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Contents

Focus

Productivity Trends in some Selected Indian Steel Firms

P. SURYA KUMAR AND V. BALAKRISHNAMA NAIDU

Many researchers have attempted to study productivity and related aspects of the steel industry in India. However studies do not throw light on productivity performance of different firms in industry. In view of the importance and need of steel, an attempt has been made to study the productivity performance of 10 Indian steel firms using partial factor productivities, capital intensity, relationship of labor productivity and capital intensity, index of efficiency of labor and Divisia total factor productivity (TFP) indices and their growth rates during the period 1989–2009. From the analysis it is concluded that labor has greater influence on overall productivity. Capital productivity has influence only 6 firms out of 10. Capital intensity growth has registered positive for all studied firms, and there is significant association between capital intensity and labor productivity for all firms. Index of efficiency of labor input clearly shows that out of 10 firms, 7 moved in the right directions and performed much better in the use of labor input, that is, the production is being organized in such an efficient manner that more gains in the labor productivity become possible than is permissible by the technical relationship of capital–labor and output–capital ratios in most of the firms. Divisia TFP indices and their growth rates revealed that 7 out of 10 firms exhibit technological progress, 2 are technological retrogression, and 1 is technological neutrality.

Steel industry is one of the basic or key industries in the national economy of any country. The iron and steel industry constitutes one of the main foundations on which the industrial structure of the country can be built. It is the core industry for the primary, secondary and tertiary sectors. The Indian steel industry is almost 100 years old now, but the real beginning was only made in the 20th century. The Indian steel sector is booming and now it occupies the fifth position globally. In the year 2009 India's crude steel output of 56.6 million metric tonnes constituted 4.64 percent of the total global production. According to the International Iron and Steel Institution (IISI), during the year 2009 world crude steel production stood at 1220 million metric tonnes. Now Asia has become the largest producer of steel in the world.

Different researchers, namely, Goldar (1986), Ahluwalia (1991), Pradhan and Barik (1998), Mongia and Sathaye (1998), Schumacher and Sathaye (1999), Mongia et al. (2001), Kathuria (2002), and Mohanan (2009), have attempted to study the productivity and related aspects of steel industry in India. However, these studies do not throw light on the relative productivity performance of the different firms in the industry. Therefore, the present study is an attempt to bridge this gap with the objective of examining the steel firms in India using the partial factor productivities, capital intensity, relationship of labor productivity and capital intensity, index of efficiency of labor, and TFP. So, it is hoped that this study will make an important contribution to the literature of growth and productivity analysis for the steel industry in India.

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Objectives of the Study

In view of the importance and the need of the steel, an attempt has been made to study the following objectives for the selected firms in Indian steel industry. The main objectives of the study are

1. to examine the partial factor productivities and capital intensity;
2. to measure the relationship of labor productivity and capital intensity;
3. to estimate the index of efficiency of labor and
4. to examine the TFP growth trends in some selected Indian steel firms.

Database and Methodology

Database

The present study is based on secondary data and covers the period from 1989-2009. To examine the objectives of the study, the data has been drawn from PROWESS, compiled by Center for Monitoring Indian Economy (CMIE). For this study, we have taken 10 Indian steel firms on the basis of their performance in terms of market share and sales during the period 1989–2009, except RINL (1991–2009). Keeping in view of the study objectives, we have collected the time series data on value of output, fixed capital, number of employees, power and fuel and material consumed of the following firms.

1. Steel Authority of India Ltd. (SAIL)
2. Tata Steel Ltd. (TSL)
3. Rashtriya Ispat Nigam Ltd. (RINL)
4. Maharashtra Elecktrosmelt Ltd. (MEL)
5. National Aluminium Co Ltd. (NALCO)
6. Hindustan Zinc Ltd. (HZL)
7. Hindalco Industries Ltd. (HIL)
8. Hindustan Copper Ltd. (HCL)
9. Bharat Aluminium Co Ltd. (BALCO)
10. GKW Ltd. (GKW)

Deflators

Since the data collected are at current prices, to bring the data into constant prices, we have used appropriate deflation techniques for the different variables. To bring the data into constant prices, we have taken 1993–94 as the base year for the study.

The value of output is deflated by the respective wholesale price index of industrial production. The capital stock is deflated by the composite price index of machinery (electrical and non-electrical). Number of employees is deflated by consumer price index of industrial workers. Energy and material inputs are deflated by the respective wholesale price indices of power and fuel, and raw material. The price indices are taken from the various issues of Reserve Bank of India (RBI) bulletins. The consumer price index (General) for industrial workers is collected from http://laborbureau.nic.in/indtab.html.

Methodology

In general the productivity can be considered as related to efficiency. Broadly, it is a relation between output and inputs, single or a combination of a few or all. M. M. Mehta (1955) observed that the word "productivity" is one of those few words in industrial economics that have aroused many different and conflicting interpretations. Considering the importance of productivity growth in raising the standard of living, it is not surprising that productivity analysis receives substantial attention from the economic and political communities. Basically, the measurement of productivity trends is useful. First we know the input structure and economic use of inputs over time (substitution of one for another input and overall reduction of inputs per unit of output) and secondly to provide guidelines for planning the use of available inputs at different levels of economic activity. By designing appropriate index number in the case of each productivity ratio, changes in productivity over time in respect of firm, an industry, a sector or an economy can be evaluated. Inter-firm, inter-industry, inter-regional, and international comparisons can also be made in respect of productivity movements.

Partial productivity

Partial productivity is the average productivity of the particular input in equation. Partial productivity indices/ measures can be computed as the ratio of output to factor input. The partial productivities have been computed as follows:

$$P_K = V/K \qquad P_L = V/L$$

where P_K and P_L, are called the partial productivities of capital and labor, respectively, and V is the value of output, L is labor, K is capital. We have also computed capital intensity as

$$Kl = K/L$$

Relationship of Capital Intensity and Labor Productivity

In order to relate labor productivity to capital intensity and to assess the changes in labor productivity consequent upon unit change in capital intensity, the following relation has been used.

$$V/L = A\left(\frac{K}{L}\right)^{\beta} \quad \ldots\ldots\ldots\ldots \quad (1)$$

where β indicates the changes in labor productivity with a unit change in capital intensity. If we isolate the rate of increase in labor productivity due to capital intensity, the residual increase would be due to residual factors including technical change. To assess the effect of technical change on labor productivity, the time parameter is added and the following function has been used.

$$V/L = A\left(\frac{K}{L}\right)^{\beta} . e^{\delta T} \quad \ldots\ldots\ldots \quad (2)$$

Index of Efficiency of Labor

Ahmed (1981) worked out an index of efficiency of labor input as the difference between the actual and desired rates of growth of labor productivity. Symbolically, the efficiency index, denoted by E_L, can be written as

$$E_L = \left(\frac{V_i}{L_i}\right) - \left[\left(\frac{K_i}{L_i}\right) + \left(\frac{V_i}{K_i}\right)\right]$$

where, $= \left(\frac{V_i}{L_i}\right)$ Actual growth rate of labor productivity in i^{th} firm, and

$\left(\frac{K_i}{L_i}\right) + \left(\frac{V_i}{K_i}\right)$ = Desired rate of growth of labor productivity in i^{th} firm.

$\left(\frac{K_i}{L_i}\right)$ = Actual growth rate of capital intensity in i^{th} firm, and

$\left(\frac{V_i}{K_i}\right)$ = Actual growth rates of capital productivity in i^{th} firm.

If the actual growth rate of labor productivity equals the desired growth rate of labor productivity, then E_L will become zero. This means that labor productivity is growing at the rate it should. The capital–labor and output–capital ratios are moving in the correct directions and in right proportions. In other words both factors are being combined in an efficient manner. The value, $E_L > 0$, occurs only if the actual growth rate exceeds desired growth rate and indicates that production is being organized in such an efficient manner that more gains in the labor productivity become possible than is permissible by the technical relationship of capital–labor and output–capital ratios. The value $E_L < 0$ exists when actual rate of growth is much lower than the desired rate of growth and thus, indicates the presence of inefficiency in the use of labor input in the production system because the growth which can be attained under given condition is not attained. The basic merit of index of labor efficiency E_L is that we do not have to specify any market condition such as perfect competition or any other restrictive condition such as profit maximization. The efficiency index simply depends on the technical relationship between labor productivity, capital–labor ratio or output–capital ratios per se are independent of market conditions. In fact, the efficiency index E_L is affected indirectly by market condition as they affect capital–labor and output–capital ratios that determine the efficiency index through a technical relationship.

Divisia Total Factor Productivity

The Divisia or Translog index of technology change is based on Translog production function which, a priori, does not restrict the input substitutability to any particular value. It allows for variable elasticity of substitution and does not require the assumption of Hicks Neutrality (Christenson and Jorgenson [1973]). Krishna also held the opinion that Translog index of measuring productivity is a better method compared to the others, because, it provides rigorous foundations for the measurement of TFP by incorporating recent developments in the theory of production and index numbers (Krishnamurthy [1986]). Under the four inputs frame work, the Translog index of TFP growth is given by the following equation.

$$\Delta\, Ln\ TFP(t) = \Delta Ln\ Q(t) - \left[\frac{S_K(t) + S_K(t-1)}{2} \times \Delta\, Ln\ K(t)\right]$$
$$- \left[\frac{S_L(t) + S_L(t-1)}{2} \times \Delta\, Ln\ L(t)\right] - \left[\frac{S_E(t) + S_E(t-1)}{2} \times \Delta\, Ln\ E(t)\right] -$$
$$\left[\frac{S_M(t) + S_M(t-1)}{2} \times \Delta\, Ln\ M(t)\right]$$

In this equation, Q denotes gross output, K capital, L labor, M materials, and E energy inputs.

$$\Delta\, Ln\, Q(t) = Ln\, Q(t) - Ln\, Q(t-1)$$

$$\Delta\, Ln\, K(t) = Ln\, K(t) - Ln\, K(t-1)$$

$$\Delta\, Ln\, L(t) = Ln\, L(t) - Ln\, L(t-1)$$

$$\Delta\, Ln\, E(t) = Ln\, E(t) - Ln\, E(t-1)$$

$\Delta\, Ln\, M(t) = Ln\, M(t) - Ln\, M(t-1)$ are defined

S_k is the income share of capital, S_L is the income share of labor, S_E is the income share of energy input, and S_M is income share of materials input. S_K, S_L, S_M and S_E add up to unity. Δ ln TFP is the rate of technological change or the rate of TFP growth.

Using the above equation, the growth rates of TFP have been computed for each year. These have then been used to obtain an index of TFP in the following way. Let A denote the index of TFP. The index for the base year, A (O), is taken as 100. Then, the index for subsequent years is computed using the following equation.

$$A(t)/A(t-1) = \exp\left[\Delta \ln TFP(t)\right]$$

Results and Discussions

Capital productivity has been measured as the ratio of value of output to fixed capital at constant prices. Tables 1 and 2 highlight the capital and labor productivity indices and their growth rates for three periods for the 10 selected Indian steel firms. The capital productivity observed has been that out of 10, 6 are registered positive growth and in that only 4 are significant. The GKW has registered

Table 1: Partial Productivity Indices of Selected Indian Steel Firms

	CAPITAL PRODUCTIVITY INDICES										*LABOR PRODUCTIVITY INDICES*									
YEAR	SAIL	TSL	RINL*	MEL	NALCO	HZL	HIL	HCL	BALCO	GKW	SAIL	TSL	RINL*	MEL	NALCO	HZL	HIL	HCL	BALCO	GKW
1989	100	100	–	100	100	100	100	100	100	100	100	100	–	100	100	100	100	100	100	100
1990	106	102	–	149	196	101	100	95	111	143	115	120	–	138	178	143	109	106	104	108
1991	100	77	100	163	182	66	109	134	126	140	131	136	100	142	173	180	127	164	122	110
1992	108	67	285	245	186	83	151	154	160	169	174	194	233	190	219	242	174	196	150	130
1993	118	62	513	346	255	123	39	168	189	206	218	251	405	242	275	331	211	225	198	162
1994	94	48	746	221	226	90	34	101	176	178	208	240	563	153	241	263	183	167	194	162
1995	86	52	1140	252	271	110	37	141	219	130	232	290	817	175	281	322	222	270	241	171
1996	79	62	1302	342	347	103	40	160	253	41	256	392	911	262	353	309	276	357	272	235
1997	70	62	1031	262	361	110	28	126	291	34	273	456	688	292	357	350	250	310	304	264
1998	63	53	683	293	381	138	28	128	314	26	292	497	464	343	386	467	312	376	331	238
1999	56	46	1080	231	325	147	22	138	333	25	301	595	752	328	365	531	401	534	385	187
2000	64	45	1371	230	377	164	25	53	255	34	326	726	951	345	504	627	453	246	424	250
2001	79	51	1703	160	322	181	28	104	274	12	375	861	1225	332	544	769	500	563	428	109
2002	82	52	2023	182	285	221	28	76	237	13	385	928	1382	310	547	1206	537	429	375	102
2003	102	62	2682	168	293	204	43	84	286	12	499	1222	1637	345	602	1508	1033	566	600	114
2004	128	68	4071	123	356	175	48	88	114	13	624	1457	2202	288	693	1785	1261	753	566	132
2005	177	76	7080	298	512	92	56	88	51	17	840	1973	2932	579	862	1914	1336	750	693	166
2006	167	68	7094	248	582	148	61	134	76	31	725	1976	2710	471	890	3176	1607	1167	1283	359
2007	179	61	7477	270	568	192	73	209	163	24	811	2068	3003	541	956	5904	2077	1890	2457	286
2008	193	60	5326	327	384	128	70	204	169	31	978	2370	3080	706	829	5696	2171	1972	2503	990
2009	156	63	2946	299	334	74	65	120	175	105	1176	3095	2779	899	924	4108	2133	1318	2746	2949

Source: Authors' calculations.
* indicates Rashtriya Ispat Nigam Ltd.
Overall period (1991–2009)

Table 2: ACGR of Partial Productivity Indices in Selected Indian Steel Firms

FIRMS	Capital Productivity Indices						Labor Productivity indices					
	Period–I (1989–1998)		*Period–II (1999–2009)*		*Overall (1989–2009)*		*Period–I (1989–1998)*		*Period–II (1999–2009)*		*Overall (1989–2009)*	
	CV	ACGR	CV	ACGR	CV	ACGR	CV	ACGR	CV	ACGR	CV	ACGR
SAIL	19.02	–5.5376 (4.27)	40.62	12.7188 (7.99)	37.82	2.9139 (2.47)	33.79	12.0501 (10.52)	45.46	13.9164 (14.69)	71.64	11.3129 (26.07)
TSL	27.8	–6.8777 (–3.787)	16.62	3.6882 (3.11)	24.02	–1.1053^NS (1.42)	52.51	18.3228 (19.41)	50.36	15.9958 (19.31)	92.13	16.9586 (52.56)
RINL*	54.08	27.4958 (3.11)	63.01	16.6946 (3.94)	95.68	18.4782 (8.95)	49.98	22.5727 (2.80)	43.23	14.4145 (8.48)	73.52	15.6524 (10.51)
MEL	34.19	10.2858 (3.62)	28.58	4.979^NS (1.89)	30.69	1.763^NS (1.46)	38.29	11.3492 (5.42)	42	9.757 (4.89)	58.72	8.5288 (11.61)
NALCO	36.16	12.436 (7.09)	27.4	3.5514^NS (1.56)	37.53	5.3425 (5.91)	35.98	12.8606 (7.72)	28.6	8.7797 (8.04)	56.28	10.0268 (19.52)
HZL	19.65	3.7652^NS (1.88)	28.9	–5.2782^NS (1.83)	34.02	2.4924 (2.21)	40.34	14.239 (6.85)	79.53	24.8631 (11.49)	125.8	19.2877 (20.40)
HIL	66.46	–18.0794 (4.52)	40.46	12.8615 (9.93)	60.44	–1.796^NS (0.90)	36.35	12.4336 (10.05)	57.08	19.3992 (12.16)	98.5	16.3728 (25.97)
HCL	19.9	2.5922^NS (1.17)	42.86	7.2782^NS (2.12)	32.5	0.1458^NS (0.12)	43.32	14.541 (7.76)	63.13	17.0446 (5.58)	92.81	13.3957 (13.91)
BALCO	38.34	12.9676 (19.44)	46.81	–9.4842 (1.90)	41.91	–0.4252^NS (0.23)	41.43	14.3703 (19.06)	84.61	22.519 (7.76)	120.49	15.4947 (15.28)
GKW	54.8	–17.6251 (2.82)	92.13	9.9454^NS (1.78)	91.94	–10.6659 (3.85)	35.31	11.314 (11.67)	165.07	22.8139 (3.16)	179.42	8.0273 (3.36)

Source: Authors' calculations.

Figures in parenthesis are t– values.

NS indicates "Not Significant."

CV = Coefficient of Variation, ACGR = Annual Compound Growth Rate

* indicates RINL

Period–I (1991–98), Period–II (1999–09), and Overall (1991–09)

negative growth rate of capital productivity accounting for –10.67% per annum during the period. From the analysis it is clear that the capital has been influenced in 6 firms only during the study period. From the coefficient of variations it is observed that there is high variability of capital productivity indices in RINL, GKW, and HIL and there is low variability of capital productivity indices in the remaining 7 firms. Labor productivity growths have been registered positive and are significant at 1% level. It is observed that the labor productivity has greater influence on overall production of the studied firms during the period. From the Coefficient of Variation (CV), it is observed that there is a greater variability in labor productivity indices of eight firms and in the remaining two MEL and NALCO firms less variability was seen during the study period.

Tables 3 and 4 present the capital intensity indices and the averages of annual growth rates of capital intensity during the three study periods. From the analysis, it is observed that the growth of capital intensity of all the selected firms have registered positive growth except RINL. The process of liberalization in the form of removing obstacles in areas of licensing, installed capacities, investment, etc., promoted the capital accumulation per employee in all the firms. The RINL has registered negative growth rate accounting for –2.86% per annum during the study period. From the CV, it is observed that there is a greater variability in capital intensity of HZL, BALCO, GKW, TSL, HIL, and HCL compared to NALCO, MEL, RINL, and SAIL firms during the study period.

Table 3: Capital Intensity Indices of Selected Indian Steel Firms

YEAR	SAIL	TSL	RINL*	MEL	NALCO	HZL	HIL	HCL	BALCO	GKW
1989	100	100	–	100	100	100	100	100	100	100
1990	108	118	–	92	91	140	109	112	93	75
1991	131	176	100	87	95	272	116	122	96	79
1992	161	290	82	77	118	291	115	127	94	76
1993	185	404	79	70	108	269	539	134	104	79
1994	221	502	75	69	107	292	541	166	110	91
1995	269	559	72	70	104	294	598	192	110	131
1996	326	636	70	77	102	300	686	223	108	571
1997	387	730	67	111	99	318	903	247	104	765
1998	462	944	68	117	102	339	1118	295	105	909
1999	540	1300	70	142	112	362	1808	388	116	756
2000	506	1604	69	150	134	381	1795	468	166	730
2001	478	1704	72	208	169	425	1769	541	156	886
2002	472	1789	68	170	192	546	1948	566	158	805
2003	490	1973	61	206	206	739	2403	675	210	943
2004	489	2129	54	235	195	1018	2636	856	494	980
2005	475	2606	41	194	168	2090	2397	854	1346	976
2006	434	2904	38	190	153	2148	2625	871	1695	1178
2007	453	3375	40	200	168	3078	2846	904	1512	1207
2008	506	3976	58	216	216	4435	3082	967	1479	3150
2009	755	4879	94	301	276	5521	3300	1098	1573	2816

Source: Authors' calculations.
* indicates RINL.
Overall period (1991–2009).

Table 4: ACGR of Capital Intensity Indices in Selected Indian Steel Firms

FIRMS	*Period-I (1989–1998)*		*Period-II (1999–2009)*		*Overall (1989–2009)*	
	CV	ACGR	CV	ACGR	CV	ACGR
SAIL	52.63	17.5878 (52.13)	16.93	1.1976NS (0.85)	45.95	8.3989 (8.37)
TSL	62.87	25.2005 (12.39)	43.59	12.3076 (18.57)	87.12	18.0638 (20.82)
RINL*	13.24	−4.897 (5.5)	27.74	−2.3138NS (0.84)	24.33	−2.8557 (3.15)
MEL	20.35	1.0634NS (0.47)	21.45	4.778 (3.58)	45.6	0.67657 (8.57)
NALCO	7.24	0.4245NS (0.52)	24.35	5.2283 (3.07)	35.6	4.6843 (8.01)
HZL	29.72	10.4738 (3.69)	94.61	30.1413 (17.69)	135.91	16.7954 (11.24)
HIL	75.57	30.513 (7.66)	22.25	6.5377 (10.5)	72.78	18.1687 (11.21)
HCL	38	11.9488 (17.39)	30.7	9.7665 (11.44)	71.55	13.2498 (29.64)
BALCO	6.09	1.4026 (2.69)	85.59	32.0033 (7.72)	128.82	15.9188 (7.64)
GKW	114.12	28.9391 (4.4)	64.32	12.8594 (4.94)	100	18.6932 (10.35)

Source: Authors' calculations.
* indicates RINL.
Period–I (1991–98), Period–II (1999–09), and Overall (1991–09)
Figures in parenthesis are *t*-values.
NS indicates "Not Significant."
CV = Coefficient of Variation, ACGR = Annual Compound Growth Rate

From Table 5, it is observed that there is a significant association between capital intensity and labor productivity in all the selected Indian steel firms. Further, the effect of technical change on labor productivity has been estimated by using the second equation. It is also observed that there is a significant effect of technical change on labor productivity in SAIL, TSL, RINL, MEL, NALCO, HZL, HIL, HCL, and BALCO.

Table 5: Relationship of Labor Productivity with Capital Intensity

Selected Indian Steel firms	Models	LOG.A	β	δ	R^2	Adjusted R^2	F
Steel Authority of India Ltd.	EQN-I	–0.197	1.039 (7.2725)	– –	0.7357	0.7218	52.8892
	EQN-II	5.0572	-0.0972^{NS} (0.9782)	0.1213 (12.894)	0.9742	0.9713	339.5783
Tata steel ltd.	EQN-I	0.1657	0.9064 (23.3783)	– –	0.9664	0.9646	546.5469
	EQN-II	3.7046	0.1675^{NS} (2.1413)	0.1393 (9.6485)	0.9946	0.994	1644.379
Rashtriya Ispat Nigam Ltd.	EQN-I	17.3678	-2.5017 (3.9905)	– –	0.4837	0.4533	15.9237
	EQN-II	8.7036	-0.7519^{NS} (2.0483)	0.1353 (7.8829)	0.8943	0.8811	67.667
Maharashtra Elecktrosmelt Ltd.	EQN-I	1.0235	0.9538 (5.7067)	– –	0.6315	0.6121	32.566
	EQN-II	5.7044	-0.2316^{NS} (1.0904)	0.101 (6.2609)	0.884	0.8712	68.6182
National Aluminium Co Ltd.	EQN-I	–1.7471	1.5813 (6.2623)	– –	0.6736	0.6565	39.2159
	EQN-II	6.2727	-0.3087^{NS} (1.5912)	0.1147 (11.0914)	0.9583	0.9537	207.0428
Hindustan Zinc Ltd.	EQN-I	–0.1182	1.0525 (15.2044)	– –	0.9241	0.9201	231.1729
	EQN-II	2.571	0.4146 (3.6774)	0.1232 (6.0681)	0.9751	0.9723	351.9233
Hindalco industries Ltd.	EQN-I	0.9213	0.7596 (8.5962)	– –	0.7955	0.7847	73.8943
	EQN-II	5.1702	-0.1770^{NS} (2.1673)	0.1959 (12.3039)	0.9783	0.9758	405.0777
Hindustan Copper Ltd.	EQN-I	0.3544	0.9673 (10.4419)	– –	0.8516	0.8438	109.0335
	EQN-II	9.1851	-1.0532^{NS} (2.3778)	0.2735 (4.6109)	0.932	0.9247	123.2787
Bharat Aluminium Co Ltd.	EQN-I	1.6958	0.7915 (9.0269)	– –	0.8109	0.801	81.4847
	EQN-II	3.44	0.2338^{NS} (2.3252)	0.1177 (6.3873)	0.9421	0.9357	146.4794
GKW Ltd.	EQN-I	2.9123	0.3943 (3.3404)	– –	0.37	0.3368	11.158
	EQN-II	3.6461	0.1963^{NS} (0.6366)	0.0436^{NS} (0.6968)	0.3865	0.3184	5.6708

Source: Authors' calculations.
Figures in the parenthesis indicate *t*-value.
NS indicates "Not Significant."
EQN-I: $V/L = A (K/L)^{\beta}$ EQN-II: $V/L=A (K/L)^{\beta}e^{\delta t}$

It is observed from Table 6 depicting the index of efficiency of labor, that out of 10, 7 firms registered greater than zero. It is clear that the actual growth rate exceeds desired growth rate and it indicates that production is being organized in such an efficient manner that more gains in the labor productivity become possible than is permissible by the technical relationship of capital–labor and output–capital ratios. On the whole, most of the firms moved in the right directions and performed much better in the use of labor input.

Table 6: Index of Efficiency of Labor input [E_L] in Selected Indian Steel Firms

FIRMS	*Actual Growth Rate of Labor Productivity*	*Capital Productivity*	*Capital Intensity*	*Desired Growth Rate of Labor Productivity*	E_L
			Period-I (1989–98)		
SAIL	12.0501	–5.5376	17.5878	12.0502	–0.0001
TSL	18.3228	–6.8777	25.2005	18.3228	0.0000
RINL*	22.5727	27.4958	–4.897	22.5988	–0.0261
MEL	11.3492	10.2858	1.0634	11.3492	0.0000
NALCO	12.8606	12.436	0.4245	12.8605	0.0001
HZL	14.239	3.7652	10.4738	14.239	0.0000
HIL	12.4336	–18.0794	30.513	12.4336	0.0000
HCL	14.541	2.5922	11.9488	14.541	0.0000
BALCO	14.3703	12.9676	1.4026	14.3702	0.0001
GKW	11.314	–17.6251	28.9391	11.314	0.0000
			Period-II (1999–2009)		
SAIL	13.9164	12.7188	1.1976	13.9164	0.0000
TSL	15.9958	3.6882	12.3076	15.9958	0.0000
RINL*	14.4145	16.6946	–2.3138	14.3808	0.0337
MEL	9.757	4.979	4.778	9.757	0.0000
NALCO	8.7797	3.5514	5.2283	8.7797	0.0000
HZL	24.8631	–5.2782	30.1413	24.8631	0.0000
HIL	19.3992	12.8615	6.5377	19.3992	0.0000
HCL	17.0446	7.2782	9.7665	17.0447	–0.0001
BALCO	22.519	–9.4842	32.0033	22.5191	–0.0001
GKW	22.8139	9.9454	12.8594	22.8048	0.0091
			Overall Period (1989–2009)		
SAIL	11.3129	2.9139	8.3989	11.3128	0.0001
TSL	16.9586	–1.1053	18.0638	16.9585	0.0001
RINL*	15.6524	18.4782	–2.8557	15.6225	0.0299
MEL	8.5288	1.763	0.67657	2.43957	6.0892
NALCO	10.0268	5.3425	4.6843	10.0268	0.0000
HZL	19.2877	2.4924	16.7954	19.2878	–0.0001
HIL	16.3728	–1.796	18.1687	16.3727	0.0001
HCL	13.3957	0.1458	13.2498	13.3956	0.0001
BALCO	15.4947	–0.4252	15.9188	15.4936	0.0011
GKW	8.0273	–10.6659	18.6932	8.0273	0.0000

Source: Authors' calculations.

* indicates RINL.

Period-I (1991–98), Period-II (1999–09), Overall (1991–2009)

The Divisia TFP indices and their growth rates of 10 selected Indian steel firms are presented in tables 7 and 8. It is observed from the analysis that out of 10 firms, 7 firms registered positive growth rates and are statistically significant at 5 percent level. In the case of GKW and HCL the growth is declining and in BALCO there is low

Table 7: Divisia TFP Indices of Selected Indian Steel firms

YEAR	SAIL	TSL	RINL*	MEL	NALCO	HZL	HIL	HCL	BALCO	GKW
1989	100	100	–	100	100	100	100	100	100	100
1990	107	111	–	119	144	118	113	98	105	106
1991	109	115	100	128	125	101	119	119	112	103
1992	124	132	189	158	130	126	137	106	126	120
1993	143	142	264	188	153	154	141	112	154	147
1994	129	128	357	140	146	123	131	87	152	129
1995	126	130	508	142	162	138	149	108	186	108
1996	118	144	536	155	172	124	163	67	187	58
1997	111	147	167	152	172	126	135	68	191	52
1998	114	140	191	169	193	159	150	88	210	43
1999	108	189	201	153	179	177	148	188	232	41
2000	114	197	235	158	219	204	166	6	221	57
2001	133	197	294	147	228	220	183	72	237	4
2002	129	160	351	177	213	293	184	31	221	4
2003	148	184	392	181	213	271	170	46	262	3
2004	169	209	502	153	225	294	167	42	171	4
2005	212	255	575	245	297	213	196	35	93	5
2006	175	209	474	190	291	306	191	19	112	7
2007	180	163	559	211	308	428	179	33	157	5
2008	196	167	537	229	224	271	167	33	155	6
2009	171	159	344	228	195	113	181	32	157	5

Source: Authors' calculations,
* indicates Rashtriya Ispat Nigam Ltd. Overall period (1991-2009)

Table-8: ACGR of Divisia TFP indices in selected Indian Steel firms

Firms	*Period-I (1989–1998)*		*Period-II (1999–2009)*		*Overall (1989–2009)*	
	CV	ACGR	CV	ACGR	CV	ACGR
SAIL	10.7004	1.0775NS (0.92)	21.4609	5.7659 (5.12)	23.4287	2.886 (6.00)
TSL	12.1819	3.6178 (4.78)	14.9996	−1.1207NS (0.8)	24.0076	2.9763 (5.38)
RINL*	56.186	7.6051NS (0.83)	32.5151	8.0945 (3.39)	42.9242	5.4281 (3.18)
MEL	17.4323	4.1077 (2.65)	18.6215	4.5526 (4.31)	22.2931	2.9468 (6.29)
NALCO	17.8791	5.6792 (6.03)	18.2632	2.161NS (1.34)	28.9583	4.166 (8.15)
HZL	15.2944	3.4586 (2.66)	32.5023	0.6679NS (0.19)	45.5706	5.1187 (4.85)
HIL	14.0141	4.0278 (4.23)	7.7994	1.0738NS (1.51)	17.1126	2.5755 (7.98)
HCL	18.6232	−4.1075NS (2.27)	100.2844	−5.1158NS (0.62)	61.5312	−8.1041 (3.65)
BALCO	26.373	8.8388 (13.79)	29.8373	6.3654 (2.51)	29.5292	1.2741NS (1.15)
GKW	35.969	−9.6359 (2.74)	143.4342	−15.6603NS (1.89)	95.8021	−21.3966 (8.36)

Source: Authors' calculations.
CV = Coefficient of Variation, ACGR = Annual Compound Growth Rate
* indicates RINL.
Period-I (1991–98), Period-II (1999–09) and Overall (1991–09).
Figures in parenthesis are *t*-values.
NS indicates "Not Significant."

growth during the study period. These results reveal that 7 out of 10 firms exhibit technological progress and technological retrogression is observed in GKW and HCL. The technical neutrality is observed in BALCO.

Conclusions

From the analysis it is concluded that capital has been influenced in 6 firms out of 10 and labor has greater influence on overall productivity of all the firms. From the CV, it is observed that there is a greater variability in the labor productivity indices of HZL, BALCO, GKW, TSL, HIL, HCL, RINL, and SAIL during the period. Capital intensity growth has been observed in GKW followed by HIL, TSL, HZL, BALCO, HCL, SAIL, NALCO, and MEL and these growth rates are statistically significant at 1 percent level. It is also observed that the process of liberalization in the form of removing obstacles in areas of licensing, installed capacities, investment, etc., promoted the capital accumulation per employee in the all firms. The relationship between labor productivity and capital intensity has observed that there is a significant association between capital intensity and labor productivity in all selected 10 Indian steel firms. Hence it is clear that there is a significant effect of technical change on labor productivity in all firms except RINL.

With respect to the index of efficiency (E_L), it is observed that the efficiency of labor is greater than zero in 7 firms, namely, MEL, SAIL, TSL, RINL, HIL, HCL, and BALCO in the study period and it implies that the actual growth exceeds the desired growth and from these it is concluded that the production is being organized in such an efficient manner that more gains in the labor productivity become possible than is permissible by the technical relationship of capital–labor and output–capital ratios. On the whole, most of the firms are moving in the right directions and performed much better in the use of labor input for the study period.

The Divisia TFP indices and their growth rates of 10 selected Indian steel firms are estimated. It is observed from the analysis that out of 10 firms, 7 firms registered positive growth rates and are statistically significant at 5 percent level. In the case of GKW and HCL the growth is declining and in BALCO there is low growth during the study period. These results reveal that 7 out of 10 firms exhibit technological progress and technological retrogression is observed in GKW and HCL. The technical neutrality is observed in BALCO.

The Managerial/Policy Implications of the Study

The article mainly concentrates on partial productivities, capital intensity, index of efficiency of labor input, and TFP for some selected Indian major steel firms, namely, SAIL, TSL, RINL, MEL, NALCO, HZL, HIL, HCL, BALCO, and GKW.

First objective of the study: The growth rates of capital productivity has registered positive in six (SAIL, RINL, NALCO, HZL, MEL, and HCL) firms but only four (SAIL, RINL, NALCO, and HZL) firms are statistically significant at 5 percent level and remaining four (TSL, HIL, BALCO, and GKW) firms have registered declining trend. It is clear that the capital input has influenced only 6 firms during the study period. The study suggests that TSL, HIL, BALCO, and GKW should concentrate to increase capital productivity particularly. The growth rates of labor productivity have registered positive and statistically significant at 1 percent level for all firms. It is concluded that the labor input has greater influence on overall production process for all studied firms.

Second objective of the study: The growth rates of capital intensity of all the selected firms have registered positive and statistically significant at 5 percent level except RINL. When we observed the relationship of labor productivity and capital intensity, they were using two equations; the first equation clearly showed that there is significant association between capital intensity and labor productivity for all studied firms; the second, from which the effect of technical change on labor productivity has been estimated, it is clear that there is significant effect of technical change on labor productivity in all firms except GKW, so the firm GKW should concentrate on technological changes in future.

Third objective of the study: Index of efficiency of labor (E_L) is observed that the efficiency of the labor is greater than zero (E_L>0) are noted in 7 firms (MEL, SAIL, TSL, RINL, HIL, HCL, and BALCO) for the overall study period and it concludes that the production is being organized in such an efficient manner that more gains in the labor productivity become possible than are permissible by the technical relationship of capital–labor and output–capital ratios. On the whole, out of 10 firms, 7 firms are moving in the right direction and performed much better in the use of labor input for the overall study period. The study suggests that the remaining 3 firms, namely, HZL, NALCO, and GKW failed the use of labor input and these firms should improve the efficiency of labor input.

Fourth objective of the study: Divisia TFP indices and their growth rates reveals that out of 10 firms, 7 (SAIL, TSL, RINL, MEL, HZL, HIL, and NALCO) firms registered positive growth rates and are statistically significant at 5 percent level. In the case of GKW and HCL the growth was declining and in BALCO there was low growth during the study period. These results reveal that 7 out of 10 firms exhibit technological progress and technological retrogression is observed in GKW and HCL. The technical neutrality is observed in BALCO. So the study suggests that these 3 (GKW, HCL, and BALCO) firms should improve their technological progress.

Bibliography

Ahluwalia, I. J. (1991), Productivity and growth in Indian manufacturing. New Delhi: Oxford University Press.

Ahmed Ausuf (1981), "Growth of partial factor productivity and economic efficiency in manufacturing sector of developing economy-A statistical analysis," *Margin*, 13(4): 53–63.

Boyce, J. K. (1986), "Kinked exponential models for growth rate estimation," *Oxford Bulletin of Economics and Statistics*, 48(4): 385–91.

Burange, L. G. (1999), "Industrial growth and structure: Manufacturing sector in Maharashtra," *Economic and Political Weekly*, February 27: M39–48.

Christensen Laurits, R. et al. (1973), "Transdentel Logarithmic Production Function Frontiers," *Review of Economics and Statistics*, 55(1): 29–45.

Economic Survey (2009–10), *Economic Division, Ministry of Finance*, New Delhi. Available online at www. indiabudject.nic.in

Goldar, B. (1986), *Productivity Growth in Indian Industry*. New Delhi: Allied Publishers.

Government of India (2009), "Index Numbers of Wholesale Price in India: Base 1993-94," *Yearly Bulletin*, Ministry of Industry Udyog Bhavan, New Delhi (various issues).

Kathuria, V. (2002), "Liberalization, FDI, and productivity spillovers – An analysis of Indian manufacturing firms," *Oxford Economic Papers*, 54: 688–718.

Kendrick, J. W. (1956), "Productivity Trends: Capital and Labor," *Review of Economic and Statistics*, August.

Krishnamurthy, V. (1986), "Industrial Productivity Upgrading Human Resources," *Economic Times*, December, 15, p. 5.

Kumar, Sunil (2001), *Productivity and factor substitution: Theory and analysis*. New Delhi, India: Deep and Deep Publications Pvt Ltd.

Mehta, M. M. (1955), *Measurement of industrial productivity*. Calcutta: The World Press Ltd., p.11.

Mitra, A. K. (1974), "Employment in the manufacturing industry: An analysis of growth rate and trend (1960-70)," *Artha Vijnana*, 16(1, March): 1–49.

Mohanan, S., and Philip Varughese (2009), "Productivity in public sector industrial undertakings: The Indian scenario," *International Journal of Indian Culture and Business Management*, 2(6): 602–24.

Mongia, P., and J. Sathaye (1998), "Productivity trends in India's energy intensive industries: A growth accounting analysis," *Lawrence Berkeley National Laboratory*, 41838, Berkeley, CA.

Mongia, P., K. Schumacher, and J. Sathaye (2001), "Policy reforms and productivity growth in India's energy intensive industries," *Energy Policy*, 29; 715–24.

Pradhan, G. and K. Barik (1998), "Fluctuating total factor productivity growth in developing economies: A study of selected industries in India," *Economic and Political Weekly*, 34 (July 31): M92–97.

Schumacher, K. and J. Sathaye (1999), "India's cement industry: Productivity, energy efficiency and carbon emissions," *Lawrece Berkely Naional Laboratory*, 41842, Berkeley, California.

Websites:

www.worldsteel.org
www.sail.co.in
www.steel.nic.in

"Quality is everyone's responsibility"

— W. Edwards Deming

Focus

Lean Manufacturing : Issues and Perspectives

S. J. THANKI AND JITESH THAKKAR

Increasing awareness of the benefits attained by application of lean principles has led many industries to incorporate lean philosophy and its tools and techniques. The basic premise of this article is to acknowledge the various issues with respect to lean implementation and explore the diverse views of lean manufacturing available in the literature. Key issues for the successful implementation of lean principles are presented and a lean implementation framework, "Tree of lean implementation," is proposed.

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In the existing global competitive environment, it is the prime need for the industries to accept the global and local market challenges and adopt the various tools and techniques to enhance their productivity, quality standards, and customer satisfaction. As far as Indian industries are concerned, India's manufacturing sector growth during quarter ending March 31 this year stood at 5.1%, which is one-third of China's factory output of 15% and also lower than the world average of 6.5% according to a UN body report. As per the Confederation of Indian Industry (CII) report (2010, p.5), the contribution of the manufacturing sector to GDP is substantially lower in India compared to other rapidly developing economies (RDEs) which is about 15% compare to China with 34%. The National Manufacturing Competitive Council (NMCC) report (2006, p.11) suggests that 2006–2015 is the manufacturing decade for India and to attain this target, the average growth rate of 12–15% needs to be achieved in respect of manufacturing. To achieve the set target, NMCC has launched a program, namely, Lean Manufacturing Competitiveness Scheme, since July 2009 with an objective to assist the Indian MSMSs to reduce their manufacturing costs through proper personal management, better space utilization, scientific inventory management, improved process flows, reduced engineering time, etc., with the application of lean manufacturing techniques having the 2010–11 budget estimate of Rs 20 crore and revised estimate of Rs 10.10 crore (MSME Annual Report, 2010–11, p. 293). The CII (2010, p. 55) report also suggests the application of lean manufacturing principles to achieve sustainable transformation.

The CII (2010, p.55) report unfolds the fact about the poor understanding and application of lean principles in the Indian industries. The report indicated that most "lean" efforts have had short-term focus and at best have created well-functioning plants, but missed on fully integrating the lean concepts into the organization. To accomplish the desired results, it is very important to realize the principles of lean manufacturing in entireness.

The various literatures have presented the term "lean manufacturing" in different perspectives:

> A set of practices focused on reduction of wastes and non-value added activities from a firm's manufacturing operations. (Shah and Ward, 2003, p. 137).

> Lean production is "lean" because it uses less of everything compared to mass production—half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products. (Womack et al., 1990, p.13).

> Integrated manufacturing system intended to maximize capacity utilization and minimize buffer inventories through minimizing system variability. (de Treville and Antonakis, 2006, p. 102).

> Production that is accomplished with minimal buffering costs. (Hopp and Spearman, 2004, p. 133).

> Collection of practices that work together synergistically to create a streamlined high quality system that produces finished products at the pace of customer demand with little or no waste. (Shah and Ward, 2003, p.129).

> Extent to which certain JIT flow and quality practices are implemented. (McLachlin, 1997, p.273).

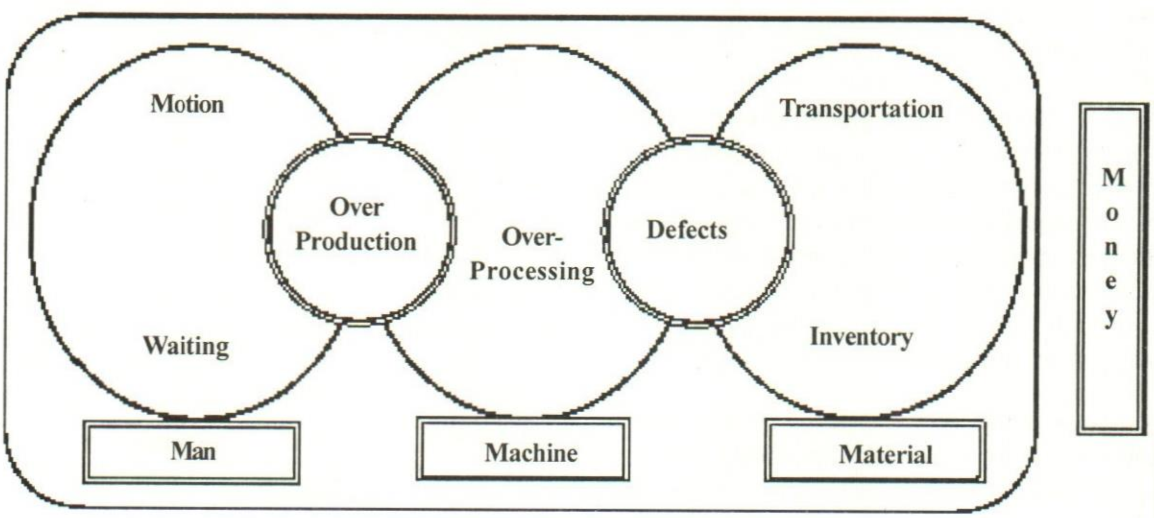
> Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability. (Shah and Ward, 2007, p.791)

We propose the following definition to capture the many aspects of lean production.

> Lean Production is a set of tools or practices to reduce or minimize the production system wastes which result in better production system performance and increased value to the customer through higher customer satisfaction in terms of product or service quality and variety.

We have defined lean production as a set of tools or practices which helps to either reduce or minimize the waste (muda) in the production system and the customer is the decision-making authority to determine what is waste and what is not. There is general consensus that there are four main aspects of lean production and frequently group-related practices together into bundles. These are practices associated with quality management, pull production, preventive maintenance, and human resource management (Shah et al., 2008, p. 6681). In an internal manufacturing context, there are three types of operation that can be categorized: non-value adding (NVA); necessary but non-value adding (NNVA); and value adding

Figure 1: Classification of Seven Wastes and their Effect on Money



Source: Rawabdeh (2005, p. 802).

(VA). The first of these is pure waste and involves unnecessary actions that should be eliminated (Hines and Rich, 1997, p.47). Waste can be defined as anything other than minimum amount of resources which do not add value to the product or service. From the perception of end users, waste is internal and external resources that are consumed without adding value to the customers (Emiliani, 2001, p. 36), that is, if a customer is not willing to pay for them, their existence is considered a waste (Rawabdeh, 2005, p. 801). Rawabdeh (2005, p.802) has classified seven different types of manufacturing wastes, namely, overproduction, waiting time, transport, inventory, motion, defects and processing into three broad categories namely man, machine, and material, as presented in Figure1.

Identification of wastes within the production process is the first step to improve the existing state of the system. Once identified, it is the foremost requirement to eliminate waste applying appropriate lean production tools to make the production process efficient.

It is important to understand the benefits exhibited by lean production over traditional manufacturing. Traditional manufacturing systems are based on the principle of economies of scale where the large fixed costs of production are depreciation intensive as huge capital investments made in high-volume operations. To minimize the unit production cost, the production batch size is kept large which results in large WIP inventories. In lean manufacturing system, production and assembly cells consisting of product focused resources (workers, machines, floor space, etc.) are closely linked in terms of their throughput times and inventory control. These cells are typically U-shaped or rectangular and contribute to obtain smooth (balanced) work flow across a wide variety of products, facilitates to elimination of waste and provides high quality output, flexible operation, and low total unit production costs. The application of lean manufacturing principles leads to incur reduced lead time and higher throughput, smaller floor space requirements, and lower work in process (Sullivan et al., 2002, p. 255). Another characteristic of lean organizations is employment of small flexible machines into work cells for the production of a family of products which minimizes the cycle time, inventory and maximizes quality.

The purpose of this article is to discuss different issues associated to lean implementation and to propose a framework for lean implementation. The article also highlights the various perspectives pertained to lean production and its applicability in services. In the following section, we review the literature pertained to lean production and raise the respective issues of lean production. The next section answers the question "why lean manufacturing?" quoting success stories of few lean organizations. In the succeeding section, the lean implementation issues are talked about and a lean implementation framework is proposed. The next section discusses the applicability of lean principles to services. Finally, the article ends with conclusions.

Literature Review

The primary idea behind this article is to highlight some of the issues related to lean manufacturing and to critically examine different perspectives about lean manufacturing. Lean production or lean manufacturing is a management philosophy derived mostly from the Toyota Production System (TPS). The book *The machine that changed the World* by Womack, Jones and Roos in year 1990 introduced the term 'lean production' and the book has become one of the most widely cited references in operations management over the last decade. Fujimoto had concluded in his seminal review of the evolution of the Toyota Production System:

> Toyota's production organization [. . .] adopted various elements of the Ford system selectively and in unbundled forms, and hybridized them with their ingenious system and original ideas. It also learnt from experiences with other industries (e.g. textiles). It is thus a myth that the Toyota Production System was a pure invention of genius Japanese automobile practitioners. However, we should not underestimate the entrepreneurial imagination of Toyota's production managers (e.g. Kiichiro Toyoda, Taiichi Ohno, and Eiji Toyoda), who integrated elements of the Ford system in a domestic environment quite different from that of the United States. Thus, the Toyota-style system has been neither purely original nor totally imitative. It is essentially a hybrid. (Fujimoto, 1999, p. 50; Holweg, 2007, p. 422).

This explains the fact that lean manufacturing is the set of practices which are not purely and entirely devised at Toyota but it is a group of various management practices which are refined and applied systematically and synergistically at Toyota. Toyota Production System (TPS) is a system of nested experiments through which operations are constantly improved (Spear, p. 80). Shah and Ward (2003, p. 129) had explained lean production as a multi-dimensional approach that encompasses a wide variety of management practices, including just-in-time, quality systems, work teams, cellular manufacturing, supplier management, etc., in an integrated system and these practices can work synergistically to create a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste. Employment of lean manufacturing practices or principles is not only improving the performance within the organization or plant but it also affects positively to the external practices. Wu (2003, p. 1371 and 1349) suggested that application of internal lean manufacturing

Table 1: Contemporary Literature on Lean Manufacturing Issues

Sr.No.	Reference	Issue	Findings
1	Sanchez, A.M. and M.P. Perez (2001)	Leanness assessment	A check-list model with 36 lean indicators disseminated in six groups to assess the changes toward lean production and also discussed the importance of lean indicators for developing company's manufacturing strategy.
2	Pavnaskar S.J., J.K. Gershenson, and A.B. Jambekar (2003)	Lean manufacturing tools	Classification scheme with systematically organized 101 lean manufacturing tools and metrics according to their level of abstraction, appropriate location of application of the tool in the organization.
3	Bruun P. and R.N. Mefford (2004)	Supply chain	The Internet is a perfect tool for accomplishing the lean supply chain with its open, easy, and cheap access.
4	Huang, C.C. and S.H. Liu (2005)	Lean control	A generalized label-correcting algorithm to determine the desired stages of lean manufacturing, which are difficult to show in the VSM.
5	Reichhart A. and M. Holweg (2007)	Lean distribution	Adopting a lean distribution strategy bears an equally strong improvement potential to that of lean production.
6	Lander E. and J.K. Liker (2007)	TPS	A true Toyota-style system is a learning organization that is constantly adapting its technical and social systems to improve its performance and ensure its long-term survival so that it may continue to fulfill its purpose of generating value for society and for its stakeholders.
7	Towill, D.R. (2007)	TPS	The prism model of TPS assists visualization of the "systems process" for performance betterment.
8	Shah R. and P.T. Ward (2007)	Lean production / Leanness measurement	Forty eight practices/tools to represent the operational space surrounding lean production. Ten measure factors which constitute the operational complement to the philosophy of lean production and characterize ten distinct dimensions of a lean system. The empirically validated measurement instrument for researchers who are interested in conducting survey research related to lean production systems.
9	Takeuchi, H., E. Osono, and N. Shimizu (2008)	Toyota production system	TPS is necessary but not sufficient to account for Toyota's success. Toyota's culture of contradictions plays as important a role in its success as TPS does.
10	Fullerton, R.R. and W.F. Wempe (2009)	Performance measurement	Shop-floor employee involvement is critical to the successful adoption of lean production, and that lean production methods encourage the use of non financial manufacturing performance (NFMP) measures.
11	Thun, J.H., M. Druke, and A. Grubner (2010)	Kanban/JIT	Kanban is the center of the TPS and it is strongly influenced by the supportive factors' quality, setup times, and shop-floor layout, which are triggered by the training and skills of the workforce. The workers are the core element of the TPS and they make it a success or a failure.
12	Eroglu, C. and C. Hofer (2011)	Inventory management	While lean inventory strategies may be economically viable in some industries, other industries may not be amenable to such approaches due to their particular product, production technology, supply or demand characteristics.
13	Naim, M.M. and J. Gosling (2011)	Leagility	Leagility attempts to get the "best of both worlds," There is strong agreement for the flexibility/service and cost criteria. Lean, agile, and leagile systems may be implemented based on the product type and where in the life cycle that product is.

techniques not only has a significant impact on plant performance, but it also facilitates many external logistics practices. Even given the same organizational constraints and resources, lean suppliers gain significant competitive advantages over non-lean suppliers in production systems, distribution systems, information communications, containerization, transportation systems, customer-supplier relationships, and on-time staging/delivery performance. Another important issue in today's industrial scenario is related to environment management practices for the improvement in environmental performance of processes and products in the forms of eco-design (for example, design for environment), recycling, waste management and life-cycle analysis. The findings of Yang, Hong, and Modi (2011, p. 5) strongly suggest that the lean manufacturing enhances the environmental management practices. Another important issue which is in line with the principles of lean manufacturing is "Lean consumption." Lean consumption is about providing the full value that consumers desire from their goods and services, with the greatest efficiency. By minimizing customers' time and effort and delivering exactly what they want when and where they want it, companies can reap huge benefits and least pain (Womack and Jones, 2005, p. 59). The other important issues associated with lean manufacturing are lean control, lean distribution, lean product development, leanness assessment etc., are included in the Table 1.

Why Lean Manufacturing?

Any organization seeking the improvement in the overall business performance in terms of market performance, operational performance, and financial performance from its current state would attempt to borrow the tools and techniques termed as "Best Practices" adopted by the other successful organizations. But it is extremely important to understand that the selection of appropriate set of tools and techniques suitable to their environment will lead to bettered performance. Thus, there is a need to determine which practices or tools to use to improve specific area of performance, in addition to analyzing any detrimental effects on other areas of performance (Davies and Kochhar, 2002, p. 292). Lean production or lean manufacturing is not about volume or mass production. It is more about delivering goods with the maximum indices achievable for the four order-winning criteria of price, quality, on-time delivery, and availability in the required quantities as measured by the customer. These indices can only be continuously improved by the constant removal of waste in the system that delivers the customers' ever-increasing expectations (Phillips, 1999, p. 19). Lewis (2000, p.959) has noted that lean production can support competitive advantage if the firm is able to appropriate the productivity savings it creates. Findings of Shah and Ward (2003, p. 146) provide univocal evidence that the synergistic effects of all lean practices are associated with better manufacturing performance. These affirm the caliber of lean manufacturing practices in improving the overall performance of the organization. To evidence the benefits earned by application of lean manufacturing practices, some cases are presented here.

Case 1. Process Industry: A Steel Production industry (ABS) (Abdulmalek and Rajgopal, 2007)

The case company produces several grades of steel that are used primarily in appliance manufacturing. The current state map prepared using VSM tool for ABS reveals several things: (a) large inventories; (b) the difference between the total production lead time (around 51 days) and the value added time (5 days), which is under 10% of the total, and (c) each process producing to its own schedule. A simulation model used to investigate the effect of lean tools like pull type production system, set-up time reduction and TPM (total preventive maintenance) on the current state. The results shows that with the new improvements at ABS the value added time (5 days) is up from approximately one-tenth of the production lead-time in the old system, to approximately one-third of the total production lead-time of slightly under 15 days (12.84 in waiting plus about 2 in processing). Put another way, non-value added time is about 8.6 times the value added time according to the current state map, but with the future state map the value of this multiplier drops to about 2. The case demonstrates the feasibility of adapting adequate lean techniques in the process industry.

Case 2. Safari park (Julien and Tjahjono, 2009)

Woburn safari park (WSP) opened in 1970 as the second safari park in UK. In 1972 the WSP had a record attendance of 1,000,218 customers where as the number of customers in 2005 was 449,402. The organization of WSP follows a typical functional structure consisting of seven areas: retail, education, animal collection, maintenance and facilities, leisure, administration, and catering. After the brainstorming sessions and rounds of meetings with management of the park, it was an agreement to focus on entrance management, customer flow, feed logistics, retail inventory management and resource allocation within maintenance. Finally, the key factors to consider when investigating these five areas further were: internal customer service level, external customer service level, number of man hours and profit. The current state maps for five key processes were prepared to identify the waste in terms of money, time, transportation, and other parameters. The future state map of feed logistic area identified two major areas of improvement: dispatch system and the feed requirements. From the areas analyzed in this project a potential annual bottom line improvement of £91,000 was identified.

Case 3. Bayer MaterialScience North America (Babe, 2011)

The company Bayer MaterialScience North America was facing the issues like unfavorable chemical import–export trends, natural gas price increases, and customer inventory shifts and so, Greg Babe, the CEO of company turned the blow into an opportunity to completely reshape his company. He selected just four key people in his core team with the right mix of skills and an ability to think outside the box: a special-projects executive with a good external view from previous experience as a consultant, a top controller, someone with a strong marketing background, and someone with organizational change experience. They planned strategies and actions through a growth lens rather than a tactical cost-reduction lens. The core team had selected leaders and a total of 100 others to oversee the four key areas of our transformation: growth, business support, supply chain, and culture. They redesigned virtually every one of the business processes following the mantra "Simplify, standardize, automate." For example, they streamlined and eliminated defects in their order to cash process to create "no touch" orders. They developed a variable transportation cost model through careful negotiations with two key vendors—which was crucial to controlling costs amid the ebbs and flows of the business. They killed several much-loved projects having limited commercial potential; instead they opted for a rigorous stage-gate development process that would require clear evidence of solid commercial potential before projects could go forward. They developed change management skills within the organization. They made their warehousing, transportation, and international freight needs and costs variable by means of outsourcing. Doing so, they reduced total SG&A (selling, general, and administrative) costs by 25% ($100 million) and head count by nearly 30%. They developed new skills in the organization. Most important, they had enabled future growth in a highly efficient and highly effective organizational model. They spent only $60 million of the $70 million they were allotted. This case explains the effectiveness of the lean manufacturing practices like team work and leadership, cross-functional team work, standardized work and total quality management.

Case 4: Material handling operations (Lee and Allwood, 2003)

A case presented here is of a manufacturing facility of the industry leader for petroleum field diamond drill bits for oil field services industry which focuses and uses the material handling system to move parts and components of parts through a variety of manufacturing processes.

Material handling is considered as a non-value adding but necessary activity for the successful completion of the manufacturing process. The cost generated by material handling systems, productivity and the incidence rate of injuries, specifically lost time injuries can be reduced if steps can be taken to improve these systems. The value stream map data identified some of the area of improvement in a process stream: *(i)* Reduction of time to transport and place shank components in the inventory area. *(ii)* The reduction of handling shanks from inventory area to the crown machine cell. *(iii)* The reduction of staging time in the crown machine cell. *(iv)* The reduction of handling time to move the component into the machine to attach to the crown. Based on the potential solutions, the following prioritization was made: *(i)* Improving shank handling and staging within the crown machine cell. *(ii)* Move location of shank inventory. *(iii)* Incorporate new lifting and handling devices to attach the shank to the crown. The company employed the lean manufacturing tools like process mapping, space utilization, travel distance, visual control, 5S housekeeping, training, communication plan, roles and responsibilities, kanban pull system and operational rules. Based on these lean tools, the shank staging device was developed to accommodate the geometry of the shank allowing for ease of loading as well as ease of shank selection and retrieval without increasing the time needed to perform these tasks, the handling time from inventory to assembly was reduced from approximately 1020 minutes per week as to 330 minutes per week and the operations after the implementation of the device saved approximately 865 minutes per week, or 14.4 hours.

Table 3 compares the above cases with respect to various lean dimensions.

Table 2: Lean Manufacturing System Implementation Issues and their Attributes

Implementation Issues in Lean Manufacturing System

Category	Attributes	Category	Attributes
	Inventory	Inventory Management	Small batch production
	Lead time		Set up time reduction
	Rejection		Nearby supplier
	Warranty claims		Nearby customer
	Transportation cost		Direct online supplier
	Breakdown maintenance	Quality	Process control
Key Issues	House keeping		Vendor development
	Product design / changes in design		Level of automation
	Process selection		Measurement of quality
	Supplier selection	Maintenance	Spare part management
	Vendor selection		Cleanliness
	Material handling		Application of TPM
	Information technology		Worker's participation

Issues In Lean Implementation

Before implementing such a concept in the organization, practitioners must realize the complexities involved in implementation and the associated pitfalls. At the organizational level, a few critical issues need to be considered.

(1) What concrete purpose is "lean" going to serve?

(2) How is this going to be worked out in an organization-wide change program?

(3) How can such a generic program be put to use in concrete change projects within the organization?

In brief, practitioners need concepts and tools, but their well-considered use is as crucial as their availability (Benders and Slomp, 2009, p. 5242). Black (2007, p. 3662) had expressed his perceptions on lean production implementation.

- When implementing lean manufacturing, start at the top with the CEO/president. Systems level changes require strong leadership.
- Perfection is not optional. Defects can be prevented. Make every process capable of zero defects. When something goes wrong, fix it right away.
- When asked to choose between cost and quality, take both.
- Maintenance is not an option. The squeaky wheel gets replaced. Zero machine breakdowns and zero tool failures is the goal.
- Continuous improvement requires continuously changing and improving the manufacturing system design.

Table 3: Comparison of cases with respect to lean dimensions

	Lean Dimensions		Lean Dimensions
Case 1	• Pull production system • Set up time reduction • TPM	Case 3	• Cross-functional work force • Self-directed work teams • Standardized work • TQM
Case 2	• 5 S housekeeping • Layout size and shape • One piece flow • Reengineered production (business) process	Case 4	• Layout size and shape • Visual control • 5S housekeeping • Multi-functionality and cross training • Team work and Leadership • Kanban pull system • Information exchange

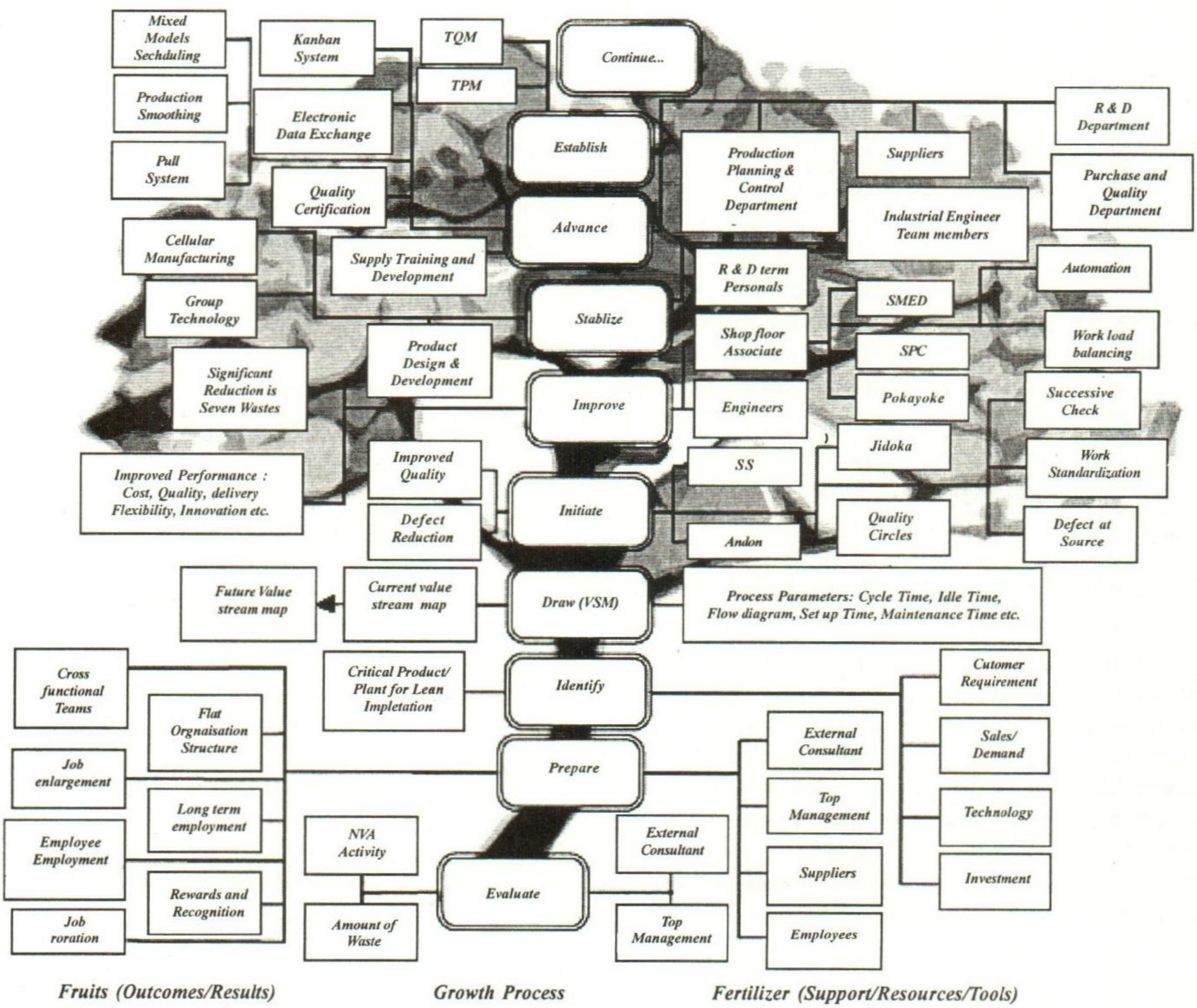
- Lowering inventory in the links will improve the throughput time (TPT), so inventory levels must be continuously lowered. Do not confuse cycle time with throughput time (TPT). However, very short CTs are not the goal.
- Build a simple MSD (manufacturing system design) so everyone who works in the factory understands how the factory works, how it functions operationally.
- In lean manufacturing, the supply chain is a design decision, that is, the production control function is built into the design and functions automatically.

Various issues related to implementation of lean manufacturing system acknowledged by Upadhye et al. (2009) are listed in Table 2.

It is crucial to realize that implementation of lean principles requires total overhauling process for the organization and firm commitment of the entire community of the organization to work as a whole for the successful lean implementation. The entities that do not have a strong customer focus, are not interested in survival and growth, and are not willing to drive out waste over the long term would not be good candidates for lean as a guiding business philosophy. In fact, in almost all cases such as this, lean simply will not work (Wilson, 2010, p.33). A lean implementation framework (Tree of Lean Implementation) based on Anand and Kodali (2010, p.107–108) is introduced in Figure 2.

The framework is presented as a growing tree which consumes fertilizer in the form of organization resources

Figure 2. Lean Implementation Framework



or top management and departmental support and operational data at each stage of maturation and produces fruits in the form of improved product and service quality, customer satisfaction, and improved organization performance. The terms used in the framework are self explanatory and not discussed here.

Can Lean be Applied to Services?

Most manufacturing companies in the world have adopted some type of "lean initiative," and this concept is now spreading to a diverse range of organizations, including the defense department, hospitals, financial institutions, and construction companies (Liker and Morgan, 2006, p.5). The product development system established at Toyota represents the clearer lessons for lean services (Liker and Morgan, 2006, p.6). Five lean principles were identified to guide organizations in all sectors of the economy, including service, in lean transformation (Womack and Jones, 1996, cited in Piercy and Rich, 2009, p. 55).

- Value: Determine what is customers value (specifically, what they are prepared to pay for) in the product or service.
- The value stream: Map out (with a process or value stream map), how value is delivered. Use this as a basis for eliminating any area that does not add value.
- Flow: Ensure products and information seamlessly flow from start to finish of the value stream. Remove inventory or buffer zones with the use of structural enablers such as modular designs, cellular working, general purpose machines, multi-skilled workers.
- Pull: Only deliver what is actually demanded (pulled) by the customer rather than serving from stocks or buffers.
- Perfection: Continually seek to improve the processes and systems with the above principles, striving for perfection.

Lee et al. (2008) highlighted a case study of a South Korean supply chain system to demonstrate the entrepreneurial application of such approaches. Cuatrecasas (2002) had reported the methodology for implementation of lean management in a services production system, as applied to the case of telecommunication services. Staats et al. (2011) had identified challenges posed by using ideas from lean production in a knowledge work setting with a case of software service provider. Piercy and Rich (2009) had validated the application of the lean approach in a pure service environment where traditional, classical management approaches are failing to deliver the necessary quality and cost requirements. Swank (2003) had explained that successful application lean production principles are not limited to manufacturing industries as many of the tools were developed in service industries. The findings reported by Kollberg et al. (2007) also confirm that lean thinking is applicable in health care settings.

These works suggest the applicability of lean in service industries also.

Conclusion

Based on the various lean definitions available in the literature, we have proposed a lean manufacturing definition, which captures the central aspect of lean philosophy. Various success stories justify the need for lean manufacturing tools and techniques to satisfy the customer requirements in terms of cost, quality and flexibility. The desired results can be achieved only if process of lean implementation is performed with great care and sincerity. The "Tree of Lean Implementation" presented here will provide necessary directions to the practitioners and managers for successful implementation of lean principles. Application of lean principles is not limited to manufacturing industries but they are equally applicable to service industries and service environment as well with great effect.

References

Abdulmalek, F. A. and J. Rajgopal (2007), "Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study," *International Journal of Production Economics*, 107.

Anand, G. and R. Kodali (2010), "Development of a framework for implementation of lean manufacturing systems," *International Journal of Management Practice*, 4(1).

Babe, G. S. (2008), "How i did it: The CEO of Bayer Corp. on creating a lean growth machine," *Harvard Business Review*.

Benders, J. and J. Slomp (2009), "Struggling with solutions: A case study of using organisation concepts," *International Journal of Production Research*, 47(18).

Black, J. (2007), "Design rules for implementing the Toyota Production System," *International Journal of Production Research*, 45(16).

Boston Consulting Group, Confederation of Indian Industry (2011), "Indian Manufacturing: The Next Growth Orbit."

Bruun, P. and R.N. Mefford (2004), "Lean production and the Internet," *International Journal of Production Economics*, 89.

Cuatrecasas, L. (2004), "A lean management implementation method in service operations," *International Journal of Services, Technology and Management*, 5(5 & 6).

Davies, A. J. and A. K. Kochhar (2002), "Manufacturing best practices and performance studies: A critique," *International Journal of Operations and Production Management*, 22(3).

Emiliani, M. L. (2001), "Redefining the focus of investment analysts," *TQM Magazine*, 13(1).

Eroglu, C. and C. Hofer (2010), "Lean, leaner, too lean? The inventory-performance link revisited," *Journal of Operations Management*, 29(4).

Fujimoto, T. (1999), *The evolution of a manufacturing system at Toyota*. Oxford: Oxford University Press.

Fullerton, R. R. and W. F. Wempe (2009), "Lean manufacturing, non-financial performance measures, and financial performance," *International Journal of Operations and Production Management*, 29(3).

Government of India, Ministry of Micro, Small and Medium Enterprises (2011), "Annual Report 2010-11."

Hines, P., Rich N. Nick (1997), "The seven value stream mapping tools," *International Journal of Operations and Production Management*, 17(1).

Holweg, M. (2007), "The genealogy of lean production," *Journal of Operations Management*, 25.

Hopp, W. J. and M. L. Spearman (2004), "To pull or not to pull: what is the question?" *Manufacturing & Service Operations Management*, 6(2).

Huang, C. C. and S. H. Liu (2005), "A novel approach to lean control for Taiwan-funded enterprises in mainland China," *International Journal of Production Research*, 43(12).

Julien, D. M. and B. Tjahjono (2009), "Lean thinking implementation at a safari park," *Business Process Management Journal*, 15(3).

Kollberg, B., J. J. Dahlgaard, and P. O. Brehmer (2007), "Measuring lean initiatives in health care services: Issues and findings," *International Journal of Productivity and Performance Management*, 56(1).

Lander, E. and J. K. Liker (2007), "The Toyota production system and art: Making highly customized and creative products the Toyota way," *International Journal of Production Research*, 45(16).

Lee, S. M., D. L. Olson, S. H. Lee, T. Hwang, and M. S. Shin (2008), "Entrepreneurial applications of the lean approach to service industries," *Service Industries Journal*, 28(7).

Lee, W. L. and J. M. Allwood (2003), "Lean manufacturing in temperature dependent processes with interruptions," *International Journal of Operations and Production Management*, 23(11).

Lewis, M. A. (2000), "Lean production and sustainable competitive advantage," *International Journal of Operations and Production Management*, 20(8).

Liker, J. K. and J. M. Morgan, "The Toyota way in services: The case of lean product development," *Academy of Management Perspectives*, 20(2).

McLachlin, R. (1997), "Management initiatives and just-in-time manufacturing," *Journal of Operations Management*, 15.

Naim, M. M. and J. Gosling (2011), "On leanness, agility and leagile supply chains," *International Journal of Production Economics*, 131.

National Manufacturing Competitive Council (2006), "National Strategy for Manufacturing."

Pavnaskar, S. J., J. K. Gershenson, and A. B. Jambekar (2003), "Classification scheme for lean manufacturing tools," *International Journal of Production Research*, 41(13).

Phillips, M., "Agile manufacturing in the aerospace industry: An industrial viewpoint," *International Journal of Agile Management Systems*, 1(1).

Piercy, N. and N. Rich (2009), "Lean transformation in the pure service environment: The case of the call service centre," *International Journal of Operations and Production Management*, 29(1).

Rawabdeh, I. A., "A model for the assessment of waste in job shop environments," *International Journal of Operations and Production Management*, 25(8).

Reichhart A. and M. Holweg (2007), "Lean distribution: Concepts, contributions, conflicts," *International Journal of Production Research*, 45(16).

Sanchez, A. M. and M. P. Perez (2001), "Lean indicators and manufacturing strategies," *International Journal of Operations and Production Management*, 21(11).

Shah, R., A. Chandrasekaran, and K. Linderman (2008), "In pursuit of implementation patterns: The context of Lean and Six Sigma," *International Journal of Production Research*, 46(23).

Shah, R. and P. T. Ward (2007), "Defining and developing measures of lean production," *Journal of Operations Management*, 25.

Shah, R. and P. T. Ward (2003), "Lean manufacturing: Context, practice bundles, and performance," *Journal of Operations Management*, 21.

Spears, S. J. (2004), "Learning to Lead at Toyota," *Harvard Business Review*, 82(5).

Staats, B. R., D. J. Brunner and D. M. Upton, "Lean principles, learning, and knowledge work: Evidence from a software services provider," *Journal of Operations Management*, 29.

Sullivan, W. G., T. N. McDonald, and E. M. Van Aken (2002), "Equipment replacement decisions and lean manufacturing," *Robotics and Computer Integrated Manufacturing*, 18.

Swank, C. K. (2003), "The lean service machine," *Harvard Business Review*, 81(10).

Takeuchi, H., E. Osono, and N. Shimizu (2008), "The contradictions that drive Toyota's success," *Harvard Business Review*, 86(6).

Thun, J. H., M. Druke, and A. Grubner (2010), "Empowering Kanban through TPS-principles - An empirical analysis of the Toyota production system," *International Journal of Production Research*, 48(23).

Towill, D. R. (2007), "Exploiting the DNA of the Toyota production system," *International Journal of Production Research*, 45(16).

Treville, S. and J. Antonakis (2006), "Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues," *Journal of Operations Management*, 24.

Upadhye, N., S. G. Deshmukh, and S. Garg (2009), "Key Issues for the implementation of lean manufacturing system," *Global business and management research: An international journal*, 1(3 & 4).

Wilson, L. (2010), *How to Implement Lean Manufacturing*. McGraw Hill.

Womack, J. P., D. T. Jones, and D. Roos (1990), *The machine that changed the world*. New York: Simon & Schuster.

Womack, J. P. and D.T. Jones, "Lean consumption," *Harvard Business Review*.

Wu, Y. C. (2003), "Lean manufacturing: A perspective of lean suppliers," *International Journal of Operations and Production Management*, 23(11).

Yang, M. G., P. Hong, and S. B. Modi (2011), "Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms," *International Journal of Production Economics*, 129(2).

"Quality is never an accident; it is always the result of high intention, sincere efforts, intelligent direction and skillful execution; it represents the wise choice of many alternatives."

— William A. Foster

Focus

Modeling and Optimization of Machining Process Parameters for Power Consumption of Al-composites

SATPAL SHARMA

In the present investigation, Aluminum—Silicon Carbide (Al—SiC) composites were machined using cutting speed, feed rate, depth of cut, and nose radius. The machining of the composites was carried out to study the power consumption using face-centered design with three levels of each factor. A response surface model for power consumption was developed in terms of main factors and their significant interaction. The developed model was validated by conducting experiments at different levels of factors used. Further, the model was optimized for power consumption. An error of 35% was observed in the modeled and experimental results.

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Machine tool, workpiece, and cutting tool are the three main components in a machining operation. The relative motion between the workpiece and cutting tool is responsible for material removal from the workpiece in order to get the desired shape and size. The basic machining operations performed on various types of materials are turning, milling, drilling, and grinding. Turning is the process in which material is removed by rotating the workpiece held between centers/chuck. The main factors in the turning operation that can affect the performance of the machining operation are cutting speed, feed rate, and depth of cut. The performance of the machining operation can be measured in terms of material removal rate, surface finish, power consumption and tool wear under operating conditions. The power consumption is known to be significantly affected by different cutting parameters such as cutting speed, feed rate, and depth of cut (Shaw, 2004).

In the last decades, Aluminum—Silicon Carbide (Al-SiC) composites have been increasingly used in the automobile and aerospace industry due to their favorable strength-to-weight ratio for production of engine blocks and housings, cylinder heads, and cylinder-crank cases. The hard silicon carbide (SiC) particles contained in the soft aluminum matrix place significant challenges on the tool in the machining of these alloys. Aluminum metal matrix composites (MMCs) are mostly produced by a stir casting process (Clyne, 2001; Uhlmann et al., 2010). Stir casting is the simplest and the most commercial technique. The development of MMCs by stir casting technology has been one of the unique and feasible processes because of producing better matrix-particle bonding, easier control of matrix structure, simplicity, higher production rate, and economy (Sahin and Sur, 2004). It involves stirring the melt along with solid SiC particles and then allowing the mixture to solidify. Due to the addition of reinforcing materials, which are normally harder and stiffer than matrix, machining becomes significantly more difficult than those of conventional materials (Tomac and Tonnessen, 1992).

The MMCs have received considerable attention in the field of machining because of the high tool wear and increase in power consumption, with the increase in hardness due to the addition of SiC particles, while the production of near-net-shape MMC products produced by casting or hot forgings shows good compromise. But, due to reasons such as component design and dimensional tolerance requirements, the need for machining of composites cannot be completely eliminated. The Aluminum Oxide (Al_2O_3) and SiC particle-reinforced MMCs are extremely difficult to machine (turning, drilling, and milling) due to their extreme hard and abrasive properties (Durante, Rutelli, and Rabezzana, 1997; Salik, Kok, and Celik, 2002). The presence of the hard Al_2O_3 and SiC particles in the aluminum alloy MMCs makes them extremely difficult to machine as they result in rapid tool wear of the cutting tools. This further results in poor surface finish and high power consumption during machining. Various researchers (Davim, 2001; Kiliçkap et al., 2005; Palanikumar and Karthikeyan, 2007;) studied the effect of machining parameters such as cutting speed, feed rate, and depth of cut on surface roughness using single factor of experiment. An experimental investigation was conducted by Muthukrishnan, Murugan and Rao (2008) on the machinability of fabricated aluminum MMC LM-25 (A356/SiC/10p). Cutting conditions and parameters such as surface roughness, specific power consumption, and tool wear were measured and it was concluded that higher cutting speed results in easier removal of the hard SiC particles and hence results in better surface finish value of Ra and Rz. Therefore, most of the work regarding machining of MMCs has focused on the study of tool wear and surface finish characteristics of various tool materials during machining aluminum alloy composites (El-Gallab and Sklad, 1998; Finn and Srivastava, 1996; Hung et al., 1995; Joshi, Ramakrishnan, and Ramakrishnan, 1999; Lane, 1992; Lin, Bhattacharya, and Lane, 1995; Looney et al., 1992; Quan, Zhou, and Ye, 1999; Yanming and Zehna, 2000). Investigations on machining of light alloy composites reinforced with Al_2O_3/SiC fibers/particles (Chandrasekaran and Johansson, 1997; Cronjager and Meister, 1992) indicate poor machinability due to rapid abrasive wear of the tools resulting in high power consumption. Moreover, quality of the machined surface also deteriorates with tool wear (Chandrasekaran and Johansson, 1997). Hence in this study an attempt has been made to study the independent as well as combined effect of various machining factors on power consumption using full factorial design (Response Surface Methodology). Based on the experimental data obtained, a power consumption model was developed to correlate the power consumption in terms of applied factors and their significant interactions. The validity of the power consumption model was evaluated under different machining parameters by comparing the experimental and modeled results. Thus the validated model was optimized for power consumption.

Experimental Setup

Materials and Methods

Stir casting process was used to fabricate the Al-alloy composites. The experiments were performed on Al alloy and 10 wt. % SiC composites. The diameter and length of the workpiece material are 30 and 100 mm, respectively. The CNC Turning Machine was used for experiments. The tungsten carbide inserts used were of ISO coding CNMG 120404, CNMG 120408, and CNMG 120412 and tool holder of ISO coding PCLNR 1616H07 (Table 1). The machine parameters are given in Table 2. Selection of machining parameters was carried out after conducting pilot experiments. A set of two watt meters was used for measuring power consumption and readings of both. The watt meters were multiplied by a suitable multiplying factor so as to get the total power consumed under each specific run.

Table 1: Specifications of the insert used

Insert Type	Insert shape	Insert clearance angle	Nose radius
CNMG 120404	Diamond 80°	0°	0.4 mm
CNMG 120408	Diamond 80°	0°	0.8 mm
CNMG 120412	Diamond 80°	0°	1.2 mm

Table 2: Machining parameters and their range used in study

Level / Parameter	Designation	Low	Middle	High
Cutting speed, m/min	S	180 (—1)	210 (0)	240 (+1)
Feed rate, mm/rev	F	0.2 (—1)	0.4 (0)	0.6 (+1)
Depth of cut, mm	D	0.4 (—1)	0.8 (0)	1.2 (+1)
Nose radius, mm	R	0.4 (—1)	0.8 (0)	1.2 (+1)

Factorial design of experiment

The vast amounts of data have been generated by the traditional approach of experiment design in which one factor is varied at a time (cutting speed, feed rate, depth of cut and nose radius). In this approach it is difficult to evaluate the combined effects of applied factors (cutting speed, feed rate, depth of cut and nose radius). Thus RSM (Response Surface Methodology) with fractional factorial design of experiments with three levels of each factor (cutting speed, feed rate, depth of cut and nose radius) has been used in the present study. These factors were designated as S (cutting speed), F (feed rate), D (depth of cut) and R (nose radius) respectively. The actual and coded value of machining parameters are shown in Table 2. The coded values are shown in parentheses of various factors used in the present study. The experimental design matrix for different runs is shown in Table 3. The relation between the actual and coded value of a factor is shown below:

$$Coded\ value = \frac{Actual\ test\ conditions - Mean\ test\ conditions}{Range\ of\ test\ conditions / 2}$$

Table 3: Design matrix showing turning test parameters (factors) with their actual and coded levels (in small braces) and power consumption under various test conditions

Run No.	Cutting speed: S	Feed rate: F	Depth of cut: D	Nose radius: R	Power consumption (Watt)
1	180 (–1)	0.2 (–1)	0.4 (–1)	1.2 (+1)	254
2	180 (–1)	0.6 (+1)	0.4 (–1)	1.2 (+1)	376
3	210 (0)	0.4 (0)	0.8 (0)	0.8 (0)	430
4	180 (–1)	0.4 (0)	0.8 (0)	0.8 (0)	418
5	240 (+1)	0.6 (+1)	0.4 (–1)	1.2 (+1)	495
6	210 (0)	0.4 (0)	0.8 (0)	0.8 (0)	478
7	210 (0)	0.4 (0)	1.2 (+1)	0.8 (0)	521
8	240 (+1)	0.6 (+1)	1.2 (+1)	0.4 (–1)	674
9	180 (–1)	0.6 (+1)	0.4 (–1)	0.4 (–1)	484
10	210 (0)	0.2 (–1)	0.8 (0)	0.8 (0)	424
11	240 (+1)	0.2 (–1)	1.2 (+1)	0.4 (–1)	402
12	210 (0)	0.4 (0)	0.8 (0)	0.8 (0)	447
13	240 (+1)	0.2 (–1)	0.4 (–1)	0.4 (–1)	436
14	210 (0)	0.6 (+1)	0.8 (0)	0.8 (0)	528
15	240 (+1)	0.2 (–1)	0.4 (–1)	1.2 (+1)	538
16	180 (-1)	0.2 (–1)	0.4 (–1)	0.4 (–1)	235
17	180 (–1)	0.2 (–1)	1.2 (+1)	1.2 (+1)	472
18	240 (–1)	0.2 (+1)	1.2 (+1)	1.2 (–1)	692
19	240 (+1)	0.4 (0)	0.8 (0)	0.8 (0)	547
20	180 (–1)	0.6 (+1)	1.2 (+1)	0.4 (–1)	535
21	210 (0)	0.4 (0)	0.8 (0)	0.4 (–1)	488
22	210 (0)	0.4 (0)	0.4 (–1)	0.8 (0)	423
23	180 (–1)	0.2 (–1)	1.2 (+1)	0.4 (–1)	393
24	240 (+1)	0.6 (+1)	1.2 (+1)	1.2 (+1)	796
25	180 (–1)	0.6 (+1)	1.2 (+1)	1.2 (+1)	543
26	210 (0)	0.4 (0)	0.8 (0)	1.2 (+1)	502
27	240 (+1)	0.6 (+1)	0.4 (–1)	0.4 (–1)	475
28	210 (0)	0.4 (0)	0.8 (0)	0.8 (0)	498

Turning operation was carried out randomly according to design matrix under different runs and average value of power consumption has been reported in Table 3.

Results and Discussion

Surface Roughness Model

In the present investigation RSM was applied for developing the statistical model in the form of multiple regression equations for power consumption (Pc in the equation). In applying the RSM, the dependent variable (power consumption) is viewed as a surface to which the model is fitted. Evaluation of the parametric effects on the response (power consumption) was done by considering a second order polynomial response surface mathematical model given by:

$$Pc = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_i^2 + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} b_{ij} x_i x_j + \varepsilon r \quad (1)$$

This equation of power consumption (assumed surface) Pc contains linear, squared, and cross-product terms of variable x_i's (S, F, D, and R). Here, b_0 is the mean response over all the test conditions (intercept), *bi* is the slope or linear effect of the input factor x_i (the first-order model coefficients), *bii* the quadratic coefficients for the variable *i* (linear by linear interaction effect between the input factor x_i and x_j) and b*ij* is the linear model coefficient for the interaction between factor *i* and *j*. The face centered composite design was used in this experimental study. Significance testing of the coefficients, adequacy of the model, and analysis of variance was carried out to using Design Expert Software to find out the significant factors, square terms, and interactions affecting the response (power consumption). And, ε_R is the experimental error.

The analysis of variance (ANOVA) is shown in Table 4. The ANOVA shows the significance of various factors and their interactions at 95% confidence level. The ANOVA shows the "Model" as "Significant" while the "Lack of fit" is "Not significant" which are desirable from a model point of view. The probability values <0.05 in the "Prob.>F" column indicates the significant factor and interaction. Further, R^2, Pred. R^2, and Adj. R^2 were found as 90.25%, 86.84%, and 72.74%, which show a reasonable agreement on the developed model. The main factors and their interactions are included in the final power consumption model while the insignificant interactions are excluded from the power consumption model. Cutting speed (S), feed rate (F), depth of cut (D), and nose radius (R) are the significant factors while cutting speed and nose radius

Table 4: Analysis of variance (ANOVA)

Source	Sum squares	Degrees of freedom	Mean square	F value	Prob. > F	
Model	3.19×10^5	7	45598.30	26.46	<0.0001	Significant
Cutting speed (S)	1.005×10^5	1	1.005×10^5	58.32	<0.0001	
Feed rate (F)	62422.22	1	62422.22	36.22	<0.0001	
Depth of cut (D)	95630.22	1	95630.22	55.50	<0.0001	
Nose radius (R)	16562	1	16562	9.61	0.0056	
Cutting speed—nose radius (SR)	17956	1	17956	10.42	0.0042	
Feed rate—nose radius (FR)	12544	1	12544	7.28	0.0138	
Depth of cut—nose radius (DR)	13572.25	1	13572.25	7.88	0.0109	
Residual error	34463.63	20	1723.18			
Lack of fit	31668.88	17	1862.88			Not significant
Pure error	2794.75	3	931.58			

Table 5: Confirmations test results

Cutting speed (S) (in m/min)	Feed rate (F) (in mm/rev)	Depth of cut (D) (in mm)	Nose radius (R) (in mm)	Modeled Power Consumption	Experimental Power Consumption	% Error
200	0.5	0.9	0.8	505	489	2.9
225	0.3	0.8	0.4	429	449	4.7
180*	0.2 *	0.4 *	0.8	276	283	2.5

Note: * indicates optimum conditions for minimum power consumption.

(SR), feed rate and nose radius (FR), and depth of cut and nose radius (DR) were the significant interactions. The power consumption model so generated is given as:

Power Consumption $(Pc)_{coded}$ = 482.29 + 74.72 S + 58.89 F + 72.89 D + 30.33 R + 33.50 SR − 28 FR + 29.13 DR $\pm \varepsilon_R$ (2)

Power Consumption $(Pc)_{actual}$ = 108.51 + 0.257 S + 574.44 F + 36.6 D − 516.05 R + 2.8 SR − 350 FR + 182.03 DR $\pm \varepsilon_R$ (3)

Equations (2) and (3) represent the power consumption model in terms of coded and actual factor values of machining parameters, respectively.

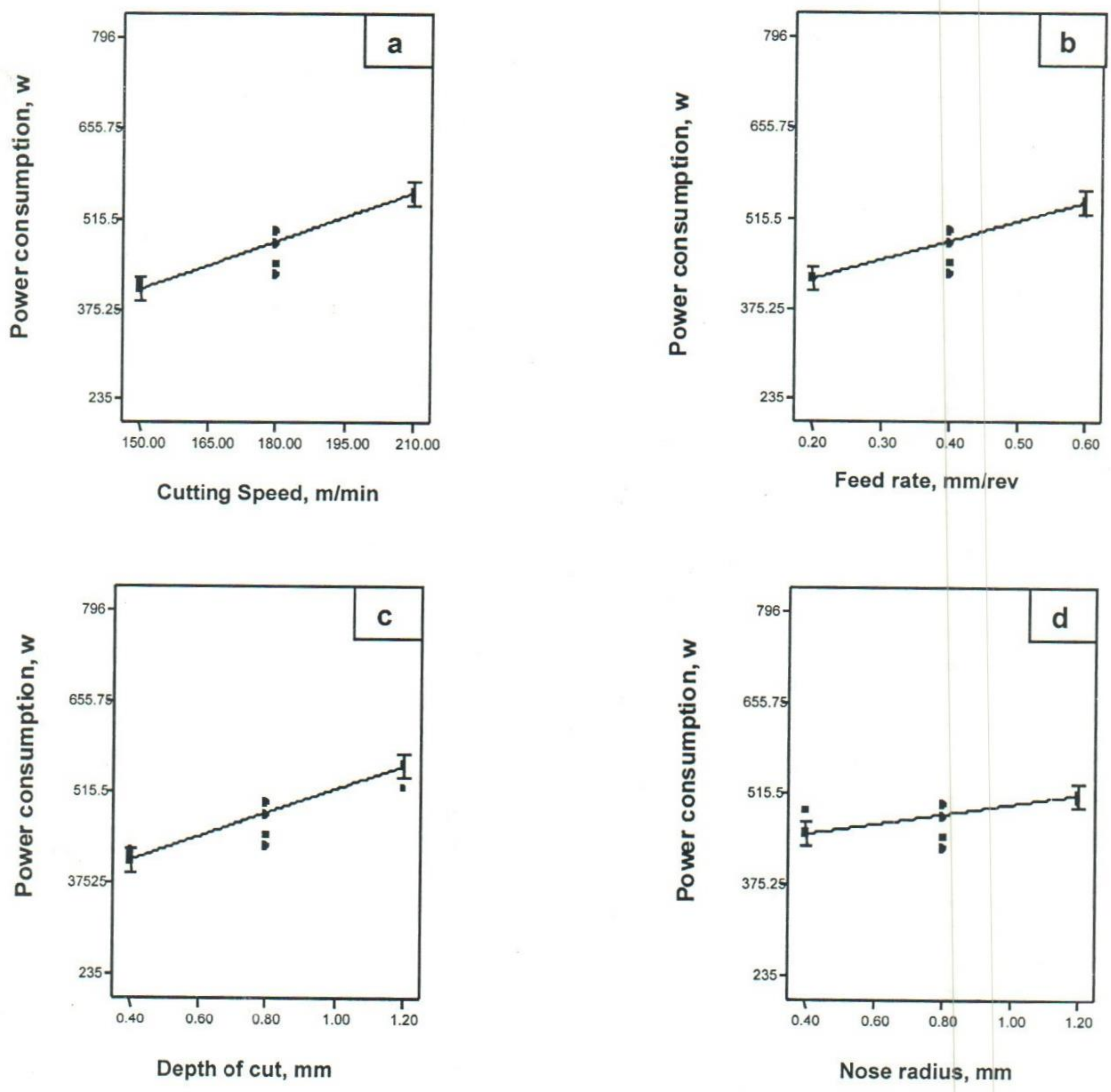
Optimization and Validity of the Power Consumption Model

The developed model was validated under different cutting conditions. The cutting conditions for validation are shown in Table 5. The validity of the developed model was further verified by turning fresh samples at different cutting parameters (not used in the model development) as shown in Table 5. The modeled and experimental values of power consumption of confirmation tests are shown in Table 5. The variations between the experimental and the calculated values are of the order of 3–5%. This validated model was further used for optimization for minimum power consumption within the range of applied machining parameters. The optimum value of cutting speed, feed rate, depth of cut, and nose radius were found to be 180 m/min, 0.2 mm/rev, 0.4 mm, and 0.8 mm, respectively. The power consumption corresponding to optimum cutting conditions is shown in Table 5. The higher nose radius was selected so as to get better surface finish because the surface finish improves with the increase in nose radius.

Effect of individual variables on power consumption

The effect of individual factors on power consumption during turning of Al—SiC composites is shown in Figure 1 (a—d). The effect of cutting speed (S), feed rate (F), depth of cut (D), nose radius (R) and that of their interactions on power consumption (Pc) are given in Equation (2), which exhibits the power consumption in terms of coded value and Equation (3) in terms of actual values of factors and their interactions for power consumption (Pc) of Al—SiC composite. However, the effects of individual factors are discussed by considering Equation (2) because all the factors are at the same level (—1, 0, and +1). The constant, 482.29, in Equation (2) indicates the overall mean of power consumption (Pc) under all the test conditions during turning. The coefficient associated with cutting speed (S), feed rate (F), depth of cut (D), and nose radius (R) are 74.72, 58.89, 72.89, and 30.33 signifies their effect on power consumption (Pc) of Al—SiC composites during turning. This signifies that cutting speed and depth of cut has the highest effect on power consumption of composite. The effect of cutting speed (S), feed rate (F), depth of cut (D), and nose radius (R) on power consumption (Pc) can be further explained as shown in Figure 1 (a-d). The power consumption increases with the increase in cutting speed (Figure 1a). This is due to the fact that with the increase in cutting speed, the more volume of material comes in contact with the tool which has to be removed, thus increasing the power consumption. The effect of feed rate on power consumption is less as compared to cutting speed and depth of cut (Equation 2). Power consumption also increases with the increase in feed rate, as shown in Figure 1(b). Similarly, the power consumption increases with the increase in depth of cut, as shown in Figure 1(c). This is again due to the fact that with the increase in depth of cut, the more volume of material has to be removed, thus increasing the power consumption. The effect of the nose radius is less as compared to other factors but again the power consumption also increases with the increase in nose radius (Figure 1d). This is due to increase in contact area with the increase in nose radius, due to which the power consumption increases.

Figure 1: Single factor effects of (a) cutting speed, (b) feed rate, (c) depth of cut, and (d) nose radius on power consumption of Al-SiC composite

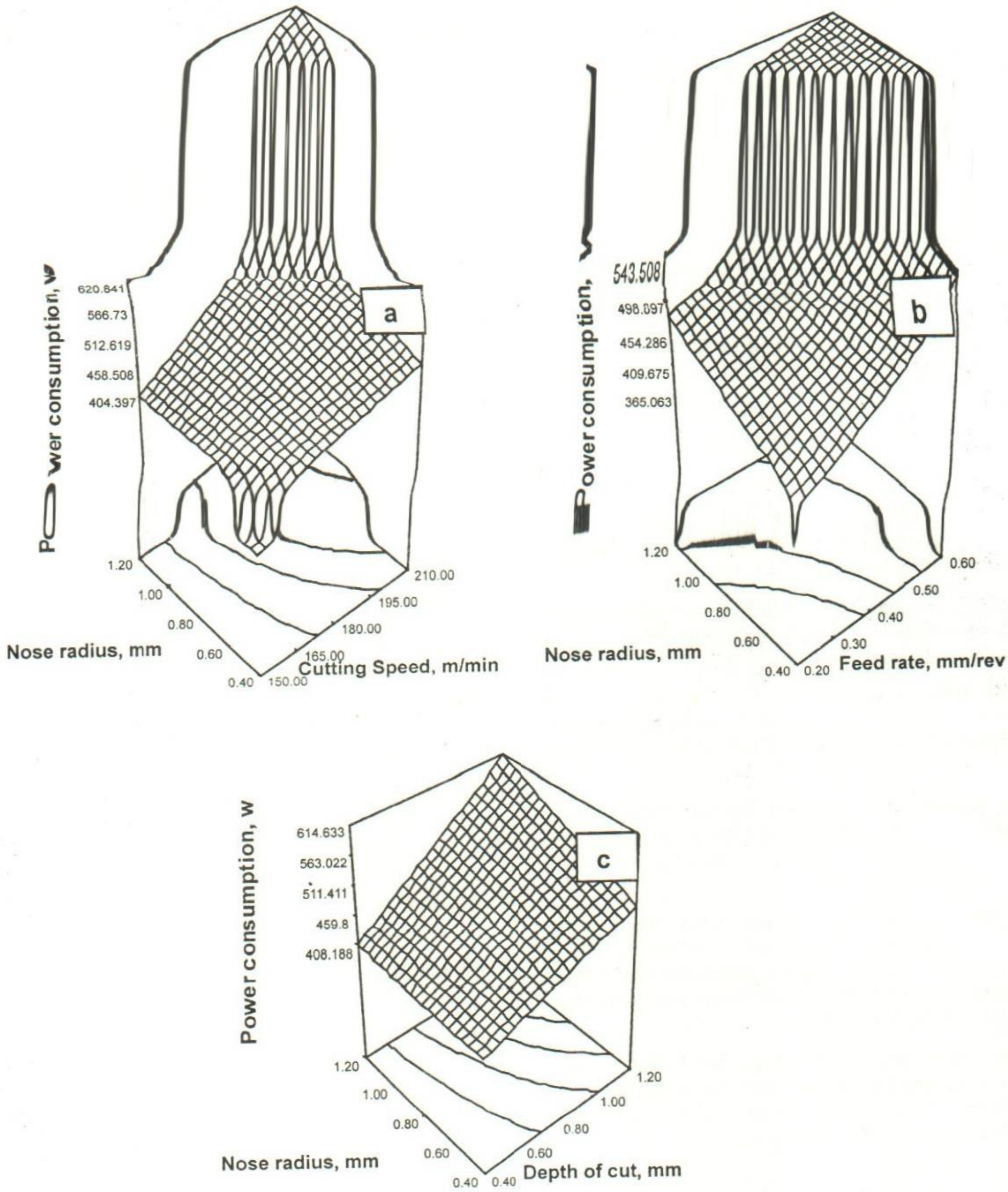


Interaction (combined) effect of the applied machining parameters

The coefficients associated with the interaction terms SR (cutting speed–nose radius), FR (feed rate–nose radius), and DR (depth of cut–nose radius) in Equation (2) are 33.50, 28, and 29.13, respectively, that showed the extent of interaction (combined) effect of different factors on power consumption of the composite. The SR and DR interactions have more significant effect on increase in power consumption as compared to FR interactions, which shows a reduction in power consumption.

The combined effect of various parameters on the power consumption of composite has been shown in the form of response surface plots (Figure 2 a–c). The combined effect of SR on power consumption of composites shows that the power consumption increases with an increase in cutting speed and nose radius. From Figure 2(a), it can be observed that the effect of nose radius on power consumption is less as compared to cutting speed. Similarly, Figure 2(b–c) shows that the effect of nose radius on power consumption is less as compared to feed rate and depth of cut. This is due to the fact that

Figure 2: Interaction effects of various factors—(a) cutting speed and feed rate (SF) and (b) cutting speed and depth of cut (SD)—on power consumption of Al-SiC composite



with the increase in cutting speed and depth of cut, more volume of the material has to be removed, which increases the power consumption.

Conclusions

1. Response surface methodology is an excellent tool for the study and development of statistical model in terms of applied machining parameters and their interaction.
2. Cutting speed, depth of cut, and feed rate have the highest effect on power consumption as compared to nose radius.
3. The interaction effect is almost 50% lower as that of main factor effects on the power consumption of Al–SiC composite.
4. The developed model can be used to optimize the power consumption within the applied machining parameter range for Al–SiC composite.

References

Chandrasekaran, H., and J.O. Johansson (1997), "Influence of Processing Conditions and Reinforcement on the Surface Quality of Finish Machined Aluminium Alloy Matrix Composites," *Ann CIRP*, 46 (1): 493.

Clyne, T.W. (2001), "3.7.12. Metal Matrix Composites: Matrices and Processing," *Encyclopedia of Materials Science and Technology Composites: MMC, CMC, PMC*, ed. A. Mortenson, Elsevier, 1–14.

Cronjager, L., and D. Meister (1992), "Machining of Fibre and Particle Reinforced Aluminium," *Ann CIRP*, 42 (1): 63.

Davim, J.P. (2001), "Turning Particulate Metal Matrix Composites: Experimental Study of the Evolution of the Cutting Forces, Tool Wear and Work Piece Surface Roughness with the Cutting Time," *Proceedings of Institution of Mechanical Engineers B Journal of Engineering Manufacturing*, 215: 371.

Durante, S., G. Rutelli, and F. Rabezzana *(1997)*, "Aluminum-based MMC Machining with Diamond-coated Cutting Tools," *Surf Coat Technology*, 94–95: 632.

E. Uhlmann, W. Reimers, F. Byrne, and M. Klaus (2010), "Analysis of Tool Wear and Residual Stress of CVD Diamond Coated Cemented Carbide Tools in the Machining of Aluminium Silicon Alloys," Production Engineering, 4 (2–3): 203–209, DOI: 10.1007/s11740-010-0213-x

El-Gallab, M., and M. Sklad (1998), "Machining of Al/SiCp Metal Matrix Composites. Part I, Tool Performance," Journal of Material Process Technology, 83: 151.

Finn M., and A. Srivastava (1996), "Machining of Advanced and Engineered Materials," *Proceedings of the CSME Symposium*. McMaster University, 616.

Hung, N.P., F.Y.C. Boey, K.A. Khor, C.A. Oh, and H.F. Lee (1995), "Machinability of cast and powder-formed aluminum alloys reinforced with SiC particles," *Journal of Materials Process Technology*, 48 (1–4): 291–297.

Joshi, S.S., N. Ramakrishnan, and P. Ramakrishnan (1999), "Analysis of Chip Breaking during Orthogonal Machining of Al/SiCp Composites," *Journal of Material Processing Technology*, 88 (1–3): 90.

Kiliçkap E., O. Cakir, M. Aksoy, and A. Inan (2005), "Study of Tool Wear and Surface Roughness in Machining of Homogenised SiC-p Reinforced Aluminium Metal Matrix Composite," *Journal of Materials Processing Technology*, 164–165 (15 May): 862–867.

Lane, C. (1992), "Machinability of Al composites as a function of matrix alloy and heat treatment," *Proceedings of the Machining of Composites Materials Symposium*, ASM Materials Week, Chicago, Illinois, 3.

Lin, J.T., D. Bhattacharya, and C. Lane "Machinability of a Silicon Carbide Reinforced Aluminium Metal Matrix Composite," Wear 181: 883.

Looney, L.A., *J.M. Monaghan, P. O'Reilly, and D.M.R. Taplin.* "The Turning of an Al/SiC Metal Composite," *Journal of Material Process Technology*, 33: 453.

N. Muthukrishnan, M. Murugan, and K. Prahlada Rao (2008), "Machinability issues in turning Al-SiC (10 p) metal matrix composites," *International Journal of Advanced Manufacturing Technology*, 39 (3–4): 211, DOI: 10.1007/s00170-007-1220-8

Palanikumar, Karthikeyan (2007), "Assessment of Factors Influencing Surface Roughness on the Machining of Al/SiC Particulate Composites," *Materials Design*, 28 (5): 1584.

Quan, Y.M., Z.H. Zhou, and B.Y. Ye (1999), "Cutting Process and Chip Appearance of Aluminum Matrix Composites Reinforced by SiC Particles," *Journal of Materials Processing Technology*, 91 (1–3): 231.

Sahin, Y. and G. Sur (2004), "The Effect Al2O3, TiN and Ti (C,N) Based CVD Coatings on Tool Wear in Machining Metal Matrix Composite," *Surface Coating Technology*, 179: 349.

Sahin, Y., M. Kok, and H. Celik (2002), Tool Wear and Surface Roughness of Al2O3-particle Reinforced Composites, *Journal of Materials Processing Technology*, 128 (1–3): 280–291.

Shaw, Milton C. (2004), *Metal Cutting Principles*. Oxford: Oxford University Press.

Tomac, N., and K. Tonnessen (*1992*), "Machinability of Particulate Aluminium Matrix Composites," *Annals CRIP*, 42 (1): 55.

Yanming, Q., and Z. Zehna (2000), "Tool Wear and its Mechanism for Cutting SiCp Reinforced Al Matrix Composites," *Journal of Material Process Technology*, 100L: 194.

"It is always safe to assume, not that the old way is wrong, but that there may be a better way"

— Henry F. Harrower

Focus

Condition-based Maintenance of Draglines–A Success Story

S. K. CHAKRAVORTY

The benefits of implementing Condition-based Maintenance for Draglines in a large open-cast mining project are discussed. Vibration monitoring and analysis was adopted by the author as a condition monitoring diagnostic tool for these critical capital intensive machines. By implementing this technique for a period of one year, about 100 potential failures of the draglines could be predicted and necessary corrective actions were taken to avoid forced outages in most of the cases. The methodology adopted has been explained by citing four real-life cases. An overall cost/benefit analysis is also included in the article.

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India's coal production is mainly dependent on open-cast mining projects. The bulk of the production from these open-cast mines is made by deploying draglines. Draglines are used basically to remove overburden deposit on the top of the coal seam. The capacity of the bucket is very large, about 20 cubic meter, and therefore the downtime cost is very high in case of a breakdown. These equipments are extremely capital intensive, amounting to the investment of about Rs 75 crore.

Due to the very high volume of production, the downtime costs are very high, ranging from Rs 40,000 to Rs 60,000 per hour, depending on their bucket size. Therefore, it is imperative to adopt condition-based maintenance for such critical capital intensive equipment deployed in modern open-cast mines, so that availability of the same can be maximized at minimum cost.

The various mechanisms which need condition monitoring in a dragline are: MG sets, hoist mechanisms, drag mechanisms, swing mechanisms, field exciters, compressors, etc.

The author has adopted vibration measurements, monitoring, and analysis techniques for predicting failures of different mechanisms of two MARION—7800 draglines deployed in an open-cast mining project. The instruments used were IRD Mechanalysis–308 and IRD Mechanalysis–880. The program was implemented for a period of one year and about 100 failures were predicted before forced outages could have been caused, helping the management to take planned corrective actions. This led to an increase of average monthly availability of 14.7% and the lowering of average downtime by 88.7 hours per month. Considering the prevailing downtime cost of about Rs 50,000 per hour, it was estimated that a saving of about Rs. 45 lakh per month could be achieved by implementing a vibration-based condition-monitoring system on the draglines. In addition, an appreciable lowering of maintenance repair and materials costs could be expected.

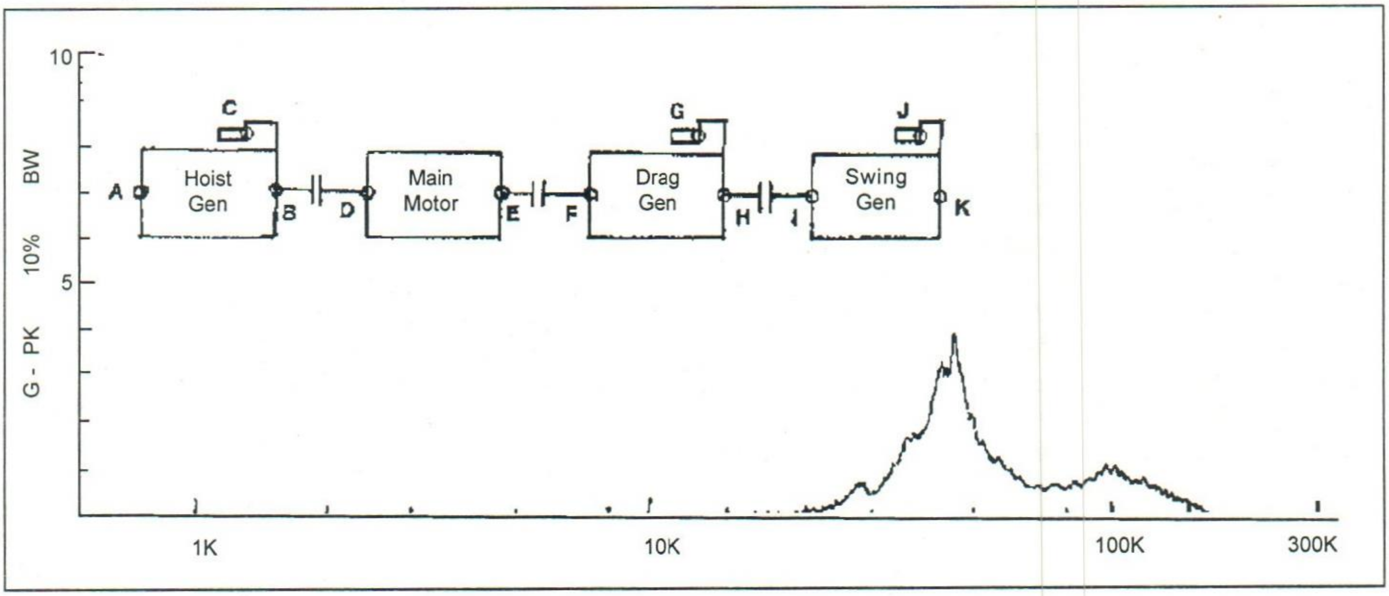
The details of four representative failure cases are given to illustrate the methodology adopted.

Case No. 1

During one inspection it was found that vibration values of the drive-end bearing of the swing generator of the MG set had increased from 1.8 mm/s to 4.5 mm/s in the horizontal direction. Although 4.5 mm/s of vibration is acceptable according to ISO:2372, it called for analysis, as the rate of increase of vibration (2.5 times the previous value) was high. Moreover, the shock pulse value also increased from 20 dB_M to 40 dB_M.

The acceleration of vibration was also measured and found to be 3.4 g, which is high according to acceptable standards. The vibration signature on the acceleration mode was taken from this bearing and is given in Figure 1. This analysis revealed that the bearing could be damaged. A planned outage was taken and on inspection it was found that the cage of the bearing was broken. Immediately, action was taken to replace the bearing and thus a major breakdown of the equipment was avoided.

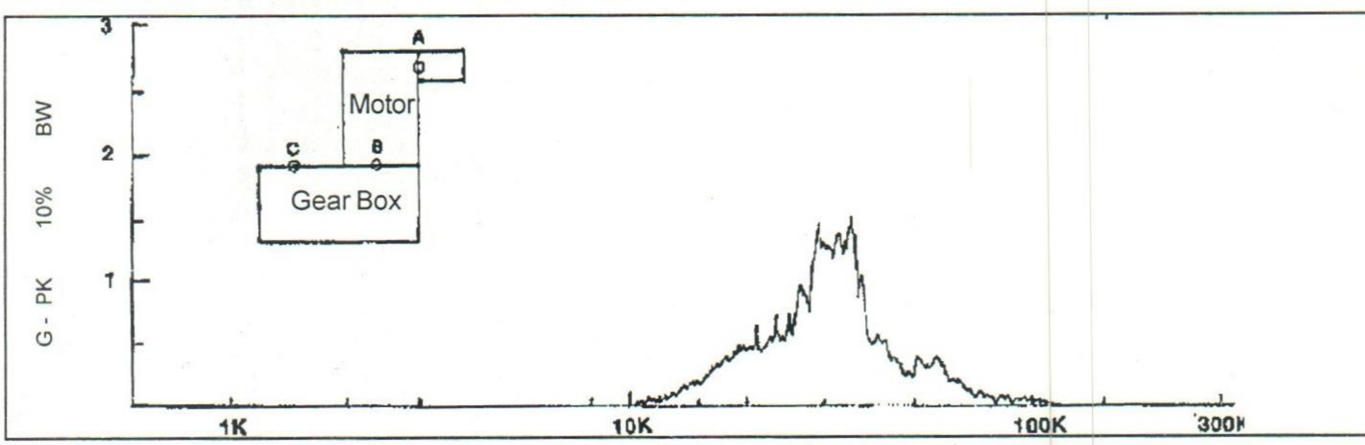
Figure 1: Vibration signature MG set swing generator DE bearing. Positing MG set. Condition I. Horizontal OA-3(2.9-4.0)



Case No. 2

In one of the inspection rounds it was observed that the vibration value on the gearbox drive-end bearing of the swing mechanism had increased from 2 mm/s to 5 mm/s in the axial direction. In this case also, the vibration acceleration

Figure 2: Vibration signature swing mechanism gearbox DE bearing. Position swing mech 2 Condition C axial OA-3.6(2.4-4.0)



was measured and found to be 3.6 g (slightly high) indicating a damaged antifriction bearing. To confirm this, a signature was taken on this bearing in the axial direction in the acceleration mode, as given in Figure 2.

The signature clearly indicates that the high vibration was due to a defective antifriction bearing. The gear-related problems would have given peaks at the harmonics of the gear-mesh frequency which were not present as depicted in the signature. This bearing was inspected at the earliest opportunity, when the dragline was idle due to mine preparation work and it was found that the bearing was damaged. The bearing was replaced by taking a planned outage of the machine and the vibration value dropped down to 1.8 mm/s.

Case No. 3

During the study, it was found that the vibration values on the compressor motor-drive end-bearing increased considerably from 10 mm/s to 35 mm/s in the axial direction. To diagnose the cause of high vibration, a signature analysis was performed. The signature (velocity vs. frequency) is given in Figure 3. As a high peak of vibration was observed at double the compressor r/min frequency in the axial direction, it was concluded that the compressor shaft and V-belt drive system were misaligned. On taking a planned corrective action, the compressor started working normally and the vibration level dropped down to 8 mm/s.

Figure 3: Vibration signature Compressor motor DE bearing. Position Compressor. Condition A axial OA-35(2.9-4.0)

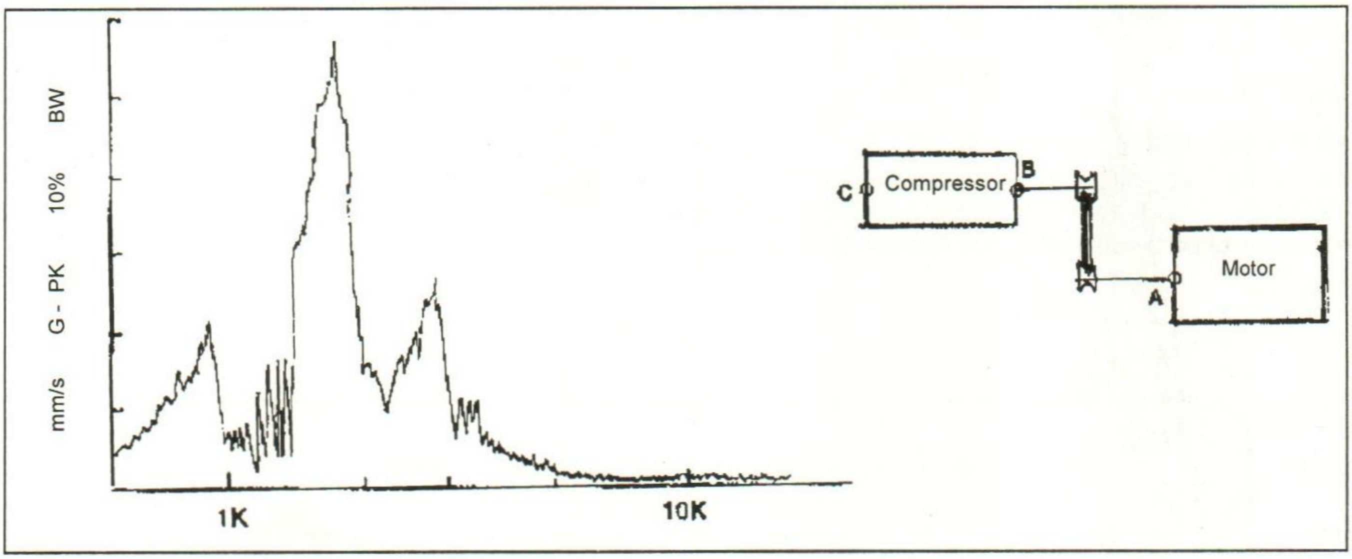
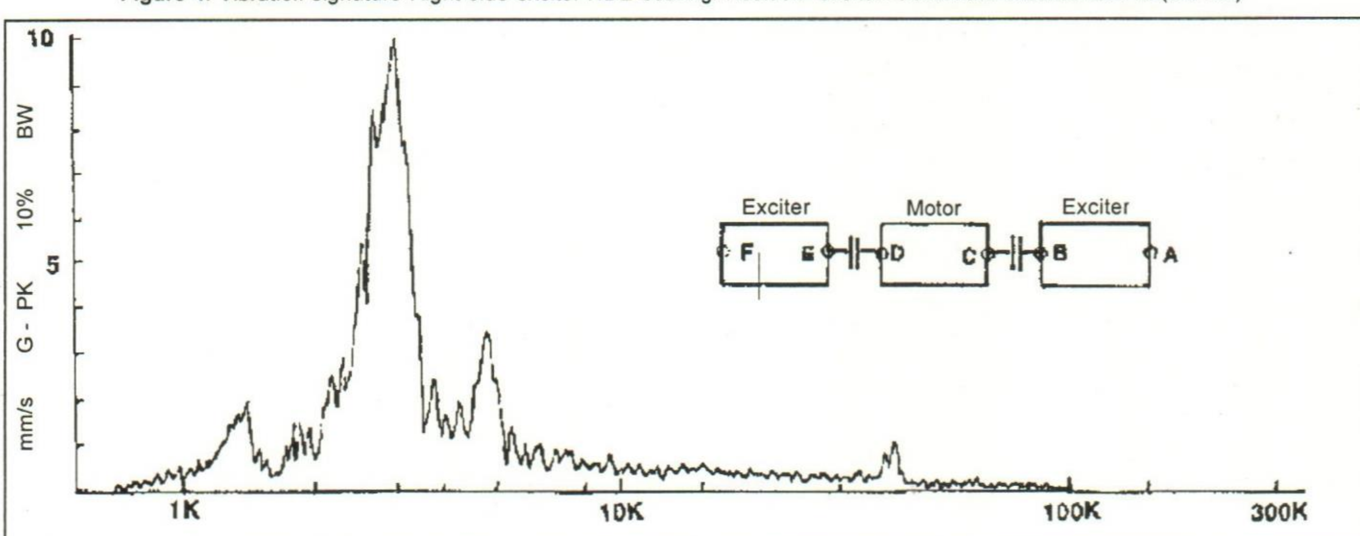


Figure 4: Vibration signature Right-side exciter NDE bearing. Position- exciter. Condition A vertical OA-1.2(9.3-1.3)



Case No. 4

While implementing the vibration monitoring system, it was observed that the vibration level on the exciter non-drive-end bearing of the motor-exciter set had increased from 4 mm/s to 12 mm/s in the vertical direction. A vibration signature analysis was carried out to predict the likely mode of failure.

The signature taken on this bearing in the vertical direction is shown in Figure 4. This depicts the peak vibration in the vertical direction at a frequency of twice the speed of the machine (1500 r/min). Hence, mechanical looseness due to loose foundation bolts and misaligned coupling were the causes of the high vibration. After tightening the foundation bolts properly in a planned manner, the problem of high vibration was solved and a catastrophic failure was avoided.

Conclusions

After implementing condition-based maintenance by measuring, monitoring and analyzing vibrations, about 100 catastrophic failures were avoided and appropriate corrective actions could be taken. The achieved benefits were calculated by analyzing the logbooks of two years of data, before and after implementing the system. The data and basis of this calculation is given in the Annexure.

It was found that the monthly availability had increased by 11.7% and 17.7%, respectively, for draglines 1 and 2, giving an average increase of 14.7%. The downtime hours reduced by 70.6 hours and 106.8 hours, respectively, for the same draglines, giving an average lowering of downtime of 88.7 hours per month. However, due to implementation of condition-based maintenance, the planned preventive maintenance workload increased by 16 hours and 14.8 hours, giving rise to an average increase of 15.4 hours per month.

Thus, it can be concluded that by implementing vibration analysis the utilization of these heavy earth-moving machines can be increased considerably and downtime costs can be reduced drastically. In addition, maintenance repair and material costs can also be reduced. All these cost benefits can be achieved by investing some money in vibration meters and analyzers and a very small increase in the preventive maintenance workload.

> *"There can be no economy where there is no efficiency"*
>
> — **Benjamin Disraeli**

ANNEXURE: PERFORMANCE ANALYSIS OF DRAGLINES

Dragline No. 1

Production hours (Average per month)		Idle hours (Average per month)		Breakdown hours (Average per month		Preventive maintenance (hours) (Average per month)	
Before study	After implemen-tation	Before study	After implemen-tation	Before study	After implemen-tation	Before study	After implemen-tation
435	471	43	61.6	133	62.4	79	95

Dragline No. 2

Production hours (Average per month)		Idle hours (Average per month)		Breakdown hours (Average per month		Preventive maintenance (hours) (Average per month)	
Before study	After implemen-tation	Before study	After implemen-tation	Before study	After implemen-tation	Before study	After implemen-tation
411	467.7	38	73.3	162.8	56	78.2	93

Cost benefit analysis

$$\text{Availability} = \frac{\text{Production hours}}{\text{Production hours + downtime hours}}$$

Dragline No. 1

$$\text{Availability before study} = \frac{435}{435+133} = 76.6\%$$

$$\text{After study} = \frac{471}{471 + 62.4} = 88.3\%$$

Increase in availability 11.7% (88.3–76.6)

Downtime reduced by 70.6 hours (133–62.4)

Preventive maintenance increased by 16 hours (95–79)

Dragline No. 2

$$\text{Availability before study} = \frac{411}{411 + 162.8} = 71.6\%$$

$$\text{After study} = \frac{467.7}{467.7+56} = 89.3\%$$

Increase in availability = 17.7% (89.3–71.6)

Downtime hours reduced by 106.8 hours (162.8–56)

Preventative maintenance increased by 14.8 hours (93–78.2)

Implementation of Food Safety Management Systems (ISO 22000:2005) Certification: A Journey towards Improvement in Quality and Food Safety

S.P. SINGH AND RACHANA SHALINI

ISO 22000:2005 *is an International Standard designed to ensure safe supply of food throughout the entire supply chain on a worldwide basis. It applies to the processes that create and control the products and services on organization supplies. It can be used by all organizations, in the supply chain—from the farmers to food services, to processing, transportation, storage, retail and packaging, that is, up to the final consumer. ISO 22000:2005 certifications have been carried out for Hafed Rice Mill, Taraori. It revealed significant achievements in system improvements to improve quality and/or food safety of the products.*

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Food Safety Management System (FSMS) is a newer concept in Food Industry. ISO 22000:2005 is a global food safety management system standard and is now widely accepted requirement. It has been designed to ensure safe supply of food throughout the entire supply chain on a worldwide basis. It is applicable to the creating and controlling the products and services on organization supplies. Food reaches consumers via supply chains that may link many different types of organizations and may stretch across multiple borders. One weak link may result in unsafe food that is dangerous to health and if this happens, the hazards to consumers may be serious. It can be used by all organizations, in the supply chain—from the farmers to food services, to processing, transportation, storage, retail and packaging, that is, up to the final consumer.

People have the right to expect the food they eat to be safe and suitable for consumption. Foodborne illness and foodborne injury are at best unpleasant; at worst, they can be fatal. But there are also other consequences. Outbreaks of foodborne illness can damage trade and tourism, and lead to loss of earnings, unemployment and litigation. Food spoilage is wasteful, costly and can adversely affect trade and consumer confidence. The food cannot be of good quality, if it is not safe and not free from all types of hazards.

International food trade and foreign travel, is increasing, bringing important social and economic benefits. But this also makes the spread of illness around the world easier. Eating habits too, have undergone major change in many countries over the last two decades and new food production, preparation, and distribution techniques have developed to reflect this. Effective hygiene control therefore is vital to avoid the adverse human health and economic consequences of foodborne illness, food borne injury, and food spoilage. Everyone, including farmers and growers, manufacturers, and processors, food handlers and consumers, has a responsibility to assure that food is safe and suitable for consumption (CAC/RCP1-1969, Rev.4-2003).

The Haryana State Cooperative Supply and Marketing Federation Limited

The Haryana State Cooperative Supply and Marketing Federation Limited (HAFED) is the largest apex cooperative federation of the state of Haryana. It came into existence on 1 November 1966 with formation of Haryana as a separate state. Hafed clearly states its mission to serve the economic interests of the farmers of Haryana by providing viable and effective support in agriculture production, marketing, and agri processing. The infrastructure and performance of Hafed is given in tables 1 and 2, respectively. The organization structure of Hafed head office and field office is given in figures 1 and 2, respectively (Hafed, 2011).

Previously, Hafed was an ISO 9001:2000 Quality Management System (QMS) and HACCP Warranty standard certified organization. The management of Hafed has decided to upgrade the QMS ISO 9001:2000 to ISO 9001:2008 and adopt ISO 22000:2005 for rice mills, oil mills, sugar mills, and cattle feed plants. Food Safety

Table 1. Infrastructure of Hafed

Owned Storage Capacity (Covered + Opened)	**24.21 Lac MT**
Rice Mills	13
Oil Mills	2
Pesticide Plant	1
Cattle Feed Plants	2
Cold Storage	1
Barley Malt Plant	1
Sugar Mill	1
Turmeric Plant	1

Table 2. Performance of Hafed in the Last Five Years

Rs In Crore		
Financial Year	**Turnover**	**Net Profit**
2005–2006	3095.10	58.36
2006–2007	2838.34	75.71
2007–2008	2628.00	58.68
2008–2009	3092.00	43.93
2009–2010	4253.55	43.45

Figure 1. Organization Structure (Head Office)

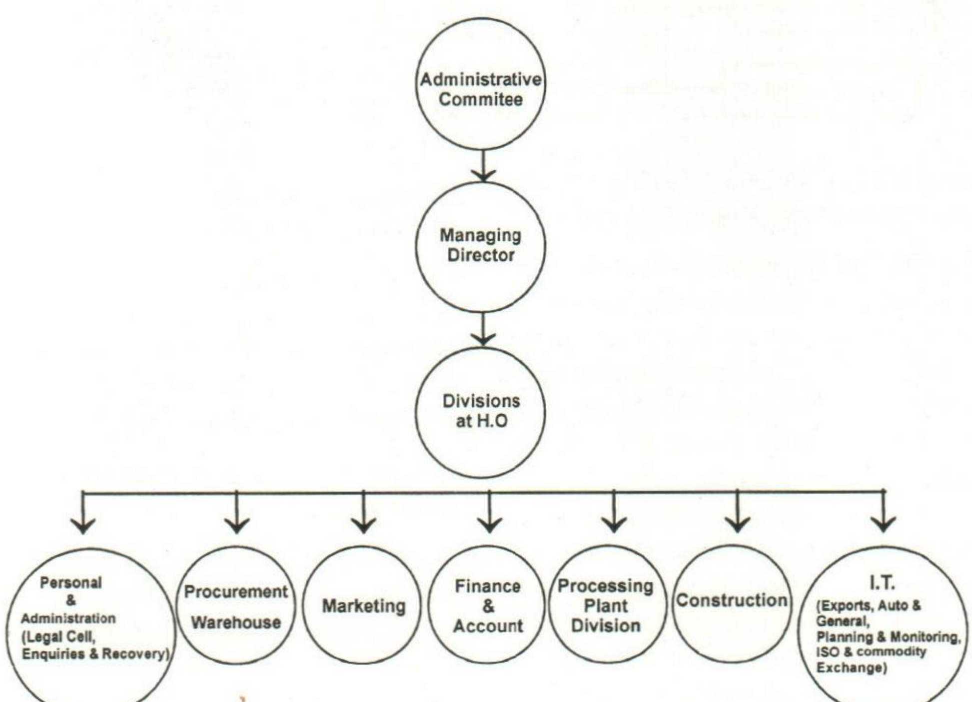
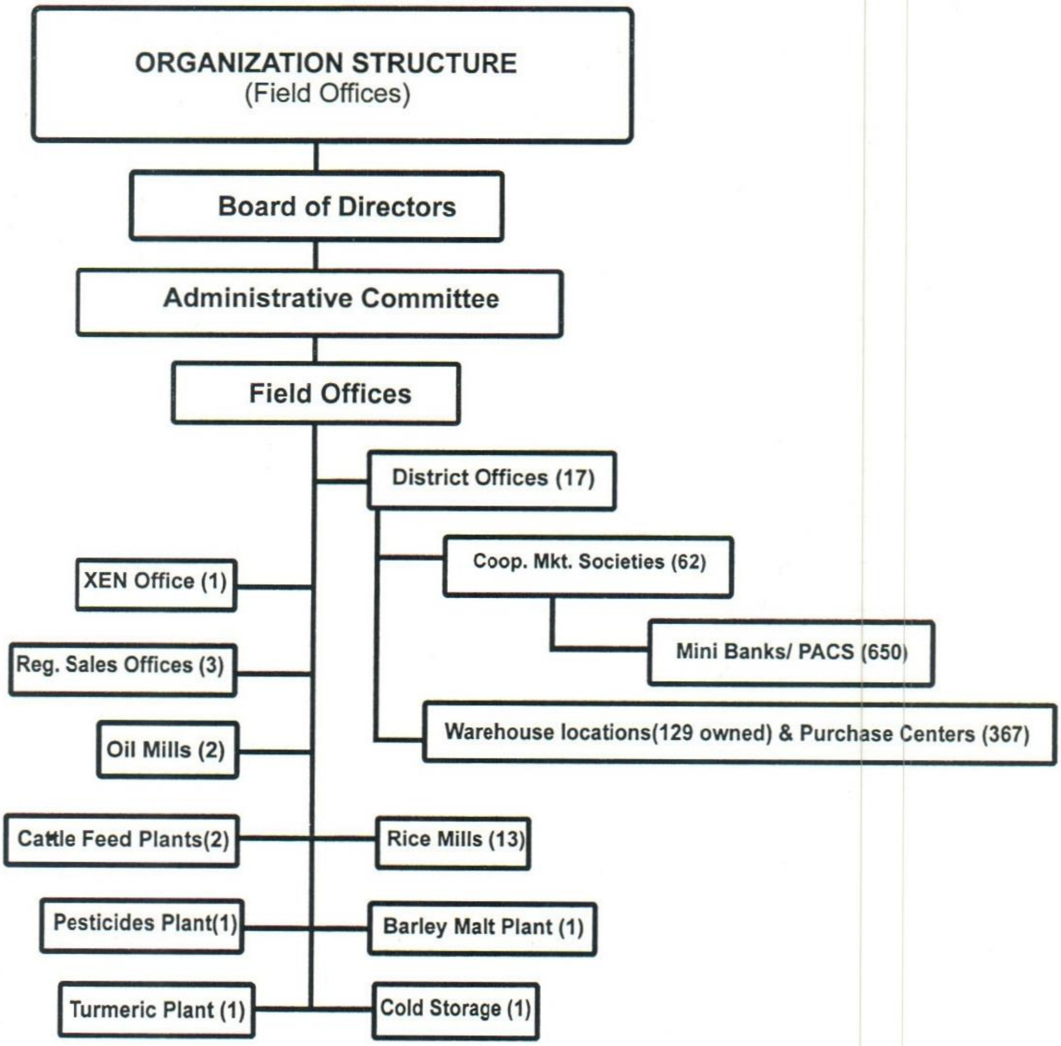


Figure 2. Organization Structure (Field Office)



Management Systems (ISO 22000:2005) Certifications of Hafed Rice Mill, Taraori have already been achieved.

The Hafed rice mill, Taraori, is exclusively being run by Hafed on basmati paddy and other similar variety of paddy. The rice produced out of such paddy is sold in consumer pack as well as export. Hafed has added new machines such as drier, whitenner, destoner, grader, etc., at an estimate cost of Rs 150 lakhs during 2008–09. In addition to this, Hafed is also planning to modernize and upgrade this unit by adding modern and latest technology of paddy pre-cleaner, destoner, husker, separator, grader, silky machine and optical sortex machine with an estimated cost of 200 lakhs. The management of Hafed rice mill is committed for total consumer satisfaction and strives for excellence in all its activities through adoption of Food Safety Management Systems (ISO 22000:2005) and QMS (ISO 9001:2008).

The product of this rice mill is being exported to countries like the USA, Australia, and Middle East Countries. Hafed rice mills strive to achieve excellence in food safety and quality of rice through their dedicated and skill manpower and well-equipped plant and machinery.

Overview: How Food Industries Handle HACCP and other Methods

About 15% of food manufacturers are actively engaged in food safety improvement by applying HACCP, mini-HACCP, or ISO, as well as comprehensive safety and quality control throughout the manufacturing process. Currently, however, 85% of corporations have yet to take up HACCP and other control methods, due to the excessive cost of investing in the facility improvements or the difficulty they perceive in maintaining documents/records. So, with this in mind, are the 85% of remaining companies not taking any measures to control the safety and quality of their food products?

Adoption of Food Safety Management Systems ISO 22000:2005

The Adoption of Food Safety Management Systems ISO 22000:2005 was carried out with the documentation of Food Safety Apex Manual, Procedure Manual, Format Manual and Work Instruction Manual. FSMS manual defines the food system management system of Hafed rice mills as per ISO-22000: 2005.

The FSMS manual specifies requirements for a food safety management system of Hafed rice mills which has been established with a purpose to demonstrate their ability to control food safety hazards in order to ensure that food is safe at the time of human consumption. This system has been implemented in order to consistently provide safe products to consumers. This FSMS system specifies requirements to enable Hafed rice mills:

1. To plan, implement, operate, maintain, and update a food safety management system aimed at providing products that, according to their intended use, are safe for the consumer.
2. To demonstrate compliance with applicable statutory and regulatory food safety requirements.
3. To evaluate and assess customer requirements and demonstrate conformity with those mutually agreed customer requirements that relate to food safety, in order to enhance customer satisfaction.
4. To effectively communicate food safety issues to their suppliers, customers, and relevant interested parties in the food chain.
5. To ensure that the organization conforms to its stated food safety policy.
6. To demonstrate such conformity to relevant interested parties.
7. To se-

1. ensuring that food safety hazards pertaining to products within the scope of system are identified, evaluated and controlled in such a manner that its products (rice) do not directly or indirectly harm the consumer;
2. communicating appropriate information throughout the food chain regarding safety issues related to its products;
3. communicating information concerning development, implementation and updating of the food safety management system throughout the Hafed rice mills, to the extent necessary to ensure the food safety required by ISO 22000:2005; and
4. Evaluating periodically, and updating when necessary, the food safety management system to ensure that the system reflects the Hafed's activities and incorporates the most recent information on the food safety hazards subject to control.

Scope of FSMS for Hafed Rice Mill, Taraori

The scope for which the Hafed rice mill, Taraori, has achieved ISO 22000:2005 certifications is "Procurement of Paddy, their processing to produce rice, packing and supply of Rice in domestic and International Market."

Educational and Training Needs

Training was conducted for the employees of Hafed to understand the concept of the relatively unconventional ISO 22000:2005 and spread it among them. Training was imparted to explain the concerned employees to be proud of their activity (jobs) as they comply with international standards. ISO 22000:2005 ensures that the accumulation of each worker's activity promotes the safety and quality of food products and culminates in enhanced food safety (shared responsibility).

ISO 22000:2005 aims to maintain or improve the safety and quality of food products by continuing PDCA cycles and connecting each safety and quality improvement activity, and thus it helped Hafed to promote educational activities to connect each activity.

Defining of Standard Operating procedures (SOPs) as part of ISO 22000:2005 system implementation in Hafed made each employee to understand the [illegible]

Physical Improvements to Comply with Requirements of ISO 22000:2005

The following physical improvements were done in the Hafed rice mill, Taraori, to comply with the requirements of ISO 22000:2005 standard:

1. Repair and maintenance including white washing of paddy milling/shelling unit were done to improve building condition as well as hygienic conditions of the plant. The annual overhaul was also done for the rice mill.
2. White washing and repair of administrative block was done to improve building conditions and cleanliness.
3. Requisite lab equipment like test rice polisher, test rice grader, test paddy cleaner, testing dryer, etc., were procured and put in use.
4. Machine and equipment identification were done by mentioning the code on each machine/ equipment.
5. Notice board were covered and put under lock and key.
6. Quality and food safety policy and jewelry policy were displayed at key locations.
7. Critical Control Points (CCPs) were displayed and controlled during day to day operation.
8. Broken glasses/jali was repaired.
9. Tubelights inside the mills were covered.
10. Cobwebs were removed from the mill and the plant incharge was made responsible to ensure that cobweb should not be present at any point of time.
11. Workers clothes not being hanged in the processing/packing area and separate changing rooms created for the purpose.
12. The workers entering the processing and packing area were made mandatory to wear neat, clean, and reserve uniform.
13. Weekly checkup of nails and hairs of the workers started to be done to ensure personal hygiene of the workers in the processing area.
14. The doors in the processing and packing area were made automatic closure.
15. Hygienic caps and reserve shoes were provided to the workers/visitors daily before entering into the processing and packaging area.
16. Plastering/concreting of the floor in the proc and packaging area was done.
17. Plastering of the ceiling in the processing and packaging area was done.
18. Machine and equipment identification was done.
19. New fly catchers/trappers were installed in potential areas. The existing fly catchers/trappers were repaired to working condition.
20. Rat catchers were provided in mills and godowns.
21. Mother cartoons storage shifted to proper storage area.
22. Proper building maintenance and repair work done.
23. The health checkups were carried out by a registered medical practitioner to identify and prevent communicable disease.
24. Rodent and pest controls were done at pre-defined frequency.
25. Foot mat and bins were provided at specified areas.
26. Use of magnets at the separator and other suitable places for removal of ferrous particles was made operational.

The above modifications led to the improvement in quality and food safety of the product and services of the Hafed rice mill, Taraori.

Benefit Derived from the Implementation of ISO 22000:2005 in Hafed Rice Mill, Taraori

1. The number of quality checks and unnecessary tests could be avoided. Costs were reduced by verification and validation.
2. There was a decrease in the number of complaints by the customers.
3. Duplicated safety and quality improvement actions could be rectified to simplify the entire process.
4. A number of issues that were already recognized in mind for the need to take actions but never taken like emergency response, directory for use in an emergency, training for emergency evacuation, simulated training to collect the products from the market if a problem with safety and quality occurs were introduced for complying with the standard requirements.

5. PDCA (Plan → Do → Check → Action) was introduced throughout the entire organization, all jobs, over and above safety and quality improvement activities alone were reviewed, which eventually improved the management efficiency of a company.

6. There was an increased credibility among customers and customer confidence.

7. Multiplicity of quality standards was reduced.

8. It helped facilitate International trade.

9. It also implements QMS.

10. It provides one standard applicable to all countries.

11. Enhancement in the image of the organization.

12. It led to system orientation and improved work culture.

13. It provided independent third party audit and certification against an internationally recognized food safety and quality standard.

14. It increased transparent working in the organization.

15. There was overall performance improvement through departmental objectives.

16. There was improved productivity, food safety, and quality.

17. It focused on human resource development and enhanced employee involvement.

Conclusion

Implementation of ISO 22000:2005 Food Safety Management Systems is very helpful for the food-related organization for consistency in maintaining food safety and quality of products and processes. This leads to increase in confidence level of the consumers/customers about the safety and quality of the food items. It also gives confidence to the organization that their systems are in place and if there is deviation from the system, the same will be detected in food chain and proper correction and corrective action will be taken. This will lead to international recognition of the system and there will be less complaints from the consumers/customers due to proactive measures taken by the organization in addressing customer/consumer needs and expectations. Hence, it is recommended that all food related organizations should go for ISO 22000:2005 certifications.

References

CAC/RCP1-1969, Rev.4- 2003. *Recommended International Code of Practice. General Principles of Food Hygiene*. Codex Alimentarius Commission.

Hafed. 2011. *The Haryana State Co-operative Supply and Marketing Federation Limited. Organization profile*. Available online at http://hafed.gov.in (accessed on 2 Aug 2011).

"Creativity is thinking up new things. Innovation is doing new things."

— **William Laird Levitt**

Focus

Productivity and Efficiency Analysis of Haryana's Dairy Industry

RAMPHUL

The study assesses the total factor productivity (TFP) growth and efficiency levels in Haryana's dairy processing industry using Tornqvist index and data envelopment analysis models over the period 1984–2008. It is found that Haryana's dairy processing industry has experienced positive growth in TFP during the 1980s. According to our TFP estimates during 1990s and 2000s, Haryana's dairy processing industry performed poorly. The decomposition of TFP growth indicates that growth is driven more by increase in scale of processing than by technical efficiency changes. Finally, it is noticed that in Haryana a high volume of milk does not reach to the milk processing plants. For efficient utilization of existing processing capacity in dairy plants, a systematic investment is needed in logistics of raw milk collection and infrastructure.

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Dairy sector plays a vital role in socio-economic development of Haryana. The sector supplements the income of rural masses. Indeed, the dairy sector has a strong influence on health and on the long-term welfare of society, and is a venture of gainful self-employment in the rural sector, particularly among landless laborers, small and marginal farmers, and women. Besides, milk species are the best insurance against the vagaries of nature like drought, famine, and other natural calamities. With per capita milk availability of 642 grams per day Haryana ranked second, next to Punjab (952 grams/day), in the country against the national average of 263 grams/day in 2009–10. Haryana is the sixth largest milk producer with a production of 6 million tonnes, accounting for 5.34% of the country's total milk production during the same period. During 2000–10, the annual average compound growth rate of milk production in the state is recorded at 2% against 3.8% at national level. While during 1990s the state has witnessed faster growth in milk production than the country at large (Sharma, 2004). Present slowdown in milk growth tempo may partially be due to the exodus of large number of very high yielding milk species for commercial milk production in the metros and mushrooming dairy herds in the peri-urban areas (GoH, 2011).

With the successful implementation of the operation flood programme (a dairy development programme), the state has contributed substantially toward increasing national milk production more than five fold, from about 22 million tonnes in 1970 to 116 million tonnes in 2010–11. It is widely known that development of milk processing infrastructure like silos, pasteurizers, storage tanks, and refrigerators has increased the nation's capacity to convert milk, a highly perishable commodity, into a commodity that can be stored and traded world-wide. In addition, increasing population, rising incomes, growing urbanization, export opportunities, and changing dietary preferences are spurring a dramatic increase in demand for, and production of, dairy products in the state as well as in the country at large. The sector represents one of the most lucrative processing industries as well. Presently, there are around 21 organized-sector processing plants of dairy products in the state. The value of their products and by-products was estimated at Rs 13.07 billion in 2008–09 (GoI, 2009). As such, the dairy industry and its future growth potential hold critical value for the Haryana's economy.

Singh et al. (2000) analysed the performance of 13 dairy cooperative plants of two north-eastern states, viz. Punjab and Haryana, for the period 1992–93 to 1996–97 and found an improvement in allocation and cost efficiencies over the period, whereas technical efficiency declined to some extent. There is a dearth of comprehensive analysis to examine and understand the efficiency level and productivity growth in Haryana's dairy industry to recent years. The study is an attempt to fill this gap in the literature. The main aim of our study is to investigate the total factor productivity growth and efficiency level of Haryana's dairy processing industry.

Methodology

Total Factor Productivity

Total factor productivity (TFP) is defined as the ratio of aggregate output produced to the weighted combination of all inputs used. The productivity is raised when growth in output outpaces growth in input. To estimate the TFP, we use the Tornqvist index. Since the translogarithmic functional form provides an approximation to any arbitrary functional form, the Tornqvist index is superlative. It gives equal importance to period t and $t+1$. (Coelli et al., 2005). Mathematically, the Tornqvist index between any two consecutive time periods, t and $t+1$ may be expressed as:

$$\ln TFP_{t,t+1} = \ln \frac{Output\ Index_{t,t+1}}{Input\ Index_{t,t+1}} = \frac{\Pi\left(\frac{y_{it+1}}{y_{it}}\right)^{\frac{w_{it}+w_{it+1}}{2}}}{\Pi\left(\frac{x_{jt+1}}{x_{jt}}\right)^{\frac{v_{jt}+v_{jt+1}}{2}}}$$

In Output Index$_{t,t+1}$ – *In Input Index*$_{t,t+1}$

$$\frac{1}{2}\sum_{i=1}^{N}(w_{it}+w_{it+1})(\ln y_{it}-\ln y_{it+1})-\frac{1}{2}\sum_{j=1}^{K}(v_{jt}+v_{jt+1})(\ln x_{jt}-\ln x_{jt+1}) \quad (1)$$

Where

In = natural logarithm, y_i = quantity of i^{th} output, w_i = share of the i^{th} output in the value of total output, x_j = quantity of j^{th} input, v_j = share of j^{th} input in the total cost, t = time.

Efficiency

For the evaluation of overall efficiency of Haryana's dairy processing industry, the study applies two Data Envelopment Analysis (DEA) models, viz. *(i)* Charnes, Cooper and Rhodes (CCR), and *(ii)* Banker, Charnes and Cooper (BCC). The DEA can separate the efficient operating units (firms, organizations, managers, etc.) from the inefficient on the basis of whether they lie on the efficient frontier which is spanned by the best units in a data set. To carry out a more detailed investigation and enable a greater understanding of the factors involved in each element's productivity or non-productivity, the study uses slack variable analysis. A brief introduction of these models is in order.

The CCR Model

The CCR DEA model assumes constant returns to scale (CRS) in its production possibility set. It can be described as follows. Let us consider a set of DMUs, $a = 1, 2, \ldots,$ n, comprise of s outputs, y_{ka}, $k = 1, 2, \ldots, s$, and m inputs, x_{ia}, $i = 1, 2, \ldots, m$. The efficiency of DMU$_a$ can be found from the following model:

$$\max h_a(u,v) = \frac{\sum_{k=1}^{s} u_k y_{ka}}{\sum_{i=1}^{m} v_i x_{ia}} \quad (2)$$

Subject to :

$$\frac{\sum_{k=1}^{s} u_k y_{kp}}{\sum_{i=1}^{m} v_i x_{ip}} \le 1,\ i = 1, 2, \ldots, m,$$

where,

x_{ip} and y_{kp} are, respectively, the i^{th} input and k^{th} output for DMU$_p$ and the variables $u_k \ge 0$, $k = 1, \ldots, s$, and $v_i \ge 0$, $i = 1, \ldots, m$, are referred to as weights, and h_a is relative efficiency value. Obviously, the optimal value to Equation (2) must not exceed unity. If the optimal value to Equation (2) is equal to unity, then a particular DMU$_a$ is located on the CRS frontier, and a score of less than unity implies that it is inefficient.

Since Equation 2 involves fractional programming, it is difficult to solve. Using the Charnes et al. (1978) transformation, this leads us to the following equivalent linear programming model:

$$\max z = \sum_{k=1}^{s} \mu_k y_{ka} \quad (3)$$

subject to:

$$\sum_{k=1}^{s}\mu_k y_{kp} - \sum_{i=1}^{m}\upsilon_i x_{ip} \leq 0 \; ;$$

$$\sum_{i=1}^{m}\upsilon_i x_{ia} = 1 \; ;$$

$\mu_k, \upsilon_i \geq 0,$

where (u,v) change to (μ, υ).

The dual of the aforementioned multiplier form is called envelopment form, which is easier to solve as it involves fewer constraints than the multiplier form. The dual model (that is, input oriented CCR model) is:

$$\min z = \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{i=1}^{s} s_k^+\right) \qquad (4)$$

subject to:

$$\sum_{p=1}^{n} x_{ip}\lambda_p + s_i^- = \theta x_{ia}, \; I = 1, 2, \ldots, m;$$

$$\sum_{p=1}^{n} y_{kp}\lambda_p - s_i^+ = y_{ka}, \; k = 1, 2, \ldots, s;$$

$\lambda_p, s_i^-, s_i^+ = 0, p = 1, \ldots, n.$

where

θ = efficiency score, λ_p = dual variables, s_i^- = slack variables of the i^{th} input, and s_i^+ = slack variables of the k^{th} output. The value of θ lies between zero and unity (that is, $\theta \leq 1$). The dairy firms for which $\theta < 1$ are inefficient while for $\theta = 1$ are on frontier and hence efficient.

The BCC Model

The CCR model described above is only appropriate when all units are operating at an optimal scale. However, imperfect competition, government regulation, constraints on finance, etc., may cause a dairy firm to not be operating at optimal scale. Banker et al. (1984) extends the CCR model to accommodate technologies that exhibits variable returns to scale (VRS):

$$\max z = \sum_{k=1}^{s} \mu_k y_{ka} - \mu_a \qquad (5)$$

subject to:

$$\sum_{k=1}^{s}\mu_k y_{kp} - \sum_{i=1}^{m}\upsilon_i x_{ip} \leq 0$$

$$\sum_{i=1}^{m}\upsilon_i x_{ia} = 1$$

$p = 1, \ldots, n; \; \theta_k, \upsilon_i \geq 0, \; k = 1, 2, \ldots, s; \; i = 1, 2, \ldots, m.$

The dual model (that is, input oriented BCC model) is as follows:

$$\min z = \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{i=1}^{s} s_k^+\right), \qquad (6)$$

subject to:

$$\sum_{p=1}^{n} x_{ip}\lambda_p + s_i^- = \theta x_{ia}, \; i = 1, 2, \ldots, m;$$

$$\sum_{p=1}^{n} y_{kp}\lambda_p - s_i^+ = y_{ka}, \; k = 1, 2, \ldots, s;$$

$$\sum_{p=1}^{n} \lambda_p = 1$$

$\lambda_p, s_i^-, s_i^+ \geq 0, \; p = 1, \ldots, n.$

The CCR technical efficiency score is decomposed into two components, viz., *(i)* scale efficiency, and *(ii)* pure technical efficiency (Banker et al., 1984). If there is a difference in the CCR and BCC technical efficiency scores for a particular firm, then this indicates that firm has scale inefficiency. The scale efficiency score is obtained by dividing the technical efficiency score resulting from the CCR model to the efficiency score resulting from the BCC model (technical efficiency = pure technical efficiency × scale efficiency). All of these efficiency scores are bounded between zero and unity.

Following Pascoe et al. (2003) and Singh (2004) an efficiency score for each observation (that is, year-wise) has been estimated relative to the efficiency of all other observations and itself. The analysis has been undertaken using the DEAP programme (Coelli, 1996). Technical efficiency based on CRS model is decomposed into Pure Technical Efficiency (PTE) and Scale Efficiency (SE) by conducting both CRS and VRS DEA upon the same data. Scale efficiency score is worked out by dividing the CRS score by the VRS score. The decomposition depicts the sources of inefficiency, that is, whether it is caused by inefficient operation (PTE) or by disadvantageous conditions displayed by the scale efficiency (SE) or both (Cooper et al., 2007).

Output Elasticity

It is useful to examine how will output response with the change in the level of inputs. This notion is examined by estimating the elasticities of output with respect to each input used. The elasticities of Haryana's dairy processing industry output (Y) with respect to three main inputs, viz., capital (k), labor (l) and materials (m) are estimated using Cobb-Douglas type production function in log-linear form:

$$lnY_{it} = \beta_{1t} + \beta_2 lnk_{it} + \beta_3 lnl_{it} + \beta_4 lnm_{it} + u_{it} \quad (7)$$

where β_2 = elasticity of output with respect to capital, β_3 = elasticity of output with respect to labor, β_4 = elasticity of output with respect to materials, and ,μ = error term with zero mean and constant variance; $\mu_t \sim N(0,\sigma^2)$. The assumptions of correct functional form of the model, no autocorrelation, no multicollinearity, homoscedasticity, and normality of residual are tested by Ramsey REST test, Breusch-Godfrey Serial Correlation LM test, Variance Inflation Factor (VIF) test, Breusch-Pagan-Godfrey (BPG) test, and Jarque-Bera test, respectively. To test the statistical significance of the parameters to be estimated (β_1, β_2, β_3 and β_4) student's *t*-statistic has been used. The validity of the model as a whole has been tested applying *F*-test. The R^2 and adjusted R^2 are also computed to ascertain goodness of fit of the model.

Data

For analysing the productivity and efficiency of Haryana's dairy processing industry, the study is primarily concerned with the five main inputs, viz. fixed capital, working capital, labor, raw materials, and fuel. Their details operational definitions are provided in *Annual Survey of Industry* (2008), Ministry of Commerce and Industry, Government of India (GoI), New Delhi. The data on Haryana's dairy processing industry inputs, net value added (NVA) and output are compiled from *Annual Survey of Industry*, Ministry of Commerce and Industry, Government of India (GoI), New Delhi. Data on prices indices are taken from *Hand Book of Statistics on Indian Economy*, Reserve Bank of India, Mumbai. The data are annual. The sample period is 1984–85 to 2008–09. During this period, Haryana's milk output has more than tripled.

Total Factor Productivity Growth

Table 1 shows the trends in indices of output, input and TFP for Haryana's dairy processing industry during 1984–85 to 2008–09 derived using Tornqvist index (Equation 1).

The table shows that TFP growth in Haryana's dairy processing industry is driven by both output and input movements. A glance at Column 2 of Table 1 reveals that output index has fluctuated widely during the period under study. Overall, it has shown a rising trend, the average upward shift in output index being 0.4% per year. A look at Column 3 illustrates that aggregate input index has also shown oscillation for the period under investigation, an annual average increase of 5.1% per annum. As a result, TPF has exhibit a downward shift of 4.7% per year. However, sub-period-wise results are more revealing.

Table 1. Trends in Indices of Output, Input and TFP for Haryana's Dairy Industry

Year	Output index	Input index	TFP
1984	1	1	1
1985	1.61	1.11	1.45
1986	0.31	0.34	0.92
1987	7.74	0.92	8.46
1988	2.40	0.65	3.69
1989	1.49	0.70	2.13
1990	1.89	0.59	3.21
1991	0.58	0.12	4.95
1992	12.44	2.38	5.23
1993	14.10	1.47	9.56
1994	23.22	7.39	3.14
1995	27.07	8.48	3.19
1996	12.79	11.02	1.16
1997	29.57	12.83	2.31
1998	19.70	10.23	2.89
1999	24.47	12.13	1.62
2000	67.74	19.18	1.28
2001	30.89	18.99	3.57
2002	30.89	16.34	1.89
2003	0.16	0.16	0.97
2004	0.43	0.57	0.75
2005	0.56	0.38	1.48
2006	1.34	0.90	1.49
2007	1.10	2.02	0.54
2008	1.23	1.97	0.62

Note: The TFP is computed with one output, that is, NVA and 5 inputs, viz. fixed capital, working capital, labor, fuel, and raw materials.

In order to understand the dynamics of the productivity growth in Haryana's dairy industry an adhoc splitting-up of 24 year period is done into three sub-periods, decade wise, viz. *(i)* 1984–85 to 1989–90, *(ii)* 1990–91 to 1999–2000, and *(iii)* 2000–01 to 2008–09. The annual average growth rates for output, input, and TFP indices are estimated for the entire period and different sub-periods and results are presented in Table 2. A glance at Column 3 of Table 2 makes it clear that during 1984–85 to 1989–90 Haryana's dairy.processing industry has experienced positive growth in total factor productivity, 25.1% per year. During 1990s, NVA in dairy processing industry grew at 70% per annum.

While the input index increased by a slightly faster rate, 72% per annum, the annual average growth rate of TFP turned down to –2.0%. During 2000–08, both output and input indices have declined substantially. However, the NVA in dairy industry has declined faster than input index, resulting into fall in total factor productivity. The deceleration in TFP in dairy processing during the post-reform period was also observed for the country at large (Elumalai and Birthal, 2010). We now measure the technical and scale efficiencies in Haryana's dairy processing industry.

Table 2. Annual Average Growth Rates: Indices of Output, Input and TFP for Haryana's Dairy Industry (percent)

Index	Pooled year 1984–2008	Sub-period I 1984–1989	Sub-period II 1990–1999	Sub-period III 2000–2008
Output	0.4	18.3	70.0	–120.2
Input	5.1	–6.8	72.0	–99.3
TFP	–4.7	25.1	–2.0	–20.9

Estimates of Technical and Scale Efficiencies

Table 3 shows the trends in technical efficiency scores obtained from both the CCR (Equation 4) and BCC (Equation 6) input-oriented models and scale-efficiency score for Haryana's dairy industry for the period 1984–85 to 2008–09. A scale efficiency score having value unity demonstrates that the industry is scale efficient and a value less than unity evinces that the industry is scale inefficient. Average scale efficiency has been observed 0.81 for the entire study period. Average TE and PTE efficiency scores, the distance of a DMU from the best practice, are worked out to be 0.59 and 0.72, respectively.

The value of TE (0.59) means that Haryana's dairy processing industry could possibly reduce the consumption of inputs by 41% (1 – TE ×100) without reducing the output.

Comparing these three efficiencies, it is observed that in dairy industry, aggregate efficiency is contributed more by the increase in size of plant than by the efficient conversion of inputs, as SE score is much higher than the PTE score. A look at the results presented in Column 5 of Table 3 makes it clear that, on an average, dairy processing industry in Haryana is operating under increasing returns to scale.

A comparison of dairy industry efficiency scores during different sub-periods brings out that during 1990s the industry has improved its technical and scale efficiencies. As against 0.59, 0.81, and 0.66 average values of TE, PTE, and SE scores, respectively, observed during 1984–89, average values of these scores are 0.77, 0.82, and 0.94 during 1990–1999. However, these efficiency scores have seen deceleration during 2000s—the TE, PTE, and SE scores have come down to 0.40, 0.56, and 0.74 during 2000–01 to 2008–09, respectively. This implies that inefficiency in the dairy industry in the later period is more due to inefficient operation (PTE) than due to disadvantageous conditions demonstrated by scale efficiency. It is observed that up to 1989–90, PTE has remained much higher than the SE, and as a result, technical efficiency is contributed more by PTE than by SE.

Looking at the year-wise performance of Haryana's dairy industry, we observe that it obtains the value of TE score (CCR score) unity for five years, viz. 1987–88, 1991–92, 1993–94, 1995–96, and 2001–02. This implies in these years: *(i)* the industry is 100% technically efficient and there are no slacks in the utilization of inputs, and *(ii)* the industry is operating under constant returns to scale. In all other years, CCR efficiency scores are less than unity, pointing out toward inefficiency in the application of

Table 3. Trends in Efficiency Scores in Haryana's Dairy Industry

Year	CCR model (TE)	BCC model (PTE)	Scale efficiency (SE)	Returns to scale
1984	0.599	1.00	0.599	Irs
1985	0.393	0.542	0.725	Irs
1986	0.179	0.753	0.238	Irs
1987	1.000	1.000	1.000	Crs
1988	0.488	0.580	0.842	Irs
1989	0.851	1.000	0.565	Irs
1990	0.484	0.857	0.565	Irs
1991	1.000	1.000	1.000	Crs
1992	0.785	0.796	0.986	Irs
1993	1.000	1.000	1.000	Crs
1994	0.966	1.000	0.966	Drs
1995	1.000	1.000	1.000	Crs
1996	0.448	0.493	0.908	Irs
1997	0.791	0.797	0.992	Irs
1998	0.721	0.722	0.999	Drs
1999	0.459	0.477	0.962	Irs
2000	0.441	0.464	0.949	Irs
2001	1.000	1.000	1.000	Crs
2002	0.595	0.686	0.868	Drs
2003	0.220	1.000	0.220	Irs
2004	0.147	0.361	0.407	Irs
2005	0.298	0.523	0.570	Irs
2006	0.497	0.503	0.988	Drs
2007	0.156	0.209	0.749	Irs
2008	0.272	0.293	0.930	Drs
Mean	0.592	0.722	0.813	Irs

Note: Same as in Table 1, irs = increasing returns to scale, crs = constant returns to scale, and drs = decreasing returns to scale.

resources. If efficiency scores based on VRS (PTE scores) are taken into consideration for assessing the performance of the dairy industry during the period under study, it is found that about 38% years stand on production frontier, as is obvious from the values of their respective scores equal to unity. In case of scale efficiency, only five years, viz. 1987–88, 1991–92, 1993–94, 1995–96, and 2001–02 are found scale efficient. For these years, these three efficiencies are equal to each other and are having value of score unity. In remaining years, the industry is scale inefficient as it is having the value of SE score less than unity. It may be concluded that the size of plant (scale) has turned out as much vital factor in enhancing the overall efficiency of dairy industry. Let us examine the slacks observed in Haryana's dairy processing industry.

Analysis of Input Slacks

Table 4 contains the values of inputs actually used in dairy industry and estimated slacks in them. To make the industry efficient in a particular year, all slacks in inputs are to be eliminated. An efficient year does not have any input slack. A perusal of Column 11 in Table 4 reveals that raw material has been most efficiently utilized by dairy processing industry. Out of 25 years, slacks are observed only for 9 years. Fuel has also been efficiently utilized by dairy industry, except for few years, viz., 1985–86, 1988–89 to 1990–91, 1994–95, 1996–97 to 2000–01 and 2002–03, as is obvious from the value of zero slacks observed in it. Highest slack in utilization of fuel is observed in 2002–03. In order to become fuel efficient during 2002–03, the industry should have reduced the expenditure on fuel from the existing amount of Rs 95394 lakh to Rs 74145 lakh to produce NVA of Rs 117800 lakh.

A scrutiny of data presented in Column 5 of Table 4 shows that the working capital (WC) has also been efficiently utilized by the dairy industry during most of the years under study. Except for nine scale inefficient years, viz. 1984–85, 1986–87, 1992–93, 1996–97 to 1998–99,

Table 4. Trends in Actual Inputs and Estimated Slack Inputs (at 1993–94 Prices) for Haryana's Dairy Industry

Year	Fixed capital (Rs lakh)		Working capital (Rs lakh)		No. of employees		Fuels (Rs lakh)		Raw materials (Rs lakh)	
	Actual	Slack	Actual	Slack	Actual	Slack	Actual	Slack	Actual	Slack
1984	21023	11749.2	5939	1412.9	461	186	1379	0	18264	0
1985	20866	6345.5	7058	0	704	157	4424	216.1	57528	0
1986	3683	359.1	4475	102.2	630	79	1378	0	22786	0
1987	6148	0	16268	0	651	0	6440	0	79120	0
1988	5783	0	8361	0	1080	350	6881	1069.1	98620	13812.97
1989	16635	11041.6	1277	0	931	720	7525	4550.8	97202	46882.9
1990	9291	549.9	2847	0	1031	407	11351	3146.010	142557	23573.2
1991	1297	0	2015	0	166	0	356	0	19801	0
1992	33979	0	32628	15147.8	771	0	19412	0	406126	17797.7
1993	29395	0	10262	0	683	0	17490	0	338324	0
1994	176755	46884.8	43285	0	1173	0	32185	4998.4	525811	0
1995	197559	0	57049	0	1142	0	30825	0	632237	0
1996	224577	7639.1	107888	21097.4	1196	0	33685	532.4	676477	0
1997	222245	0	164096	55697.8	1286	0	46375	3648.240	1190857	0
1998	192163	0	109563	7976.8	1352	0	57385	8109.4	1414613	0
1999	258136	15964.06	100838	0	1490	0	57223	4058.143	1388508	0
2000	387853	38685.82	169675	0	1456	0	120947	26921.9	2191392	0
2001	353955	0	224413	0	1534	0	71994	0	2902227	0
2002	370341	106546.99	106183	0	1832	0	95394	21249.0	2401400	391061.1
2003	1498	115.98	1897	0	833	158	541	0	14111	28.8
2004	6048	322.76	8624	150.9	460	0	2200	0	60934	838.4
2005	4667	883.85	3719	0	1444	385	1630	0	52704	9319.2
2006	6840	1496.3	14852	3753.8	2429	977	2006	0	55495	0
2007	37802	4739.92	12711	0	2535	312	6447	0	136979	7000.3
2008	33291	6894.04	16782	841.6	2642	449	3108	0	118946	0
Mean	109242.9	10408.6	51362.7	4274.2	1246	167	26607.5	3140.0	626792.5	20412.6

2004–05, 2006–07 and 2008–09, for all the remaining years, the estimated value of working capital slack is zero. Highest slacks are observed in the use of fixed capital. Out of total 24 years, excess use of fixed capital is observed during 19 years. For instance, in 2002–03 the industry applied Rs 106546.99 lakh fixed capital in excess. To make the industry fixed capital efficient in this year, the fixed capital is to be reduced to Rs. 263794 lakh from existing level of Rs 370341 lakh.

Slacks are also found in utilization of labor. It is clear from Column 7 of Table 4 that before 1990–91 (except 1987–88) labor has not been efficiently employed by the dairy industry. For example, in 1988–89, the industry occupies 720 employees in excess to produce NVA of Rs 9166 lakh.

To make the industry labor efficient in this year, about 77% of the existing strength of employees could be reduced without affecting the NVA. In 1991–92 dairy industry has drastically reduced the labor force, that is, 84% decline. During 1991–92 to 2002–03, dairy industry evinces zero slacks in it. Next we estimate the elasticities of Haryana's dairy processing industry output with respect to inputs used.

Output Elasticities

The elasticities of Haryana's dairy processing industry output with respect to three main inputs, viz. fixed capital (ek), labor (el) and raw materials (em) (Equation 7) are estimated. The results are presented in Table 5.

The estimated value of adjusted R^2 is 0.99 which indicates that our model fits the data well. The value of '*F*'-

TABLE 5. Output Elasticities with respect to Capital, Labor, and Materials

Elasticity	Coefficient	Std. error	*t*-statistic	Prob.
Ek	0.03	0.03	1.10	0.28
El	–0.01	0.04	-0.26	0.80
Em	0.95	0.03	29.97	0.00
Diagnostic				
R^2	0.996			
Adjusted R^2	0.996			
F-statistic	2340			0.00
Normality χ^2	1.07			0.58
Homoscedasticity χ^2	1.34			0.29
Autocorrelation χ^2	1.82			0.20
Durbin-Watson *d* stat.	2.07			
Functional form χ^2	2.08			0.15

Note: The values of diagnostic tests are estimated using E-Views 7. Normality χ^2 = Jarque-Bera test statistic, Homoscedasticity χ^2 = Breusch-Pagan-Godfrey test statistic, Autocorrelation χ^2 = Breusch-Godfrey Serial Correlation LM test statistic, and Functional form χ^2 = Ramsey RESET test statistic.

test is statistically significant at 1% level. It suggests the validity of the model. The results presented in last five rows of the table suggest that our estimates of parameters are fit for reliable interpretation, that is, normal distribution of the residuals, homoscedasticity, no autocorrelation and correct functional form of the model. The presence of multi-collinearity is detected by estimating Variance Inflation Factor (VIF) values. The estimated values of VIF for all explanatory variables were less than ten. This result suggests the absence of multi-collinearity problem. We note that in Haryana dairy processing industry output is highly sensitive to supply of raw materials. The estimated materials elasticity coefficient suggests that a one per cent increase in raw materials increases the total dairy output by 0.95%. The elasticities coefficients of dairy processing industry output with respect to labor and fixed capital are statistically insignificant at any conventional level.

Policy Implications

The study has assessed the total factor productivity growth in Haryana's dairy processing industry using Tornqvist index and measured the technical and scale efficiencies applying DEA models, viz. *(i)* Charnes, Cooper and Rhodes (CCR), and *(ii)* Banker, Charnes and Cooper (BCC) over the period 1984-2008.

The results suggest that during 1980s total factor productivity in Haryana's dairy processing industry has grown at a rate of 25.1% a year. While during 1990s and 2000s, TPF has declined. The study finds that Haryana's dairy processing industry is on an average 81% scale efficient. The decomposition of TFP growth indicates that growth are driven more by increasing scale of processing than by technical efficiency changes. Highest input slacks are observed for fixed capital. The average technical efficiency score is estimated at 0.59. The policy implication is that Haryana's dairy processing industry can reduce the inputs use by 41% while at the same time maintaining the same level in output. It is established that Haryana's dairy processing industry output is highly sensitive to the supply of raw materials. World Bank (2009) has reported that a high volume of milk (85%) does not reach to the processing plants. The main conclusion to be drawn from our analysis is that major improvements in dairy processing industry productivity are possible and can contribute to economic growth in Haryana, but increased investment in logistics of raw milk collection and infrastructure development is needed.

References

Banker, R.D., A. Charnes, and W.W. Cooper (1984), "Some Models for Estimating Technical and Scale Inefficiency in Data Envelopment Analysis", *Management Science*, 30(9): 1078–1092.

Caves, D.W., L.R. Christensen, and W.E. Diewert (1982) "The Economic Theory of Index Numbers and the Measurement of Input, Output and Productivity," *Econometrica*, 50(6): 1393–1414.

Charnes, A., W.W. Cooper, and E. Rhodes (1978), "Measuring the Efficiency of Decision Making Units," *European Journal of Operations Research*, 2(6): 429–444.

Coelli, T.J. (1996) *A Guide to DEAP Version 2.1: A Data Envelopment Analysis Computer Program*, CEPA Working Papers No. 8/96, Armidale, Australia: University of New England.

Coelli, T., D.S.P. Rao, C.J. O'Donnell, and G.E. Battese (2005) *An Introduction to Efficiency and Productivity Analysis*, 2nd Edition, New York: Springer.

Cooper, W.W., Seiford L. M. and Tone K. (2007) *Data Envelopment Analysis, A Comprehensive Text with Models, Applications, References and DEA-Solver Software*, Second Edition, USA: Springer.

Elumalai, K., and P.S. Birthal (2010), "Effect of Trade Liberalization on the Efficiency of Indian Dairy Industry," *Journal of International and Area Studies*, 17(1), 1–15.

Farrel, M.J. (1957), "The Measurement of Productive Efficiency," *Journal of Royal Statistical Society*, Series A General, 120(3): 253–290.

GoH (2011) *Approved Annual Plan* 2011–12. Planning Department, Government of Haryana, Panchkula.

GoI (2009) *Annual Survey of Industry*, Ministry of Commerce and Industry, Government of India, New Delhi.

GoI (2010) *Basic Animal Husbandry Statistics*, Ministry of Agriculture, Government of India, New Delhi.

Pascoe, S., James E. Kirkely, and D. F. Greboval (2003) *Measuring and Assessing Capacity in Fisheries: Issues and Methods*. Rome: Food and Agriculture Organization of the United Nations.

Nin, A., S. Ehui, and S. Benin (2007) "Livestock Productivity in Developing Countries: An Assessment," *Handbook of Agriculture Economics*, 3, 2461–2532.

Ramphul (2010), *WTO and Indian Agriculture*. New Delhi: Global Research Publications.

(2012a), *Globalization and Competitiveness of Indian Dairy Sector*, Report, Major Research Project, New Delhi: University Grants Commission.

(2012b), "Globalization and World Dairy Trade: An Assessment," *Journal of World Investment and Trade*, 13(1): 77–103.

Sharma, V.P. (2004), "Livestock Economy of India: Current Status, Emerging Issues and Long Term Prospects," *Indian Journal of Agriculture Economics*, 59(3), 512–554.

Singh, S., E. Fleming, and T. CoeUi (2000) *Efficiency and Productivity Analysis of Cooperative Dairy Plants in Haryana and Punjab States of India*, Working Paper No. 2000-2, Graduate School of Agricultural and Resource Economics, University of New England.

Singh, S.P. (2004) *Post WTO Era: Impact on Export Prospects of Livestock Products*, Occasional Paper-32, Department of Economic Analysis and Research, Notional Bank for Agriculture and Rural Development, Mumbai.

World Bank (2009) *South-South Exchange: Sharing of Knowledge and Innovation: The Case of India, Uganda and Tanzania*, Report No. 52074.

"You seldom improve quality by cutting costs,
but you can often cut costs by improving Quality"

— Karl Albrecht

Delay Minimization of Furnace Save Electricity Consumption

SHIVAJI BISWAS

This article highlights the energy loss areas in a continous ductile iron pipe industry which can be reduced to an optimum value by proper line balancing .In this article the loss areas were calculated by taking field observations

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Synopsis

The ductile iron pipe manufacturing unit's one part, that is, electrically operated reheating furnace area was studied considering the high energy intensity area. A close observation of the process identified many delays due to improper line balancing resulting in loss of electrical power. Such a plant has considerable savings potential if a long-term plan is initiated.

Ductile iron pipe industry has all sorts of energy consuming as well as generating equipments like blast furnace, tunnel furnace, annealing furnace, turbine and boiler, compressor, etc. Such a type of plant of 5.00 lakh MT annual capacity uses various types of fuels like electricity, fuel oil, coal gas, coke, LPG, etc. As mentioned, plants with such type of production consume 1146776.32×10^6 Kcal of fuel which is equivalent to 114677 MTOE. As a result of continuous implementation the specific energy consumption was brought down from 4.92×10^6 Kcal/MT in 2006–07 to 2.45×10^6 Kcal/MT in 2008–09.

When a ladle full of molten material has to wait for the next operation, it results in a quick drop of temperature due to the combined effect of radiation and convection. Blast furnace produces a fixed quantity of molten mass which require the right processing time. The study identified 503 Kwh of energy loss per cycle due to delay, which needs immediate attention. The company has a monopoly, so inefficiency like this is directly tolerated by Indian consumers in terms of higher cost. This needs further detailed analysis.

In our area of study, molten iron from miniblast furnace is taken to a series of reheating furnaces named as mini heel furnace having 30 MT holding capacity, the molten material is taken to magnesium treatment at 1463°C by means of a ladle. Next destination after magnesium treatment is pipe conversion. Sometimes rejected material is returned back to reheating furnaces causing wastage of energy. The procedure to avoid unproductive operations and their energy consumption implications will be discussed.

Methodology

In order to achieve the objective of the present study, the methodology used was batch-to-batch observation of different sub-operation movement studies of metal in a ladle along with power-drawl estimation. This analysis provided the clue about where did an unproductive operation take place.

Observation

Mini heel furnaces of three plants were studied for about seven hours. During the study period, power consumption was noted on the panel by taking the KW reading. Table 1 shows at KW drawl at different duration.

TABLE 1. Mini Heel Furnace-1, Cycle Time and Energy Consumption

Time (Hrs.)	Duration (Min.)	Power drawn (KW)	KWH
10.07–10.54	47	500	391
10.54–11.21	27	200	90
11.21–11.38	17	800	226.6
11.38–11.52	14	1000	233.3
11.52–11.57	05	800	66.66
11.57–12.04	07	2100	245
12.18–12.32	14	400	93.33
12.32–12.36	04	500	33.33
12.36–13.16	40	400	266
13.16–13.29	13	300	65
13.29–13.40	11	320	58.66
13.40–13.43	03	2700	135
13.43–13.45	02	2150	71.66
TOTAL	216		2350.3

Similarly for other two furnaces along with this furnace, the total energy consumption for 216 minutes as 3.63 hours recorded was (3300 + 3980 + 2350) Kwh or 9665 Kwh.

The metal handled by all 3 MHF furnaces was 161.8 MT during the period. Therefore, specific consumption as recorded 59.73 Kwh/MT.

30 MT MHF furnaces tap liquid metal through ladle. Once the ladle pouring of liquid metal is over to holding furnace services, activities take place—some activities are productive rest are unproductive. This story of activities is narrated in Table 2.

In this cycle, total energy consumption was calculated as 2014 Kwh. Out of this, holding time for liquid metal was 94 minutes and corresponding power consumption was 503.3 Kwh.

Therefore, in the whole cycle holding time/delay due to improper line balancing accounts for 24.99% of total energy consumption.

Energy Savings by Reduction of Delay

This delay was caused by improper line balancing of furnaces. Line balancing right from pouring of heat molten metal from blast furnace to transferring heat metal to 6 MT furnace is to be studied by industrial engineering team.

Table 2. Activities to Mini Heel Furnace

Step	Activity	Duration (Hr.)	Time (min.)	Power drawn (Kw)	Kwh consumption
01	Liquid metal pouring from MBF(Mini blast furnace) to Mini Heel Furnace	10.25 –10.37	12	2700	540
02	Melting	10.37–10.45	08	2700	360
03	Holding	10.45–11.32	47	350 Kw (11.27) + 150	245 + 12.5
04	Discharge 3.5 T	11.32–11.36	04	150	10
05	Discharge 3.5 ton	11.42–11.45	03	150	7.5
06	Holding	11.45–11.52	07	150	17.5
07	Melting Note: Metal returned 3MT	11.52–11.57	05	2750	229
08	Melting	11.57–12.00	03	2750	20
09	Discharge 3.57mt	12.00–12.04	04	300	20
10	Holding	12.04–12.11	07	300	35
11	Metal Returned (3.5 T)	12.11			
12	Melting	12.11–12.14	03	2800	140
13	Holding	12.14–12.36	4 + 14 + 4	500 + 400 + 1000	33.3 + 93.3 + 66.7
14	Discharge (8.27)	12.36 –12.40	04	1000	66.7
15	Holding	12.40–12.51	11	0	0
	Total 2014				140

While annual energy consumption for three furnaces was 16.98x10^6 Kwh, the delay causes wastage of 24.99% energy or, 4145241 Kwh or, in financial terms Rs 183.21 lakh. There was only a 20% of delay time reduction which can easily be achievable by creating additional capacity at user point or, controlling blast furnace output 829048 Kwh can be saved.

Energy Savings Options

Hood Heat Less

One 30T MHF hood has an area of 1.815m^2. The surface thermocouple measured temperature as 182°C. On the basis of 40°C ambient temperature, the high radiation loss of 2.12 Kwh/hr was taking place which may be minimized by proper insulation. The annual savings by putting insulation cover 2.07 Kwh/hr and if ceramic casteble is used, the savings at the rate of Rs 4.42/unit would be Rs.1.98 lakh.

This radiation and convection is so intense that in one hour 350 Kwh is lost to the atmosphere. During the study, exposure time was noted with respect to the ladle and MHF activity (Table 3).

Table 3. Hood Open Duration for Various Activities for Mini Heel Furnace–1

Step	Activity	Duration (Hrs.)	Time (min.)	Remarks
01	Liquid metal "pouring from "blast furnace" to "MHF–1".	10.25–10.37	12	
02	Temperature reading	11.27–11.29	02	Can be reduced
03	Discharge to small ladle	11.32–11.37	O5	
04	Return from small ladle to MHF.	11.54–11.61	07	
05	Discharge to small ladle	12.00–12.05	05	
06	Return from small ladle to MHF	13.17–13.22	05	
07	Discharge to small ladle	12.36–12.41	05	
08	Return from small ladle to MHF	13.17–13.22	05	
09	Temperature Reading	13.29–13.31	02	Can be reduced
10	Liquid metal pouring from MBF to MHF-1	13.40–13.47	07	
11	Temperature reading	13.47–13.49	02	Can be reduced
			Total: 57 min.	

Liquid metal pouring to Ladle and MHF is a time consuming and unavoidable activity that results in considerable heat losses to atmosphere.

Due to high radiation from molten metal during pouring, extensive heat loss takes place which is unavoidable. Only six minute temperature measurement time can be avoided, that is (6/57) x 100 or 10.57% of total cycle time.

Summary and Conclusion

It can be concluded from above observations that in a continuous ductile iron pipe industry which is an energy intensive process, waiting time is very unproductive which is one of the causes of high specific electricity consumption. Reworking of molten metal as a reuse 6.5 MT as shown in Table 2 contributed another source of loss.

"Our future growth relies on competitiveness and innovation, skills and productivity...and these in turn rely on the education of our people."

— Julia Gillard

Feature

Decision Support System for Vendor Selection in a Medium Merchant and Structural Mill

V. DURGA PRASADA RAO, P. RAMAMURTHY RAJU AND T. V. SUBBA RAO

Vendor selection is a multi-criteria problem which includes both qualitative and quantitative factors. In order to select the best supplier it is necessary to make a trade off between tangible and intangible factors, some of which may conflict. When capacity constraints exists, this problem becomes more complicated as in these circumstances, managers should decide about two problems, viz., which suppliers are the best and how much should be purchased from each supplier. Some methodologies have applied mixed integer programming and goal programming to solve this problem. As these techniques are mathematical, they have significant problems in considering qualitative factors that are very important in supplier selection, especially when supplier partnership is desired. So in this article, a Decision Support System (DSS), which integrates an Analytical Hierarchy Process (AHP) and Linear Programming (LP), is proposed for the products of a medium merchant and structural mill. It considers both tangible and intangible factors (like cost, quality, service and capacity) in choosing the best suppliers and placing the optimum order quantities among them such that the Total Value of Purchasing (TVP) becomes maximum. A sensitivity analysis is done to identify the impact of changes in the priority of criteria on the supplier's performance and order quantities.

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Decision Support System (DSS) is a system that supports the manager seeking to solve a semi-structured problem by providing information and suggestions. The suggestions can take the form of recommended decisions and also recommended processes to follow. The key factor is that by means of a user friendly DSS the managers themselves can build up the scenarios based on their own experience and creativity.

Vendor selection and evaluation have become one of the major topics in production and operations management literature, especially in advanced manufacturing technologies and environment (Motwani et al., 1999). The Multiple Attribute Utility Theory (MAUT) method has the advantage that it is capable of handling multiple conflicting attributes. However, this method is only used for international supplier selection, where the environment is more complicated and risky (Bross and Zhao, 2004). According to Chen-Tung et al. (2006), the Fuzzy logic approach measures for supplier performance evaluation. This approach can help Decision Making (DM) to find out the appropriate ordering from each supplier. Another useful method is the Analytical Hierarchical Process (AHP), a decision-making method developed for prioritizing alternatives when multiple criteria must be considered and allows the decision maker to structure complex problems in the form of a hierarchy, or a set of integrated levels. The AHP was introduced by Saaty (1980). There has been wide discussion about the empirical effectiveness and theoretical validity of this technique. Similar to that of the MAUT, AHP allows the decision maker to structure complicated problems in the form of a decision hierarchy. Because AHP utilizes a ratio scale for human judgments, the alternatives' weights reflect the relative importance of the criteria in achieving the goal of the hierarchy (Maggie and Tummala, 2001).

The use of the AHP approach offers a number of benefits. One important advantage is its simplicity (Liu and Hai, 2005). Ghodsypour et al. (1998) proposed a decision support system for supplier selection using an integrated analytical hierarchy process and linear programming. Chan et al. (2007) implemented a fuzzy extended method using critical decision criteria to determine critical factors such as the risk factors, cost, quality, service performance for selecting efficient global supplier in present business scenario. Gencer et al. (2007) have introduced Analytic network process (ANP) model in their study which has been developed on the basis of evaluating the relations between supplier selections criteria in a feedback system. This proposed model is implemented in telecommunication organization. However Integration of Taguchi loss function, analytical hierarchy process and multi-choice goal programming (MCGP) model for solving the supplier selection problem was proposed by Liao et al. (2010) and the advantage of this proposed method is that it allows decision makers to set multiple aspiration levels for the decision criteria.

An integrated approach of analytical hierarchy process improved by rough sets theory and multi-objective mixed integer programming has also been proposed to simultaneously determine the number of suppliers to employ and the order quantity to be allocated to the supplies in the case of multiple sourcing, multiple products, with multiple criteria and with suppliers capacity constraints (Xia et al., 2007). In quantity discount factor and minimizing the total cost of purchasing an integral model of AHP and non-linear integer program was to determine the best supplier and optimal order quantity (Kokangul et al., 2009). Chakraborty et al. (2011) have found the initial solution of the vendor selection problem using AHP and thereafter the quality of the solution is improved using a heuristic technique. In order to validate the proposed methodology the experimentation is carried out on real-life industrial data collected from an Indian construction firm.

In this article, a case of a Medium Merchant and Structural Mill (MMSM) is considered. Actually the cold saw blades which are used for cutting the products of MMSM into required customer lengths are imported from three foreign suppliers and two indigenous suppliers. Here the quality, capacity, and delivery time varies from supplier to supplier. Also the cost of each cold saw blade obtained from different suppliers is different. Thus the present article focuses on the application of AHP integrated with linear programming in order to find the best suppliers and optimum order quantities of cold saw blades. Also sensitivity analysis is done to highlight the impact of changes in the priority of criteria on the supplier's performance and order quantities.

Methodology

The methodology consists in applying AHP, which uses pair-wise comparision to make a trade-off between tangible and intangible factors like cost, quality, service and capacity, and calculating a rating of suppliers. These rating coefficients are then applied to formulate the objective of an LP problem, which is optimized to find the order quantities among the suppliers. The complete algorithm consists of the following steps:

Step 1: According to the level of buyer–supplier integration, the company's competitive situation and its corporate strategies, define the important criteria for supplier selection. There are five levels of buyer–supplier integration strategies, viz., levels 1, 2, 3, 4, 5. In the present work, level 2 strategies are selected. At this level, logistical integration exists between buyer and the supplier has an important role in the buyer's competitiveness. Therefore great importance is given to supplier's logistical performance. Hence in these circumstances, besides the quality and price, the operational logistic elements such as reliability, flexibility, supply lots, lead time, and so on are considered in the supplier selection process.

Step 2: Once the hierarchy has been structured, the weights of the criteria are calculated. By using pair-wise comparision the preference between criteria will be asked from top and purchasing management. Then by applying Saaty's 1–9 scale, which is presented in Table 1, these preferences are quantified.

Step 3: For rating suppliers, any real existing data are applied as quantitative criteria and Saaty's 1–9 scale is used for qualitative criteria. The question for pair-wise comparision for quantitative criteria is "Of two elements i and j, how many times i is preferred to j." If the values for alternative i and j are W_i, W_j, respectively, then the pair-wise comparision matrix is given by:

TABLE 1: Saaty's scale for AHP preference

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally
3	Weak importance of one over another	Experience and judgement slightly favour one over another
5	Essential or strong importance	Strongly favor one over another
7	Very strong and demonstrated	Strongly favored and its dominance demonstrated in practice
9	Absolute importance	Evidence favoring one over another is of the highest possible order
2, 4, 6, 8	Intermediate values between adjacent scale values	When compromise is needed

$$\begin{bmatrix} W1,W1 & W1,W2 & \cdots\cdots & W1,Wn \\ W2,W1 & W2,W2 & \cdots\cdots & W2,Wn \\ \cdots & \cdots & \cdots & \cdots \\ Wn,W1 & Wn,W2 & \cdots\cdots & Wn,Wn \end{bmatrix}$$

As this matrix is consistent, the weight of each element is its relative normalized amount which is given by:

Weight of i^{th} element = $Wi / \Sigma Wi$

Weight of i^{th} element for inverse criteria = $(1/Wi) / \Sigma (1/Wi)$

Step 4: By combining the weight of criteria and supplier's rating, the final score (or final rating) of each supplier is determined.

Step 5: Use the suppliers' final ratings as coefficients of an objective function in linear programming problem (LPP) to assign order quantities to the suppliers such that the total value of purchasing (TVP) becomes maximum. The important constraints on the problem are supplier capacity, buyer's demand and quality.

If Ri = Final rating of i^{th} supplier; Xi = Order quantity from i^{th} supplier; Vi = Capacity of i^{th} supplier; Qi = Defect percent of i^{th} supplier; Q = Buyer's maximum acceptable defect rate; D = Demand of the product or item for the period, then the LPP is:

Maximize: $TVP = \sum Ri\, Xi$ (Objective function)

Subject to: $\sum Xi.\ Qi \le Q.\ D$ (Aggregate quality constraint)

$\sum Xi = D$ (Demand constraint)

$Xi \le Vi$, $i = 1,2,\ldots\ldots,n$ (Suppliers' capacity constraints)

and $Xi \ge 0$, $i = 1,2,\ldots\ldots,n$ (Non-negativity constraints)

Step 6: Solve the linear programming model using Microsoft Excel Solver.

Calculation of Ratings of Suppliers

In the present case, there are five alternatives for supplier or vendor selection, viz., S1, S2, S3, S4, and S5, and the criteria chosen for vendor selection are capacity, quality, on-time delivery, and cost. The suppliers' quantitative information is given in Table 2. The annual demand (D) for the cold saw blades is 300 and the maximum acceptable defect rate (Q) fixed by MMSM is 0.02. The quantities of blades supplied by the suppliers S1, S2, S3, S4, and S5 are 10, 262, 0, 0, and 28, respectively.

Calculation of weights of the criteria

The preferences on the criteria are made as per the choices of values given in Table 3. Then the values upon comparing a criterion with the remaining criteria will be as given in Table 4. The summary of the column values after filling the empty cells of Table 4 with the inverse of their corresponding values is as shown in Table 5. The Table 6

Table 2. Suppliers' Quantitative Information

Supplier	Cost/Blade(Ci in Rs.)	Quality (Qi)	On time delivery (Si)	Capacity (Vi)
S1	20,673	0.033	0.70	275
S2	23,572	0.028	0.51	300
S3	22,570	0.029	0.23	200
S4	18,950	0.020	0.98	150
S5	17,850	0.043	0.19	100

Table 3. Value–Preference table

Value	Preference
1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Very strongly preferred
8	Very strongly to extremely preferred
9	Extremely preferred

Table 4. Pair-wise Comparison of Criteria

Criteria	Capacity	Quality	On time delivery	Cost
Capacity	1	2	2	3
Quality		1	4	4
On time delivery			1	2
Cost				1

Table 5. Summary of Column Values of Criteria

Criteria	Capacity	Quality	On time delivery	Cost
Capacity	1.00	2.00	2.00	3.00
Quality	0.50	1.00	4.00	4.00
On-time delivery	0.50	0.25	1.00	2.00
Cost	0.33	0.25	0.50	1.00
Total	2.33	3.50	7.50	10.00

Table 6: Average Weights of Criteria under Consideration

Criteria	Capacity	Quali ty	On time delivery	Cost	Average Weight
Capacity	0.4291	0.5714	0.2660	0.30	0.3917
Quality	0.2145	0.2857	0.5333	0.40	0.3583
On-time delivery	0.2145	0.0714	0.1333	0.20	0.1548
Cost	0.1430	0.0714	0.0666	0.10	0.0950

shows the calculation of average weights of the criterion under consideration.

Calculation of weights of the suppliers

The pair-wise comparison of the five suppliers with respect to capacity results in the calculation of average weights of the suppliers as given in the Table 7. In a similar way, the pair-wise comparison of the five suppliers with respect to on-time delivery, quality, and cost results, respectively, in the calculation of average weights of the suppliers, are given in tables 8, 9, and 10. Table 11 shows the average values of the weights or relative scores for each criterion against the five suppliers.

Table 7. Average Weights of Suppliers with Respect to Capacity

Supplier	S1	S2	S3	S4	S5	Average weight
S1	0.2699	0.2301	0.3831	0.32	0.315	0.303
S2	0.5338	0.4602	0.3831	0.4	0.3684	0.4291
S3	0.088	0.1518	0.1277	0.16	0.1578	0.137
S4	0.0667	0.092	0.0638	0.08	0.1052	0.0815
S5	0.044	0.0657	0.0425	0.04	0.052	0.0489

Table 8. Average Weights of Suppliers with Respect to on-time Delivery

Supplier	S1	S2	S3	S4	S5	Average weight
S1	0.1696	0.2087	0.2461	0.1468	0.35	0.2242
S2	0.048	0.1043	0.2461	0.0978	0.15	0.1366
S3	0.0424	0.026	0.0615	0.0838	0.1	0.0627
S4	0.6787	0.626	0.4307	0.5874	0.35	0.5345
S5	0.0242	0.0344	0.0153	0.0838	0.05	0.0415

Table 9. Average Weights of Suppliers with Respect to Quality

Supplier	S1	S2	S3	S4	S5	Average weight
S1	0.1071	0.0638	0.0869	0.0661	0.1875	0.1022
S2	0.2143	0.1277	0.1739	0.0529	0.1875	0.1512
S3	0.2143	0.1277	0.1739	0.0873	0.25	0.1706
S4	0.4287	0.6385	0.5217	0.2645	0.3125	0.433
S5	0.0353	0.0421	0.0434	0.0529	0.0625	0.0472

Table 10. Average Weights of Suppliers with Respect to Cost

Supplier	S1	S2	S3	S4	S5	Average weight
S1	0.0956	0.2083	0.2069	0.0551	0.1112	0.1354
S2	0.0191	0.0416	0.017	0.0314	0.0695	0.0357
S3	0.0239	0.125	0.0515	0.0314	0.0794	0.0622
S4	0.3827	0.2916	0.3621	0.2204	0.1835	0.288
S5	0.4784	0.333	0.3621	0.6614	0.5562	0.4782

Table 11. Average Weights for Each Criterion against the Five Suppliers

	S1	S2	S3	S4	S5
Capacity (0.3917)	0.303	0.4291	0.137	0.815	0.0489
On time delivery (0.1548)	0.2242	0.1366	0.0627	0.5345	0.0415
Quality (0.3583)	0.1022	0.1512	0.1706	0.433	0.0472
Cost (0.095)	0.1354	0.0357	0.0622	0.288	0.4782

Table 12. Overall Score (Rating) of Each Supplier

Supplier	Calculation	Rating
S1	0.303(0.3917) + 0.2242(0.1548) + 0.1022(0.3583) + 0.1354(0.095)	0.208
S2	0.4291 (0.3917) + 0.1366 (0.1548) + 0.1512 (0.3583) + 0.0357(0.095)	0.249
S3	0.137 (0.3917) + 0.0627 (0.1548) + 0.1706 (0.3583) + 0.0622 (0.095)	0.130
S4	0.815 (0.3917) + 0.5345 (0.1548) + 0.433 (0.3583) + 0.288 (0.095)	0.300
S5	0.0489 (0.3917) + 0.0415 (0.1548) + 0.0472 (0.3583) + 0.4782(0.095)	0.090

Calculation of overall scores of suppliers

The calculation of the overall score (rating) of each supplier is done using the results obtained in the Table 11 and shown in Table 12. As the rating of the vendor or supplier S4 is greater than those of other suppliers, we choose S4 as the optimum supplier.

Results and Discussion

The Linear Programming model as defined in Section 2 is derived by using the information given in Section 3, Table 2, and Table 12. The LP model is then solved by using Microsoft Excel Solver Expert choice11 software. The optimum order quantities to be placed to the five suppliers as observed from the results of the software are given by:

X1 = 0 ; X2 = 107 blades ; X3 = 0 ;

X4 = 150 blades ; X5 = 43 blades.

The total cost per year of the existing system

= 262 X 23,572 + 28 X 18,950 + 10 X 17,850 = **Rs 68,84,964**

The total cost per year of the proposed system, that is, by the above optimal solution

= 107 X 23,572 + 150 X 18,950 + 43 X 17,850

= Rs 61, 32,254

The net savings per year **= 68,84,964 – 61,32,254**

= Rs 7,52,710

From these results it is observed that the best supplier, S4, is placed with highest order quantity of the blades. It is also found that the scientific application of AHP integral with LP modelling to the problem of vendor selection will help MMSM in a decrease of about 11% in the total cost.

Sensitivity Analysis

The aim of sensitivity analysis is to identify the impact of changes in the priority of criteria on the supplier's performance and order quantities. In the present case it is necessary to investigate how sensitive the optimal solution of the LP model is to changes in the cost priority. The sequence of changes in this problem is different from the sequence of changes in general sensitivity analysis because the variations of cost priority affect the supplier's ratings, which are the coefficients of the objective function of LP model and they can have an influence on order quantities.

In order to do the sensitivity analysis, parametric linear programming has been applied (Hillier et al., 2007, p. 312). Then the Gradient analysis of Expert choice represents the variation of suppliers' rating to changes in cost priority. It is found from the results that the order quantities are not sensitive to the weighing of cost in the interval 0 to 0.315, and the optimum order quantities remain at 0, 107, 0, 150, and 43 blades.

Now considering the sensitivity of order quantities to the buyer maximum acceptable defect rate (Q) change from 0.02 to 0.01, there is a change in the values of order quantities. In case of Q = 0.01 and D = 300, the optimum order quantities change to 0, 0, 0, 100, and 0. In this case, the suppliers can satisfy the quality constraint, but the demand remains unsatisfied. In these circumstances the buyer should purchase all the capacity of the maximum score supplier and then the next in line until the demand becomes satisfied.

Conclusions

In this article a dynamic model is suggested to establish good linkage between supplier selection and buyer company's policy for the case of MMSM. It is found by AHP that the supplier S4 is the optimum supplier for MMSM under consideration. The optimum solution of the LP model shows that there will be a decrease of about 11% in the total cost which will help MMSM in a net savings of about Rs 7,52,710 per year. This model also enables the management to make a trade-off between several tangible and intangible factors with different priorities. The sensitivity analysis shows the affect of change in the priority of criteria on the optimum solution. The results obtained in this article thus helps in improving the decision-making ability of managers and the operating personnel.

References

Bross, M. E. and G. Zhao (2004), *Supplier selection process in emerging markets - The Case Study of Volvo Bus Corporation in China*, M.Sc. thesis, School of Economics and Commercial Law, Göteborg University.

Chakraborty, T., T. Ghosh, and P. K. Dan (2011), "Application of analytic hierarchy process and heuristic algorithm in solving vendor selection problem," *Business Intelligence Journal*, 4(1): 167–77.

Chan, F. T. S. and N. Kumar (2007), "Global supplier development considering risk factors using fuzzy extended AHP-based approach," *Omega*, 35(4): 417–31.

Chen-Tung, C. and Ching-Torng, L. (2006), "A fuzzy approach for supplier evaluation and selection in supply chain management," *Production Economics*, 102: 289–301.

Gencer, C. and D. Gürpinar (2007), "Analytic network process in supplier selection: A case study in an electronic firm," *Applied Mathematical Modelling*, 31(11): 2475–486.

Ghodsypour, S. H. and C. O'*Brien* (1998), "A decision support system for supplier selection using an integrated analytical hierarchy process and linear programming, *International Journal of Production Economics*, 56–57, 199–212.

Hillier, S. and G. J. Lieberman (2001), *Introduction to operations research* (Seventh Edition). New Delhi: Tata McGraw-Hill Publishing Company Limited.

Kokangul, A. and Z. Susuz (2009), "Integrated analytical hierarch process and mathematical programming to supplier selection problem with quantity discount," *Applied Mathematical Modelling*, 33(3): 1417–429.

Liao, C. N. and H. P. Kao (2010), "Supplier selection model using Taguchi loss function, analytical hierarchy process and multichoice goal programming," *Computers and Industrial Engineering*, 58(4): 571–77.

Liu, F. H. F. and H. L. Hai (2005), "The voting analytic hierarchy process method for selecting supplier," *International Journal of Production Economics*, 97(3): 308–17.

Maggie C. Y. T. and V. M. R. Tummala (2001), "An application of the AHP in vendor selection of a telecommunications system," *Omega*, 29:171–82.

Motwani, J. and M. Youssef (1999), "Supplier selection in developing countries: A model development," *Emerald*, 10(13):154–62.

Saaty, T. L. (1980), *The Analytic Hierarchy Process.* New York: McGraw-Hill.

Xia, W. and Z. Wu (2007), "Supplier selection with multiple criteria in volume discount environments," *Omega*, 35(5): 494–504.

"Stressing output is the key to improving productivity, while looking to increase activity can result in just the opposite."

— Paul Gauguin

Feature

Customer Preferences: A Pilot Study on Organized Retail Industry

SUNITA MALL AND TUSHAR RANJAN PANIGRAHI

The Indian retail sector is witnessing unparallel growth. Unmatched demographics, rising income levels, shifting lifestyles, and changing aspiration of the middle class has developed a retail revolution in the country. Fresh retail geographies are emerging, innovative formats are being introduced, and retailers are tapping new customer segments with prolific product offerings. India has witnessed a boom in organized retail trade in the last five years. More and more players are coming into the retail business in India to introduce new formats like malls, supermarkets, discount stores, and departmental stores. The consumer preference toward these retail stores depends on the service quality provided by the retailers.

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Organized retail business in India is developing at a rapid pace. The retail format that has shown maximum growth among all is the multipurpose shopping complexes or shopping malls. The malls are being positioned as a one-stop entertainment destination for a family, where they cannot only do their shopping, but also watch movies and then eat at the restaurants and food courts inside the mall. India has witnessed a boom in organized retail trade in the last five years. More and more players are coming into the retail business in India to introduce new formats like malls, supermarkets, discount stores, departmental stores, etc. Customers differ from each other with respect to both earnings and consuming units. When there is the question of consumption, the consumer preference toward quality products or services starts. Service quality has become a critical competitive consideration. This pilot study is an attempt to study the buyer's behavior and perception about organized retail with reference to Bhubaneswar city.

Relevance of the Study

A customer usually purchases a wide variety of goods and services during the year. The satisfaction varies from customer to customer with respect to different goods and services. Moreover, this satisfaction ultimately helps the customer to choose the favorite retail store.

The purpose of this research is to determine the influencing factors of service quality in the selection of organized retail stores.

Research Problem

The study is conducted to know how age, educational qualification, and income influence the consumer preferences. How do demographic features affect the consumer preferences about retail service quality in the organized retail store?

Objective

The main objective of this survey is:

(1) to study the customer preferences toward retail service quality;

(2) to study how the demographic parameters affect the retail service quality in an organized retail store.

Research Methodology

The present study is based on the preference of the customer for organized retail industry. For this survey, Bhubaneswar, the capital of the state of Odisha, is taken. Though the universe for this survey is very large, five groups have been made with respect to their consumption habits for the convenience of the research work. These groups are: (1) students, (2) professionals, (3) teachers, (4) service people, (5) others. Total 100 respondents have been selected on a random basis for the study and 20 respondents for each group. Primary data was collected for the survey. However, a structured questionnaire was prepared for the survey.

Demographic Profile

To study how the demographic parameters, say, age, education, and income affect the retail service quality in the organized retail store, consumers' preferences are analyzed.

Influence of Age

Age is one of the major factors in defining the customers' preference toward organized retail sector. Table A1 depicts the age distribution of the respondents. For the present study, five different age groups are taken. They are: below 20, 20–30, 30–40, 40–50, and 50 above.

It is clear from Table A1 that the maximum percent (47%) of the respondents fall in the 20–30 age group and 35% fall in the 30–40 age group. Similarly, 7% fall in 40–50, 6% in above 50, and 5% in below-20 age group. Refer to Table A1 (Annexure).

Table A1. Influence of Age Distribution

No.	Age in Years	Percentage
1	Below 20	5
2	20–30	47
3	30–40	35
4	40–50	7
5	Above 50	6
	Total	100

Influence of Income Distribution

The income level plays a very vital role in defining the financial decisions of the respondents or customers. Table A2 depicts the customers' preference toward organized retail sector and influence of income on customers' preference. The income status of the respondents is categorized as <10,000; 10,000–20,000; 20,000–30,000; and >30,000.

It is seen in Table A2 that 37% respondents fall in 5,000–10,000 income group, 25% in 10,000–15,000, 13% in below 5,000, 16% in above 20,000, and 9% in 15,000–20,000 income group. Refer Table A2 (Annexure).

Table A2. Influence of Income Distribution

No.	Income Distribution	Percentage
1	Below 5000	13
2	5000–10000	37
3	10000–15000	25
4	15000–20000	9
5	Above 20000	16
	Total	100

Analysis of Customers' Preference for Organized Retail Sector

To judge the reasons of customers' preference toward the organized retail sector, data is collected through the questionnaire from the respondents and the reasons are defined as per the responses given by the respondents. Six different factors are defined for this purpose. They are: Factor 1, say, service; Factor 2, say, price; Factor 3, say, in-store experience; Factor 4, say, look of the store; Factor 5, say, location; Factor 6, say, product quality.

Table A3 depicts that out of the total sample, 51% customers prefer organized retail sector due to quality products provided by the organized retail stores. Out of these, 22% customers prefer it due to services provided by them and subsequently, 13% due to in-store experience, 9% due to prices, 3% due to location, and 2% due to the look of the store. It is very clear that organized retail stores are highly preferred for product quality. Refer to Table A3 (Annexure).

Table A3. Analysis of Customer Preference for Organized Retail Sector

No.	Factor	Percentage
1	Service	22
2	Price	9
3	In-store Experience	13
4	Look of the Store	2
5	Location	3
6	Product Quality	51
	Total	100

Data Analysis

Preference and Education

The levels of education affect the perception or behavioral pattern of the customers. However, education can explore new vision, better understanding, and potential opportunities. This may reflect in the buying behavior of the customers. Consumers' preferences toward retail service quality factors are analyzed with respect to different education groups in Table A4. Refer to Table A4 (Annexure).

To test whether any significant relationship exists between the sample mean of preference toward organized retail sector and education of the respondents, let us take a hypothesis:

Table A4. Comparison between Preference and Education

No.	Attributes Defining Preference	UG		G		PG		P&T	
		No.	%	No.	%	No.	%	No.	%
1	Product Quality	1	25	6	50	18	43.9	25	58.14
2	Service	1	25	3	25	9	21.95	9	20.93
3	In-store Experience	2	50	2	16.67	9	21.95	6	13.95
4	Price	0	0	0	0	3	7.32	2	4.65
5	Location	0	0	0	0	1	2.44	1	2.33
6	Look of the Store	0	0	1	8.33	1	2.44	0	0
	Total	43	100	14	100	12	100	4	100

Ho: There would be no significant difference in sample mean of customers' preference and the educational qualification of the respondents.

To test the significant difference between sample mean of customers' preference and education, ANOVA is used. It is clear from Table A5 that the calculated value of *F* is 1.93, which is less than the table value of 3.10 at 5% level of significance. So the hypothesis may be accepted. Thus, it can be concluded that there is no significant difference between sample mean of perception and education of the respondents. Refer to Table A5 (Annexure).

Table A5. ANOVA Table for Preference and Education

Source of Variation	S.S	d.f	M.S	*F*-Ratio	*F* Calculated Value at 5%
Between Samples	193.34	4 – 1 = 3	198.34/3 = 66.113		
Within Samples	684.99	24 – 4 = 20	684.99/20 = 34.249	1.93	3.1

Preference and Age

Age is one of the prime factors that affect the perception or behavioral pattern of the customers. However, the choices, income and of course the lifestyles differ in different age groups. Consumer preferences toward retail service quality factors are analyzed with respect to different age groups in Table A6. Refer to Table A6 (Annexure).

Table A6. Comparison between Preference and Age

No.	Attributes Defining Preference	Below 20		20–30		30–40		40–50		50–60		Above 60	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	Product Quality	1	20	23	48.94	17	48.6	4	57.14	3	60	1	100
2	Service	1	20	12	25.53	7	20	0	0	1	20	0	0
3	In-store Experience	3	60	4	8.51	1	2.86	0	0	0	0	0	0
4	Price	0	0	7	14.89	8	22.9	3	42.86	1	20	0	0
5	Location	0	0	1	2.13	2	5.71	0	0	0	0	0	0
6	Look of the Store	0	0	0	0	0	0	0	0	0	0	0	0
	Total	5	100	47	100	35	100	7	100	5	100	1	100

To test whether any significant relationship exists between the sample mean of preference toward organized retail sector and age of the respondents, let us take a hypothesis:

Ho: There would be no significant difference in sample mean of customers' preference and the age of the respondents.

To test the significant difference between sample mean of customers' preference and education, ANOVA is used. Table A7 depicts that *F* ratio is significant at 5% level. Though the calculated value is more than the table value, the hypothesis is rejected. It can be concluded that there is significant difference in preference toward organized retail sector due to age groups. Refer to Table A7 (Annexure).

Table A7. ANOVA Table for Preference and Age

Source of Variation	S.S	d.f	M.S	*F*-Ratio	*F* Calculated Value at 5%
Between Samples	311.16	6 – 1 = 5	311.16/5 = 62.23	3.05	2.53
Within Samples	611.57	36 – 6 = 30	611.57/30 = 20.38		

Preference and Income

Customers differ from each other with respect to both earnings and consuming units. When there is the question of consumption, the consumer preference toward quality products or services starts. Moreover, purchasing power of the customer can directly affect the potential demand as well as preference of the product. Consumer preferences toward retail service quality factors are analyzed with respect to different income groups in Table A8. Refer to Table A8 (Annexure).

To test whether any significant relationship exists between the sample mean of preference toward organized retail sector and income of the respondents, let us take a hypothesis:

Ho: There would be no significant difference in sample mean of customers' preference and the income of the respondents.

To test the significant difference between sample mean of customers' preference and income, ANOVA is

Table A8: Comparison between Preference and Income

Attributes Defining Preference	Below 5000		5000–10000		10000–15000		15000–20000		Above 20000	
	No.	%	No.	%	No.	%	No.	%	No.	%
1 Product Quality	1	7.1	1	2.7	8	32	6	66.67	8	50
2 Service	2	15.38	3	8.11	3	12	1	11.11	4	25
3 In-store Experience	5	38.46	20	54.05	12	48	1	11.11	2	12.5
4 Price	0	0	0	0	1	4	1	11.11	2	12.5
5 Location	2	15.38	6	16.22	1	4	0	0	0	0
6 Look of the Store	3	23.08	7	18.92	0	0	0	0	0	0
Total	13	100	37	100	25	100	9	100	16	100

used. From the above table, it is clear that the calculated value of *F* ratio is 1.1147 which is less than the table value of 4.2 at 5% level of significance. So, the null hypothesis may be accepted. Thus, it can be concluded that there is no significant difference between the preference toward organized retail sector and income level of the respondents. Refer to Table A9 (Annexure).

Table A9. ANOVA Table for Preference and Income

Source of Variation	S.S	d.f	M.S	*F*-Ratio	*F* Calculated Value at 5%
Between Samples	83.35	5 – 1 = 4	83.35/4 = 20.8375	1.1147	4.2
Within Samples	467.32	30 – 5 = 25	467.32/35 = 18.6928		

Conclusions

India has witnessed a boom in organized retail trade in the last five years. More and more players are coming into the retail business in India to introduce new formats like malls, supermarkets, discount stores, and departmental stores. Organized retail business in India is developing at a rapid pace than never before. But still this sector has to focus more on certain issues like reasonable price, frequent discounts, etc., and better service should be provided. It is clearly proved from the survey that most of the people prefer organized retail due to its product quality, service provided, and of course due to the store-experience, that is, the ambiance. It is also seen that the youngsters basically prefer it due to in-store experience whereas others prefer due to product quality and service. Look of the store and location does not affect much the customers' preference. Lastly, income level does always affect the customer preference. However, retail sector is the industry of study and extension of these research findings to other industries is left to future researchers.

"The simple act of paying positive attention to people has a great deal to do with productivity."

— Tom Peters

Enabling Small and Medium Enterprises Target Globalization

D. NAGAYYA AND T. V. RAO

The MSME sector is undergoing metamorphosis in the era of globalization for over a decade and a half. Developments have taken place nationally and internationally, of relevance to SMEs. Globalization resulting in fierce competition in various product lines has forced the SME sector to adopt strategies in tune with the global trends. A number of programs of cluster-specific and firm-specific approaches are being pursued by all Indian organizations with a wide network of institutions associated with various functions supporting the SME sector at different levels. The article covers a few key approaches—(i) MSMED Act 2006; (ii) Policy of de-reservation, and facilitating greater equity participation including foreign direct investment (FDI); (iii) Cluster Development Approach (CDA); (iv) National Manufacturing Competitiveness Programme (NMCP) covering ten components; and (v) Suggestions. In an increasingly globalized competitive scenario, SMEs have to upgrade their capabilities by innovation and adoption of advanced technologies and modern management practices.

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The Micro, Small and Medium Enterprise (MSME) sector, also known as Small and Medium Enterprise (SME) sector, has a prominent role to play in ensuring that growth is inclusive and regionally balanced. In the context of liberalization from 1991, the sector has been integrating itself with globalization and global trends in a phased manner as part of the overall strategies adopted for industry and trade at the national level. It has been steadily reorienting itself to face the challenges posed by increased competition—domestically and internationally. The SMEs with their dynamism, flexibility, and innovative spirit will have to adapt themselves to the fast-changing needs of the market—driven economy, where the government acts as a facilitator and promoter, no longer as a regulator. The strategies evolved in recent years, from 2000 in particular, are to help the sector to become globally competitive and graduate from micro to small, small to medium, and from medium to large. Advanced manufacturing techniques and management practices can be sourced and adopted with greater ease. As participants in the global value chain, the SMEs can gain entry into larger avenues, expand their markets, find new niche markets for their products, and become prominent in the global arena with "Made in India" brand. Gainful participation in the global value chain can be used as a strategic measure for SME development. Despite competition from large enterprises, SMEs certainly have the potential to enter global value chains provided they adapt to the market shifts globally.

The MSME sector contributes 8% of the country's gross domestic product (GDP), 45% of the manufactured output, and 40% of the country's merchandise exports. The MSMEs provide employment to about 60 million persons through 26 million enterprises, as revealed by the Fourth All India Census on MSMEs covering registered and unregistered segments for the reference year 2006–07. As per the quick results of the Census released by Development Commissioner (MSME), registered MSMEs account for 1.55 million (5.95%), and unregistered 24.55 million (94.05%), totalling 26.1 million enterprises, as against the earlier projected figure of 13 million enterprises for 2006–07 based on the Third Census of Small Scale Industries.

For the first time, the present survey includes service enterprises, apart from manufacturing. Out of 26.1 million MSMEs in 2006–07, 28.6% fall in the category of manufacturing and the remaining 71.4% are service enterprises. In the registered enterprises category, the corresponding percentages are 66.7 and 33.3 and in the unregistered enterprises, services account for 74%, and manufacturing for 26%. Manufacturing enterprises are 7.46 million (1.04 million registered (13.9%) and 6.42 million unregistered (86.1%)); and service enterprises are 18.65 million (0.52 million registered (2.8%) and 18.13 million unregistered (97.2%)). Out of 1.04 million registered manufacturing enterprises, 94.2% are micro, 5.6% small, and 0.3% medium enterprises. Among 0.52 million registered service enterprises, 96.9% are micro, 3.1% small, and 0.1% medium enterprises. Unregistered units account for 50.3 million employment (84.5%), compared to 9.2 million for registered units (15.5%). Registered units, thus, account for nearly 6% of enterprises and 15.5% of employment in the MSME sector. Out of 1.55 million MSMEs registered, 95.1% are micro enterprises (1.48 million), followed by 4.7% small enterprises (73,581), and 0.2% medium enterprises (3,230) as per the current definitions. The corresponding percentage share of employment of the three segments out of total registered enterprises employment is 69.1, 24.0, and 6.9. Women-promoted enterprises are 1.92 million–0.22 million registered, and 1.70 million unregistered (13.9% of registered units, 7% of unregistered units, and 7.4% of all enterprises). Women-managed registered enterprises are 0.16 million (10.1% of registered enterprises).

In 2006–07, production of MSMEs is estimated at Rs 7,094 billion at current prices, fixed investment Rs 5,008 billion, employment 59.5 million, and exports Rs 1,825 billion (US$40.36 billion) at current prices. In relation to all India export figure of US$126.4 billion for 2006–07, MSME sector's contribution is 32%, and has grown at 18.9% over the previous year, compared to 22.6% for overall exports. The projected estimates for MSMEs for 2007–08 as released by Development Commissioner (MSME) are 27.3 million enterprises, Rs 5,582 billion fixed investment, Rs 7,908 billion production at current prices, 62.6 million employment, and Rs 2,020.2 billion exports at current prices (US$50.25 billion), which works out to 30.8% of the country's exports; and has grown at 24.5% over the previous year, compared to 29.0% for overall exports. The projected estimates for 2008–09 for MSMEs are 28.5 million enterprises, Rs 6,218 billion fixed investment, Rs 8,808 billion production at current prices, and 65.94 million employment.

The projected estimates for 2009–10 for MSMEs are 29.81 million enterprises, Rs 6,938 billion fixed investment, Rs 9,829 billion production at current prices, and 69.54 million employment. From 2006–07, data relating to medium enterprises are included in the revised estimates. For earlier years, data cover only micro and small enterprises.

In the context of enhancing competitiveness of MSME sector, it is important to recall the landmarks/recent developments which have resulted in increased fierce competition globally, and even in the domestic market.

July 1991	Announcement of liberalization policy in industry and trade sectors.
January 1995	World Trade Organization (WTO) becomes operational on January 1, 1995 for administering rule-based international trade of goods and services across member countries which number 153 by early 2010. India has been a founding member of General Agreement on Tariffs and Trade (GATT) and WTO.
April 2001	Virtual dismantling of all the quantitative restrictions (QRs) by India permitting liberal import of goods from other countries.
January 2005	In the WTO framework, Agreement on Textiles and Clothing (ATC) was in operation for a period of 10 years (January 1995–December 2004). With the expiry of the Agreement on January 1, 2005, developed countries—USA, European Union (EU), and Japan—have removed QRs regarding import of textiles and clothing from developing nations including India. However, in respect of China, EU removed the restrictions on January 1, 2008 and

USA on January 1, 2009. Many developing countries which have heavily relied on markets of these three main regions could freely trade their textiles and clothing in these countries in the quota-free regime. Indian experience in international trade reveals that developed countries are continuing protectionist tendencies by replacing QRs in many cases through non-tariff barriers (NTBs), so as to restrict the inflow of imports. In addition, Regional Trade Agreements (RTAs)/Preferential Trade Agreements (PTAs) of developed countries have facilitated some countries in getting preference for sale of goods in these markets. India is not included in these agreements. India is trying to promote RTAs/PTAs/ Comprehensive Economic Cooperation and Partnership Agreements (CECPAs) on its own in recent years to diversify its markets to developing countries in Asia, Middle East, Africa, and Latin America by reducing its heavy reliance on developed countries. China becoming a member of WTO and its high degree of export intensiveness have intensified competition among developing countries. The China factor is, thus, referred to as an important aspect of international trade.

August 2007 — Global financial crisis, particularly in the USA, EU, and Japan.

September 2008 — Global meltdown spreading to developing countries, with the collapse of the Lehman Brothers in the US.

October 2009 — Starting of slow recovery in the Indian real sector through better performance of industry and agriculture.

January 2010 — Prime Minister's Task Force on MSMEs submits its report to the Prime Minister. Vigorous action steps are being taken thereafter on various areas for overcoming the problems faced by the MSME sector. Apart from the general decline in industrial production during the period of recession from September 2008 in the country, labor-intensive export-oriented small enterprises have been adversely affected to a greater degree. These include industries such as textiles, readymade garments, gems and jewellery, leather, handicrafts, handlooms, silk carpets, marine products, toys, and sports goods. Export-oriented industrial enterprises have been hit hard in a number of directions such as fierce global competition because of relatively low competitiveness of some of the Indian products, and rupee appreciation apart from recession in developed countries.

Micro, Small and Medium Enterprises Development Act 2006

The MSMED Act has become operational from October 2006. Being a comprehensive legislation for the promotion, development, and enhancement of competitiveness of the MSME sector, a number of measures were provided for in the act for enhancing competitiveness of SMEs and for enabling the enterprises to avail of the benefits of global markets.

Under the act, the enterprises have been categorized into those engaged in *(i)* manufacturing and *(ii)* providing/ rendering of services. Both categories have been further divided into micro, small and medium enterprises, based on their investment in plant and machinery (for manufacturing) or in equipment (in case of service enterprises) as shown in Table 1.

Table 1. Classification of SMEs by Investment Limit

(in Rs million)

Category of Enterprise (in plant & machinery)	Manufacturing Service (in equipment)
Micro	up to 2.5 up to 1.0
Small	>2.5 and up to 50 >1 and up to 2
Medium	>50 and up to 100 >20 and up to 50

The act provides for a statutory consultative mechanism at the national level with wide representation of all stakeholders, and an advisory committee to assist the National Board and the Centre and State governments. The other features include: *(i)* establishment of specific funds for the promotion, development, and enhancement of competitiveness of these enterprises; *(ii)* notifications of schemes/programmes for this purpose; *(iii)* progressive credit policies and practices; *(iv)* preference for government procurement to products and services of micro and small enterprises; *(v)* problem of delayed payments to MSEs; and also *(vi)* simplification of the process of closure of business by all the three categories of enterprises.

De-reservation of Products for Manufacture in Micro and Small Enterprise Sector, and Facilitating Greater Equity Participation Including Foreign Direct Investment

The policy of reservation of products for exclusive manufacture in the MSE (earlier SSI) sector was started in 1967. The objective of reservation was to protect the interests of the SSI sector. However, with the gradual opening up of the economy and policy of reservation, there has been progressive de-reservation of a number of items reserved for exclusive manufacture by the MSE sector. The objective of progressive de-reservation was to provide for opportunities for technological upgradation, promotion of exports, and economies of scale, in order to encourage modernization, and enhance the competitiveness of MSEs in view of the liberalization and globalization of the economy. After due consultation with the stakeholders, the Advisory Committee of the Ministry of MSME, de-reserved a number of items from the reserved list. The recent ones are 125 items in March 2007, 79 in February 2008, and 14 in October 2008. The total number of items continuing in the reserved list by March 2009 stood at 21. In September 2009, the remaining 21 items were also notified as de-reserved, with the condition that medium and large units entering these items with or without foreign direct investment (FDI) should commit for exporting 50% of their production within a maximum period of three years. They should obtain an industrial license. If the FDI is more than 24%, big players had to obtain prior approval of Foreign Investment Promotion Board. The 2009 September press release removed this process of obtaining permission if the FDI in equity is above 24%, and permitted FDI or participation by other businesses in MSMEs without a ceiling. This enabled MSMEs to attract FDI or investment from other companies to a greater extent. Other developments which enabled MSMEs to attract FDI or investment from other companies to a greater equity are passing of two acts, Limited Liability Partnership Act, and single person promoted companies under the Companies Act. De-reservation has, thus, led to availing the benefits of economies of scale by bigger units by using advanced technologies.

Cluster Development Approach

For over a decade, cluster approach is being implemented as a potent tool for achieving the overall development of clusters or groups of small and medium enterprises, covering artisan and microenterprises as well. Various ministries and departments of the Centre are adopting the cluster approach as a pivotal strategy for enhancing productivity and competitiveness as well as capacity building of SMEs in the country. The primary characteristic of the cluster-based approach consists in nurturing the value chain through a range of carefully crafted demand-side and supply-side policy interventions. Key benefits of a cluster-based approach to developing the SMEs are as follows: *(i)* networking among enterprises, *(ii)* strengthening of the human capital, *(iii)* technology and skill upgradation, *(iv)* lowered costs, *(v)* improved bargaining power, *(vi)* global visibility, *(vii)* easier access to finance, *(viii)* greater government support, and *(ix)* external players within the value chain.

Under the scheme of cluster development, the benefit of a whole variety of interventions, ranging from exposure to skill development, from credit to marketing, and from technological improvements to better designs and products is given to concentrations of enterprises in a contiguous belt. With the government funding and participation of cluster actors, developmental interventions are carried out for a period of three to five years to enhance the competitiveness and collective efficiency of the clusters, and to integrate them with the global economy, and global supply chain in addition to addressing the need for enhancing domestic marketing.

The Micro and Small Enterprises Cluster Development Programme (MSE-CDP) was reviewed in 2006–07 to accelerate holistic development of clusters, including provision of common facility centers, developed sites for new enterprises, upgradation of existing industrial infrastructure, and provision of exhibition grounds/halls, and also for creation and management of infrastructure-related assets in public–private partnership mode. The ceiling on project outlay for infrastructure development has been raised to Rs 10 crore per cluster. From October 2007, scope of the scheme has been enlarged to include provisions for development/upgradation of physical infrastructure also. Modifications made to the scheme are as follows: *(i)* The scheme of "Integrated Infrastructure

Development Centres" has been subsumed under the cluster development program, with all its existing features and funding pattern. Assistance under the scheme will also be available for setting up new clusters/industrial estates, and for improving infrastructure in the existing industrial estates; *(ii)* Assistance under the scheme shall be available for clusters developed exclusively for MSEs operated, and/or owned by women; and *(iii)* Assistance shall be available to associations of women entrepreneurs for establishing exhibition centers at central places for display and sale of products of women-owned MSEs. The guidelines of the MSE-CDP were revised in February 2010 with enhanced funding and simplification of procedures. In the recent years, the cluster approach has been made an integral part of most of the schemes being implemented by the Ministry of MSME, covering all the components of the NMCP. Provisions under different phases of MSE-CDP are briefly recalled here.

Under MSE-CDP, financial assistance is provided as grant-in-aid by Government of India (GoI), Ministry of MSME, and administered by Office of Development Commissioner (MSME), and its field offices for five identified phases of the cluster development program: *(i)* For preparing diagnostic study report (DSR) for a cluster of MSEs, GoI grant per cluster is a maximum of Rs 2.5 lakh; *(ii)* For soft interventions like awareness generation, capacity building, exposure visits, technology upgradation, market development, brand equity, trust building, business development, etc., GoI grant is 75% of the sanctioned amount of the maximum project cost of Rs 25 lakh per cluster [90% for north eastern and hill states, clusters with more than 50% *(a)* micro/village, *(b)* women-owned, and *(c)* SC/ST enterprises]; *(iii)* For preparation of detailed project report (DPR), GoI grant is up to Rs 5 lakh per cluster; *(iv)* For hard interventions such as setting up of Common Facility Centre (CFC), GoI grant is 70% of the cost of the project of maximum of Rs 15 crore [90% for NE & Hill states, clusters with more than 50% *(a)* micro/village, *(b)* women-owned, and *(c)* SC/ST enterprises]. Hard interventions include creation of tangible assets like testing facility, design center, production center, effluent treatment plant, training center, R&D center, raw material bank/sales depot, product display center, information center, and any other need based facility; *(v)* For infrastructure development in a cluster, GoI grant is 60% of the cost of the project of a maximum of Rs 10 crore, excluding the cost of land [80% for north eastern and hill states, industrial estates/areas with more than 50% *(a)* micro, *(b)* women owned, and *(c)* SC/ST enterprises]. For existing clusters, upgradation proposals will be based on actual requirement. The State/UT Governments will provide suitable land for the projects. In the estimated cost to set up an infrastructure development project (excluding cost of land), GoI provides grant-in-aid. The remaining amount may be obtained as loan from SIDBI/ banks/financial institutions or equity from State/UT Government. The State/UT Government will meet the cost in excess of Rs 10 crore or any escalation in cost. Office of the Development Commissioner (MSME) with the approval of the Steering Committee, may appoint Competent Programme Management Service Providers (PMSPs) for facilitating formation of various proposals and their implementation. In the present scenario of knowledge-based economy, formation of consortia, self-help groups, dynamic associations may yield benefits for pursuing issue-based strategic interventions in industrial clusters. A critical mass of MSEs can join hands under the umbrella of a formal entity called cluster led by a group of beneficiaries (Special Purpose Vehicle [SPV]). Confidence building and trust building are two main pillars of building up cluster development initiatives. Guidelines under MSE-CDP are published in Laghu Udyog Samachar (LUS), November 2010, pp. 3–22.

Dimensions of Manufacturing Competitiveness

The MSE-CDP was the major initiative geared to enhancement of collective efficiency of firms and for promoting collaborative efforts among firms located in the vicinity. The rationale is that the thinning of promotional initiatives among a large number of individual firms would imply a significant erosion of the intended benefits. A decade of experimentation in the collective efficiency models indicates this. While these models have contributed to enhancement of overall productivity of firms under clusters, manufacturing capabilities of the country have suffered. It was in this context that the NMCP was launched in 2005. The NMCP mainly deals with firm-level competitiveness. The broad elements of manufacturing competitiveness policy are: *(i)* technology and innovation enhancement, *(ii)* protection of intellectual property rights (IPRs), and *(iii)* entrepreneurship policy.

The National Manufacturing Competitiveness Council (NMCC) was set up in 2004, as an interdisciplinary and autonomous body to energize and sustain the growth of the manufacturing industry. Broadly, the objectives of the council are: identification of manufacturing sectors having globally competitive potential, as also their problems and constraints with respect to structure and size, technology gaps, modernization needs, etc., and evolving sector-specific strategies for enhancing the competitiveness of manufacturing sectors. Its functions would, inter alia, include: sectoral and enterprise-level initiatives, innovation and technology development (R&D), entrepreneurship promotion, infrastructure and enabling facilities, trade and fiscal policies and employment generation. The NMCC has helped a number of enterprises in sunrise sectors such as food processing, textiles and garments, pharmaceuticals, leather, and information technology (IT) in increasing their capabilities for global competitiveness, minimizing technological gaps, providing infrastructure and enabling facilities, and supporting with trade and fiscal policies.

Globalization of businesses has increasingly drawn SMEs into global value chains through different types of activities. The networking of globalization has been developed in recent years through joint efforts in selling, buying, technological development, quality standards, learning networks, and market research. Many SMEs are trained to establish collaborative linkages with global suppliers in which the role of the government is important in promoting the network. The Micro, Small and Medium Enterprises Development Act, 2006, has been designed to solve the constraints and problems faced by SMEs, and enable the enterprises to avail of greater market opportunities arising from globalization in the World Trade Organization (WTO) administered foreign trade.

The NMCP, started in 2005, covers 10 components for the SME sector. The coverage and main aspects of these components are explained in this section. Guidelines for implementing each of the components of NMCP are periodically published in the LUS by development commissioner (MSME). The relevant issues of LUS in which guidelines for each of the schemes have been published are indicated at appropriate places in subsequent paragraphs. Some of them have also been released as booklets. Website www.dcmsme.gov.in/schemes of development commissioner (MSME) furnishes provisions of various schemes of the Ministry of MSME.

Marketing Support and Assistance to MSMEs through Bar Coding

Bar coding is a series of parallel vertical lines (bars and spaces), that can be read by bar code scanners. It is used worldwide as part of product packages, as price tags, carton labels, and even on credit card bills. When it is read by scanners, the restored information on product profile and its other attributes is made available to the consumer, and this facilitates better marketing of products. Bar coding is a unique, universal, and international concept which can be recognized anywhere in the world. Bar coding is essential in many ways, inter alia, to eliminate delays and inaccuracies inherent in manual checking/identification of each category of goods indicating price and other essential details, maintaining simultaneous inventory entries, management and control, ordering timely replacements, rapid issuing printed memos, receipts after accounting, etc. Bar coding has become a prerequisite for all suppliers and buyers in today's digitalized market, and Indian MSEs will have opportunities to grow by adopting it. Bar coding enables higher price realization at the exporter's end, instead of at the buyer's end; and helps promote Indian value added products globally. Using international digitalized numbering standards represents a small but significant step in accessing global and ever growing domestic markets (LUS, February 2010, pp. 12–13).

Bar coding is an important marketing tool having wide global acceptability. In order to encourage units in the sector to adopt bar coding, a provision for reimbursement of 75% of one-time registration fee from January 2002, and annual fees for the first three years from June 2007 paid to Global Standard One (GS1) India (formerly EAN India) (an autonomous body under the Ministry of Commerce and Industry) by MSEs for adoption of bar coding has been made under SSI–MDA (Market Development Assistance) Scheme. Besides, there is a provision for organizing a one-day sensitization awareness programs and preparation of publicity material for MSEs and other stakeholders concerned. Interested MSEs can approach GS1 India, 330, 2nd Floor, 'C' Wing, August Kranti Bhavan, Bhikaji Cama Place, New Delhi-110 066 (Phone: 011-2616 8720/721/725). The state-level Micro, Small and Medium Enterprise Development Institute may be contacted for claiming reimbursement. Application forms may be downloaded from the website www.dcmsme.gov.in.

Support for Entrepreneurial and Managerial Development of MSMEs through Incubators (Business Incubator)

The concept of business incubation is relatively new for MSMEs. The incubator scheme makes available a new window for supporting and nurturing business based on new ideas. The idea is to promote development of knowledge-based technological innovative ventures and to improve the competitiveness and survival strategies of

MSMEs. Incubation of ideas under the guidance of an incubator will facilitate sustainable development. Under the scheme, knowledge institutions like engineering colleges, research laboratories, and university science and technology departments are provided financial assistance up to Rs 6.25 lakh for incubating each of the new ideas. The incubator institution provides technology guidance, workshop and laboratory support, and linkages with other agencies for successful launching of the business, and guides the entrepreneurs in running the business for about 3 years. During the Eleventh Plan period, up to March 2012, provision of Rs 135 crore had been made by Government of India for incubating 2000 ideas (LUS, January 2011, pp. 23–27).

Under the scheme, 100 'Business Incubators (BIs)' are to be set up under Technology (Host) Institutions over a four-year period at 25 per year; and each BI is expected to help the incubation of about 10 new ideas or units. For this service, which includes the provision of laboratory/ workshop facilities and other assistance/guidance to young innovators, each BI will be given between Rs 4 lakh and Rs 8 lakh per idea/enterprise nurtured by them, limited to a total of Rs 62.5 lakh for 10 units. In addition, Rs 4 lakh will be provided for upgradation of infrastructure, orientation/ training, and administrative expenses, resulting in a total of Rs 66.5 lakh for promoting 10 enterprises.

Setting up of Mini Tool Room and Training Centres (Mini Tool Room)

Mini Tool Room and Training Centres will be promoted on Public–Private Partnership (PPP) model for providing technological support to MSMEs by creating capacities in the private sector for designing and manufacturing quality tools, and for providing training facilities in related areas. Total project cost for the scheme for the Eleventh Plan period is Rs 210 crore including Government of India's contribution of Rs 135 crore. Implementation is planned in three ways: *(i)* Private Partner (Centre PPP model), (ii) Special Purpose Vehicle set up by the states in partnership with private partners (State PPP model), (iii) State or State agency other than NGOs (Centre–State model). The objectives of Mini Tool Rooms are (LUS, December 2010, pp. 9–16):

1. to improve the competitiveness of the MSMEs engaged in manufacturing activity by creating capacities in the private sector for designing and manufacturing quality tools;
2. to bridge the gap betwēen demand and supply of trained manpower in the industry; and
3. to encourage R&D and optimization of cost and quality of delivery, leading to enhanced competitiveness of the manufacturing sector.

In model I (Centre PPP model), project to be set up and operated by a private partner, financial assistance will be given by GoI to meet the viability gap on a case-to-case basis, and it will be restricted to 40% of the project cost (not exceeding Rs 9 crore). In model II (State PPP model), project to be set up by State Government in cooperation with NGOs (SPVs), who will run the project on mutually agreed terms, financial assistance will be equal to 90% of the cost of machinery, restricted to Rs 9 crore. However, in order to retain a say in the management, at least 26% of the share should be with the State Government. This model can be considered if model I is not found to be feasible. In model III (Centre–State model), project to be set up and managed by State Government/ State Government Agency, financial assistance will be equal to 90% of the cost of machinery, restricted to Rs 9 crore. Financial assistance equal to 75% of the cost of machinery, restricted to Rs 7.5 crore can also be sanctioned for upgradation of an existing State tool room. This model could be resorted to only where both model I and model II are not found to be practicable. First preference will be to adopt model I. Others can be considered in the sequence stated above. Project sponsor's contribution should be at least 15% of the overall project cost.

Building Awareness on Intellectual Property Rights

The objective is to create and enhance awareness about Intellectual Property Rights (IPRs) among units in the sector so as to enable them to take appropriate measures for protecting their ideas and business strategies, and also avoiding infringement of the intellectual property (IP) belonging to others. Intellectual property refers to legal rights that result from intellectual activity in the industrial, scientific, literary, and artistic fields to preserve the innovations and R&D efforts of individuals and companies. It could be in the form of patents, trademarks, geographical indications, industrial designs, layout designs of integrated circuits, plant variety protection, and copyright. Utilization of IPR tools will enhance the competitiveness of MSMEs through technology upgradation. These initiatives are proposed to be developed through the PPP mode to encourage economically sustainable models for the overall development of MSMEs. The scheme provides for financial assistance for taking up the following identified initiatives on a cluster basis: *(i)* awareness/sensitization programs on IPRs, *(ii)* pilot studies in selected clusters/groups of industries, *(iii)* interactive seminars/workshops, *(iv)* specialized training, *(v)* assistance for grant of patent/GI registration, *(vi)* setting up of IP facilitation center, and *(vii)* interaction with international agencies (LUS, February 2011, pp.11–20).

Application of Lean Manufacturing Techniques

The focus is on helping MSMEs adopt lean manufacturing techniques (LEAN) so as to enhance their productivity, efficiency, and competitiveness by reducing or eliminating manufacturing waste, and streamlining the system through application of various lean manufacturing (LM) techniques, for example, 5S System, Visual Control, Standard Operating Procedures (SOPs), Just in Time (JIT), KANBAN System Cellular Layout, Value Stream Mapping, Poka Yoke or Mistake Proofing, Total Productive Maintenance (TPM), etc. Worker empowerment is also emphasized. Initially the scheme will be implemented in 100 mini clusters (each of a group of 10 enterprises) for one year at a total cost of Rs 30 crore. The scheme is in operation from July 2009. Later it will be extended to 300–500 clusters in a few years. Results will be in the form of improved process flows, reduced engineering time, proper personnel management, better space utilization, scientific inventory management, etc. These will improve the quality of products and reduce costs. The LM counselors appointed for a few clusters will identify and implement appropriate LM techniques. The effort will bring about improvement in the quality of products at lower costs, which will enhance the competitive ability of enterprises. The National Productivity Council, New Delhi, has been appointed the National Monitoring and Implementation Unit for the pilot project. The MSME-Development Institute at the state level has nominated the nodal officer for coordination with NPC at the local/field level. Awareness programs will be conducted in the clusters. Consultant's fee for each mini cluster up to 80% will be borne by Government of India, and 20% by the beneficiary enterprises (LUS, November 2009, pp.6–8).

Quality Management Standards and Quality Technology Tools

This was launched during 2008–09, with a budget provision of Rs 40 crore for four years. The scheme aims at improving the quality of the products in the MSME sector and inculcating quality consciousness among units of the sector. The major activities envisaged under the scheme are: *(i)* introduction of appropriate modules for technical institutions with a target coverage of 2000 technical institutions, *(ii)* organizing awareness campaigns every year for MSMEs, *(iii)* organizing competition-watch (c-watch) every year in the two sectors, *(iv)* implementation of Quality Management Standards (QMS) and Quality Technology Tools (QTT) in 100 selected micro and small enterprises every year, and *(v)* monitoring at least two international study missions per year. The focus is on sensitizing and encouraging MSMEs to adopt the latest QMS and QTT techniques so as to strengthen their operations, and to keep a watch on the sectoral developments in the country by undertaking defined activities (LUS, October 2009, pp. 16–19).

Energy Efficiency and Quality Certification Support (Energy)

The focus is on sensitizing enterprises and spreading an awareness about the need and benefits of adopting energy efficient technologies and using different quality certification measures for reducing emission of green house gases (GHGs), and improving the quality of products at reduced costs so as to improve the competitiveness of the enterprises in the global arena. The following initiatives are being pursued under this scheme: *(i)* Conducting awareness programs on energy efficient technologies, availability of energy efficient equipments, and benefits from energy efficient techniques and clean development mechanism (CDM); *(ii)* Supporting energy audits in sample units in clusters; and *(iii)* Promoting replication of model energy efficient technologies (EET) after preparing detailed project reports in the clusters, and implementation of the cluster plan; *(iv)* An innovative concept of cluster-based carbon credit aggregation centers (CCACs) has been planned under the scheme to initiate MSMEs to CDM benefits; (v) MSMEs are encouraged to acquire product certification/licenses from national/international bodies, and adopt other technologies mandated as per global standards (LUS, March 2011, pp. 16–25).

The activity will be implemented through SIDBI which will function as the implementing agency. Both technical and overall project appraisal by SIDBI/Bank will be taken into consideration prior to the sanction of assistance in the form of grants by the Ministry of MSME. About 390 units will be supported for implementing EETs in MSMEs in potential clusters under this activity. While 25% of the project cost will be provided as subsidy by Government of India, the balance amount is to be funded through loan from SIDBI/banks /financial institutions. The minimum contribution as required by the funding agency will have to be made by the MSME. Besides reducing energy cost, the activity will also enable the implementing enterprises in obtaining credits, which are tradable in the National and International Commodity Exchanges. Clusters for setting up the Carbon Credit Aggregation Centres (CCACs) for introducing and popularizing Clean Development Mechanism (CDM) will be identified on the basis of the CDM implementation potential in the cluster or applications received from the stakeholders.

Marketing Assistance and Technology Upgradation (Modern Marketing Techniques)

Competitiveness in marketing is sought to be improved through Marketing Assistance and Technology Upgradation Scheme, by using the latest techniques and technologies suitable for specific product groups on a cluster basis. The broad activities under the scheme include technology upgradation in packaging, development of modern marketing techniques, competition studies, state/district exhibition, corporate governance practices, marketing hubs, etc. Under the scheme introduced in 2010, 10 product groups have been identified for studies on packaging. Further, 140 units have been identified for participation in industry fairs and exhibitions (LUS. February 2011, pp. 7–10).

Promotion of Information and Communication Technology Tools

The scheme envisages that SME clusters, which have quality production and export potential, shall be identified, encouraged and assisted in adopting Information and Communication Technology Tools (ICT) applications to achieve competitiveness in the national and international markets. The activities planned under the scheme include identifying target clusters for ICT intervention, setting up of E-readiness infrastructure, developing web portals for clusters, skill development of MSME staff in ICT application, preparation of local software solution for MSMEs, construction of e-catalogue, e-commerce, etc., and networking MSME cluster portal on the national level portals in order to outreach MSMEs into global markets. The scheme launched in 2010 has been initially implemented in 100 clusters (LUS, February 2011, pp. 7–10).

To Bring Design Expertise through Design Clinics

The scheme brings design experts on a common platform to enable MSMEs to access expert advice and solutions for their real time design problems, resulting in continuous improvement and value addition to the existing products. It also aims at developing value added cost effective solutions. The scheme introduced in 2010 comprises of two major parts—design awareness, and design project funding. The design awareness stage comprises activities like seminars, workshops, diagnostic studies of clusters. In design project funding, projects of students, consultants/ designers, and consulting organizations are assisted by providing 60% of the project cost by way of government grant. The scheme has been initially implemented in 200 MSME clusters (LUS, February 2011, pp. 7–10).

Suggestions

SMEs in the competitive environment need to plan for globalization as part of their strategy to enhance competitiveness and not as a reaction to venture into new markets. Based on the experiences of recent years in the country and the recommendations of various studies, including the Prime Minister's Task Force on MSMEs, whose recommendations are currently being implemented, a few suggestions are made for improving the environment for SMEs in the globalization context.

1. **Promoting Entrepreneurship and Skill Development**: Private sector organizations and non-governmental organizations (NGOs) need to be involved to a greater degree with appropriate trainers' training programs to equip them to shoulder the responsibility on the PPP mode. The corporate sector may take the lead role in infusing enterprise education, skill upgradation, and management induction programs. Promoting synergy is necessary to achieve integration in order to attain the desired goals by involving public sector and private sector organizations. Encouragement should be given for private corporate sector to establish business incubation support network, as also institutional framework and policy framework for business turn around, for the benefit of SMEs.

2. **Upgradation of Clusters and Creation of Value Chain**: SMEs can achieve high level of competitiveness if they work in a cluster environment ensuring complementarities, common activities, and institutional stability. Collective innovations should flow from these efforts. Through strengthening of linkages and creation of value chain, clusters can

be upgraded. These can include linkages among firms, strengthening the local position within the value chains, building cluster-specific skill centers to develop cluster-specific labor force, strengthening the linkages with the local suppliers, and facilitating greater level of interactions among the stakeholders of clusters.

3. **Strengthening Sub-contracting Relationships within the Region/other Parts of the Country/ Other Countries**: Sustainability and growth of SMEs would largely depend on their capacity to become part of the strategies of larger firms in the national and global arena. This is particularly important for technology-oriented and export-oriented SMEs, which serve as sub-contractors for large enterprises in sectors such as IT, biotech, pharmaceuticals, light engineering, electronics, and automobile components. SMEs should be equipped to meet the global standards and delivery mechanisms.

4. **Focused R&D Institutions for SMEs**: There is need for focused institutions encouraging R&D activities in the SME sector in a coordinated manner. They may identify thrust areas for research, new areas for technology application, opportunities for commercialization of R&D, and hand-holding of SMEs in their R&D intensification. This can lead to higher level of technology intensive firms coming up in various product lines in thrust areas.

5. **Linking SME Strategy with Regional Trading Arrangements**: Linking the SME development strategy with regional trading arrangements would encourage learnings from regional and cross-continental peer groups. Multinational corporations (MNCs) may be encouraged to assist SMEs to upgrade them to meet quality standards that may be required by them. They should become SME-friendly by developing suitable tendering policies.

6. **Increasing SMEs' access to Finance**: The screening methodology of financing institutions needs to consider non-financial parameters and management competencies, while evaluating loan proposals of SME units. Export-Import Bank of India, Mumbai, in collaboration with International Trade Centre, Geneva, has implemented a unique enterprise management development services program, which is an IT-based tool, loan.com, to enable SMEs to prepare business plans with international market in focus. This is implemented as a pilot project for SMEs at present, and needs to be extended to more regions. The working group on credit flow to SMEs under the chairmanship of K.C. Chakrabarty and the Prime Minister's Task Force on SMEs have suggested a number of measures for sustained development of the SME sector. These included establishment of a few funds in the SME sector for specific purposes. Action is to be initiated on a priority basis to implement these recommendations.

7. **Proactive Role of Industry Associations/Cluster Associations**: It is suggested that the key associations at the state level/cluster associations at the cluster level should take the lead in implementing various programs in the interest of their members. Proactiveness from their side will enable institutions concerned to perform in an appropriate manner, review the performance of a program in various locations periodically, and bring out lessons for the future. Periodic monitoring and review of implementation of programs is to be pursued regularly. Interaction across states is also necessary.

References

Export-Import Bank of India (2009), *MSMEs and Globalization: Analysis of Institutional Support* Systems *in India and in Select Countries*. Mumbai, Occasional Paper No. 132 of the EXIMBank. Available online at www. eximbankindia.in

Government of India (2010), *Report of the Prime Minister's Task Force on Micro, Small and Medium Enterprises (MSMEs)*. New Delhi: Prime Minister's Office (Chairman of the Task Force: T.K.A. Nair)

Government of India, Ministry of MSME (2011), *Annual Report 2010-11*. New Delhi. Available online at www.msme.gov.in

.**Institute of Small Enterprises and Development (ISED)** (2010), *India Micro, Small and Medium* **Enterprises Report** *2010 (MSMER 2010)*, ISED, Kochi (Kerala). Available online at www.isedonline.org.

Laghu Udyog Samachar (LUS) (Monthly Journal), published by Development Commissioner (MSME), New Delhi, various Issues of 2009, 2010, and 2011. Available online at www.dcmsme.gov.in

ANNEXURE I:

Select Websites of National Organizations and Others of Relevance to MSME Organizations and MSMEs

1. Ministry of MSME, New Delhi – www.msme.gov.in
2. Development Commissioner (MSME), New Delhi – www.dcmsme.gov.in www.smallindustryindia.com
3. State level MSME Development Institute, e.g. for Hyderabad – www.msmehyd.ap.nic.in
4. National Small Industries Corporation (NSIC), New Delhi – www.nsic.co.in
   web portal for MSMEs - www.nsicindia.com
   International portal of NSIC - www.nsicpartneRs com
5. Small Industries Development Bank of India (SIDBI) – www.sidbi.com
   Web portal on information on technologies - www.techsmall.com.
6. National Bank for Agriculture and Rural Development (NABARD), Mumbai – www.nabard.org
7. Export-Import Bank of India, Mumbai - www.eximbankindia.in
8. Reserve Bank of India, Mumbai – www.rbi.org.in
9. Industrial Development bank of India, Mumbai – www.idbi.com
10. Department of Commerce, Ministry of Commerce and Industry, New Delhi – www.commerce.nic.in
    Special Economic Zones (SEZ): all India - www.sezindia.nic.in
11. Ministry of Textiles, New Delhi – www.texmin.gov.in
12. Ministry of Food Processing Industries, New Delhi - www.mofpi.nic.in
13. Commissioner of Industries, Andhra Pradesh, Hyderabad – www.apind.gov.in
    SEZs of Andhra Pradesh – www.apsez.com
14. Khadi and Village Industries Commission (KVIC), Mumbai – www.kvic.gov.in
15. National Institute for Micro, Small and Medium Enterprises (ni-msme), Hyderabad – www.nimsme.org
16. Entrepreneurship Development Institute of India (EDI), Gandhi Nagar (Gujarat)- www.ediindia.org
17. National Institute for Entrepreneurship and Small Business Development (NIESBUD), Noida (Uttar Pradesh) – www.niesbud.nic.in
18. Indian Institute for Entrepreneurship (IIE), Guwahati (Assam) - www.iie.gov.in
19. World Trade Organisation (WTO), Geneva – www.wto.org
20. Global Information Network for SMEs covers information on SMEs in various countries – www.gin.ne.ip

ANNEXURE II:

Web Portal of NSIC to Enhance the Reach of MSMEs in the Global Market

www.nsicindia.com has been developed by National Small Industries Corporation (NSIC) at its head quarters in New Delhi as a B2B web portal for the benefit of MSMEs in India and abroad. It provides an excellent opportunity for MSME fraternity to not only promote information exchange Pan-India but also enhance its reach to a large number of clients abroad, besides improving its service delivery. The Portal will also help MSMEs to enhance their inland and global trade through promotion of their products and services. The portal provides a number of helpful features such as product specific database searches, sector specific domestic and international tender notices with alert facility, business trade leads (buy/sell) from more than 200 countries, and opportunities to MSMEs to develop their products, and show case them through the portal, and reach out to the global markets. The portal helps MSMEs in expanding their trade opportunities Pan-India and in other countries. E-commerce is becoming a global trend, the advantages of which should be accessible to the smaller entities. The comprehensive portal comprises more than 2.5 lakh MSME contacts, and helps the enterprises in reaching out to the buyers in the world from their work place by using information and communication technology (ICT) tools.

ANNEXURE III:

NSIC Sets Up MSME Info-call Centre at New Delhi

The call center can be contacted on toll free number 1800-11-1955 which works from 8.00 hrs to 22:00 hrs every day. This center will help in providing the required information about the vendors and technology suppliers to the potential first generation entrepreneurs and existing small enterprises as and when required by them. Salient features of the information center are as follows: Customer care services and solutions including tele and internet marketing, and infomediary services. The center has the state of the art technology computers and dedicated call center equipment which are managed by NSIC trained staff conversant with call center operations and telemarketing applications. Some of the activities covered by the center are as follows:

- Tracking of all incoming and outgoing calls with date and time
- Recording the entire conversation
- Tele conferencing
- Responding to the queries through IVRS (interactive voice response system)
- e-news letters
- e-mail notifications for unattended calls
- voice mails which can be forwarded to mail boxes
- Report generation on the basis of different criteria such as pending queries, queries concerning relevant schemes, suggestions and complaints
- Remote monitoring
- Database integration

ANNEXURE IV:

Ministry of MSME sets up Udyami Helpline at New Delhi

The call center can be contacted on Toll Free number 1800-180-6763 which works from 6:00 hRs to 22:00 hRs , and responds in English and Hindi on all days of the year. The center guides MSMEs in providing the requisite information for existing and prospective entrepreneurs about opportunities and facilities available under various schemes of Government of India. The relevant websites are: www.msme.gov.in of the Ministry of MSME, and www.dcmsme.gov.in of Development Commissioner (MSME), New Delhi. Udyami Helpline provides assistance and guidance to entrepreneurs regarding marketing assistance, export promotion, credit support, cluster development, technology upgradation, skill development, process of setting up an enterprise, and details of various schemes of the Ministry of MSME.

CORRIGENDUM

'Productivity Improvement in an Engineering Firm Through Computer Applications' published in 'PRODUCTIVITY', Vol. 51, No. 4, (Jan.-March, 2011). First author of the article may be read as Satyajit Patil instead of S. N. Jalwadi and the co-author may be read as S. N. Jalwadi instead of Satyajit Patil.

"Productivity is never an accident. It is always the result of a commitment to excellence, intelligent planning and focused effort."

— Paul J. Meyer

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