and 4 percent of fruit production are being processed, which is in sharp contrast to the extent of processing of fruits in several other developing countries such as Brazil (70 percent), Malaysia (83 percent), Philippines (78 percent) and Thailand (30 percent). The number of F&V processing units has increased from 171 in 2003 to 241 in 2011, while in the same time Brazil increased its industries from 385 to 550. The F&V processing industry in India is highly decentralized. A large number of units are in the small scale sector, having small capacities up to 250 tonnes/annum, though big Indian and multinational companies have capacities in the range of 30 tonnes per hour or so. The prominent processed items are fruit pulps and juices, fruit-based ready-to-serve beverages, canned fruits and vegetables, jams, squashes, pickles, chutneys and dehydrated vegetables. Though India's horticultural production base is reasonably strong, wastage is sizeable. Processing and value addition is the most effective solution to reduce the wastage. The analysis is presented in Figures 1 to 3.

4. Regional Disparity in F&V Sector Growth Within India and Its Causes

Analysing the relation between production and commercial processing capacity in different states of India, Figure 4 gives an impression that some states such as Maharashtra, Punjab, Tamil Nadu, Karnataka, etc., have better statistics for processing capacity in spite of having not so massive production as in states like West Bengal, UP, Bihar, Madhya Pradesh, Andhra Pradesh, etc. Tamil Nadu and Punjab in spite of having around half and one-fifth annual production of fruits and vegetables, respectively, when compared to West Bengal, are home to five times more F&V processing units than West Bengal. Additionally, for almost same amount of F&V production, neighbouring states Punjab and Haryana have 147 and 9 F&V processing units, respectively (NHB 2015 report, CMIE Data).

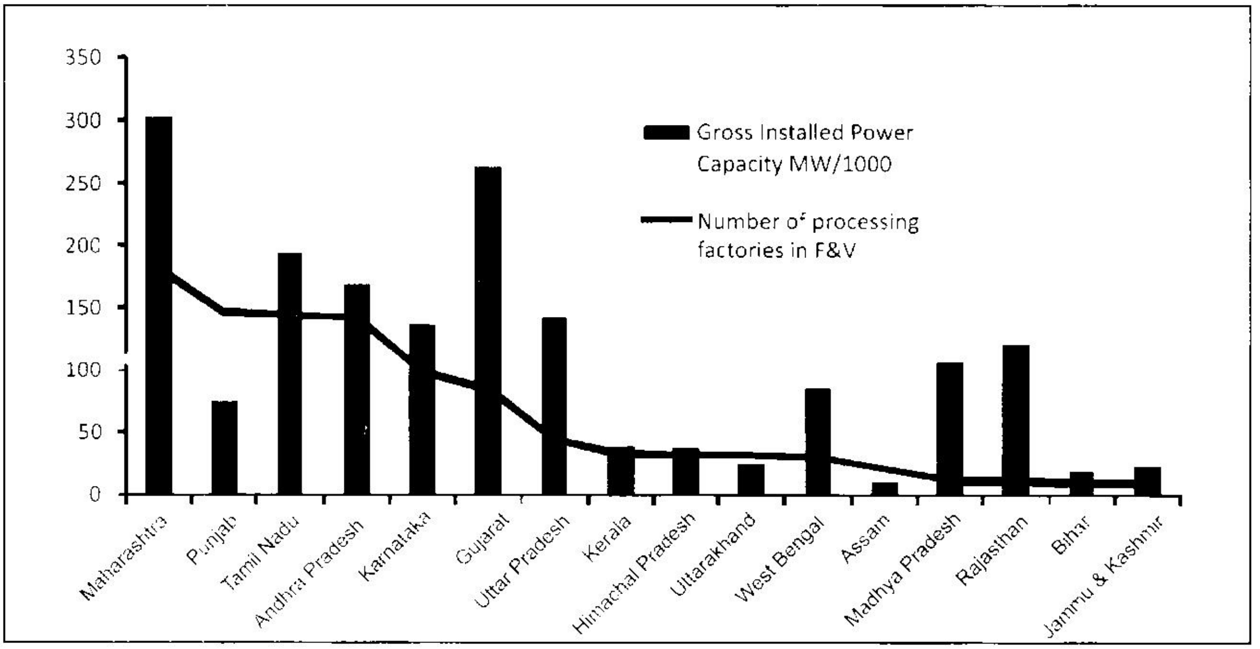


Source: NHB 2015 report, CMIE (2015).

Figure 4: Fruits and Vegetables Production vs Number of F&V Processing Factories (2012–13)

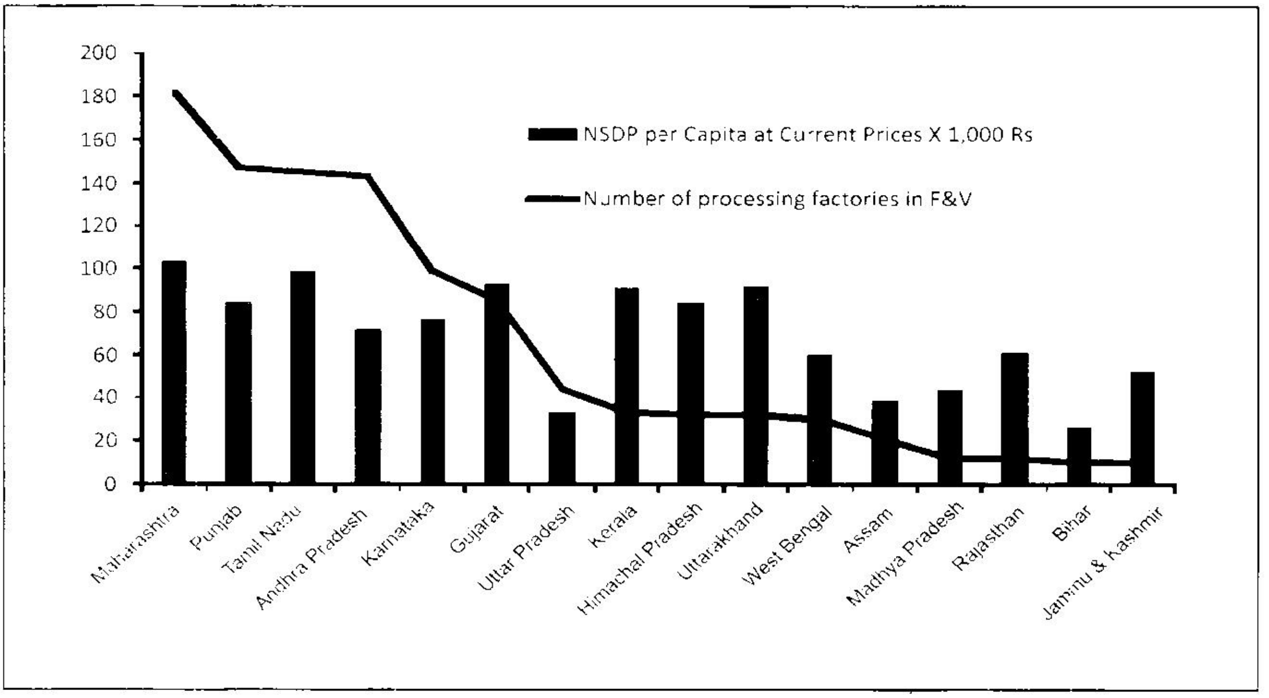
Figures 5 and 6 describe the relation of number of F&V processing units with installed power capacity and Net State Domestic Product (NSDP) per capita, respectively, for different states.

This scenario of regional disparity has some historical reasons including pre-Independence British commercial agriculture policies. Agriculture in India was majorly exploited by these policies which were based on drain of



Source: CMIE (2015).

Figure 5: Gross Installed Power Capacity MW/1000 vs Number of F&V Processing Factories (2012–13)



Source: MOSPI website accessed on 30th September, 2015 and CMIE (2015).

Figure 6: Net State Domestic Product per Capita vs Number of F&V Processing Factories (2012–13)

wealth. The total food grain output during the period 1893–1947 increased at an annual rate of 0.11 percent while non-food grains increased at the rate of 1.31 percent. Bengal–Orissa–Bihar region experienced largest decline in prosperity. Green revolution in 1960s increased the inequality between states. States with rich farmers owning large landholdings who were able to invest in HYV seeds, irrigation, fertilizer and other technical input became increasingly prosperous in comparison to eastern region (Eastern UP, Bihar, Bengal).

After green revolution, next major change in agricultural economy was LPG reforms of 1991. This helped in realizing commercial potential of the sector by enabling a competitive, transparent and challenging environment in trade. India witnessed the entry of number of small and big investors in F&V sector too. Some of these business houses are promoting contract farming by dealing directly with farmer which mostly offers the small F&V producer a better farm gate price (Singla et al., 2011). This development received a boost when FDI was encouraged post global economic crisis of 2008. The food processing sector in India has received around US$6,215.46 million worth of foreign investments during the period April 2000–January 2015 according to

Table 1: Region-wise Inflow of Foreign Direct Investment in India: Amount Rupees in Crores (US$ in millions)

S. No	RBI Regional Office	State Covered	2010–11 (April–March)	2011–12 (April–March)	2012–13 (April–January)	Cumulative Inflows (April 2000–January 2013)	% to Total Inflows
1	Mumbai	Maharashtra, Dadra & Nagar Haveli, Daman & Diu	27,669 (6,097)	44,664 (9,553)	40,909 (7,523)	287,044 (62,144)	33
2	New Delhi	Delhi, Part of UP and Haryana	12,184 (2,677)	37,403 (7,983)	17,020 (3,135)	68,112 (36,207)	19
3	Bangalore	Karnataka	6,133(1,332)	7,235(1,533)	4,342(799)	48,234(10,561)	6
4	Chennai	Tamil Nadu, Puducherry	6,115(1,353)	6,711(1,422)	11,850(2,176)	49,408(10,449)	6
5	Ahmedabad	Gujarat	3,294(724)	4,730(1,001)	2,470(455)	38,893(8,612)	5
6	Hyderabad	Ardhra Pradesh	5,753(1,262)	4,039(848)	5,635(1,037)	36,236(7,846)	4
7	Bhopal	Madhya Pradesh, Chattisgarh	2,093(451)	569(123)	858(155)	4,436(932)	0.5
8	Kochi	Kerala, Lakshadeep	167(37)	2,274(471)	342(63)	4,273(902)	0.5
9	Jaipur	Rajasthan	230(51)	161(33)	556(102)	3,163(655)	0.3
10	Bhubaneshwar	Orissa	68(15)	125(28)	285(52)	1,617(341)	0.2
11	Kanpur	Uttar Pradesh, Uttaranchal	514(112)	635(140)	136(25)	1,584(342)	0.2
12	Guwahati	Assam, Arunachal Pradesh, Meghalaya, Manipur, Nagaland, Tripura, Mizoram	37(8)	5(1)	27(5)	348(78)	0
13	Patna	Bihar, Jharkhand	25(5)	123(24)	41(8)	190(37)	0

Source: FDI Statistics 2012–13, Department of Industrial Policy and Promotion.

Department of Industrial Policies and Promotion (DIPP). To facilitate investors and also to attract more FDI, an *Investors' Portal* was launched by The Ministry of State for Agriculture & Food Processing on 15 October 2013. The portal is intended to disseminate information on the state specific resource potential, policy support and fiscal incentives for food processing sector. The investors, both domestic and foreign, can also seek guidance on specific issues by posting their queries in the *Investor Query* of the portal which will be promptly responded by experts, engaged by *Invest India* exclusively for the purpose on behalf of the ministry.

The point worth noting is that inflow of FDI is not uniform across the states in India. There are various factors which constitute the attractiveness of a state as a destination for investment. Accessibility through ports, road and rail network, presence of critical infrastructure, mode of governance, law and order, human resource are the most important factors among them. On observation of cumulative inflows of past fifteen years we find that Maharashtra and New Delhi obtain major FDI inflows. The FDI inflows obtained by these states account for 52 percent of total FDI inflows. States like Uttar Pradesh, Bihar, Rajasthan, Orissa and North-eastern region receive less than 2 percent of total FDI inflow. Thus, we can see a strong FDI disparity among states for in the producing states they do not have substantial foreign backing for establishment of processing industries. Region wise inflow of FDI in India is presented in Table 1.

In the field of legislation, there have been several reforms aimed at improving post-harvest management in the sector. The need for a separate head for post-harvest policy management was observed and in 1988, Ministry of Food Processing Industries was established which promotes policies for value addition, loss minimization, infrastructure development, tech support, research and development and skill development. Recent legislative reforms worth mentioning in post-harvest management worth mentioning are Model Agriculture Produce Marketing Committee Act of 2003, Food Safety and Security Act (FSSA) 2006, and so on. Some of the currently operational policy initiatives related to horticulture are summarized in Table 2.

One of major reasons of abysmal export of India in Global F&V trade is that most of our produce does not comply with safety and international standards of hygiene.

Table 2: Current Fruits and Vegetables Related Government Missions/Initiatives

S. No.	F&V Related Government Schemes	Launch Year	Salient features
1.	National Horticulture Mission	2005–2006	• Holistic Development of Horticulture with ensuring backward and forward linkages. • Coverage in three Union Territory, Andaman and Nicobar, Lakshadweep, Puducherry and all states except eight north eastern states, J&K, Himachal and Uttarakhand.
2.	Horticulture Mission for North East and Himalayan States	2001–2002 (Earlier Technology Mission for North East for integrated Development of Horticulture)	• Coverage in states not covered by NHM • Aims to harness the potential of region by increasing production and productivity with help of technological development.
3.	Mission for Integrated Development of Horticulture	2014–2015	• Aims to achieve a growth rate of 7.2% in horticulture sector during twelfth plan. • Strategizes on production of quality seeds and planting material, creation of infrastructure to reduce post harvest losses, improved marketing.
4.	Vegetable Initiatives for Urban Cluster	2012–2013	• A component of Rashtriya Krishi Vikas Yojana. • Promotion of group farming. • Protected cultivation of high value vegetable crop like capsicum, broccoli, bhut jolokia, etc.

Government initiatives to address this include the scheme of implementation of HACCP/ISO 22000/ISO 9000/GHP/GMP/Quality Safety Management Systems which was introduced in draft of Twelfth Five Year Plan (MOFPI Report, 2011). One of its objectives was to prepare industry to face global competition in post WTO regime. Other important initiative is FSSA, 2006, which has been drafted to replace the Archaic Act of 1954, that is, the Food Adulteration Act. Few other Acts related to food safety rendered obsolete by FSSA (2006) are Vegetable Oil Products (Control) Order-1947, Solvent Extracted Oil, De-oiled Meal and Edible Flour (Control) Order-1967, Meat Food Products Order-1973, Milk and Milk Products Order-1992. Ambit of FSSA is quite wide when compared with the former Acts because it regulates the manufacturing, storage, distribution, sale and import, ensures availability of safe and wholesome food for human consumption, etc. In F&V sector, this largely concerns with primary/secondary processed food and value added products, their production and marketing.

After a revolutionary first phase, second phase of green revolution is aimed at more emphasis on horticulture which was relatively ignored in the former phase. It will encompass the benefits greatly in the eastern region which is relatively underdeveloped in agriculture. The finance minister mentioned during Union Budget 2014–2015 that 'we are committed to sustaining a growth of 4% in agriculture and for this we will bring technology driven second green revolution with focus on higher productivity and include protein revolution as an area of major focus'.

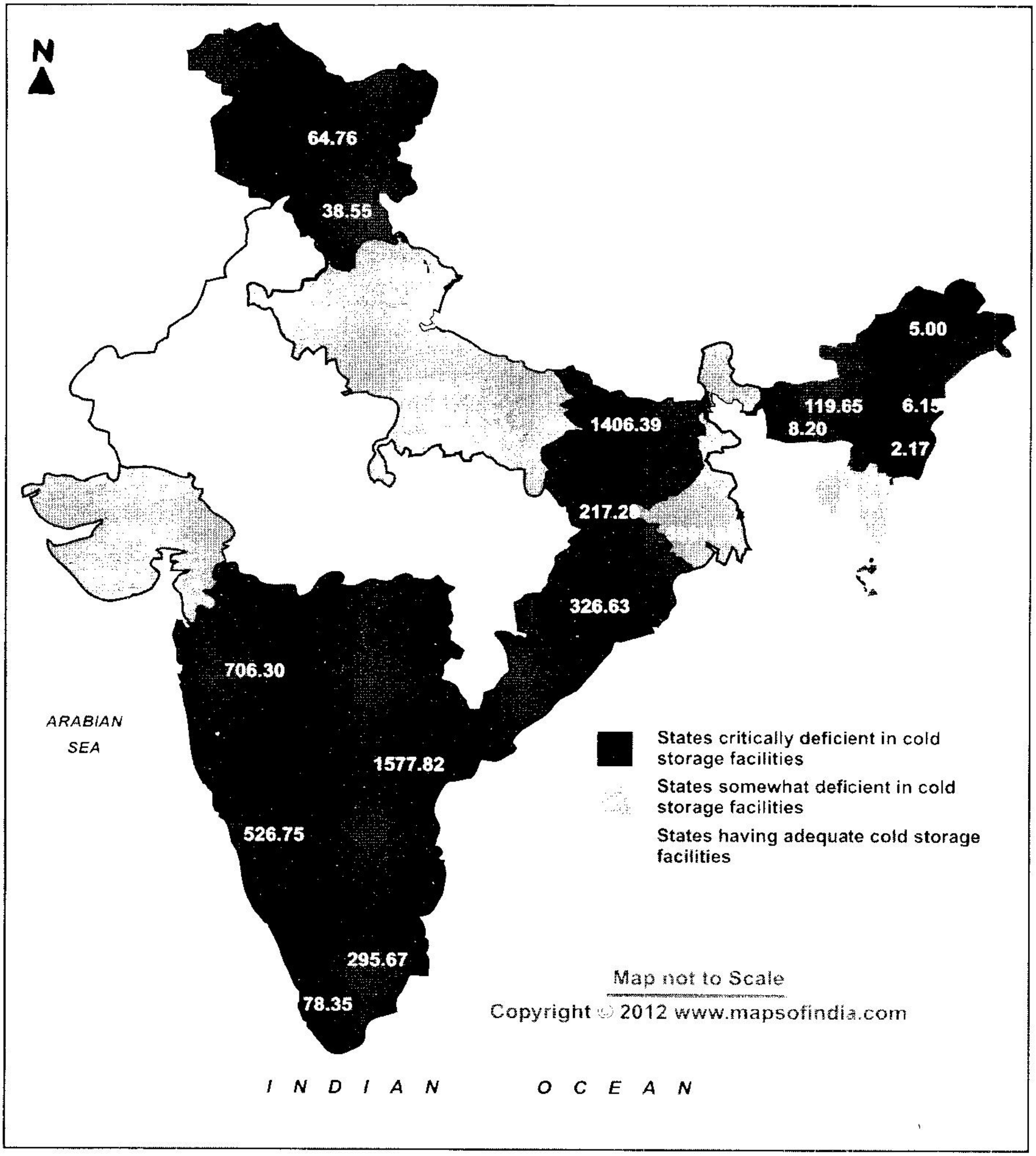
Since agriculture is a state subject, the initiatives of central government and the directive given by centre to states result in various extents of implementation in every state. A suitable example of this is inconsistency in country-wide response of states to the enactment of Model APMC Act 2003.

5. Infrastructure Related to Fruits and Vegetables

i) Cold Storage: As of March 2014, India has approximately 6,891 cold storage facilities, with a capacity of 31.82 million metric tons of the total number of facilities. About 60 percent of cold storages are concentrated in just four states: Uttar Pradesh, Gujarat, West Bengal and Punjab. Figure 7 categorizes states into three regions based on availability of cold storage in thousand metric tons. Uttar Pradesh has the highest capacity of 13.633 million metric tonnes. The remaining states and the bulk of the country remain inadequately resourced (National Centre for Cold Chain Development).

On an average, a farmer needs to carry his horticulture produce as far as 10 to 125 km for renting a cold storage facility according to a study done as a part of socio-economic research by Planning Commission in Bihar and UP. Small-scale cold storage facilities need to be developed at distances which are convenient and economically feasible to travel for the farmer (GoI, Planning Commission Report, 2003). Additionally, since different type of F&V produce need different type of parameters for storage (say, temperature and humidity conditions), there should be different chambers available for such commodities in cold storage houses. Presently, majority of cold storage in country is dedicated to potato crop. Multi-purpose cold store capacity created by India so far stagnates at 7.63 percent against 92.82 percent for potato and 1.07 percent for fruits and vegetables which hardly suffice for 10 percent of our F&V produce (Planning Commission, 2012; PHDCCI Report, 2014). Infrastructure needs to be increased to double and an investment of INR 550.74 billion in new cold storage capacity by 2015–16 is required to keep up with the F&V production increase (Emerson Climate Technologies, 2013). Majority of Indian farmers with low disposable income depend on daily sales and an immediate low price seems more favourable to them than an uncertain higher price after keeping the produce in cold storage for a specific period of time. This combined with lack of access to big markets and price discovery networks make farmers reluctant for investing in rental to the cold storage. Moreover, power shortage and frequent load shedding makes our cold storage less efficient and adds up to the loss.

ii) Mobile Cold Chains: About 105 million MT of perishable produce is transported annually in India. To minimize loss of produce during transportation, a strong network of mobile cold chains with efficient technology is required. In India, cold chain sector is fragmented. Around 85 percent of transportation is covered by cold chain service providers, and rest 15 percent is refrigerated trucks, reefers, etc. Like permanent cold storage is skewed towards potato, here also 80 percent of vehicles are absorbed in dairy industry and 20 percent caters to the need of rest of agriculture produce. Additionally, cold chain sector is also a capital intensive sector, which makes its spread across the nation difficult. The permits for vehicles are also one time, granted for short period of eight years for interstate movement, after which they need to be renewed. Other problems faced by mobile cold chains are octroi, poor roads, traffic congestion, lack of cost effective indigenous technology.

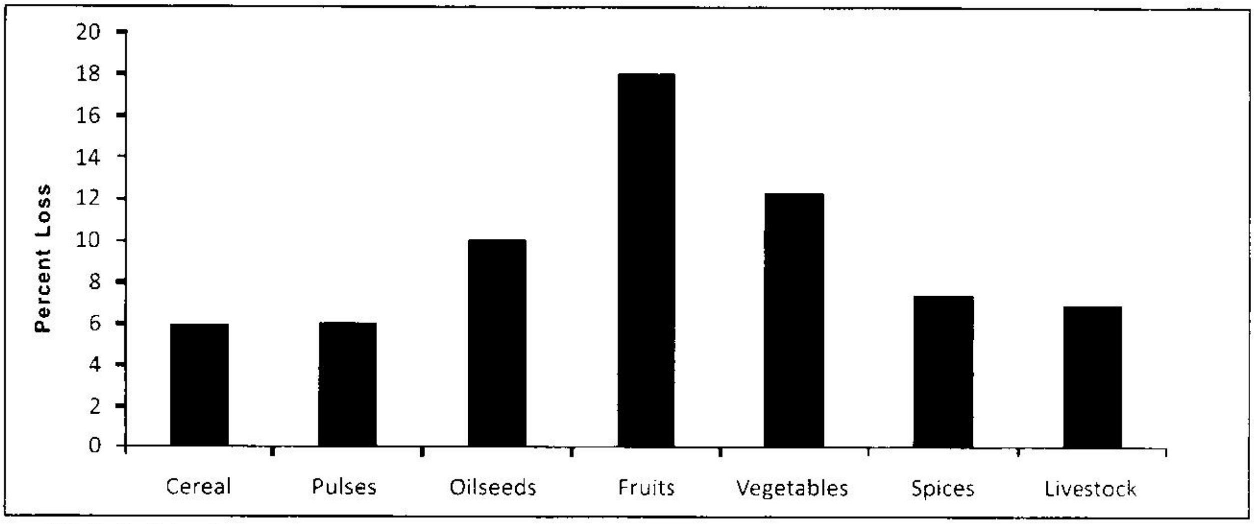


Source: National Centre for Cold chain Development (NCCD), 2014 Report

Figure 7: State-wise capacity of Cold Storage in Thousand Metric Tonnes (as on 31.03.2014)

Technology advancement in F&V Post-harvest Processing in Recent Years: The need for innovation in technology can be stressed by the fact that due to the short shelf life of these crops, as much as 30–35 percent of fruits and vegetables perish during harvest, storage, grading, transport, packaging and distribution. Post-harvest loss of fruits and vegetables in contrast with that of different agricultural commodities are shown in Figure 8.

Major methods to increase shelf life of fruit and vegetable harvest are to delay the ripening of food, storing the harvest in appropriate environment, using protective surface coating, etc.



Source: ICAR, 2010 Study

Figure 8: Percent Post-harvest Losses in Different Agricultural Commodities

The level of food processing in the country is at infancy stage and meagre quantity of agricultural commodities is processed. The growth in Indian food processing industry is mainly constrained due to lack of productivity augmenting technologies as the major quantity of food is being produced in the unorganized sector, where resource utilization is very limited. The analysis suggests that the food processing industry in the country is growing at a rate of 10 percent per annum. The growth in output is driven by the incremental use of input doses. This implies that the average technical inefficiency could be reduced by 10 percent by increasing scale efficiency and eliminating pure technical inefficiencies.

It is also very important to note that technical efficiency scores for food processing industry have declined during 1990s as compared to 1980s. The reasons for inefficiency and low factor productivity change have been analysed in terms of input slacks at optimal level of production process. The analysis of input slacks in food processing industry suggests that the industry is labour intensive and the effects of expansion of food industry on labour employment and productivity appears to be favourable. Analysis shows that food processing industry has been scale inefficient due to slacks in raw material, capital and energy use. Policymakers should use these findings to improve productivity and efficiency in the Indian food processing industry to work out the optimal levels of input mix, to rationalize the process of acquiring and usage of these inputs and to design the proper policy framework to address the identified problems in the food processing sector. The industry needs to modernize its production system to improve the capacity utilization of factor inputs mainly of raw material, capital and energy.

Table 3 shows the estimated average annual rate of productivity and efficiency change in the Indian food

Table 3: Efficiency/Productivity Trend in Fruit and Vegetable Processing Industry (1981–2001)

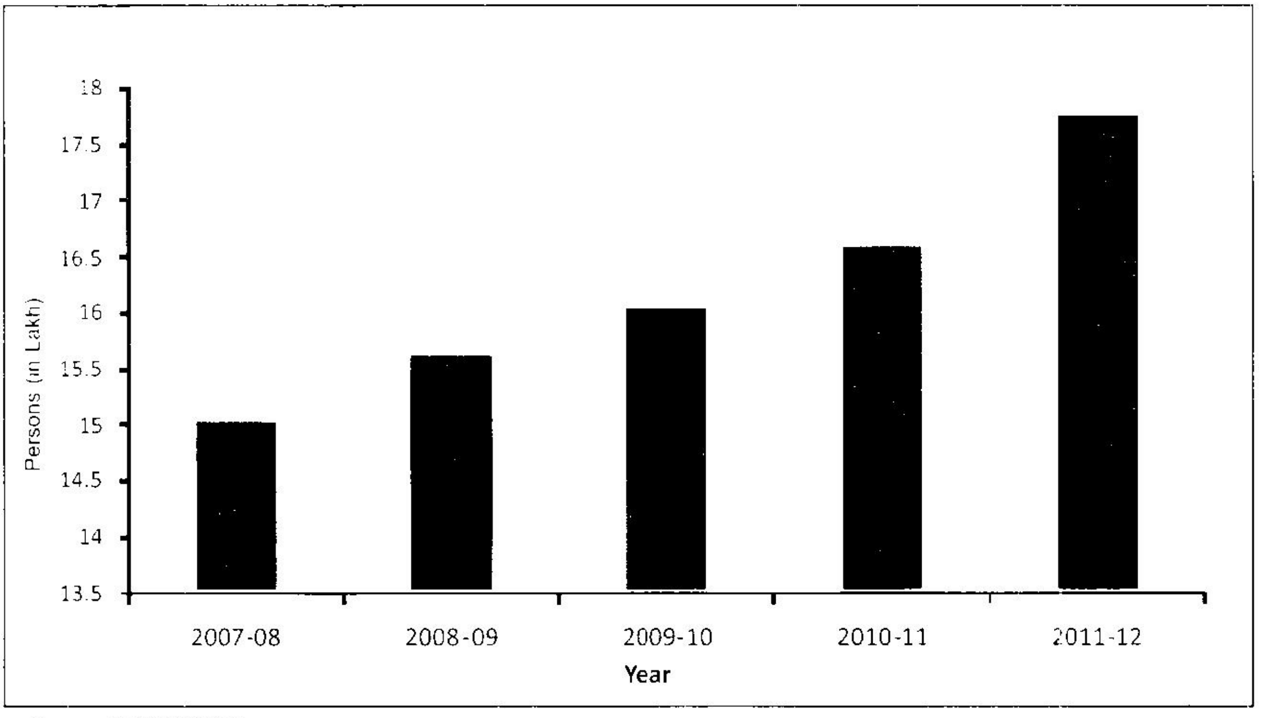
TEYear	Technical Efficiency Change	Total Factor Productivity Change	Gross Value Added (%)
1981–1989	1.03	0.95	7.4
1990–2000	0.97	0.96	4.8
2001–2010	1.02	0.95	4.2

processing industry during the last two decades. The Malmquist TFP index measures the productivity change over period t to period $t + 1$. This output-based index explains the change in productivity level in given level of inputs. The TFP change in a firm occurs either due to technological progress (that is, shift in the production frontier) or due to efficiency improvements in the firm (Hossain and Bhuyan, 2000). A productivity value index larger than one indicates a productivity improvement and a value less than one indicates productivity decline.

Information Dissemination Targeting Grass root Farm workers: The NSSO 70th round survey indicates that about 59 percent of farmers do not get much technical assistance and know-how from government-funded farm research institutes or extension services. To solve this, government has been trying to connect with even the most remote villages, occasionally with the help of private players. Keeping in mind the popularity of television in rural India, recently a channel 'Kisan' has been launched with Doordarshan which will broadcast programmes with an aim of connecting the farmers with new technology advancement, research and development, global standard, price discovery, etc. Additionally, since India has a good rural tele-density of near 50 percent (CCI report, 2015), a Kisan call centre with a toll free number has been started which will provide expert advice to farmers in regional languages related to all aspects of farming.

Human Resource in Fruits and Vegetable Post-harvest Management in India: It is broadly accepted that food processing sector is among the most appropriate sectors for creating jobs for rural poor because of their familiarity with agriculture sector. The multiplier effect of investment in food processing industry on employment generation is also believed to be higher than any other sector. These are the reasons why Twelfth Five Year Plan mentioned special emphasis on mapping the skill gaps and identifying priority areas for human resource development in food processing sector. Figure 9 depicts the rising number of persons employed by food processing sector. Additionally, according to Annual Survey of Industries Report 2012–13, food products related industries provide employment to maximum number of people, that is, 11.94 percent followed by textile, 10.87 percent, and basic metals, 7.85 percent. However, by the same survey, the order is reversed in wages to workers parameter, and food products industry is at the third place.

Profile of persons across the segments of organized sector of Food Processing Sector in India is represented in Table 4. Most of the persons employed are minimally



Source: MOFPI (2011).

Figure 9: Person Employed in Registered Food Processing Units

Table 4: Distribution of Human Resource by Education Level

Total Employment	Industry Aggregate
Employees with management graduation	1–2%
Proportion of food technologist	20%
Post graduates	0.5%–1%
Graduates	10%
Diploma holders	2%–5%
Certificate holders	2%–5%
10th standard or below (those requiring short term/modular training/skill building of some form or the other)	80%

Source: Primary Research and IMaCS analysis.

Table 5: Profile of Human Resources in Food Processing Industries

FUNCTIONS	LEVEL	SKILLS REQUIRED	SKILL GAPS
Operations	Supervisor	• Good documentation skills in order to report the status of production, challenges faced and recommendations to top level management	• Inadequate/limited motivational skills • Inadequate documentation skills/not adapted to working on computers
		• Excellent communication skills so as to effectively interact with workers on daily targets production techniques, quality issues • Ability to take coercive actions in times of crisis to manage issues such as mishandling of goods in plants and output not conforming to requirements	
	Floor Level	• Ability to visually examine fruits and vegetables separate rotten ones from fresh ones • Basic reading//writing skills in order to read the standard operating instructions • Ability to operate machines and set parameters such as temperature, running time of machines specific to process requirement • In the case of manual operations the ability to appropriately size/dice as well as the ability to make end produce visually appealing is critical	• Inadequate knowledge of operations resulting in losses • Lack of knowledge and interest and knowledge in tracking the productivity and improve the same over a period of time
Quality		• Ability to conduct visual examinations and identify unacceptable color / flavor of the fruits procured • Undertake chemical analysis and assess PH levels vis-à-vis the requirement, chemical requirements and biological requirements	• Inadequate ability to apply technical expertise and procedural knowledge in actual work situations, especially at the entry level

educated and most have studied till 10th standard or below. Very few persons have graduate or post graduate degree (not constituting more than 10 percent). There is a severe lack of highly qualified workers in the country and there should be establishment of education centres to enhance the developing skills of workers. Functions of human resources in F&V processing, skill required, level of skill and existing skill gap are mentioned in Table 5.

Labour Requirement in F&V Sector as compared to Food Grain Production: This sector is far ahead of traditional agriculture in the avenue of employment generation. The average labour requirement for fruit production is 860 man days per hectare per annum as against 143 man days for cereal crops. Crops like grapes, bananas and pineapple generate much larger employment roughly from 1,000–2,500 man days per hectare per annum (GoI Planning Commission Report 2003).

Promoting Entrepreneurship and MSMEs in F&V Sector: Given that Indian agriculture is characterized with small land holdings and lack of capital for investment, this sector is highly unorganized and with limited geographical spread. Nearly 70 percent F&V processing units are in the cottage and household sector while around 17 percent are in the small scale sector. For maintaining quality of the produce and promoting entrepreneurship, entrepreneurship development programme and scheme for creating Primary Processing Centres/Collection Centres in rural areas was announced in Eleventh and Twelfth Five Year Plan, respectively (Rais, Acharya and Sharma, 2013).

Table 6: Leading Companies in F&V Processing

Company	Products
Capital Foods	Frozen Foods
Dabur India Ltd	Jams, Pickles, Fruit Beverages
Godrej F&B	Fruit Juices, Fresh F&V(retail)
Green Valley	Frozen Fruits and Vegetables
Hindustan Unilever Limited	Jams, ketchups, Fruit Beverages
Mafco	Frozen Fruits and Vegetables
Mother Dairy (Safal)	Frozen Processed F&V
MTR Foods	Pickles, Chutneys (Dips)
Priya Foods	Pickles, Fruit Juices
Temptation Foods	Frozen Fruits and Vegetables, Purees
V P Bedekar & Sons Pvt. Ltd	Spices, Pickles, Fruits and Vegetables Foods, Gravy Mixes

Source: NSDC Human Resource and Skill Requirements in the Food Processing Sector (2013–17).

Leading companies in F&V processing and their products are mentioned in Table 6.

Price Management at both Farm gate and Consumer Level: As mentioned earlier, the desired link between production, marketing and demand in horticulture produce is missing. The McKinsey analysis on intermediary economics (F&V) shows that farm gate prices available to the farmers is only 25 percent of the retail price in India, whereas the same is as high as 70 percent in case of Dutch and US farmers, where more efficient system is in place. Some of the government initiatives are enlisted further.

a) To mitigate price volatility in agricultural produce, 2014–15 Union Budget includes a provision of a sum of Rs 500 Crore for establishing a Price Stabilization Fund.

b) Advisory for the states to allow free movement of fruits and vegetables by delisting them from the preview of the APMC Act. A number of state governments have acted on the same.

c) Bringing onions and potatoes under the preview of the Essential Commodity Act 1955, thereby allowing state governments to impose stock limits to deal with cartelization and hoarding, and making violation of stock limits a non-bailable offence.

d) Imposing a minimum export price (MEP) of US$ 450 per MT for potatoes with effect from 26 June 2014 and US$ 300 per MT for onions with effect from 21 August 2014.

e) Another initiative for rapid dissemination of F&V market-related information with the help of technology is AGMARKNET-NICNET based Agricultural Marketing Information System Network. It was included as a Mission Mode Project under National e-Governance Action Plan. Earlier, e-Chaupal by private player ITC was based on the same vision.

Conclusions

The following conclusions can be drawn from the study:

a) Agriculture being a state subject renders it important that a holistic view should be analysed while forming policies. Additionally, every state has unique potential and weakness, requiring a state specific policy approach.

b) There is a need to simplify the issues and policies. In institutions there is a lot of overlap of working areas which must be reduced so that there is a clear assignment of role and responsibility among all government bodies.

c) In view of low productivity and poor quality, there is urgent need for effective transfer of technology within the country to improve production, productivity and quality. Certification of testing labs should receive high priority.

d) To get the optimal returns out of opening economy, increase in FDI inflows in, ventures like Make in India - food processing; role of government should shift from controlling to enabling gradually. Linkage with corporate sector and regulated form of practices like contract farming should be encouraged efficiently.

e) Food safety and hygiene standards need to be standardized and strongly complied with. To be at par with global standards, we should internalize practices such as HACCP. Also, Domestic market has to be strengthened in order to maximize exports. Without organized domestic market base, we cannot promote exports. Models like HOPCOM (Horticulture Producers' Co-operative Marketing and Processing Society) need to be created in all the metropolitan cities in the country.

f) For better price management, farmers need to be educated about price discovery, contracts, marketing and other related technical support. Black marketing and hoarding needs to be strictly penalized.

g) In infrastructure there is an urgent need for reforms, such as, building some F&V dedicated cold storage, regulation of Mobile cold chain sector, and easy credit should be provided to aspiring entrepreneurs. Skill development to bridge human resource gap is required.

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Never before in history has innovation offered promise of so much to so many in so short a time.

—Bill Gates

Feature

Counterfeit Processed Food Products: Retailers' Perspective

SAPNA ARORA, ANUPAMA PANGHAL AND SHILPA SINDHU

This article is an effort towards identifying and analysing factors impacting retailers perspective towards counterfeit processed food products. Around 180 retailers were contacted and interviewed regarding their perspectives and factors responsible. Factor Analysis was applied to identify the major factors. Finally, eight factors emerged out like retailer's flexibility, retailer's individual perceptions, social factors, etc. The identified factors may help the policymakers and businessmen to take judicious actions to discourage counterfeit products.

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1. Introduction

The Indian food processing sector is gaining importance due to factors like changing lifestyle, urbanization and Westernization, changed customer preferences. Various initiatives taken by the Government of India towards promoting the Food Processing Sector is also supporting the growth of this sector. Less stringent entry/exit barriers make large number of companies to enter into this sector and existing companies are also into expansion phase. The aim is to provide standard quality goods and services to the consumers with more variety of products at reasonable prices. But what has been observed is that there is emergence and proliferation of counterfeit processed food products which also may pose a serious threat to this sector. Counterfeit products are the fake imitations of products done by few producers for fetching profits. Product counterfeiting may be defined as 'Any unauthorized manufacturing of goods whose special characteristics are protected as intellectual property rights (trademarks, patents and copyrights) constitutes product counterfeiting' (Cordell et al., 1996). 'When applied to food, the consumer product fraud or product counterfeiting is referred to as food fraud, or economically motivated adulteration' (Spink John, 2011). Since the last two decades, the Indian economy has seen changes in various ambits. On one side, factors like increased commerce and FDI leads towards strengthening the economy, on other side factors like low-cost manufacturing status attracts counterfeiters to operate their business for production and sales both. With a matter of effect, growth of spurious, fake and counterfeit products results into a menace to consumer choices, health and economy. Counterfeiting trade in the international market has been growing exponentially in major sectors and the real force behind that are the consumers. India is also amongst the few countries who are notorious for violating

IPRs, and promoting counterfeiting in one way or another (Teresko, 2008). Several times mismatch between supply and demand of products creates more scope for counterfeit business (World Health Organization, 1999). Counterfeiting is gaining momentum these days because of ease provided by the Internet, less costly and easily available technologies for counterfeit products production and distribution. Shaken with the rising incidents of adulteration of food products, manufactured in India and sold locally and abroad, the Food Safety and Standards Authority of India (FSSAI)—under the Ministry of Health and Family Welfare—is all set to usher in a *product recall* procedure to ensure food safety in the country. Counterfeit products lead to fiscal loss to the government, health hazards to consumers and risk to enterprises as well. As per FICCI CASCADE study, 2012, the expected tax loss to the Indian government due to counterfeiting, piracy and smuggling in packaged food products (FMCG) is as follows:

Various studies have been carried out regarding consumers' perception and experiences for counterfeit goods and its find the tendency to buy counterfeit goods is related with consumers' individual perceptions about counterfeit goods and their experiences (Bamossy and Scammon, 1985). But apart from consumers, other stakeholders of the supply chain cannot be ignored as far as counterfeiting is concerned. One of the major stakeholders of counterfeit markets are the retailers, because retailers are the final stage holders in the chain, making the product available to end consumers. This study is an effort towards understanding the perceptions and attitude of retailers towards counterfeit food products. This has been realized greatly that consumers in many cases opt for buying counterfeit goods not only because of their perceptions but also because of the availability provided by the market participants. That is why the role of market participants (retailers/distributors/producers/suppliers) is crucial and worth studying.

S. No.	Industry Sector	Direct Loss (Rs crore)	Indirect Tax Loss (Rs crore)	Total Loss to the Exchequer (Rs crore)
1	FMCG (packaged food)	552	5,108	5,660

Source: FICCI Cascade Study (2012).

2. Literature Review

Watson (2005) showed his concerns regarding fraudulent labelling and also said that there has been an exponential increase in fake food products over the last five years. Wade (2005) reported that illegal imports, product piracy and counterfeiting of food products are threatening the integrity of local industry and posing a serious risk to consumers. Celso et al. (2007) tested a model that integrates the main predictors of consumers' attitude and behavioural intentions towards counterfeits. The author carried out interviews in the streets of selected areas of two large Brazilian cities. Lewis (2009) investigated the reasons, consequences and possible solutions to counterfeit products in America's economy. The paper stated various serious threatening issues of counterfeiting and consumers, government, businesses entities cooperate, then it is quite possible that their efforts will reduce the global incidence of counterfeiting, make consumers safer, eliminate disincentives to innovation and growth, remove opportunities for unscrupulous criminals to finance deadly activities and protect the ideas and concepts that form the backbone of our economy. Alauddin (2012) stated that the adulteration of food products has grown into monstrous proportions. The author suggested some activities which must be undertaken by the Ministry of Health and Family Welfare such as punishments to adulterants, coordination with international bodies like FAO, ISO, WHO and Codex, creating consumer awareness about the programme by holding exhibitions/seminars/training programmes and publishing pamphlet, etc. Hanzaee et al. (2012) provided insights into factors affecting consumer attitude towards counterfeit products and different behaviour intentions based on generation differences. The confirmatory factor analysis has been conducted to confirm the factor structure for measuring consumer attitude from different generations towards counterfeit products. Breyer (2012) questioned on food made in lab rather than the field. Paula (2013) studied the effects of food tempering on consumer health and aimed at understanding and easy identification of counterfeit food. Spink et al. (2013) conceptualized the types of counterfeiters, counterfeiting and offender organizations and provided foundation for developing a method or tool to help organize a complex set of information that assists in explaining the opportunity structure of the problem based on the type of counterfeiting, counterfeiter and offender organization. Tiwari (2014) attempted to show the present status of counterfeit sector in India and also to show various actions initiated to combat fakes and counterfeits. As per the BASCAP, November 2009 Report, 'More than 50 percent of C/P product purchases are carried out in "regular" stores. This is particularly true for medicines and alcohol (more than three purchases out of four are carried out in regular stores for these product categories).'

3. Methodology

This article is an empirical cum analytical study with the major aim of identifying and analysing factors impacting retailers' attitude and perceptions towards counterfeit products on their shelves.

3.1 Sampling and Data Collection

For the purpose of data collection for this article, a survey was conducted in few villages under Sonipat District, Haryana. The primary data was collected through structured questionnaire from retailers. The questionnaire consisted of 28 items related to retailers' opinion towards keeping counterfeit food products. A five-point Likert scale ranging from strongly agree (1) to strongly disagree (5) was used to assign values to each item. Total of 180 respondents were interviewed or discussed with.

3.2 Statistical Tool and Analysis

Descriptive Analysis and Factor Analysis were carried out to analyse the data in SPSS 20.0 version. Descriptive Analysis highlighted few major demographical characteristics of respondent retailers and Factor Analysis identified and grouped major items impacting retailer's opinion towards counterfeit products.

4. Results and Discussion

4.1 Descriptive Analysis

Total respondents under the study were 180 retailers which were having varied years of experience, in which 13.8 percent retailers were having less than 3 years of experience, 15 percent were having between 3 to 6 years, 17.5 percent were having 6 to 10 years of experience and 53.8 percent were having more than 10 years. Apart from the experience, retailers were also being asked for the quantum of sales they are having in their shops, just to have an idea about their business volumes. It was found that 50 percent of the retailers reported a monthly sales of Rs 15,000 to 20,000, around 23.8 percent retailers observed a monthly sale of Rs 20,000 to 35,000, then 13.8 percent had monthly sale of Rs 35,000 to 45,000 and rest 12.5 percent were having sales of more than Rs 45,000 in a month. The retailers were having different Stock Keeping Units (SKUs) and around 47 percent retailers were dealing in less than 10 different types of packed food products, then only 2.5 percent were keeping product ranges between 11 and 15 and rest 50 percent retailers were keeping more than 20 SKUs. These product ranges were for both original as well as counterfeit food products. Further in around 48 percent cases the counterfeiting was observed in confectionary items, then in 15 percent cases it was in beverages, in around 21 percent cases the counterfeiting was observed in bakery items and rest 15 percent was in the case of snacks. Counterfeiting was observed to be carried out in various ways. Most of the products were having similarities with name (47.5 percent), then there were similarities with logos of original brands (6.2 percent) and also there found similarities in packaging also (46.5 percent). The detailed Descriptive Analysis is shown in Table 1.

Table 1: Descriptive Statistics

Particulars	Frequencies	Percentage
Experience:		
less than 3 years	241	3.8
3 to 6 years	271	5.0
6 to 10 years	33	17.5
More than 10 years	96	53.8
Estimated Monthly Sale (Rs.):		
15,000-20,000	91	50.0
25,001-35,000	42	23.8
35,001-45,000	25	13.8
More than 45,000	22	12.5

Product Range:		
Less than 10	83	47.5
11–15	4	2.5
More than 20	93	50.0
Counterfeit Products:		
Confectionery	87	48.8
Beverages	27	15.0
Bakery	39	21.2
Snacks	27	15.0
Similarities:		
Logo	12	6.2
Name	87	47.5
Packaging	81	46.2

4.2 Factor Analysis

Factor Analysis is a tool for data reduction. For the present article, Kiaser-Meyen-Olkin (KMO) and Bartlett's Test measured strength of the relationship among variables. The KMO score came out as 0.63, thereby supporting the tool. The Bartlett's test of sphericity was also highly significant ($p < .000$), thus confirming the correlation between the attributes of the population. The communality value for each attribute came out as 0.55 or higher (Table 2). Total eight factors were extracted as shown in Table 3 which explains total 75.0 percent of variance. All the extracted factors are having eigen values more than one. The remaining factors were not found significant. Table 4 shows the Rotated Component Matrix to reduce the factors on which attributes under study have high loadings.

Table 2: Communalities

Communalities		
	Initial	**Extraction**
Doesn't Contribute towards Endangering Health of Consumers	1.000	.819
Higher Margin Offered by Distributors	1.000	.704
Flexible MRP	1.000	.811
Consumers Get Same Status Symbol at Lesser Prices	1.000	.607
Comfortable Mode of Payment	1.000	.895
Credit Facility from Distributors	1.000	.844
Easy Return Policies	1.000	.836
Buy Back Arrangements	1.000	.666
Availability with Existing Supplier	1.000	.823
Distributors' Influence	1.000	.821
Support Neighborhood and Local Producers	1.000	.701
Surprise Gifts/Cash Coupons Inside Packaging	1.000	.785
Indifferent Towards Keeping Original or Counterfeit Products	1.000	.906
Nothing Unethical in It	1.000	.837
More Sale of Counterfeit Products	1.000	.879
Doesn't Illegal	1.000	.852
Gifts for Retailers	1.000	.615

No Long Term Supplier Contract Required	1.000	.778
No Awareness about Original Products	1.000	678
Local Flavours	1.000	.648
Consumers Want Counterfeit Products	1.000	.758
Affordability	1.000	.647
More Pervasive	1.000	.691
Consumers Get More Variety	1.000	.781
Compete with Other Retailers	1.000	.665
Customized Packing Sizes	1.000	.772
Brand/Originality Doesn't matter	1.000	.757
Contribution Towards Growth of Local Economy	1.000	551
Extraction Method: Principal Component Analysis.		

Table 3: Total Variance Explained (eigen values)

Total Variance Explained									
Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.305	18.945	18.945	5.305	18.945	18.945	3.699	13.212	13.212
2	3.917	13.991	32.936	3.917	13.991	32.936	3.602	12.866	26.078
3	2.747	9.812	42.748	2.747	9.812	42.748	3.323	11.868	37.946
4	2.439	8.710	51.458	2.439	8.710	51.458	2.718	9.707	47.654
5	2.031	7.253	58.712	2.031	7.253	58.712	2.392	8.544	56.198
6	1.930	6.891	65.603	1.930	6.891	65.603	2.177	7.775	63.974
7	1.549	5.532	71.134	1.549	5.532	71.134	1.638	5.850	69.824
8	1.208	4.313	75.448	1.208	4.313	75.448	1.575	5.624	75.448
9	.995	3.552	79.000						
10	925	3.304	82.303						
11	.878	3.135	85.438						
12	.762	2.723	88.161						
13	.551	1.969	90.130						
14	.505	1.805	91.935						
15	.481	1.718	93.653						
16	.427	1.524	95.178						
17	.343	1.226	96.404						
18	.318	1.134	97.538						
19	.219	.784	98.322						
20	.157	.561	98.883						
21	.107	.381	99.264						
22	.072	.256	99.520						
23	.050	.180	99.700						
24	.034	.121	99.821						
25	.021	.077	99.898						
26	.016	056	99.954						
27	.010	.036	99.990						
28	.003	.010	100.000						

Extraction Method: Principal Component Analysis.

Table 4: Rotated Component Matrix

	Component							
	1	2	3	4	5	6	7	8
Doesn't Contribute Towards Endangering Health of Consumers			-.550					
Attractive Shapes/Packaging				-.609				
Flexible MRP	.613							
Consumers Get Same Status Symbol at Lesser Prices					.615			
Comfortable Mode of Payment						.928		
Credit Facility from Distributors						.824		
Easy Return Policies	.768							
Buy-Back Arrangements								
Availability with Existing Supplier	.548							
Distributors' Influence		.778						
Support Neighborhood and Local Producers		.612						
Surprise Gifts/Cash Coupons Inside Packaging				.835				
Indifferent Towards Keeping Original or Counterfeit Products			.819					
Nothing Unethical In It			.834					
More Sale of Counterfeit Products	.863							
Doesn't Illegal			.566					
Gifts for Retailers								.674
No Long Term Supplier Contract Required								-.697
No Awareness about Original Products							.521	
Local Flavours				-.604				
Consumers Want Counterfeit Products					.839			
Affordability					.599			
More Pervasive			-.624					
Consumers Get More Variety		.824						
Compete with Other Retailers		.659						
Customized Packing Sizes	.756							
Brand/Originality Doesn't matter							.823	
Contribution Towards Growth of Local Economy		.653						
Extraction Method: Principal Component Analysis.								
Rotation Method: Varimax with Kaiser Normalization								

Eight extracted factors based on loading of different items that account for 75 percent of total variance are shown in Table 5 and are explained below.

Table 5: Factors Extracted from Factor Analysis

S.No.	Factor Description	Variables Included
1	Retailer's Flexibility	▪ Flexible MRP ▪ Easy Return Policy ▪ Availability with Existing Supplier ▪ More Sale of Counterfeit Products
2	Social Factors	▪ Distributors' Influence ▪ Support Neighbor-hood and Local Producers
3	Retailer's Individual Perception	▪ Doesn't Contribute Towards Endangering of Health ▪ Indifferent Towards Keeping Original or Counterfeit Products ▪ Nothing Unethical In It ▪ Doesn't Illegal
4	Product-related Factors	▪ Attractive Shapes/ Packaging ▪ Surprise Gifts/Cash Coupons Inside Packaging ▪ Local Flavours
5	Consumer Response	▪ Get Same Status Symbol at Lesser Price ▪ Consumer Want Counterfeit Products ▪ Affordability
6	Flexible Financial Facility	▪ Comfortable Mode of Payment ▪ Credit Facility from Distributors
7	Ignorance	▪ No Awareness About Original Products ▪ Brand originality doesn't matter
8	Relationship with Supplier	▪ No Long Term Supplier Contract ▪ Gifts for Retailers

1. Retailers' Flexibility

The most significant factor which emerged is that retailer's feel more flexibility in context to profit making by keeping counterfeit goods in their shop. Few retailers feel they can have flexible MRP for counterfeit food products because of various obvious reasons. Retailers also find the product return policies much flexible, and many of the times more availability is there with the existing suppliers. Few retailers have observed quantum of sale of counterfeit products is more as compared to original brands, may be because of reasons like affordability by customers. The same has been discussed by various other authors, as stated by Lewis (2009), 'Counterfeiting is so prevalent in part because it is extremely lucrative. Unscrupulous merchants can generate staggering profits from counterfeiting operations.'

2. Social Factors

Many of the times retailers opt for keeping counterfeit products because of persuasion by their local distributors. Many of the times retailers believe that promoting counterfeit products which are manufactured by the local producers would support the neighbourhood development and growth of local producers. So, personal acquaintances many times impact the decision of retailers. Retailers operating in rural areas intend to support the local producers especially from their own village because of all apparent sympathetic factors. Retailers believe that this is one of the ways to oblige their acquaintances, many times for future also. Also, convenient availability of the counterfeit products is also one big reason for retailers to keep these products. It has been realized that if the counterfeit goods can be made easily available then their purchase frequencies will be increased (BASCAP, November 2009).

3. Retailers' Individual Perception

Majority of respondent retailers of the study were found less informed about the impacts of counterfeiting. Retailers were found indifferent towards keeping the original or counterfeit products and also they find nothing unethical in keeping the counterfeit products on shelf and also nor they find it as illegal. Also, many retailers believe that counterfeit food products may not pose any type of threat to health of consumers, so do not feel it as harmful. Majority of retailers interviewed for the study were not having good level of education; rather, many were missing the elementary one. In absence of education and training or information, much cannot be expected from them also. In Indian rural scenario, much of the supply chain participants, which include retailers also are into this business just with the prime motive of making profits.

4. Product Related Factors

Many of the retailers keep the counterfeit food products because their customers find the shapes or packaging of products as attractive. In some products there are options like surprise gifts/cash coupons inside the packets which attract the customers. Also, in some cases retailers feel that people like the flavour of counterfeit products as compared to original branded ones because of some touch of their local flavours. The shapes or the designs or packaging styles of the original product are being copied by counterfeiters and many times, by doing this the products becomes rather more attractive for rural or local communities. Counterfeiters being aware about this fact, try to misuse this fact.

5. Consumer's Response

Many retailers claim that the decision of keeping counterfeit products is actually because of customer's perception and response towards counterfeit food products. They believe consumers themselves like and demand for counterfeit products because of their affordability or getting more volume or quantity at comparatively lesser price. 'The price for a counterfeit product of a luxury brand is just a fraction of the price of a genuine product and people tend to buy counterfeit products to reduce the risk of buying the original for a lot of money. Many times consumers relate it with their tendency of conspicuous consumption they feel they can get same status symbol at lesser prices. 'Consumers buy counterfeit products as status symbols to classifying themselves into a prestigious social group where they want to belong' (Arvid, 2012).

6. Flexible Financial Facilities

Retailers find that distributors of counterfeit food products sometimes provide more options like comfortable mode of payment, may be in form of instalments, etc. Also, retailers can avail credit facility from distributors at the hour of need. Rural retailers find financial flexibilities as one of the most attractive option. Usually it was observed that counterfeiters use this opportunity to get the retailers support in their unscrupulous business growth.

7. Ignorance

Ignorance about counterfeit food products is also one of the major factors impacting retailers' perspectives towards counterfeit goods. In many cases, the retailers were actually not aware about the existence of original product or brand and that the product which they are selling is actually a counterfeit version. Few of the retailers, even if were aware about the original products, but actually were not bothered to keep original products in place of counterfeit products.

8. Relationship with Suppliers

Retailers several times prefer to keep the counterfeit food products in their shop because of their personal relationships with the suppliers of the products. Because mostly suppliers are from unorganized sector, they do not expect or look for long-term formal contracts; rather, they mostly deal with flexible arrangements. Also, retailers want to get associated with them sometimes in lurance of other benefits in kinds.

5. Conclusion

The study has highlighted few major factors which can impact the retailers' perspective towards counterfeit food products. These factors although not so exhaustive ones but still can help the policymakers and businessmen to take necessary steps in the direction of discouraging and restricting the entry of counterfeit food products in the market. The global anti-counterfeit packaging (food and beverages) market has generated revenue of $26.4 billion in 2014 and is forecast to reach $62.5 billion by 2020, at a CAGR of 16.1 percent over the forecast period (Report by Allied market Research). The Prevention of Food Adulteration Act, 1954, empowers government agencies to seize and confiscate *adulterated* or *misbranded* goods and also to suspend manufacturing licenses of manufacturers. The government should take a holistic view on counterfeit and fake products in order to maintain international food standards. In absence of strict legal penalties to the counterfeiters (producers as well as distributors) they put very little concern on negatives of counterfeiting. Also, the retailers or distributors involved in selling of counterfeit goods are equally responsible for promoting this illegal and unethical market. The retailers as well as consumers need to be educated enough about the drawbacks of counterfeiting. The manufacturers of counterfeit food products would find it difficult to encourage the sale of such products if other supply chain partners and the consumers become reluctant in participating. Also, the manufacturers of original branded products need to be alert and proactive. The products and the business need to be protected by way of Intellectual Property Rights. Every manufacturer should get their products protected either by patents, or trademarks, or industrial designs, or copyrights. whichever applicable. Each and every food supply chain participant needs to understand that counterfeiting in case of food products is actually much more dangerous than in any other products. Any type of food adulteration may lead towards serious health hazards for consumers. Any business apart from to be seen from profit motive aspects should also consider the ethical front of that. Sustainability of any business activity relies on its ethical conduct as well as maintaining quality standards. This study actually tries to cover various such above mentioned interrelated factors so as to come to a conclusive fraction.

6. Future Scope of Study

One of the biggest limitations of this article is that the authors have missed studying the impact of legal structure and rules and regulations with respect to counterfeiting in India. The future work will therefore be in the direction of studying and analysing the impact of formal legal system in India on the practice of counterfeiting. The type of penalties and punishments associated with the type of crime will be studied and later on an effort would also be done to educate the retailers and consumers about the negative side of counterfeiting.

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One Machine can do the work of fifty ordinary man. No machine can do the work of one extraordinary man

—Elbert Hubbard

Feature

Evaluation of Kaizen Technique Across Manufacturing Unit—A Case Study

JAGDEEP SINGH AND HARWINDER SINGH

Kaizen is a management approach of achieving major enhancement in a process through small incremental improvement. In the present article, CI strategies are applied to the manufacturing system processes. Kaizen Improvement projects are performed to enhance the performance of manufacturing operations by small incremental changes. Results indicate the significant increase in MTBF of the production equipments. Policy Deployment X Matrix has been used to apply CI strategies for significant increase in MTBF of production equipment.

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1. Introduction

Manufacturers have realized the need to continuously improve their operations to compete successfully. In an effort to increase organizational capabilities, companies have made investments in programmes such as Just-in-Time and Total Quality Management. However, benefits from these programmes have often been limited because of unreliable or inflexible equipment. Therefore, many looked towards TPM, JIT and TQM programmes in a drive for continual improvement. In order to achieve world-class performance, more and more companies are undertaking efforts to improve quality and productivity and reduce costs. For more and more companies, part of this effort has included an examination of the activities of the improvement function (Tajiri and Gotoh, 1992). Product quality is important in the manufacturing industry to ensure that a company has competitive advantage in the market. Thus, when a product is manufactured by a machine works without complying with the prescribed specifications, the product will be marketed. When the repulsion is high then it will affect the cost of having to bear losses and wastage. Therefore, in order to avoid this, the company should take some steps in handling this problem (Dale, 2006). The continuous improvement strategies are shown in Figure 1.

Any industry needs to keep proper vigilance for producing product without defect, reducing product rejection and wastage, reducing equipment breakdown and down time, increasing worker and equipment efficiency, maximize equipment and manpower utilization, eliminate accident of any types. Continuous improvement is the new concept evolving to meet this tremendous requirement of the modern competitive industry. It ensures the maximum use of the existing equipment and performs the increased production within regular working hour to achieving the cost reduction without sacrificing the product quality. Any company can achieve production efficiency and other

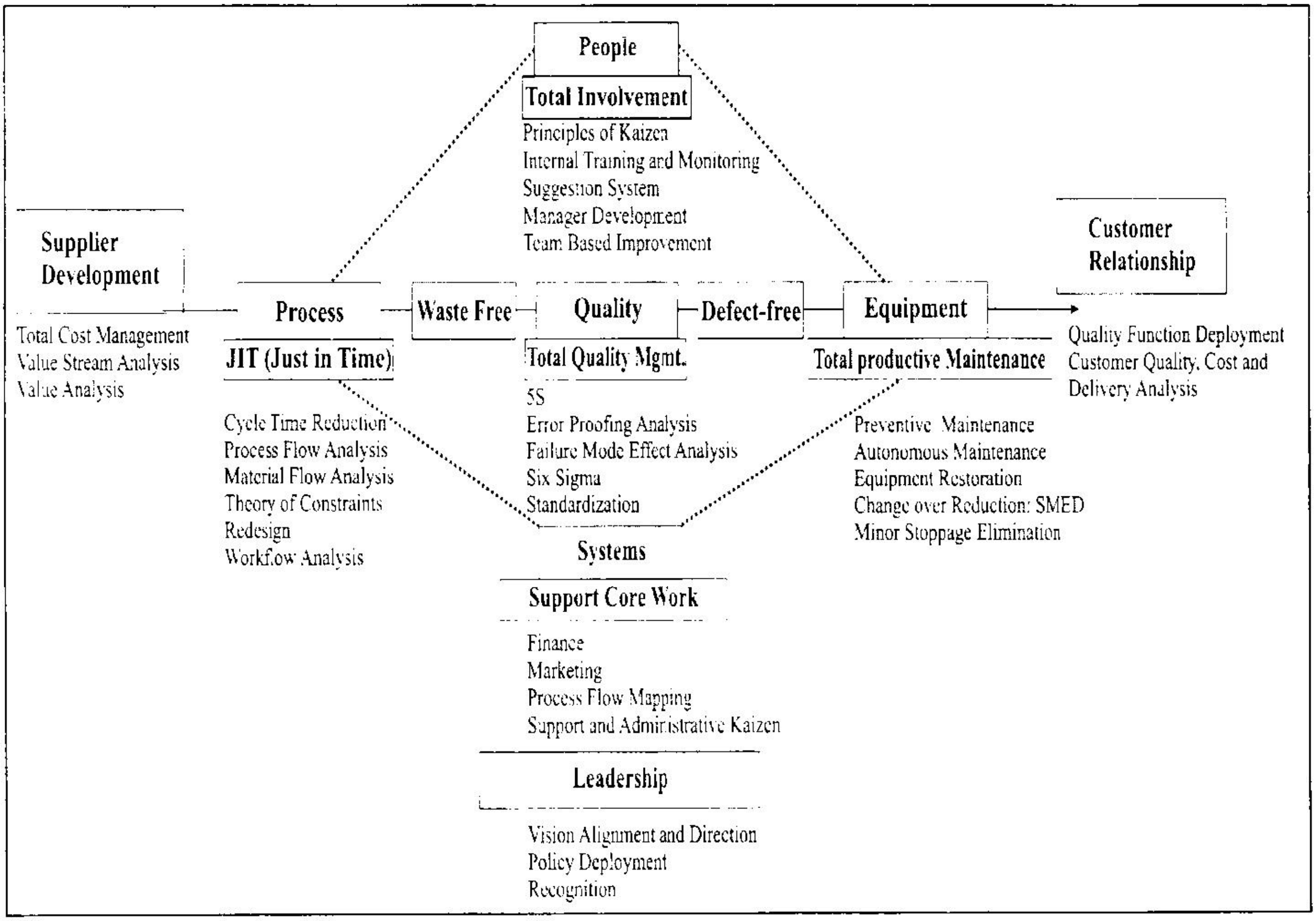

Figure 1: Continuous Improvement Strategies

excellence by successful utilization of the Kaizen concepts and the tools and techniques of the Kaizen. As a result, companies are applying these strategies to enhance the performance of manufacturing system processes. This study is an attempt to access the performance of CI strategic implementation in a manufacturing unit of northern India. The KIPs have been performed to access the policy deployment goals for strategic success. The CI strategies applied includes preventive maintenance, internal training and monitoring and standardization.

2. KIPs, MTBF and OOE

Kaizen improvement projects are continuous performance improvement activities. It is never ending process. As per Figure 2, the saving increases continuously as time increases. But in Small Group Activities (SGA), the improvement is one time and we try to maintain the achieved level.

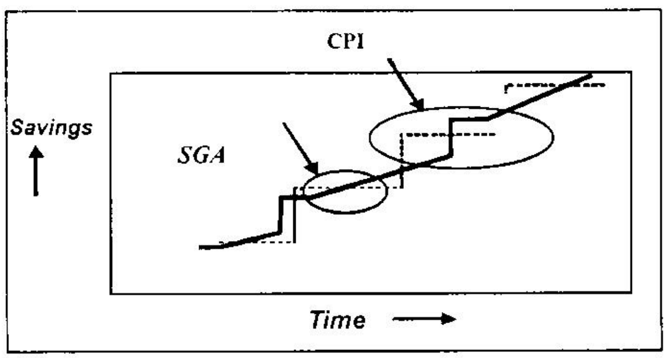

Figure 2: Continuous Performance Improvements

MTBF: Mean time between failures (MTBF) is the predicted elapsed time between inherent failures of a system during operation. It can be calculated as the arithmetic mean (average) time between failures of a system. It is calculated by using formula:

$$\text{MTBF} = \frac{\text{Total Production hours} - \text{Total breakdown hrs}}{\text{Number of breakdowns}}$$

OOE: Overall Operator Efficiency measures the utilization, performance, and quality of the workforce and its impact on productivity. It is calculated by using formula:

$$\text{Overall Operator Efficiency} = \frac{\text{Total pieces made by an operator* SAM of operation}}{\text{Total hours worked *60 min}}$$

3. Case Study Setting and Identification of KIPs

3.1 Introduction to Company

The Company A was founded in 1984 having more than 2,700 employees. The plant is concerned with manufacturing and supply of forgings, components and assemblies for three-point linkage for tractor farm equipments and Jondier tractor. It is equipped with a wide variety of CNC, VMC and conventional machining equipment. The main aim of the company is to become global business and supply partner of core system to the off-highway market with a significant market presence in agricultural and construction market. The company has developed core competencies along the value chain like dual-shore manufacturing, warehousing solutions and an unparalleled supply chain capability. With strategic location across the globe, Company A with state-of- the-art equipments is able to survive their OEM customer and all main markets like Uniparts in India. The forging division of the company is equipped with state-of-art-equipment to ensure world-class standards. The group has the capacity to forge 500 tonnes per month. Different range of product are manufactured like PTO Shaft, Draw and Stray Straps, Weldons, Balls, Hub, Hitch Ball and Cluch Sleeve, etc. The company strategy is organic growth horizontal extention with existing customers by adding in new capabilities to address size ranges of existing products higher than current capabilities. The aim is to enhance design and R&D competence to become an *engineered solution provider* for global OEMs with off-shore engineering and testing capability. Total quality is achieved through implementation of Quality Management Systems. State-of-the-art testing and measuring equipments ensure perfect quality of all the products. Technologies like microscope, image analyser, hardness tester, surface roughness tester are used for ensuring the perfection and precision of our products.

3.2 Formulation of Steering Committee for CI Practices

Kaizen core-committee has a team of six members representing the heads of different departments and the chairman is usually the plant head. The committee has to work based on the following roles: selecting Kaizen themes based on losses, setting targets and assigning teams to take responsibility for each identified project, identify bottleneck areas, fixing targets, set priorities and launching of project teams with pilot projects.

- Identifying aim and scope of Kaizen, training requirement and guiding the facilitators to focus losses on company performance.
- Knowledge sharing through horizontal deployment activities.
- Develop the master plan for Kaizen and track progress of Kaizen.
- Motivate people to do Kaizen.
- Giving inputs to the education and training pillar.
- Working in close coordination with other sub-committees for achieving the targets of Kaizen improvement projects. This committee will meet at least once a week or month for the above-mentioned points.

Formation of core committee team is the very essential part of any movement at new place. Kaizen is new to this plant and it is required that this movement should be supported by the top management of the company. So it has been decided that following members are incorporated in the core committee team. This team will work together and they will decide all the major decision regarding the implementation of Kaizen practices in the company.

- Chief Executive Officer
- General Manager – Production
- General Manager – Mechanical Maintenance
- General Manager – Finance and Accounts
- General Manager – Systems
- Kaizen – Coordinator

3.3 Selection of Kaizen Improvement Projects (KIPs)

Kaizen improvement projects are the planned activities that do not need big investment, large resources, lengthy time and technology upgradation in order to make continuous improvement. Kaizen pillar deals only with those losses that cannot be handled by any other pillar. All the losses have to be considered by the Kaizen core committee. Collecting all relevant data on losses and losses are based on priorities. The Kaizen core committee had identified the priorities and assigned project on specific losses on different machines and areas. The core committee had selected the Kaizen improvement projects on the basis of potential improvement needed for the basic requirement of the plant including OEE improvement, productivity improvement and quality improvement. The Kaizen office has done substantial homework before selecting these projects. Low OEE, high down time and high rejections leads to the implementation of CI strategies Following are the Kaizen improvement projects (KIPs) that have been identified by Kaizen core committee based on critical areas identified earlier:

- KIP1: To increase MTBF of various production machines
- KIP2: To deploy policy goals of X-Matrix
- KIP3: To increase operator efficiency by technical training

4. KIP1: To Increase and Validate Increase in MTBF of Various Production Machines

The critical machines have been identified, MTBF is calculated and CI strategy (preventive maintenance) schedule has been prepared to improve MTBF. The monthly, half yearly and annual maintenance schedule has been prepared. Table 1 shows MTBF of critical machines.

Table 1: MTBF of Critical Machine Before Preventive Maintenance

Machine	Total Planned Hours	Total Braeakdown Hrs	No. of Breakdowns	MTBF Hrs
CNC-12	572	4	3	189.33
VMC-4	572	17	4	186.33
Broach Machine- 4	572	28	2	272
Drill Machine- 2	572	13	3	279.5

4.1 Preventive Maintenance Schedule of CNC12

1) Monthly routine by maintenance
   - Clean the coolant pipe, joints, filter and tank.
   - Check the hydraulic and pressure gauges for healthy operation.
   - Check for any leakage in all distributed hydraulic and lubrication pipes.
   - Clean the spindle belt encoder belt and turret belt.
   - Inspect ball screw, bearings and slides visually.
   - Check main electric wires for proper tightness.
   - Clean all fans and air filters.
2) Half yearly routine by maintenance
   - Repeat all monthly checks.
   - Check the sliding gaurds for any play.
   - Check for any abnormal sound during running of machine.
   - Measure the neutral to earth voltage that should be below 0.3 to 3 volt AC.
3) Annual routine by maintenance
   - Check hydraulic and lubricating oil filters, if require replace it.
   - Remove all side covers of machine and clean the machine fully from dust and chip.
   - Check all limit switches for healthy operation.

4.2 Preventive Maintenance Schedule of VMC4 Machine

1) Monthly routine by maintenance
   - Clean all coolant filters and tanks.
   - Check for any leakage in all distributed hydraulic and lubricating pipes.
   - Check the hydraulic pressure gauge for proper tightness.
   - Check main electrical wires for proper tightness.
   - Clean the compressor air filter.
   - Measure all safe input and output voltage.
   - Clean all fans and air filters.
   - Clean the Automatic Tool Changer (ATC) and provide proper greasing to all wearing parts.
   - Check the lubrication oil level and clean the oil filter.
   - Open the top cover of z axis spindle unit and clean all parts carefully.

2) Half yearly routine by maintenance
   - Repeat all monthly checks.
   - Check the sliding guards and wipers for any play.
   - Measure the neutral to earth voltage that should be below 0.3–3 volts A.C.
   - During working of the machine, check for any vibrations
3) Annual routine by maintenance
   - Repeat all half yearly checks.
   - Remove all side covers of machine and clean the machine fully from dust and chips.
   - Check all limit switches for healthy operation.
   - Check the level of the machine using micron level meter.

4.3 Preventive Maintenance Schedule of Broach Machine

1) Monthly routine by maintenance
   - Clean the hydraulic valve and pilot valve.
   - Clean the hydraulic oil filter, replace it if required.
   - Check the movement and alignment of the piston.
   - Check the operation of hydraulic pump.
   - Check the limit switch condition.
   - Check the coolant pump and its leakage.
   - Check the motor load current equal to 20.25 Amperes.
   - Check the electrical connection, tighten if required.
2) Half yearly routine by maintenance
   - Repeat all monthly by maintenance.
   - Check the alignment of slide with reference to bed.
3) Annual routine by maintenance
   - Repeat all half yearly checks.
   - Check the seal of the piston, replace it if required.
   - Filter the hydraulic oil if required.

4.4 Preventive Maintenance Schedule for Drill Machine

1) Monthly routine by maintenance
   - Check the shaft of the machine for any outness.
   - Check the feed and feed gear for any wear and tear.
   - Clean the hydraulic filter and valve.
   - Check the tightness of electric connection and clean whenever required.
   - Check the motor load current.
   - Check the tightness of gear box.
   - Rectify all leakages found during check or intimated by operator.
2) Half yearly routine by maintenance
   - Repeat all monthly checks.
   - Check the shaft and motor bearings, lubricate with grease, if required change.
   - Check all oil seals and packing, if required change it.
3) Annual routine by maintenance
   - Repeat all half yearly checks.
   - Completely open the gear box, check the gears and bearings.
   - Check the level and condition of hydraulic oil.

Table 2: MTBF After Implementing Preventive Maintenance

Machine	Total Planned Hours	Total Breakdown Hrs	No. of Breakdowns	MTBF Hrs
CNC-12	572	2	1	570
VMC-4	572	8	2	282
Broach Machine- 4	572	14	1	558
Drill Machine- 2	572	7	2	282.5

4.5 Average Increase in MTBF and Validation of Increase in MTBF

So average increase in MTBF from 189.29 to 358.125, that is, about 168.84 hrs. To validate the increase in MTBF paired sample, *t* test has been applied.

Null Hypothesis:

HO: There is no significant difference in the percentage improvement of MTBF before and after Preventive Maintenance.

Alternate Hypothesis:

Ha: There is a significant difference in the percentage improvement of OEE before and after Preventive Maintenance.

Calculated t = 2.776445

Table value is 2.447 at 5 percent level, which is less than calculated *t*. As a result, null hypothesis is rejection. So it is concluded that there is a significant increase in MTBF before and after Preventive Maintenance.

5. KIP2: To Deploy Policy Goals of X-Matrix

X matrix is a document strategic plan of any organization that includes goals, strategies, strategic activities and owners. It is also known as Policy Deployment (PD) document. The *X* matrix has been prepared to deploy annual objectives, top level improvement priorities and area to be targeted by small incremental improvements. Deploying policy goals effectively throughout the organization is helpful to achieve organizational goals. Different targets are setup, which have to be followed daily and areas to be improved. Primary and secondary responsibilities are assigned to the various employees of the organization to achieve policy goals. The OEE target of 63 percent has to be achieved. Figure 3 shows *X* matrix for production department of organizations with targets to improve in various aspects.

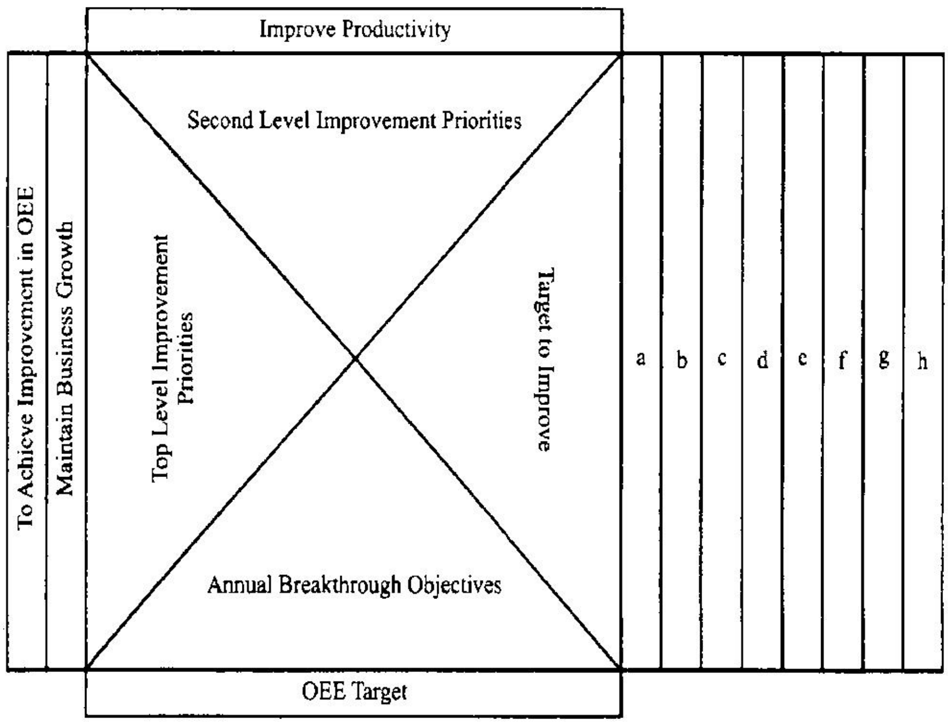

Figure 3: Productions *X* Matrix

Table 3: Target to Improve Areas

A	To reduce rejection to 2,000 ppm
B	To improve the breakdown hours from 1.85% to 1.39%
C	Improve OEE from 50.75 % to 63%
D	Reduce operator nonavailability from 3.755% to 2%
E	Raw material non-availability from 1.65% to 1%
F	Reduce plan down time from 10.7% to 3%
G	Improve 5S rating from current level 7.43 to 9 points
H	Start monitoring and controlling the man hours/tonne

The various activities performed to deploy various targets as discussed below.

1) Identification of low OEE
   - To make yearly plan to trained the CNC setter
   - To implement the training plan
   - To make monthly training plan for operator
   - To implement the production incentive
2) Reduce machine breakdown time
   - To prepare downtime data
   - Analyse and find the route cause
   - Prepare action plan

- Implement reduce breakdown
- To prepare the list of CNC machine
- To replace old CNC machine

3) Reduce setup time
   - To make plan for SMED training
   - To ensure availability of tools, jig, fixtures and drawing before setup
   - To reduce inspection time during setup

4) Non-availability of operator
   - To ensure availability of worker
   - To maintain the base level

5) To reduce plan downtime
   - To prepare data for less order
   - To make plan to arrange order
   - To monitor monthly plan downtime

6) To reduce in process trouble shooting
   - To prepare data and analysis for over trouble shooting nature
   - To take action plan of the trouble shooting

5.1 KIP 2.1 To achieve 63% OEE

Table 4 shows the Target and Achieved OEE of Equipments.

Table 4: OEE Target and Achieved

	April	May	June	July
OEE Target	63%	63%	63%	63%
Achieved	51.16	54.25	54.36	43.21

As the average achieved OEE is 50.75 which is less than target of 63 percent. The root causes of low OEE are identified and counter-measures are taken to achieve target. The causes are discussed below.

- Major breakdown of CNC-25, CNC-2
- External and internal raw material not available
- In process trouble shooting

Counter-measures are discussed below.

- Maintenance department will provide the action plan to minimize the breakdown.
- The SMED training provided to setter to reduce the setup time as per plan.
- Production planning and control department will ensure the availability of material as per plan.
- identify the major reason of troubleshooting and provide the training to setter and operator.

KIP 5.2: To improve the breakdown hours from 1.85 percent to 1.39 percent

Table 5 shows the actual breakdown, plan breakdown and breakdown hours.

Table 5: Breakdown of Machine

	April	May	June	July	August
Plan Breakdown	1.39%	1.39%	1.39%	1.39%	1.39%
Actual Breakdown	1.69%	2.03%	2.48%	1.47%	1.59%
Breakdown Hrs	574	1760	2069	1913	1679

Major causes of breakdown of different machines are as follows.

1. CNC Machine
   - In CNC machine, spindle head was defective.
   - In DLS Section CNC-7 motor encoder, cable jack was defective.
   - Spindle belt broken due to motor pulley defective.
   - CNC-23 spindle encoder jack loose.
   - CNC-9 tool clamp and unclamp lock broken and carousal plate was damaged.
2. Milling Machine
   - M-31 motor belt was loose and coil was defective after tightened the motor belt and hydraulic coil was replaced.
   - M-19 main gear box was damaged after gear send to market for hardening teeth cutting.
   - M-24 Main gear box and bearing damage.
   - M-13 feed gear box clutch broken and spindle shaft bush was loose.
3. Broaching Machine
   - Broach machine B-6 hydraulic cylinder seal was defective.
   - In *U* drill BS2, main gear broken.
4. Drill Machine

Drill machine D-2, D-17, D-18 main gear shaft and gear broken.

Countermeasures

- Demand was raised for *z* axis new encoder cable.
- Keep spindle motor pulley in spare stock.
- The CNC machine motor encoder jack should be checked in for preventive maintenance.
- Clamp and unclamp lock replaced and keep carousal plate in spare stock.
- Motor belt and hydraulic coil should be checked in for preventive maintenance.
- M-19 Keep gear in spare stock.
- M-24 Keep gear and bearing in spare stock.
- M-13 Keep gear and bearing in spare stock.
- M-13 Keep Feed gear box clutch plate in spare stock.
- B6 Keep hydraulic cylinder seal in spare stock.
- B92 Keep main gear in spare stock.
- Drill D2, D17 and D18 main gear shaft and gear required in spare stock.

KIP 2.3: To reduce rejection to 2,000 ppm

Table 6 shows the planned ppm and Actual rejection in ppm.

Table 6: Planned and Actual ppm

Month	April	May	June	July
Plan ppm	2,000	2,000	2,000	2,000
Actual ppm	3,397	2,290	2859	2,033

As the average rejection in ppm is 2644.75, which is more than 2000, so action has to be taken.

The causes are discussed below.

- Major rejection of wrong clamping due to use of other section manpower.
- Major rejection of fixture fault of slip end, hitch ball and actuation cover.
- Major rejection of setting part.

Countermeasures are discussed below.

- Identify the operators to provide the training of wrong clamping.
- Provide the training to operator about proper clamping of component on machine.
- Modify and rectification of fixtures of rejection due to fixture fault.
- Identify the setter and reason of setting rejection.
- Provide the training to setter about 1st piece okay in setting.

6. KIP3: To Increase Operator Efficiency by Technical Training

In order to increase the operator efficiency, technical training about CI strategies has been imparted to every employee in the organization. Kaizen team will impart training on various principles of implementing the CI strategies. These strategies are used to reduce seven types of waste from the shop floor. Various principles behind these strategies are explained and followed by every employee in the organization. The main goal is to create a better process using small incremental improvements on a continual basis. Table 7 shows the production technical training chart for employees in the present article.

Table 7: Production Technical Training Chart

Topic	April	May	June	July	August	September	October	November	December
SMED	√	√	√	√					√
Troubleshooting			√						√
X Matrix	√								
Quality Control	√			√	√		√	√	√
5S		√				√		√	
Basic Operating Skills			√			√		√	
Autonomous Maintenance		√				√			
Poka-Yoke								√	√

Table 8 shows that with the application of this Production Technical Training, overall operator efficiency has been increased from 73.04 to 84.79.

Table 8: Overall Operator Efficiency

Month	April	May	June	July	August	September	October	November	December
OEE	73.04	75.41	75.75	80.66	82.14	82.07	84.44	83.51	84.79

7. SAP-LAP ON CASE STUDY

7.1 Situation

- Technology has been built in the organization.
- Leading manufacturer in different components of tractor parts.
- Enhanced manufacturing capabilities because of innovative efforts by every individual.
- Relative increase in turnover and profits even during recession period.
- Special purpose machines (SPMs) and VMCs (vertical machining centers) at different sections for improving productivity.
- Modern facilities available in forging shop.

7.2 Actors

- Management of the company as the motivating force.
- M/S SKJ Limited is providing the technological support.
- Proper hierarchy has been followed.
- Innovative engineers to utilize the available technologies by modifying the same to suit the local requirements.
- High configuration workstations are used for design activities.
- Reputed tractor parts manufacturing organization.

7.3 Process

- Keep upgradation of incremental technology to enhance the production.
- Flexible workforce to tackle different types of machines.
- Enhanced product flexibility by launching new parts of tractors.
- Making use of local facilities, operator skills and raw materials.
- Generating employment for a large number of persons.
- Significant reduction in rejection rate through continuous improvement approach.

7.4 Learning Issues

- Strong technical support from M/S JONDIER tractors helps in grabbing the large market share.
- Higher productivity is the main objective of the organization.
- Company is investing regularly in machinery and equipment to keep it updated with new technologies.
- New technologies to be used in most of the critical processes.
- Organization need to change its infrastructure to effectively utilize advanced techniques.

7.5 Actions Suggested

- Employees need to be updated with latest technologies.
- In-house training needs to be extended.
- Faculty from respective department should be involved in the training programme.
- Considerable support is recuired from managers, supervisors and workers for optimum utilization of technologies.
- Make the technology utilization more flexible by introducing volume flexibility, product flexibility and process flexibility.
- Flexible motivation by management.
- Formation of cross functional teams leads to new technologies utilization.

7.6 Performance Expected

- Leading manufacturer of tractors parts.
- Enhancement of market share.
- Strategic alliance resulting in increased export to other countries.

- Launch of new air-condition tractor in the Indian market.

9. Conclusion and Limitations

It is concluded from the study that OEE parameters seeks to encourage the setting of ambitious but attainable, realistic goals for raising the OEE by focusing on the losses related to availability, performance and quality of a system. It prepares the plant to meet the challenges of competitive manufacturing by adopting and implementation of a well-conceived plan with the help of preventive maintenance teams for effective equipment maintenance. The study reported in this work has revealed that there is an emerging need for CI strategic implementation in the Indian farm parts industry and the need to develop an indigenous action plan to foster CI implementation practices and procedures.

The present article is limited to medium-scale industry located in northern India. Precise results can be obtained from large-scale industry due to better managerial and infrastructural facilities. Secondly, limited number of strategies has been implemented to ascertain the important benefits occurred after strategic implementation of CI approach. Furthurmore, study is not associated with implementation of sophisticated CI methodologies, viz., lean six sigma, automation, etc.

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The science of today is the technology of tomorrow.

—Edward Teller

DATA BASE

Technological Investment: India Vis-à-vis Major Countries

RAJESH SUND

Introduction

Institute for Management Development (IMD) World Competitiveness Yearbook published by IMD, Lausanne, Switzerland, measures how well major countries manage all their resources and competencies to facilitate ***long-term value creation***. The overall ranking reflects more than 300 criteria. The technological infrastructure is a criterion that assesses how the Information and Communication Technology (ICT) and Research and Development (R&D) resources meet the competitiveness needs of business.

Among large emerging economies, Brazil, China and India experience substantial growth in Internet users as well as broadband subscribers as compared to other countries. In case of high-tech exports, Brazil, Japan and the United States suffer from a drop while on the other hand slight increase has been reported in case of India and Germany. There is difficulty in grouping emerging markets in one category, as the issues impacting their technological infrastructure differ.

A comparison is drawn from the IMD reports for important Asian, European countries and the United States to understand the competitiveness of these nations in terms of technological infrastructure. The adaptability of Internet in India is increasing from 156 in 2012 to 200 in 2014 (Table 1). Much of the increase is driven by a boom in mobile data users and falling smart phone prices. Yet, Internet adoption in India was hamstrung by low computer ownership and poor quality and expensive broadband connections as compared to Asian and European countries.

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Table 1: Internet Users

(Number of Internet users per 1,000 people)

Countries	2012	2013	2014
Brazil	392	449	499
China Mainland	359	399	427
France	813	827	832
Germany	832	848	865
India	**156**	**186**	**200**
Japan	857	861	869
Malaysia	732	702	730
Philippines	190	233	311
Switzerland	837	821	829
Thailand	369	396	437
United Kingdom	838	830	834
United States	858	868	880

Source The IMD World Competitiveness Year Book. (Various years)

The broadband subscribers in India have increased per 1,000 inhabitants from 9.23 in 2010 to 12.18 in 2012 (Table 2). But this figure is disappointing in relation to other countries. India has roughly 3 percent share as compared to level of the total share of the United Kingdom.

Table 2: Broadband Subscribers

(Number of subscribers per 1,000 inhabitants)

Countries	2010	2011	2012
Brazil	69.55	87.49	93.77
China Mainland	94.21	116.14	129.38
France	339.89	359.97	367.25
Germany	319.34	334.45	335.46
India	**9.23**	**11.03**	**12.18**
Japan	265.86	273.32	276.76
Malaysia	72.67	74.06	83.39
Philippines	18.65	19.13	22.61
Switzerland	369.71	389.1	400.98
Thailand	47.29	52.8	84.59
United Kingdom	315.23	327.42	331.46
United States	276.77	274.5	286.28

Source: The IMD World Competitiveness Year Book. (Various years)

Technology-oriented manufacturing exports induce higher returns and also strengthen other forms of industries while creating capabilities to deepen manufacturing, for example, aerospace, computers, pharmaceuticals, scientific instruments and electrical machinery. This will not only lead to augmenting exports but also reduce the country's dependence on high-tech imports, thereby rendering the country's trade deficit more manageable. While the demand and the production of high-tech technology-oriented products have gained significance, it becomes important to convey the benefits of such an endeavour. Despite having one of the world's largest and fastest growing markets, the country captures only a very limited part of the export chain, roughly 15 percent of the share of Philipinesby the end of 2013 (Table 3).

Table 3: High-tech Exports

(Percentage of manufactured exports)

Countries	2011	2012	2013
Brazil	9.72	10.49	9.63
China Mainland	25.81	26.27	26.97
France	23.75	25.41	25.89
Germany	14.96	15.8	16.08
India	**6.87**	**6.63**	**8.07**
Japan	17.46	17.41	16.78
Malaysia	43.39	43.71	43.5
Philippines	46.35	48.86	47.11
Switzerland	24.41	25.78	26.55
Thailand	20.74	20.54	20.09
United Kingdom	21.31	21.74	21.74
United States	18.09	17.83	17.76

Source: The IMD World Competitiveness Year Book. (Various years)

Lack of telecom infrastructure in semi-rural and rural areas is one of the major hindrances in tapping the huge rural potential market, going forward. The service providers have to incur a huge initial fixed cost to enter rural service areas. Further, India lacks basic infrastructure, such as, road and power, developing telecom infrastructure in areas involve greater logistical risks and also extend the time taken to roll out telecom services. The lack of trained personnel to operate and maintain the cellular infrastructure, especially passive infrastructure, such as, towers, is also seen as a hurdle for extending telecom services to the under penetrated rural areas. So, the investment in telecommunication sector has seen a major downfall from

2010 to 2012. There is also the major fall when compared with the other countries.

India is spending more on R&D with 0.91 percent of GDP as compared to Philippines (0.12 percent) and Thailand (0.48 percent) in 2013 (Table 4). Yet the trend in expenditure is gradually constant throughout the years. Countries like Japan and the United States are far ahead of India. The business expenditure on R&D is not increasing at a substantiate level not only in India but also in almost all other Asian countries as well. It accounts for 0.34 percent of GDP in India in 2013, which is higher than the expenditure done by Philippines and Thailand in the same year. The state of Indian economy is not much impressive when compared with European and Asian countries.

Table 4: Total Expenditure on R&D

(Percentage of GDP)

Countries	2011	2012	2013
Brazil	1.16	1.16	1.15
China Mainland	1.84	1.98	2.08
France	2.25	2.27	2.23
Germany	2.84	2.92	2.94
India	**0.9**	**0.9**	**0.91**
Japan	3.25	3.35	3.47
Malaysia	1.07	1.07	1.08
Philippines	0.1	0.1	0.12
Switzerland	2.99	2.99	2.96
Thailand	0.22	0.39	0.48
United Kingdom	1.77	1.73	1.63
United States	2.75	2.79	2.81

Source: The IMD World Competitiveness Year Book. (Various years)

Table 5: Business Expenditure on R&D

(Percentage of GDP)

Countries	2011	2012	2013
Brazil	0.55	0.55	0.53
China Mainland	1.39	1.51	1.6
France	1.43	1.46	1.44
Germany	1.9	1.95	1.99
India	**0.3**	**0.33**	**0.34**
Japan	2.49	2.6	2.26
Malaysia	0.61	0.6	0.69
Philippines	0.05	0.05	0.08
Switzerland	2.2	2.17	2.05
Thailand	0.1	0.2	0.22
United Kingdom	1.09	1.1	1.05
United States	1.88	1.95	1.96

Source: The IMD World Competitiveness Year Book. (Various years)

Source: The IMD World Competitiveness Year Book 2013, 2014 and 2015.

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