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Editorial

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GLOGIFT – Global Conference on Flexible Systems Management

Global Conference on Flexible Systems Management acronymed as GLOGIFT has been institutionalized as an annual event

The giftjourn@l has been launched to contribute towards a resynthesis of the systems and management disciplines with the bottomline of "flexibility". In order to support this endeavour, another major activity is institutionalized by GIFT, that is Global Conference on Flexible Systems Management, acronymed as "GLOGIFT". This is an annual event to take place in various parts of the world, with a different theme which in contemporary and contributing towards the resynthesis of the knowledge as mentioned above.

GLOGIFT 2000 was organized with the theme "New Business Paradigm-Global, Virtual and Flexible" having representation, from 12 countries

The First Global Conference on Flexible Systems Management, GLOGIFT 2000, was organized with the theme "New Business Paradigm–Global, Virtual and Flexible" during December 17-20, 2000 at Hotel Le Meridien, New Delhi. A round up of the event is presented here for the benefit of those who could not participate in this inaugural event of the GLOGIFT series. The event received an enthusiastic response from all over the world representing contributions from 12 countries, viz. Australia, Austria, Bangladesh, Canada, China, France, Germany, India, Japan, Korea, Thailand and USA.

Nearly 250 professionals from academia, industry, and government participated in GLOGIFT 2000

Nearly 250 professionals from academia, industry and government participated in the Conference representing 50 academic institutions and 70 industrial and governmental organizations. The proceedings containing 90 full papers have been published by Thomson Learning, which is a rich volume containing reportings of researches and experiences consisting of more than 1100 pages.

Some of the authors have contributed excellent papers that have the potential to be developed and considered for publication in giftjourn@l. We are approaching the select authors with our feedback to enrich the papers and resubmit them in the format of giftjourn@l. It is hoped that a few of these contributions will appear in giftjourn@l after the regular review process is completed.

There were three tracks, viz. Strategy, Technology, and Operations and Organization

The New Business Paradigm was presented in the Conference from three major dimensions, i.e. Strategy, Technology, and Operations and Organizations. Accordingly, there were three tracks of presentations.

The various tracks and subparts that made the Technical Sessions of the Conference were:

Part A: Global Strategic Change and Flexibility

- Strategic Flexibility
- Emerging Strategic Thinking
- e-Business Strategy
- Global Competitiveness
- Strategic Alliances, Mergers and Acquisitions for Globalization
- Management of Innovation and Development

Part B: Technology Enabled Flexible/Virtual Business Models

- Technology Management Flexibility
- Technology Transfer
- Information System Flexibility and Management
- e-Business Models and Applications

- Supply Chain Management
- Knowledge Management

Part C: Operations and Organizational Flexibility

- Manufacturing Flexibility
- Flexibility in Quality Management
- Flexibility in Service Sector
- Flexibility in Business Operations
- Organization Learning and Flexibility
- Organizational Culture and Effectiveness

GLOGIFT 2001 will be organized by European School of Management, ESCP-EAP, Paris

The Second Global Conference on Flexible Systems Management–GLOGIFT 2001–will be organized by the European School of Management, Paris. The proposed theme of the Conference is "Perspective on International Technology and Know how Transfer : Towards a Flexible Enterprise". The Conference is scheduled during January 27-30, 2002. More details can be obtained either from Prof. Daniel Rouach, European School of Management, ESCP-EAP, Paris, email: drouach@eap.schamp.ccip.fr, or from the GIFT website www.giftsociety.org, email: glogift@giftsociety.org.

Proposals for GLOGIFT 2003 and 2004 are invited

The Third Global Conference on Flexible Systems Management–GLOGIFT 2002–is proposed to be hosted by NITIE, Mumbai, India. Proposals for GLOGIFT 2003 and GLOGIFT 2004 can be submitted to the President, GIFT online at president@giftsociety.org.

Select presentations from GLOGIFT series will be reviewed and regularly published in giftjourn@l

Select presentations from the GLOGIFT series will be reviewed and regularly published in giftjourn@l for the benefit of wider dissemination and meeting the objectives of the resynthesis in the form of "Flexible Systems Management". This will generate the synergy in these two major institutional channels of GIFT. Active participation of all members is solicited to contribute to this movement towards evolving and enriching this new paradigm of management.

Sushil
Editor-in-Chief

Empirical Study

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New Flexible Paradigms in Equity Valuation: Knowledge Based Enterprises

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Abstract

The relationship between flexibility and market valuations has recently started attracting attention. Information Technology (IT) industry, by definition, is one of the most flexible industries. The primary assets for this industry are re-deployable human capital and embedded knowledge. IT Industry participants are unhampered by large fixed investments in physical assets and rigid processes. The incremental value placed by the stock market investors on this flexibility is measured using Initial Public Offering returns. The results indicate that investors in information technology industry IPOs earn significant excess positive returns. These excess returns occur across the board and are robust to market capitalization and exchange listing choices

Keywords: excess returns, flexibility, information technology, initial public offerings

Introduction

This paper empirically examines the degree of premium placed by investors on enhanced flexibility. Initial public offerings (IPO) of corporate stock provide an interesting opportunity to observe the pattern of demand for the portfolio of assets being offered to the investors at large. Existing research appears to attribute any IPO price run up to a deliberate under pricing on the part of the issuers and/or underwriters. The role of interaction between supply and demand for the stock being issued seems to have been ignored. The current research focuses on the relative attractiveness of the asset portfolio being offered to the investors and the value placed by investors on this portfolio. Since the supply of stock is fixed and introduced instantaneously, unmet demand from willing buyers should result in a higher price being offered to the initial stockholders. This higher price should, in turn, generate secondary selling by buyers till a new market clearing price and volume of trading is reached. It follows that as the demand for an asset increases, its value and, therefore, the premium offered by interested buyers should also increase. Under these conditions, enhanced value should result from an increase in flexibility of the enterprise. This suggests that if some stocks offer a higher degree of flexibility to investors and if the investors value such higher flexibility, such stocks should exhibit significantly higher IPO returns as compared to other stocks.

During the recent stock market boom, market capitalization of information technology (IT) sector firms quickly surpassed conventional manufacturing industry firms. Standard & Poor's index of 100 largest firms today includes thirty firms that did not even exist ten years ago. Conventional equity valuation models that rely on balance sheet and income statement data fail to justify the lofty valuations assigned to companies bent on burning cash rather than making money. These valuations have been variously attributed to a wave of euphoria, irrational herd behaviour, or plain inability of conventional valuation models to deal with the high degree of uncertainty involved in a rapidly evolving industry. It has been suggested that the appropriate model for IT industry stock valuations is equity options rather than traditional discounted cash flow methods as the options valuation methods incorporate the inherent flexibility of enterprises.

Meteoric rise and spectacular crash of dot COM enterprises has also attracted a lot of investor and media attention. It has been suggested that IT firms can realign their resources efficiently in the short run, as they are not hampered by large capital investments in fixed assets and rigid processes. Assets specificity can exist in tangible as well as intangible assets. Prime asset in IT sector may be the embedded knowledge created in the firm. Anecdotal evidence suggests that IT firms organized in flexible teams that readily disseminate this knowledge (e.g. CISCO) have fared consistently better than firms where this embedded knowledge has been tightly controlled by a small group within the firm (e.g. Yahoo!). In spite of the dot com flameout IT firms have turned in a better performance than the market at large as measured by the NASDAQ composite index.

The Information Technology industry comprises of a number of subgroups. The recognized subgroups included in the NASDAQ index and their performance during the twelve months ending March 2001 are listed in Table 1.

Table 1 : Perofmance of Subgroups in NASDAQ Index

Composite Index NASDAQ		12-month returns ending March 2001 -56.45%	
IT industry sector	**SIC**	**12 month Returns Raw**	**Excess**
Computer Services	7374	-34.00%	22.45%
Computer Storage Devices	3564	-33.70%	22.75%
Computer Peripherals	3577	-32.90%	23.55%
Computer Networks	3576	-21.50%	34.95%
Communications Equipment	3661	-9.80%	46.65%
Software & Programming	7372	-3.30%	53.15%
Scientific & Technical Instruments	3829	7.50%	63.95%
Semiconductors	3674	107.40%	163.85%
Communications Services	4813	137.80%	194.25%
Computer Hardware	3571	143.10%	199.55%

It is interesting to see that the survivors in the recent stock market crash are the firms providing tools rather than single applications products in the IT marketplace. The returns have varied in the direct order of flexibility enjoyed by the firms.

A business firm can be defined as a portfolio of contracts, capabilities and assets. The composition of this portfolio determines the firm's degree of flexibility in operational, financial, technological and strategic decision- making. The relationship between flexibility and market valuations has recently started attracting attention. Tang and Tikoo (1999) explore the relationship between firms' stock returns and accounting earnings for different levels of operational flexibility. They define operational flexibility as a firm's ability to respond profitably to environmental fluctuations by shifting factors of production within a multinational network of subsidiaries. They find a significant positive impact on stock returns and accounting earnings for multinational firms that operate in many countries and limit their concentration in any one country. Anand and Singh (1997) analyze firms from a resource-base perspective and suggest that firms are bundles of assets, some of which are fungible in nature. They propose that firms should be able to re-deploy these fungible assets to enter new markets when their existing businesses decline. This ability to enter new businesses is a valuable asset and contributes to firm performance. Busby and Pitts (1995) suggest that investment decisions can be analyzed as options to adapt the operations of the firm to environmental changes. They propose that projects with flexibility are more appealing and that this flexibility is a valuable asset in itself. Gronhaug and Nordhaug (1992) propose that a firm's capacity to retain, develop, organize, and utilize its competencies determines its future success. They also suggest that the firms' competencies create valuable flexibility if these competencies can be extended to alternate business applications, and hence facilitate strategic change. An alternative explanation for the role of flexibility in enhancing value by increasing the demand for a risky but flexible asset has been offered by Gollier et al. (1997). They propose that willingness to accept risk rises as the flexibility of an investor's portfolio increases. Aivazian and Berkowitz (1998) show that production flexibility increases potential tax shields from debt and lowers expected bankruptcy costs. The results suggest that in industries where assets are easily re-deployable, the impact of taxes on both investment and financial leverage will be positive and increasing with the size of capacity adjustment.

If some stocks offer a higher degree of flexibility to investors and if the investors value such higher flexibility, such stocks should exhibit significantly higher IPO returns as compared to other stocks.

A sample of initial public offerings (IPOs) made from 1989 to 1998 was analyzed for realized excess returns. Factors influencing initial IPO pricing were identified and the impact of the IT industry's flexibility on investor returns was analyzed. Returns on IPOs have been studied extensively in finance literature. Excess IPO returns have been observed, measured, and attributed to information signaling, lawsuit avoidance, underwriter reputation, competition, and price stabilization behaviour. Prior research has concentrated on explaining the observed positive event day excess returns as a systematic pattern of under-pricing in IPOs. Carter and Manaster (1990) suggest that uninformed investors require IPO returns as compensation for the risk of trading against superior information. Their results indicate that prestigious underwriters are likely to be associated with lower risk offerings requiring lower returns. Chishty et al. (1996) provide evidence that actual or potential competition among underwriters provides at least as much explanatory power as the more standard reputation variable in determining the price run-ups in the post issue trading.

Drake and Vetsuypens (1993) present empirical evidence on the lawsuit avoidance hypothesis. According to this hypothesis, large positive initial public offering (IPO) returns reduce the probability of a lawsuit, the conditional probability of an adverse judgment if a lawsuit is filed, and the amount of damages in the event of an adverse judgment. Evidence presented by Ruud (1993) substantiates the hypothesis that underwriter price supports play a role in explaining high

average initial IPO returns. Jagadeesh et al. (1993) suggest that deliberate IPO under pricing is used by issuers to convey their private information about the value of their projects and prepare the market for subsequent issues of seasoned equity.

In a general supply and demand driven price framework, we should expect to observe the following relationships.

- Higher supply of tradable stock should result in lower IPO returns.
- Larger trading volume should result in higher IPO returns.
- Higher flexibility of the enterprise should result in higher IPO returns.

It is interesting to see that the survivors in the recent stock market crash are the firms providing tools rather than single applications products in the IT marketplace. The returns have varied in the direct order of flexibility enjoyed by the firms.

Data and Methodology

The sample consists of all common stock initial offerings during the period 1989–1998 for which data were available from the CRSP-NASDAQ tapes. Following prior studies, some categories of offerings were excluded, as shown in Table 2.

Table 2 : Categories of Offerings Excluded

Type of Observation	Sample Size
Total IPO registrations	7481
Excluded observations	
Offerings in exchange for existing stock	31
Offerings for closed end mutual funds	232
Offerings with zero trading volume	127
Offerings with missing returns	79
Final sample size	7012

The final sample size is 7012 IPO offerings. The sample IPO offerings are divided into three categories based on the industry characteristics.

Group I	– all firms involved in general Manufacturing and Extractive industries	3389
Group II	– all firms engaged in providing Financial and other services	2488
Group III	– all firms engaged in Information Technology related activities	1135

The abnormal return for each IPO is defined as the value X_t,

$$X_t = [((P_t - P_0)/ P_0) - ((I_t - I_0)/I_0)]$$

where

P_t = the closing price of the security t trading days after the initial offering, adjusted for stock dividends and splits;

P_0 = the initial offering price of the security;

I_0 = the value of the NYSE - AMEX- NASDAQ composite index on the date of the offering; and

I_t = the value of the NYSE - AMEX- NASDAQ composite index t days after the offering.

In order to evaluate market performance of the IPOs, raw returns and excess returns are computed for the day of the offering (day 0) and for two days following the offering (days 0,2). Appendix I shows the degree of abnormal appreciation from the offering price over the first day of trading and two trading days following the offering for the entire sample and classified by our groups of industries. The results indicate that if an investor had purchased each IPO at the offering date and price and held the investments for one day, the rate of return earned would be 2.316% or 1.120% higher than that of similarly timed investments in the composite index. The excess returns are positive and statistically significant. These results also show that virtually all price adjustment takes place during the first trading day. This suggests that the aftermarket for IPOs is quite efficient. Both of these results are consistent with the results of prior research.

There is substantial variation in the degree of abnormal returns over the industry groups. The mean IPO day returns for IT firms at 4.30% are significantly higher than those for manufacturing (2.79%) and other services (0.76%). Appendix II presents the ANOVA results for differences in IPO returns for the classification groups supporting the continued existence of these differences. Again, the tendency for full price adjustment to occur in the first trading day is apparent.

Further analysis is carried out to establish the existence of supply and demand effects of the size of the offering, and the trading volume of the securities, on the IPO day returns.

The proposed regression model is

$$X_t = B_0+B_1 * ADJSHR_t+B_2 * ADJVOL_t$$

Where Xt is the abnormal IPO return, and

$ADJSHR_t$ = CRSP adjusted shares outstanding for the stock for time period t

$ADJVOL_t$ = CRSP adjusted volume for the stock for time period t

The results of the regression are presented in Appendix III. These results show that the effects are as hypothesized

and statistically significant (F = 14.85, P>F=0.0000). The coefficient of trading volume, representing demand is positive and significant, while the coefficient of outstanding shares, or supply, is negative and significant. Analysis of variance is also performed for the effect of these variables while using industry classification grouping as class variables. The results show that the differences in IPO returns are significant for the three groups (F = 8.842, P>F = 0.0000). These results are presented in Appendix IV.

Cross-Sectional Analysis

The previous analysis was performed on the aggregate sample and time series of IPOs and may, therefore, be masking important cross-sectional variations. In particular, prior literature suggests that stocks with smaller market capitalization tend to out perform larger stocks, and that NASDAQ market tends to host smaller stocks. Therefore, it may be that the IPOs conforming to these classifications or the patterns are driving the results and that the reported results are not descriptive of the IPO market as a whole. Instead, the observed higher returns for IT firms may be a function of the presence of the smaller, riskier issues with little following among investors and investment banks.

To examine this possibility, the regression analysis for IPO returns is rerun with added variables representing the market capitalization and exchange listing. The results show that while the returns are influenced by the trading volume, number of shares outstanding, and the industry classification, variables representing market capitalization and choice of exchange listing do not add explanatory power to the model (F=6.069, P>F=0.0000). Further analysis shows that there is no significant difference in market capitalization (F=0.739, P>F= 0.4775) between the industry groups formed for the analysis. The results indicating significant differences between IPO returns for the industry groups appear to be robust to the firm capital size. These results are presented in Appendix V.

A sample of initial public offerings (IPOs) made from 1989 to 1998 was analyzed for realized excess returns. Factors influencing initial IPO pricing were identified and the impact of the IT industry's flexibility on investor returns was analyzed.

To summarize, the results of this analysis show that in aggregate, the investment returns behaviour of IPOs is supportive of IT industry premium. It has also been demonstrated that these results were not driven by a subset of smaller, more speculative, issues. Instead, the superior performance of IT industry IPOs is a robust "across the board" phenomenon in the IPO market, appearing in aggregate, over time, and across capitalization size categories.

Concluding Remarks

The results suggest that the possibility that underwriters do not systematically price IPOs below their intrinsic values should be explored. The presence of statistically significant excess returns that can be explained by the number of the shares offered, the IPO day trading volume and industry groupings indicates that the IPO returns may be driven by the balance of supply and demand in the market place, and that IT industry stocks may command premiums in view of the considerably higher flexibility enjoyed by the industry.

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Appendix I : Event Returns for IPOs during 1989-1998

Variable	N	Mean	Std Dev	T
Raw(day 0)	7012	0.0023167	0.0448266	4.3277514
Raw(day 0,2)	7012	0.0023272	0.0448563	4.3443378
Excess(day 0)	7012	0.0011206	0.0450470	2.0830957
Excess(day 0,2)	7012	0.000520971	0.0465293	0.9375800

Manufacturing Industries

Variable	N	Mean	Std Dev	T
Raw(day 0)	3389	0.0027933	0.0461233	3.5256214
Raw(day 0,2)	3389	0.0028090	0.0461273	3.5450942
Excess(day 0)	3389	0.0018724	0.0463426	2.3520648
Excess(day 0,2)	3389	0.0014772	0.0478290	1.7980248

Financial and Other Services

Variable	N	Mean	Std Dev	T
Raw(day 0)	2488	0.000760177	0.0397216	0.9545809
Raw(day 0,2)	2488	0.000800643	0.0397671	1.0042480
Excess(day 0)	2488	-0.000653173	0.0399772	-0.8149689
Excess(day 0,2)	2488	-0.0013945	0.0416004	-1.6720304

Information Technology

Variable	N	Mean	Std Dev	T
Raw(day 0)	1135	0.0043058	0.0509632	2.8464043
Raw(day 0,2)	1135	0.0042347	0.0510415	2.7951044
Excess(day 0)	1135	0.0027641	0.0511185	1.8217155
Excess(day 0,2)	1135	0.0018645	0.0523684	1.1994612

Appendix II

Analysis of Variance for Raw returns (Day 0)

Classified by Industry

IT	N	Mean	Among MS	Within MS
Manufacturing Industries	3389	0.002793319	0.005644213	0.002008388
Financial and other services	2488	0.000760177	F Value	Prob > F
Information Technology	1135	0.004305817	2.810	0.0603

Analysis of Variance for Raw returns (Day 0,2)

Classified by Industry

IT	N	Mean	Among MS	Within MS
Manufacturing Industries	3389	0.002808987	0.005357216	0.002011137
Financial and other services	2488	0.000800643	F Value	Prob > F
Information Technology	1135	0.004234711	2.664	0.0698

Analysis of Variance for Excess returns(Day 0)

Classified by Industry

IT	N	Mean	Among MS	Within MS
Manufacturing Industries	3389	0.001872380	0.00604605	0.002027982
Financial and other services	2488	-.000653173	F Value	Prob > F
Information Technology	1135	0.002764146	3.158	0.0426

Analysis of Variance for Excess returns(Day 0,2)

Classified by Industry

IT	N	Mean	Among MS	Within MS
Manufacturing Industries	3389	0.001477240	0.007138126	0.002163555
Financial and other services	2488	-.001394494	F Value	Prob > F
Information Technology	1135	0.001864479	3.299	0.0370

Appendix III : Relationship Between IPO Excess Returns, Volume of Trading, and Outstanding Shares

Response: Excess Returns for IPO(Day 0)

R-square	0.0042	Root MSE	0.045
Adj R-square	0.0039	C.V.	4011.9

Source	DF	SS	MS	F	Pr > F
Model	2	0.06	0.03	14.85	0.0000
Error	7009	14.17	0.002		
Total	7011	14.23			

Parameter Estimates

Term	DF	Estimate	Std. Err.	T	Pr > |T|
INTERCEPT	1	0.0005	0.0006	0.858	0.3910
ADJVOL	1	32E-10	59E-11	5.450	0.0000
ADJSH	1	-57E-9	18E-9	-3.170	0.0015

Appendix IV : Relationship Between IPO Excess Returns, Volume of Trading, and Outstanding Shares, using Industry Classification as Classes

Response: Excess Returns for IPO(Day 0)

R-square		0.0050	Root MSE		0.0449
Adj R-square		0.0045	C.V.		4010.9
Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	4	0.0714	0.0179	8.842	0.0000
Error	7007	14.16	0.002		
Total	7011	14.23			

Analysis of Variance: ANOVA Table
Type III Sum of Squares

Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
ADJVOL	1	0.0586	0.0586	29.03	0.0000
ADJSH	1	0.0194	0.0194	9.627	0.0019
Industry Class	2	0.0114	0.0057	2.822	0.0596

Appendix V

Response: Excess Returns for IPO(Day 0)

R-square		0.0052	Root MSE		0.0449
Adj R-square		0.0043	C.V.		4011.2
Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	6	0.0736	0.0123	6.069	0.0000
Error	7005	14.15	0.002		
Total	7011	14.23			

Analysis of Variance: ANOVA Table
Type III Sum of Squares

Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
ADJVOL	1	0.0586	0.0586	28.99	0.0000
ADJSHR	1	0.0147	0.0147	7.265	0.0070
Industry Class	2	0.01	0.005	2.482	0.0837
Exchange	1	0.0011	0.0011	0.546	0.4600
Capitalization	1	0.001	0.001	0.518	0.4717

Model: Capitalization = Industry Classification

Source	**DF**	**SS**	**MS**	**F**	**Pr > F**
Model	2	113E10	565E9	0.739	0.4775
Error	7009	535E13	764E9		
Total	7011	536E13			

ANOVA Weighted for Unequal Variances

F	**Df num**	**Df denom**	**Pr > F**
0.8214	2	4029	0.4399

Flexibility Mapping : Practitioner's Perspective

1. What types of flexibilities you see in the practical situation of "*Equity Valuation*" on the following points:
   - Flexibility in terms of *"options"*
   - Flexibility in terms of *"change mechanisms"*
   - Flexbility in terms of *"freedom of choice"* to participating actors.
2. Identify and describe the types of flexibilities that are relevant for your own organizational context? On which dimensions, flexibility should be enhanced for higher equity valuation.
3. Try to map your own organization on following continua. (Please tick mark in the appropriate box(es)).

Operational Flexibility

Low ☐ ☐ ☐ ☐ ☐ High

Type of Issue

Small and Risky ☐ ☐ ☐ ☐ ☐ Robust Superior Performance

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of "*Equity Valuation*".

Reflecting Applicability in Real Life

1. What is the practical significance of the empirical research on equity valuation presented in this paper?
2. How can you utilize the findings of this study for portfolio management?

Management Tool & Case Study

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Economic Value Added (EVA): A New Flexible Tool for Measuring Corporate Performance

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Abstract

With increased competition and greater awareness among investors, new and innovative ways of measuring corporate performance are being developed. New tools/techniques provide flexibility to managers in their functions, be it in terms of operational aspects or evaluation parameters. Economic Value Added (EVA) is one such innovation. Besides the measures like Return on Equity (ROE), Return on Net Worth (RONW), Return on Capital Employed (ROCE) and Earnings per Share (EPS), EVA is a new measure available to the corporate managers.

This paper describes and compares the EVA with other measures. Apart from this, taking the real financial data of a company, the paper shows how EVA calculations can be done to demonstrate whether the company is adding to shareholder value by generating profits over and above the capital charge. EVA is not a tool to create wealth. Yet, it encourages managers to think like owners and, in the process, may impel them to strive for better performance.

Keywords: corporate performance, economic value added, flexible tool

Introduction

Today's business environment is rife with challenges that have a major impact on performance of companies. Prominent among these are a creation of level playing field due to ease of availability of capital, easy flow of information and mobile talent and turbulence caused by life cycle inflections, factor costs, global competition, deregulation, foreign exchange and interest rate volatility. (Copeland et al, 1990)

The challenges cited above have opened the eyes of managers to the importance of value creation and its difference with other parameters like earnings. The stock markets are not naïve and have been punishing the value destroyers. Hence, it is not surprising to see even the largest conglomerates with long successful track record disintegrating recently in search of value. Flexibility and responsiveness, *new avatars* of value enhancement have now taken the centrestage and value based management framework seems to be the key to success in future.

Economic Value Added (EVA) is one among various frameworks within value based management framework. EVA is based on the common accounting based items like interest bearing debt, equity capital, net operating profit etc. The idea behind EVA is that shareholder must earn a return that compensates the risks taken by him. In other words, equity capital has to earn at least the same return as similar risky investments in equity markets. If that is not the case, then there is no real profit made and actually company operates at a loss from viewpoint of shareholders. On the other hand, if EVA is zero, this should be treated as sufficient achievement because shareholders have earned a return that compensates the risk.

EVA is not a new discovery. An accounting performance measure called residual income, first mentioned by Alfred Marshall in 1890, is defined as operating profit subtracted with capital charge. Broadly, EVA is variation of residual income with adjustment to how one calculates income and capital. Hailed by *Fortune* as "Real key to creating wealth" and "Today's hottest financial product", EVA evinced interest in researchers worldwide. Biddle et al. (1997) carried out empirical study on correlation of four performance measures, that is, cash flow from operations (CFO), residual income (RI), EVA and Earning before extraordinary items (EBEI) with stock returns. The study concluded that there is no empirical evidence in support of EVA having a higher correlation than other parameters. In fact, EBEI had highest correlation with stock returns amongst the performance parameters considered. However, in another study, they (Biddle et al. 1999) provided empirical evidence that EVA motivated managers to create shareholder value and the firms, which adopt EVA based incentive plans tend to increase capital disposition and decrease new investments leading to higher capital turnover.

Ho et al. (2000) contended that EVA is especially useful in Internet companies because operations of such companies are marked by high marketing and advertising expenses, which need to be amortized over an extended period of time. Shrieves and Wachowicz (2000) outlined EVA framework

from valuation perspective and reconciled the approach with more popular Net Present Value (NPV) and Free Cash Flow (FCF) methodologies.

Weissenreider (1998) criticized EVA because it is based on accounting items only. He opined that financial managers might be compelled to act on information that is accounting in disguise and might have serious consequences. Weissenreider (1998) compared EVA with Cash Value Added (CVA) and concluded that the latter is a better performance measure.

In short, research carried out till date has shown that EVA does drive value though its utility as performance measure has a defined scope? But then which performance measure is not limited in scope. We feel that no measure is a panacea for all the ills. In India, economic liberalization in 1991 and subsequent globalization has changed the ways industry worked. The traditional performance measures are no more sufficient to manage value. Our paper revisits the EVA concept to find out its utility and limitations in today's value based management framework. Also, the paper provides limitations of traditional performance measures and a case study showing EVA calculation for a better grasp of the concept.

Flexibility and responsiveness, new avatars of value enhancement have now taken the centrestage and value based management framework seems to be the key to success in future.

The EVA Theory

EVA can be defined as follows:

$$EVA = NOPAT - WACC \times CAPITAL\ EMPLOYED$$

where

NOPAT refers to net operating profits after taxes. NOPAT is equal to earnings before interest and tax *(EBIT)* minus adjusted taxes *(AT)*.

EBIT refers to the earnings before interest and tax.

Following accounting items are not to be considered:

(i) *Income*

- Interest income on loans given by the company
- Dividend income on financial investments made by the company
- Profit on sale of assets
- Profit on sale of investments

(ii) *Expenses*

- Loss on sale of fixed assets
- Loss on sale of investments
- Expenses by subsidiaries

Others Issues

- *Brand expenses:* The expenses incurred in brand development should be amortized over a period of years in case the brand is launched and the same survives over the period. The expenses incurred on a brand not subsequently launched should be written off in the same year rather than amortizing the same over a period of years.
- *Capitalization of R&D expenses:* Similarly, only those R&D expenses which contribute to the revenue in future periods should be deferred. Else, they be written off in these years when they are incurred.
- *Currency translation:* The reversible currency translation effects should be ignored. The irreversible, periodic and gradual translation effects should be considered to the extent they result in losses. Gains should be ignored to be on conservative side.
- *Sinking fund depreciation:* The depreciation should be charged in line with the utilized life of assets. However, cases with steady capital investment policy would not require this adjustment.

The objective behind all this adjustments is to reflect the operational efficiency of the company under purview.

AT refers to the adjusted taxes. It is equal to cash taxes paid + tax advantage on interest.

WACC refers to weighted average cost of capital. It comprises of following two components:

(i) *Cost of debt* (C_D) : Company's post tax marginal rate of borrowing.

$$C_D = Borrowing\ rate \times (1 - marginal\ tax\ rate)$$

(ii) *Cost of equity* (C_E) : Required rate of return on company's share.

$$C_E = Risk\ free\ rate + Risk\ premium \times Beta\ (Capital\ Asset\ Pricing\ Model)$$

$$WACC = D/V \times C_D + E/V \times C_E$$

Here,

- D = Average debt
- E = Average equity (market capitalization)
- $V = D + E$ (Total value of firm)
- The risk free rate is equivalent to government's long-term bond yield
- Beta measures the volatility of share price relative to the market

- Market risk premium is the extra return investors expect from equity market over and above risk free rate

Capital Employed: Stewart[1] defined capital to be total assets subtracted with non-interest bearing liability in the beginning of the period. This definition does not consider the capital infused into the business at different times during the year and hence has a favorable impact on the resulting values. However, use of average capital employed shall correct this bias. Following care should be taken:

- Exclude the profits from the ending balance sheet.
- Average assets can be calculated on average of individual months.
- Exclude capital work-in-progress since it does not give any returns till commissioned.
- Funds locked in investments should be excluded.
- Add customer advance where it is considerable.

There is a school of thought which is against including capital work-in-progress since it does not contribute to earnings in that year. The counter view is that capital work in progress is a cost that company needs to pay today for growth tomorrow. Generally, the values are not considerable, still calculating from both views is beneficial.

EVA is especially useful in Internet companies because operations of such companies are marked by high marketing and advertising expenses, which need to be amortized over an extended period of time.

It is important to note that it is not wise to do all adjustments suggested above because of the marginal effects of some of them.

Following questions should be asked before implementing EVA:

- Will operating managers understand the change?
- Will it influence their decisions?
- How big difference does it make?
- Can necessary data be obtained?
- How much does it cost?

An example of an organization is included at the end of this paper to help the reader with better understanding of micro issues involved.

EVA vs Traditional Performance Measures

The development of the concept of EVA has added flexibility in measurement of performance. The traditional methods can continue side by side with EVA. Some of the traditional ways of measuring corporate performance are described here.

Return on Investment (ROI)

Return on capital is a very good and relatively good performance measure. Different companies calculate this return with different formulae and call it also with different names like return on invested capital, return on capital employed, return on net assets, return on assets etc. The main shortcoming with all these rates of return is that in all cases maximizing rate of return does not necessarily maximize the return to shareholders. Following example will clarify this statement:

Suppose a group has two subsidiaries *X* and *Y*. For both subsidiaries and so for the whole group the cost of capital is 10%. The group has maximizing ROI as its target. Subsidiary *X* has ROI of 15% and the other has ROI of 8%. Both subsidiaries begin to struggle for the common target and try to maximize their respective ROIs. Company *X* rejects all the projects that produce a return below the current 15% although there would be some projects with return 12–13%. *Y*, in turn, accepts all the projects with return above 8%. For a reason or another, it does not find very good projects, but the returns of its projects lie somewhere near 9%.

Suppose that both subsidiaries manage to increase their ROI. The ROI of subsidiary *X* increases from 15 to 16% and that of *Y* increases from 8 to 8.5%. The company's target to increase ROI has been achieved, but what about the shareholder value. It is obvious that all the projects of subsidiary *Y* decrease the shareholder value, because the cost of capital is more than rate of return (and so the shareholders money would have been better off with alternative investments). The actions of the better subsidiary are not optimal for shareholders. Of course shareholders will benefit from the good projects with return greater than 15% but also all the projects with returns of 10–14% should have been accepted even though they decrease the current ROI of subsidiary *X*. These projects still create and increase the shareholder value.

Hence, the capital can be misallocated on the basis of ROI. ROI ignores the definite requirement that the rate of return should be at least as high as cost of capital. Further, ROI does not recognize that shareholder's wealth is not maximized when the rate of return is maximized. Shareholders want the firm to maximize the absolute return above the cost of capital and not to increase percentages.

Return on Equity (ROE)

The level of ROE does not tell the owners if company is creating shareholders' wealth or destroying it. With ROE,

1 EVA is a registered trademark of Stern Stewart & Co. Inc, USA.

this shortcoming is much more severe than with ROI, because simply increasing leverage can increase the ROE. In other words, decreasing solvency does not always make shareholders' position better because of the increased financial risk.

Earning per Share (EPS)

EPS is raised simply by investing more capital in business. If the additional capital is equity (retained earnings) then the EPS will rise if the rate of return of the invested capital is just positive. For example, let us assume that as on March 31, 1999, company A has net worth of Rs 50 million and 5 million equity shares. At a profit after tax of Rs 100 million for FY 1999, the EPS would work out to be 20. The entire income can be ploughed back in the business at a marginal return of 5%. Assuming that the return on previous net worth remains the same, the profit after tax would be Rs 105 million and EPS would be 21. Though the performance has gone down, the EPS has increased.

If the additional capital is debt then the EPS will rise if the rate of return of the invested capital is just above the cost of debt. In reality, the invested capital is a mix of debt and equity and the EPS will rise if the rate of return on the additional investment is somewhere between the cost of debt and zero. Therefore EPS is completely inappropriate measure of corporate performance and still is very common yardstick and even a common bonus base.

EVA points / centres can be created within an organization and these centres would have capital, revenue and expenditure issue attached to them. It helps identify value drivers and destroyers. Responsibility of positive EVA can be delegated at these centres.

Unlike conventional profitability measures, EVA helps the management and other employees to understand the cost of equity capital. At least in big companies, which do not have a strong owner, shareholders have often been perceived as free source of funds. These flaws are taken care of by the concept of economic value added. The key feature of this concept is that for the first time any measure takes cares of the opportunity cost of capital invested in business.

The Utility of EVA

Better Decision-Making

EVA clarifies the concept of maximizing the absolute returns over and above cost of capital in creating shareholders' wealth. Hence better investment decisions can be taken with above aim rather than maximizing percentage of ROI. Understanding of EVA enables monitoring of investment decisions closely not only at the level of corporate but at line staff as well.

Fosters New Era of Corporate Control

EVA points / centres can be created within an organization and these centres would have capital, revenue and expenditure issue attached to them. It helps identify value drivers and destroyers. Responsibility of positive EVA can be delegated at these centres. It questions the decisions harder.

Long-Term Thinking

Perhaps the biggest benefit of this approach is to get employees and managers to think and act like shareholders. EVA encourages long-term perspective among the managers and employees of organization. It emphasizes that in order to justify investments in the long run they have to produce at least a return that covers the cost of capital. In other case, the shareholders would be better off investing elsewhere. This approach includes that the organization tries to operate without the luxury of excess capital and it is understood that the ultimate aim of the firm is to create shareholder value by enlarging the product of positive spread multiplied with capital employed. The approach creates a new focus on minimizing the capital tied to operations. Firms have so far done a lot in cutting costs but cutting excess capital has been paid less attention.

Capital Allocation Tool

EVA is a capital allocation tool inside a company as it sets minimum level of acceptable performance with regard to the rate of return in the long run. This minimum rate of return is based on average (risk adjusted) return on equity markets. The average return is a benchmark that should be reached. If a company cannot achieve the average return, then the shareholders would be better off if they allocated the capital to another industry or another company.

Bonus System

EVA has provided a platform on which a flexible bonus payment system can be based. Employees will be paid bonus only when they earn at least equal to the cost of capital employed. This links the bonus with the end result and forces employees to act like shareholders. Proponents of bonus systems based on EVA have suggested that bonuses for corporate managers should always be tied to the long-term capital because short-term EVA can sometimes be manipulated upwards to the cost of long run EVA. The long run can be incorporated into EVA-based bonuses, that is, by banking the bonuses. This would mean that when EVA is good, the managers earn a certain percentage of it, but the bonus should not be paid out of them entirely. If the periodic EVA is negative, then the bonus put in the bank is negative and it decreases the balance already earned. This exposes the managers partly to the risk the shareholders are used to bear. At the same time, it gives incentives to good performers and encourages the bad performers to improve their performance.

For example, manager earns a bonus of an amount X of the annual salary for leading its centre to a positive EVA to the extent of 10% of capital employed. Out of the entire bonus, 50% can be paid out and the rest can be banked as entitlement if the next year EVA is not negative. In case the EVA next year is negative, the banked bonus can be reduced as disincentive for bad performance.

Flexibility in EVA

Today's business environment is marked by presence of a lot of change drivers like globalization, an intense competition, etc and the uncertainty surrounding them has created chaos and confusion in organizations. Consequently, flexibility has assumed key role in every facet of organization management and finance function, known for its rigidity, is not too far from application of this paradigm.

EVA can lend a helping hand in this connection in two ways: one that it is inherently flexible and second, it helps generate flexibility within the organization:

1. The EVA concept allows adjustment of various accounting parameters (mentioned in Section on EVA theory) to suit the desired end purpose. There can be various purposes for which EVA exercise might be carried out such as award of bonus to employees, relative performance of various divisions, assessment of business as a whole etc. For the purpose of award of bonus to employees, the focus is on the operational income and capital employed to generate such income. Various accounting adjustments are made accordingly. However, for the purpose of assessment of business as a whole, the strategic investment and its returns also come into picture. While comparing various divisions, the capital employed and expenses incurred on corporate centre take a back seat. Thus, EVA concept provides flexibility in hands of finance manager in measuring performance. In the case study discussed later, we have discussed EVA from the point of view of award of bonus.

2. Not only is EVA concept inherently flexible, but also it induces flexibility in the organization. The application of concept forces the organization to release/ free the excess capital employed. This deployment of excess capital provides the much-required flexibility to finance manager to improve performance. Since application of concept questions every decision harder, it forces the managers to keep exploring options and encourages to keep the system flexible. This effect is more pronounced in companies which are in distress, and where restructuring is being carried out.

EVA has provided a platform on which a flexible bonus payment system can be based. Employees will be paid bonus only when they earn at least equal to the cost of capital employed.

Implementing EVA

Implementing EVA should be more than just adding one line in the monthly profit report. EVA affects the way capital is viewed and therefore, it might create some kind of change in management's attitude. Of course this depends on how shareholder-value-focused the management is and how the company has been in the past. While implementing EVA represents some kind of change in the organization, it should be implemented with care in order to achieve understanding and commitment.

It is vital that group level managers thoroughly understand the characteristics of the concept, how these characteristics affect control and above all where the Strategic Business Units (SBUs) stand currently from the viewpoint of these characteristics. Before implementing EVA to any SBU, the group management ought to assess whether the business units are currently cash flow generators in mature businesses or companies in rapidly growing businesses. This assessment should absolutely include careful estimation of relative age and structure of assets in order to know whether the current accounting rate of return is over or under estimating the true rate of return. Only then can the concept be properly tailored to the unique situation of each individual business unit. Group level managers should also know how to support strategic goals of SBU with EVA and how to create value with EVA in individual SBU.

At the level of SBU, gaining understanding and commitment are also the most important issues. First task is to get the support of all the managers, not only of the Managing Director but also of directors of production and marketing etc. This is achieved with intense and thorough training. For managerial level, attaining thorough commitment can be facilitated very much by introducing good incentive plan based on EVA.

Gaining commitment of middle level managers and other employees below the top management of business unit is also important. Training and some kind of EVA based compensation plans should also be considered with these target groups. Keeping EVA simple is also viewed as an important feature in successful implementation. In principle, EVA is simple concept and it should be offered to business units as such.

A Case Study: XYZ Television Network Limited[2]

The Company

XYZ Television Network Limited (hereafter also referred to as XYZ), was incorporated in 1994 as a public limited

2 The name of the company has been changed to maintain anonymity

company. The company is engaged in the production of entertainment software, mainly for television media.

The company was promoted by first generation entrepreneurs of India. The day-to-day affairs of the company are managed by both of them, assisted by a team of professionals.

In 1995, the company came out with its maiden public issue which was over-subscribed. The company has 150 employees on its rolls.

The company is a producer of various entertainment software programmes being telecast in terrestrial and satellite channels. All kinds of programmes like situational comedy serials (called 'sitcoms'), family drama, social drama, song countdowns, women-oriented programmes, thrillers and detective serials are being produced by the company.

Operations

The company carries on software production at hired studios, private bungalows and open locations, on an eight-hour-shift basis. Some of the equipment required for production are hired on shift basis from outside parties. Post- production activities like editing, mixing, dubbing, etc. are done at the company's own studio at New Delhi.

XYZ has a library of around 1000 hours of programming. The programmes of the company are telecast mainly on the national channel. The channel charges telecasting fee which varies with the timing of the telecast. Prime-time programmes invite higher telecast rates in comparison to non-prime time programmes.

The company prefers the national channels to other satellite channels, as, unlike in case of satellite channels, the copyrights of the programmes remain with XYZ and can be sold or used for re-runs. This gives additional revenue to the company when the programme is re-run, with no additional cost except for telecasting fees. Private cable channels do not charge telecasting fee but buy the copyrights outright with no revenue accruing to the producing company when the programmes are re-telecast.

Not only is EVA concept inherently flexible, but also it induces flexibility in the organization. The application of concept forces the organization to release/ free the excess capital employed. This deployment of excess capital provides the much-required flexibility to finance manager to improve performance.

Marketing

The company gets free commercial time (FCT) programme telecast on the national channel. The company sells these FCTs to ad-agencies. These FCTs are normally sold on 'per ten second' basis, which is the standard duration of a TV commercial.

The selling rates of FCTs are negotiated between the company and the ad-agencies and are normally dependent upon the viewership of the programme, which is measured by 'Television Rating Points' (TRPs). TRPs are determined by market research organizations.

Revenue Profile

The revenue earned by XYZ is of four types:

- Free Commercial Time (FCT) sold to the ad-agencies when the episode of the serial is being telecast for the first time;
- Revenue from FCTs when the programme is re-telecast;
- Sale of copyrights of entertainment software; and
- Exports

The expenditure heads consist of telecast expenses, production expenses, administrative expenses and selling and distribution expenses.

Analysis of Annual Report for the Year 1999—2000

The Balance Sheet and Income Statement along with major schedules forming part of these statements are at the Appendix I. Major highlights of the financial year are as follows:

- After the conversion of warrants, there has been an increase in equity (including share premium) to the extent of INR 1205 million.
- Till FY 1999 the company had been following an accounting policy of deferring the production expenses attributable to programme software over their useful life irrespective of the year of telecast. With effect from FY 2000, this policy has been changed and henceforth the production expenses are being written off in year of telecast of the programme.
- The company has set up a wholly owned subsidiary in USA for channel broadcast operations.

Our opinion on the accounting policy followed by the company is:

- The policy adopted by the company in FY 2000, of writing off the entire production expenses in the year of telecast, is prudent and is on conservative side.
- The company recognizes revenue in respect of sponsored telecast programmes as and when the episode of the programme is telecast. In case of export of software, income is recognized when the relevant program is delivered to and accepted by the buyers and all significant risks and rewards of telecasting rights have been transferred to the buyer. The policy as per our opinion is prudent and matches with the general practice in the industry.

- The company follows standard policies on depreciation, fixed assets and inventory valuation.
- The foreign exchange loss/gain on account of transaction/ translation is reflected in income statement. This is fine considering the fact that Indian currency's gradual downward movement against US Dollar is of nearly permanent nature.
- The policy of deferring preliminary expenses and share issue expenses followed by the company is reasonable. Deferred revenue expenditure, preliminary expenses and share issue expenses to the extent, not written off are accounted for under the 'Miscellaneous expenses not written off' head in balance sheet.

The EVA Calculation

The effort through this example would be to calculate the EVA of XYZ Television Network Limited for the financial year 1999-2000 and present the underlying concept to the reader in a more vivid manner.

Calculation of NOPAT

Revenue : The sales recorded by the company in FY 2000 are INR 400.13 million. The other income of INR 40.25 million is composed of interest income, dividend, incentive on mutual fund, insurance claim, exchange rate gain and credit balance written off.

Income on account of dividend and incentive on mutual fund are due to investments made in this year and hence do not relate to operations.

Interest income is unusually high on account of high amount of fixed deposits in cash and bank balances account head. There has been a 33% (approx.) growth in sales and accordingly, the closing cash and bank balance for operational purposes can be considered at 1.33 times the opening balance, that is, at INR 9.2 million. The balance INR 158.5 million is conceptually considered as Investments. Interest income on INR 9.2 million will be marginal and hence for practical purposes we shall consider entire Interest income as non-operational.

Exchange rate gain is ignored to be on conservative side. Accordingly, the operational other income shall be comprised of Insurance claim and credit balance written off. The same works out to INR 1.1 million. Hence, total income for operations is INR 401.23 million.

There were no sales of fixed assets and investments and hence no adjustments for the same.

Expenditure : Total expenses(including depreciation and stock adjustments) work out to INR 256.6 million. We have not made any adjustments to the depreciation assuming steady capital investment policy.

This leads to net operating profit of INR 144.63 million.

Adjusted Taxes : The company has made provision for taxes to the tune of INR 5.2 million. Add to this tax advantage on interest (@38.5%, marginal tax rate), that is, 0.385 times 4.23 million, equals INR 1.63 million. The adjusted taxes work out to INR 6.83 million.

NOPAT (Net Operating Profits less Adjusted Taxes)

NOPAT of XYZ for FY 1999—2000 is INR 137.8 million.

Calculation of Capital Charge

Capital Employed

The capital employed is calculated as sum of net fixed assets (includes capital work in progress and goodwill) and net working capital. There are no advances to subsidiaries and hence no adjustments to current assets, however, the fixed deposits being interest bearing liability should be excluded from the current liabilities.

Capital employed for FY 2000 (opening): INR 123.2 million

Capital employed for FY 2000 (closing) : INR 166.3 million

The latter figure needs some explanation. We have arrived at this figure by deducting the retained earnings of FY 2000 (INR 146.8 million) from the operating capital employed (INR 313.1million).

The capital employed (closing) for FY 2000 can be calculated as follows:

Net Fixed Assets	:	INR170.5 million
Add Goodwill	:	INR 1.0 million (See schedule 'E')
Add Current Assets (see schedule 'G')		
Inventory	:	INR 24.9 million
DebtoINR	:	INR120.1 million
Cash/Bank Balance	:	INR 9.2 million (as discussed earlier balance considered as investments)
Loans and advances	:	INR 80.3 million
Less Current liability	:	INR 58.1 million (take out INR 27.6 million Fixed deposits)
Less Provisions	:	INR 34.9 million (See Schedule 'H')
Less Retained Earnings	:	INR 146.8 million
Total capital employed	**:**	**INR 166.3 million**
Average capital employed:		INR 144.75 million

Capital Structure

The operating capital is composed of following components:

Average Debt deployment: INR 26.35 million

Average Equity deployment: INR 118.4 million

The debt-equity[3] ratio work out to 1:4.5 (approx.)

Cost of Capital

Cost of debt : The lending rates are 16% and after factoring in the tax advantage the cost of debt is 9.84%.

Cost of equity : Risk free rate of return (R_f): We shall use the coupon rate for government bond maturing in year 2008, that is 11.40%.

Market return (R_m): Over past 9-10 years, the stock market (Bombay Stock Exchange Sensex) has moved from 1000 point level to 5500 point levels indicating a return of 20% per annum. The underlying assumption is that Sensex is a good representation of market.

Risk premium (R_m - R_f) : This is equal to 20 minus 11.40, 8.60%.

Beta: In order to calculate beta of XYZ, we used weekly closing prices for last 52 weeks. The beta of XYZ is 1.60.

Using capital asset pricing model (Cost of equity=R_f + Beta *(R_m - R_f))the cost of equity works out to, 11.40 + 1.60* 8.60 that is, 25.16.

The cost of capital would be equal to 22.37% (1.0*9.84+4.5*25.16)/(1.0+4.5). Accordingly, the **capital charge** would be 0.2237 multiplied with average capital employed (INR 144.75 million), that is, INR 32.4 million.

The **Economic Value Added** (from operations) works out to INR 137.8 million minus INR 32.4 million, that is, INR 105.4 million. XYZ has generated a positive EVA of the order of 72% (105.4/144.75) of average capital employed.

This value can be a very good measure for bonus, as the performance in operations can be attributed to the rank and file of the company. The investments decisions have not been finalized and would depend upon the top management's strategic directions.

The above calculations are not intended to give exact numbers but to provide readers an understanding of the underlying concept. There can be variance in the micro procedures based upon the extent and quality of data available, and the end purpose, viz. shareholder value/bonus/ management's review for which the exercise is being carried out.

Limitations of EVA

It would be wrong to say that EVA is not beset with any drawbacks. Though it provides a new tool in the hands of management, it has its own limitations. For example, EVA does not take into cognizance current market value of assets and book value is taken into account in calculations. This is of course misleading and presents distorted picture but estimating the current market value of assets is very difficult and often impractical.

EVA has established superiority over other measures of performance but that does not mean that EVA alone can clearly tell how the plans are going and strategic goals being met. The companies that have invested heavily today and expect positive cash flow only in distant future are extreme examples that have negative EVA in near future. Their performance can be better judged by market share, sales growth etc.

For the equity analysts, there is a word of caution. The concept of EVA requires knowledge of accounts internal to organization to a great extent and their availability to the external world is a big constraint. This constraint becomes even more pronounced in countries like India where even the annual reports published by companies have scanty disclosures. Moreover, it has to be borne in mind that EVA gives one year snapshot of company's operational performance.

At best EVA helps create a mindset throughout the organization that encourages managers and employees to think and behave like owners. At operational level, this often leads to increased shareholder value through increased turnover.

Concluding Remarks

At best EVA helps create a mindset throughout the organization that encourages managers and employees to think and behave like owners. At operational level, this new approach often leads to increased shareholder value through increased capital turnover. EVA has been helpful because it forces companies to pay attention to capital employed and especially to excess working capital. The advent of this concept has provided flexibility to the management in measuring the performance of their business operations. EVA is not a wealth creator; it only measures value. The experience of some of Indian companies is good after they have implemented EVA, especially NIIT Limited where EVA has doubled after introduction of the concept itself.

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Appendix I : XYZ Television Network Limited Financial Statements and Schedules

Balance Sheet as at 31st March, 2000

Particulars	Sch.	As at 31.03.2000	As at 31.03.1999
Sources of Funds			
Shareholders' funds			
Share Capital	A	84,100,000	50,000,000
Share Warrants	A	0	7,500,000
Reserves and Surplus	B	1,368,165,599	118,498,230
Loan Funds			
Secured Loans	C	6,397,369	17,720,177
Unsecured Loans	D	0	1,019,973
Total		**1,458,662,968**	**194,738,380**
Application of Funds			
Fixed Assets	**E**		
Gross Block		181,307,338	50,020,939
Less: Depreciation		9,787,687	4,963,215
Net Block		171,519,651	45,057,724
Capital Work in Progress	0	16,281,833	
Investments	**F**	978,599,250	0
Current Assets	**G**		
Inventories		24,924,267	12,623,514
Sundry Debtors		120,058,683	87,533,144
Cash and Bank Balances		167,730,047	6,878,325
Loans and Advances		80,332,905	33,729,826
		393,045,902	**140,764,809**
Less			
Current Liabilities and Provisions	**H**		
Current Liability		85,609,048	40,078,712
Provisions		34,937,089	38,778,058
		120,546,137	78,856,770
Net Current Assets		272,499,765	61,908,039
Miscellaneous expenditure (To the extent not written off)	**I**	36,044,302	71,490,784
Total		**1,458,662,968**	**194,738,380**

All figures are in Indian Rupee (INR)

Profit & Loss Account for the Year Ended 31.03.2000

Particulars	Schedule	YE 31.03.20s00	YE 31.03.1999
Income			
Sales		400,127,763	304,953,043
Other Income	J	40,254,534	329,949
Increase/(decrease) in inventory	K	-320,179	3,791,560
		440,062,118	**309,074,552**
Expenditure			
Production Expenses	L	58,525,276	42,749,437
Telecasting Expenses		117,525,570	134,642,959
Administrative Expenses	M	57,764,293	35,629,549
Selling and Distribution Expenses	N	17,990,842	8,754,469
		251,805,981	**221,776,414**
Profit before interest, depreciation Tax		**188,256,137**	**87,298,138**
Interest		4,228,040	1,344,952
Profit before depreciation and tax		**184,028,097**	**85,953,186**
Depreciation	E	4,461,691	1,893,045
Profit before tax		**179,566,406**	**84,060,141**
Provision for taxation		5,200,000	13,842,000
Profit after tax		**174,366,406**	**70,218,141**
Add Profit b/f from previous year		5,287,230	10,380,089
Add Transfer from General Reserve		75,575,429	0
Surplus Available for Appropr.		**255,229,065**	**80,598,230**
Appropriation			
Prior Period Adjustments		75,575,429	0
Interim Dividend		11,727,124	0
Proposed Final Dividend		11,986,698	11,000,000
Interim Dividend Tax		1,172,712	0
Provision for Dividend Tax		2,637,074	1,100,000
Transfer to General Reserve		100,000,000	63,211,000
Balance carried to Balance Sheet		52,130,028	5,287,230
		255,229,065	**80,598,230**

Schedules Forming Part of the Balance Sheet as at 31.03.2000

Particulars	31.03.2000	31.03.1999
Schedule "A"		
Authorised Capital		
10,000,000 Equity Shares of Rs 10 Each	**100,000,000**	**100,000,000**
Issued subscribed & Paid up capital		
84,100,00 (Prev. year 50,000,00) Equity share of Rs 10 each fully paid up	84,100,000	50,000,000
Warrants		
(Prev year 25,000,00 Warrants to be converted on or before 25 Feb, 2000)	0	7,500,000
	84,100,000	**57,500,000**
Schedule "B"		
A) General Reserve		
As per last balance sheet	113,211,000	50,000,000
Add: Set aside during the year	100,000,000	63,211,000
	213,211,000	113,211,000
Less: Transfer to P&L App. a/c	75,575,429	0
	137,635,571	113,211,000
B) Profit and Loss A/c	52,130,028	5,287,230
C) Share Premium A/c	1,178,400,000	0
	1,368,165,599	**118,498,230**
Schedule "C"		
Secured Loan		
From Scheduled Bank	3,021,127	15,854,182
Hire Purchase Loans	3,376,242	1,865,995
	6,397,369	**17,720,177**
Schedule "D"		
Unsecured Loans	**0**	**1,019,973**
Schedule "E"		
Gross Block		
Goodwill	1,000,000	1,000,000
Media Software	22,932,167	22,932,167
Land, Building, Furniture etc.	157,375,170	26,088,772
Capital Work in Progress	0	16,281,833
	181,307,337	**66,302,772**
Depreciation		
Goodwill	0	0
Media Software	0	0
Land, Building, Furniture etc.	9,787,687	4,963,215
Capital Work in Progress	0	0
	9,787,687	**4,963,215**

Schedules Forming Part of the Balance Sheet as at 31.03.2000

Particulars	31.03.2000	31.03.1999
Net Block		
Goodwill	1,000,000	1,000,000
Media Software	22,932,167	22,932,167
Land, Building, Furniture etc.	147,587,483	21,125,557
Capital Work in Progress	0	16,281,833
	171,519,650	**61,339,557**
Schedule "F"		
Investments		
A. Ordinary Shares in Sub. Company XYZ TV Ltd (Unquoted)	128,599,250	0
B. In Mutual Funds		
Quoted		
Bonds	325,000,000	0
Gilts	525,000,000	0
Total (Quoted)	850,000,000	0
Total	**978,599,250**	**0**
Schedule "G"		
Current Assets		
A. Inventories		
Software ready for Telecast	5,126,078	5,446,257
Software under production	19,798,189	7,177,257
	24,924,267	**12,623,514**
B. Sundry Debtors		
More than six months	14,603,639	10,291,735
Others	105,455,044	77,241,409
	120,058,683	**87,533,144**
C. Cash and bank balance		
Cash on hand	2,622,429	2,344,906
Current account	36,496,042	2,330,009
Fixed Deposits	128,611,576	2,203,410
	167,730,047	**6,878,325**
D. Loans and advances		
(Unsecured, considered good)	**80,332,905**	**33,729,826**

Schedules Forming Part of the Balance Sheet as at 31.03.2000

Particulars	31.03.2000	31.03.1999
Schedule "H"		
Current liabilities and Provisions		
Current Liabilities		
Sundry Creditors	56,443,873	39,445,134
Fixed Deposit (General Public)	27,563,000	0
Unclaimed Dividend	1,530,950	562,353
Unclaimed Refund (Public issue)	71,225	71,225
	85,609,048	**40,078,712**
Provisions		
For expenses	3,007,347	1,066,584
For taxation	17,305,970	25,611,474
Proposed Dividend	11,986,698	11,000,000
Dividend Distribution tax	2,637,074	1,100,000
	34,937,089	**38,778,058**
Schedule "I"		
Miscellaneous Expenditure		
Preliminary Expenses and Share issue expenses	1644321	
As per last balance sheet	1,644,321	
Add: Addition during year	38,526,704	
Less: Written off during year	4,126,723	36,044,302
Deferred revenue Expenses	0	69,846,463
Total	**36,044,302**	**71,490,784**
Schedule "J"		
Other Income		
Interest Income	1,794,444	236,175
Dividend	36,591,955	0
Incentive on Mutual Funds	272,611	0
Insurance Claim	151,556	41,000
Exhange rate difference	498,281	28,262
Credit Balance written off	945,687	0
Excess provisions written off	0	24,512
	40,254,534	**329,949**
Schedule "K"		
Increase /(decrease) in inventory		
Opening Balance	5,446,257	1,654,697
Closing Balance	5,126,078	5,446,257
	-320,179	**3,791,560**

Schedules Forming Part of the Balance Sheet as at 31.03.2000

Particulars	31.03.2000	31.03.1999
Schedule "L"		
Production expenses		
Location charges	5,255,545	2,956,377
Shooting charges	20,062,698	13,661,091
Direction charges	369,395	2,434,767
Camera charges	2,193,781	1,506,607
Light expenses	2,365,832	1,549,782
Sound expenses	3,398,516	3,109,724
Artist remuneration	11,412,635	12,507,678
Cassette purchase	6,024,114	1,875,063
Technical charges	7,442,760	3,148,348
	58,525,276	**42,749,437**
Schedule "M"		
Administrative Expenses		
Salaries, Allowances	10,872,093	8,182,292
Contribution to PF	501,330	290,837
Power and fuel	2,041,992	604,650
Telephone charges	2,593,227	2,910,491
Rent, rates and taxes	2,024,766	2,172,552
Vehicle lease rent	1,223,580	1,236,207
Repairs and maintenance	2,096,607	1,600,087
Travelling and conveyance	2,392,952	3,416,720
Professional charges	13,462,352	7,752,284
Printing and stationary	1,278,838	757,499
Bad debts written off	281,672	0
General expenses	12,028,161	6,251,877
Auditors remuneration	340,000	180,000
Preliminary expenses written off	28,203	28,203
Share issue expenses written off	4,098,520	245,850
Y2K expenses	2,500,000	0
	57,764,293	**35,629,549**
Schedule "N"		
Selling and Distribution Expenses		
Business Promotion Expenses	1,939,921	3,138,758
Advertising Expenses	4,425,862	3,206,556
Commission on sales	1,727,459	2,409,155
Marketing Expenses	9,897,600	0
	17,990,842	**8,754,469**

Flexibility Mapping : Practitioner's Perspective

1. What types of flexibilities you see in the practical situation of "*Measuring Corporate Performance*" on the following points:
   - Flexibility in terms of *"options"*
   - Flexibility in terms of *"change mechanisms"*
   - Flexbility in terms of *"freedom of choice"* to participating actors.
2. Identify and describe the types of flexibilities that are relevant for your own organizational context? On which dimensions, flexibility should be enhanced?
3. Try to map your own organization on following continua. (Please tick mark in the appropriate box(es)).

Useof EVA

Operational ☐ ☐ ☐ ☐ ☐ Strategic

Measure of Performance

Quantitative ☐ ☐ ☐ ☐ ☐ Qualitative

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of "*Measuring Corporate Performance*".

Reflecting Applicability in Real Life

1. Based on this paper, how will you select a suitable measure of corporate performance?
2. Estimate EVA for your own organization for different types of decision-making and assess the flexibility it offers.

Methodology and Models

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A Flexible Approach for Prioritization in Product Development Process

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Abstract

Integrated Product Development is the twenty-first century response to global competitiveness. Given the customer awareness and competition, if we don't deliver a quality product fast at least cost to our customer, somebody else will. In such a scenario, it is imperative to sustain the company's growth that we keep on improving the products. However, it is impossible to attack every problem given the limited resources.

In this paper, we propose a flexible approach for prioritization in the product development process. The approach is illustrated by a case study.

Keywords: goal programming, integrated product development, interrelationship digraph, prioritization

Introduction

The twenty-first century's response to the competitive conditions of the world market is integrated product development (IPD). If IPD is so much of strategic importance to corporations, then there is a need to evolve a robust IPD strategy. The development of IPD strategy is not easy. The integrated product development is an integration of issues ranging from design, manufacturing, assembly through disposal in the product development life cycle. Therefore, we need to consider the interactions of various strategies involved. Figure 1 shows the feasible set for developing IPD strategy. This strategy has to be modified based on the feedback from various stages of product development as shown in Figure 2.

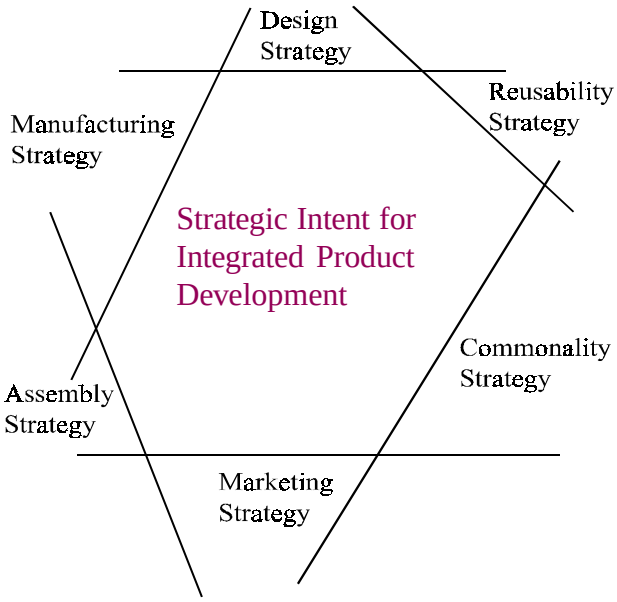

Figure 1: Organization's Strategic Intent for Integrated Product Development

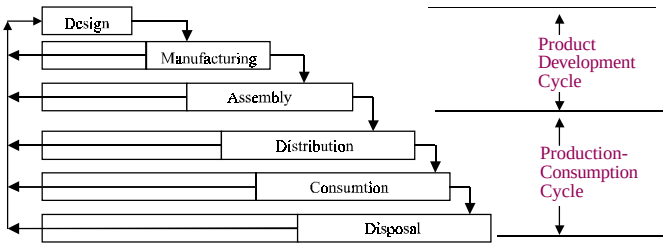

Figure 2: Product Life Cycle

What is then required is to simultaneously consider the requirements of assembly and manufacturing with design requirements in order to reduce unit cost of production, improve quality and reduce total lead time. A broader view of product development process involves managing the mutual dependencies between all stages of the product life cycle, whether in design, manufacturing, distribution, support, or disposal. In that case, the aim is to minimize life cycle costs, maximize customer satisfaction, minimize total product quality loss, maximize flexibility, and minimize lead times from product concept to customer delivery. A simultaneous

consideration of these issues requires the integration of decision-making in the design process with those of manufacturing and all other stages in the product life cycle.

In addition to stages of the product life cycle, the product development process must concern itself with other orthogonal considerations which impact on the environment within which it operates and which impact significantly on its chances for success. These dimensions of product development include the people involved, the information infrastructure, the management and control system, the engineering issues, the business issues, and the tools available to support product development process. Only by carefully managing each of these, as well as their interactions, can a successful product development strategy and process be achieved.

The traditional fragmented, specialized design process leads inevitably to sub-optimization — the optimal design of sub-systems rather than the optimization of the complete system or product. Such sub-optimized products will not be competitive with products optimized simultaneously for manufacturability, assemblability, supportability and disposability. What will eventually happen under these circumstances is that the present global marketplace for those manufactured products will tend to eliminate such inefficient producers.

Integrated product development is an integration of a lot of issues ranging from design, manufacturing, assembly and all the way to disposal in the product development life cycle. Therefore, we need to consider the interactions of various strategies involved.

The present paper is a step towards understanding the issues of integrated product development process. This will then eventually help develop IPD strategies. The focus is on a major element of the IPD process, the prioritization process and the flexibility needed in the prioritization process for integrated product development.

Flexibility in Prioritization for Product Development Process

A successful product development process cannot be achieved without a proper focus and prioritization. Every company has to decide the areas of weakness and concentrate on it for improvement. Prioritization is one of the key inputs for the successful Product Development (PD) process. It is always necessary, even for organizations that are devoted primarily to small projects because talented business and technical resources are always scarce compared to demand. Prioritization is a management decision, which has to be taken at early stages of PD. At early stages of PD, information required for prioritization is very uncertain and in many cases that promotes the idea of taking decision just on gut feeling.

Another important dimension in prioritization decision is added by organizational politics. Using only politics to "solve" prioritization problem often results in failures and unnecessary delays. Politics is almost always a factor in prioritization decisions, however it need not to be the only or most important factor.

For this research, priority is defined as the relative urgency of a system compared to other system in order to develop and launch a successful product. Priorities are relative within organization at which a product is owned, developed and managed. Systems at any level in product compete for resources. Therefore, conflict is inherent in prioritization. Rather than allowing politics and gut feeling to solve priority conflicts, they should be resolved on the basis of perceived value to the organization, customer and society. This requires a framework for decision-making that includes process and solution methodologies.

There are several tools/methodologies/techniques available in literature for prioritization. Examples of subjective techniques are Pareto Analysis or 80-20 rule, analysis based on criticality, prioritization matrix, full analytical criteria method and interrelationship digraphs. Some more mathematical techniques are AHP, goal programming and other multi-criteria decision-making methods. These techniques need to be adapted and integrated for prioritization of systems in PD. Thus there exists flexibility in the selection of tools and techniques. A flexible approach will lead to a proper integration of quantitative and qualitative techniques to suit the decision of prioritization.

Different criteria for prioritization will give different conclusions. For example, in identifying priority systems for PD, warranty may be one criterion and we can identify significant systems based on warranty. Another criterion may be customer satisfaction and significant systems based on this will be different. The real challenge is how do we decide the final list of priority systems, which are based on considerations of all the relevant factors. There are three important decisions to be taken here:

- First, relevant criteria/factors for prioritization need to be defined
- Second, for each criterion significant few need to be identified
- Third, a final list of priority systems need to be developed

These three decisions need not to be taken separately, for example, Goal Programming and Analytic Hierarchy Process (AHP) combines second and third. There may be more sub decisions to be taken depending upon what method we use. One way to simplify the list of criteria and sub-criteria to reach a workable list would be using the Interrelationship Digraph (ID). This paper provides an integrated and flexible approach for prioritization work in Product Development based on Interrelationship Digraphs and Goal Programming.

The approach will be illustrated with the help of an Automotive Product Development example. Next section provides brief introduction to Interrelationship Digraphs and Goal Programming.

Interrelationship Digraph (ID)

Interrelationship digraph is a systematic technique to identify, analyze, and classify the cause and effect relationships that exist among all critical issues so that key drivers or outcomes can become the heart of an effective solution (GOAL/QPC, 1994). It is a team-oriented approach that encourages team members to think in multiple directions. It allows the key issues to emerge naturally rather than allowing the issues to be forced by a dominant team member. The following seven steps describe the approach:

1. Agree on the issue/problem statement
2. Assemble the right team
3. List and layout all the ideas/issues that are important for the problem
4. Look for cause/influence relationships between all of the ideas and draw relationship arrows. Ask for each combination:
   (a) Is there a cause/influence relationship?
   (b) If yes, which direction of cause/influence is stronger?
5. Review and revise the first round ID based on additional input
6. Tally the number of outgoing and incoming arrows and select key items for further analyses
7. Draw the final ID.

Figure 3 shows a typical ID. A high number of outgoing arrows indicates an item that is a root cause or driver. A high number of incoming arrows indicates an item that is a key outcome. This analysis is subjective in nature and team approach is very important for the success of this approach. Issues with close tallies must be reviewed carefully but in the end, it is a judgement call, not science.

In IPD, the aim is to minimize life cycle costs, maximize customer satisfaction, minimize total product quality loss, maximize flexibility, and minimize lead times from product concept to customer delivery.

Goal Programming

Goal programming (GP) is an efficient and effective tool for modelling the solution and analysis of mathematical models that involve multiple and conflicting goals and objectives. It provides the flexibility of resolving the conflicts, bringing the aspirations of the decision-makers upfront in the decision-making process. Many researchers have applied goal programming to solve design, development, and planning problems with conflicting objectives (Singh 1983 and 1989, Tachikawa and Hitomi 1988). In general, goal programming can be applied to model situations for which:

- objectives can be expressed as desired goals,
- attainment of these goals depends on the values of decision variables,
- the decision variables are constrained by a series of relationships, and
- the decision-maker has made some subjective judgment concerning the relative importance or priorities for these goals.

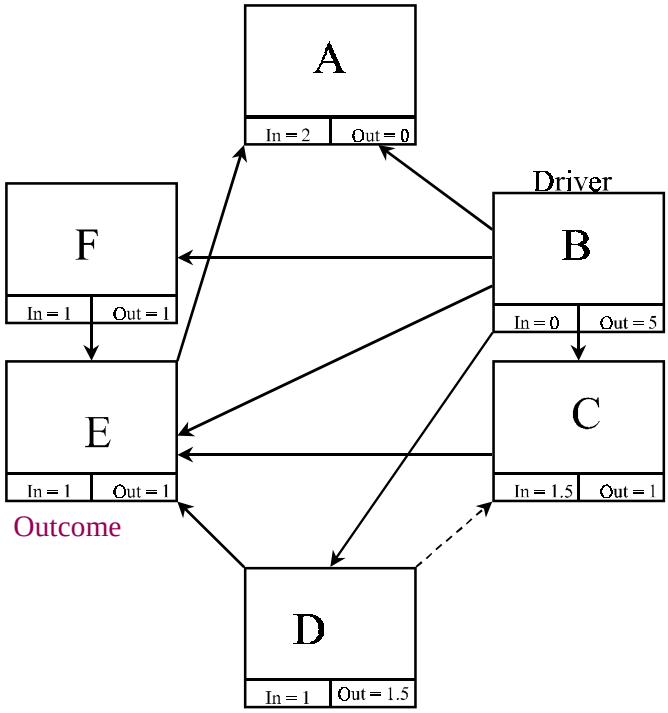

Figure 3: Interrelationship Digraph

Goal programming optimizes multiple objectives simultaneously by setting a goal for each objective and determining its priority. Priorities may be preemptive or weighted; with preemptive priorities we get a lexicographic minimum. The general GP model can be developed as given in Appendix I (Kornbluth, 1973).

The objective function (equation 1) to be minimized is the weighted sum of deviations from the ideal or best-expected values for all objectives. Equation (2) represents the goal constraints for all of the objectives. All objectives should be expressed as a function of controllable decision parameters. Equations (3), (4), and (5) represent the other organizational or market constraints. Equation (6) is a non-negativity constraint.

Figure 4 shows the process of integrated flexible approach for prioritization using ID and Goal Programming. This process and techniques imbedded into this process will

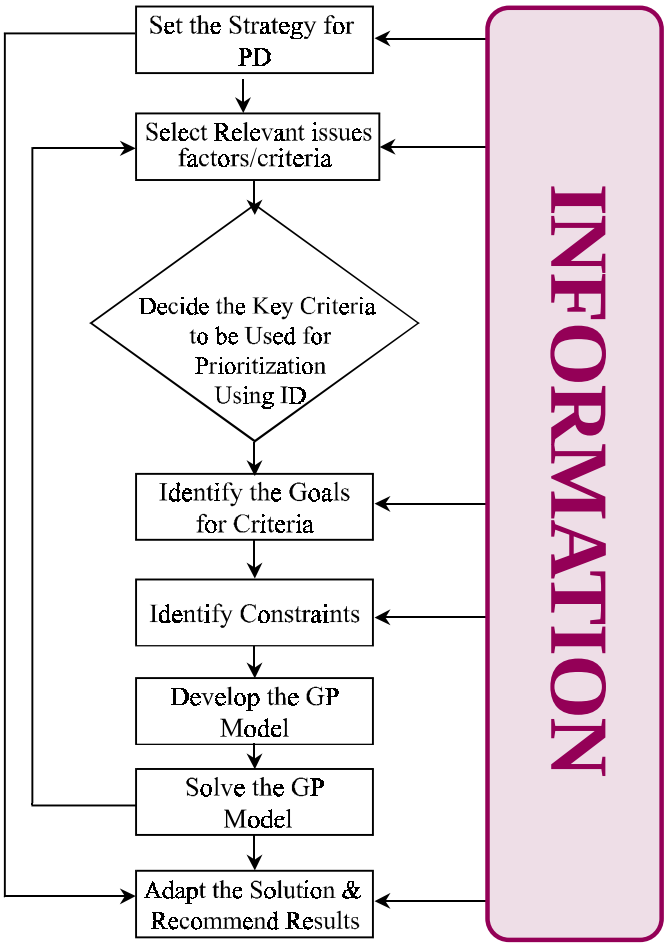

Figure 4: Integrated Flexible Process for Priotization in PD

provide a framework to the organizations for prioritization of PD resources. This will avoid failures from prolonged decisions over resource allocation, as it gives a simple mechanism for prioritization. Next we describe a case study of the development of a midsize car by an internationally reputed automotive company.

Rather than allowing politics and gut feeling to solve priority conflicts, they should be resolved on the basis of perceived value to the organization, customer and society.

A Case Study

An internationally reputed automotive company is planning to develop and launch a midsize car, in several markets worldwide. This car will be based on an existing car company is producing in its home country for the last 20 years. The extisting car has been a great success and company has launched a new model of this car every year. For the last five years sales volume of this car has been growing with an average rate of 8% per year. The 2000 Model year sales volume was over 300K. However, there has been only four major design upgrades in the last twenty years. The last design upgrade was only two years back and it represents the latest technologies used by auto manufacturers in this market segment.

The company needs to build its image in new international markets and will use this car as their flagship product. There is extreme competition in the international markets and therefore, it has to be launched as soon as possible with minimum PD cost. Based on the latest international treaty on green house effect, engine of this car will need some modifications to meet new emission standards. In recent years, company's sales volume has increased, however its profit margin has declined and its warranty cost is high compared to the competition. Board of Directors has set a corporate imperative for warranty cost and company's CEO is very serious about meeting this imperative and cutting PD cost in order to improve the profit margins.

The company is organized on the basis of product lines in a matrix type of organizational structure. An Executive Vice President of Product Development heads each product line, and reporting to the Vice President are: Vehicle Line Directors and other supporting function Directors (e.g., Quality, Finance, HR, Marketing). Functional directors also reports to the Vice President of their respective function. Vehicle Line Directors have Managers responsible for each major system and important attributes, such as noise, vibration and harshness (NVH), durability and styling.

The above-described scenario can be summarized as higher quality, lower cost, and shorter lead-time demand with limited resources and tougher market constraints. It is a very common scenario for many companies operating in a global competitive environment. One of the very important decision in this situation is prioritization and focusing all the efforts and energy on high value items. Integrated flexible approach for prioritization using ID and Goal Programming described earlier in this paper will be used for selecting the systems and their level of improvement for this case study.

Following factors were identified as important for the case of midsize car project:

1. Product Quality
2. Warranty
3. Things Gone Wrong (TGW)
4. Things Gone Right (TGR)
5. Number of Repairs
6. Profit Margin
7. Customer Satisfaction
8. Resources
9. PD Lead Time
10. Brand Image
11. Market Share

All of these factors were used in developing Interrelationship Digraph as shown in Figure 5.

- Major improvement
- Significant improvement

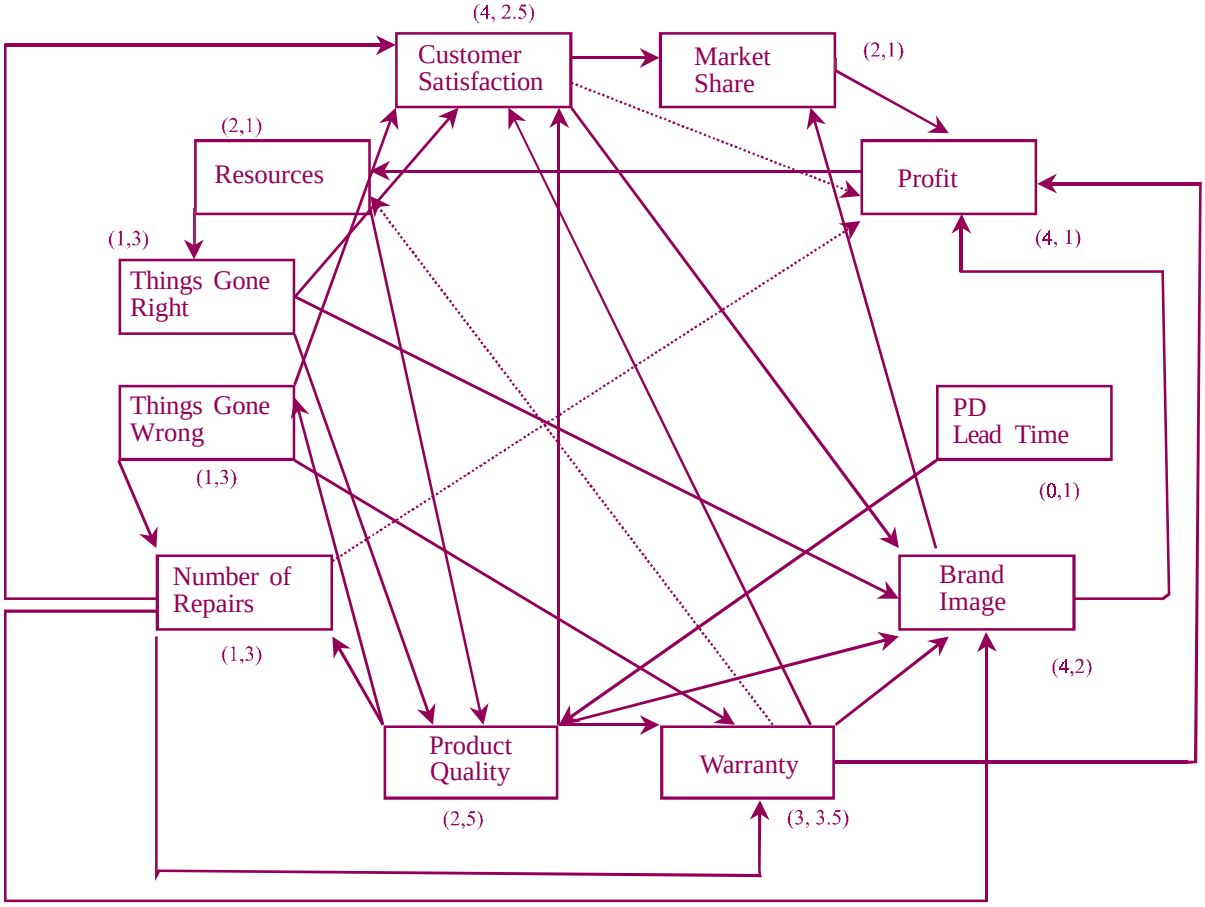

Figure 5 : ID for Case Study

Analysis of the case ID indicates that quality, customer satisfaction and warranty are the most important factors for this project. We also looked at what factors influence quality and warranty. We find that TGW, number of repairs, resources, and lead-time have influence over quality and warranty. We will consider all these influencing factors, customer satisfaction and warranty in constructing Goal Programming model for prioritization. Since quality is subjective, we considered only the factors influencing it rather than quality itself as a factor.

We will consider car consisting of 18 systems listed in Table 1. Each of the 18 systems is considered a separate entity from the product development point of view and is headed by a supervisor. Our objective is to decide what level of improvement we should be doing in each of these systems so that we can meet all the goals as closely as possible. We will consider following four levels of improvement for each system.

- No improvement (carry over system)
- Minor improvement

Table 1 shows the historical data for all the systems based on one year in service (1YIS) performance. TGW, repairs and warranty shows the negative side of quality and lesser the number better it is. Customer satisfaction is rated on a 1 to 5 scale, 1 indicates complete dissatisfaction and 5 indicates complete satisfaction or a thrilled customer. Market Position (MP) indicates where we stand relative to the competition: 1 indicates being leader, 3 shows a bad reputation and 2 means somewhere between the two extremes. Table 2 lists the information related to efforts and time required for improvement and Customer Desirability Index (CDI) for each system. CDI shows how much customer care about that particular system. CDI and efforts both are based on 1 to 20 scale. Time is given on a 1 to 3 scale: 3 indicates a long-term project and any significant improvement cannot be achieved within one program timing. Two indicates that significant improvement can be achieved within one program timing. One indicates that the system can be significantly improved in a relatively shorter time period.

Table 1: Historical Information based on 1 YIS

System	TGW (per 1000)	Repairs (per 1000)	Warranty per Unit	Customer Satisfaction	Market Position
1. Braking System	75	100	5	3	2
2. Chassis	25	39	2	2	2
3. Climate Control	100	90	6	4	1
4. Electrical System	40	50	3	3	2
5. Engine	100	125	18	3	2
6. Entertainment	25	20	1	5	2
7. Glass	20	50	1.5	5	1
8. Instruments	60	125	4.5	4	2
9. Interior Trim	100	85	3.5	2	3
10. Instrument Panel	50	60	3.5	2	2
11. Lighting System	30	45	1	3	2
12. Paint Appearance	120	90	1	4	1
13. Restraints	30	20	0.5	3	2
14. Seating	45	25	1	2	3
15. Sheet Metal	105	75	5	4	1
16. Steering	35	90	6	2	3
17. Transmission	100	145	25	1	3
18. Wiper	45	70	0.5	3	2
Total	**1105**	**1304**	**88**	**55**	

Table 2: Relative Efforts, Time and Customer Desirability

System	Efforts	Time	CDI
1. Braking System	10	2	20
2. Chassis	20	3	16
3. Climate Control	8	2	9
4. Electrical System	8	1	8
5. Engine	20	3	20
6. Entertainment	2	1	4
7. Glass	2	3	8
8. Instruments	5	1	12
9. Interior Trim	5	1	9
10. Instrument Panel	5	2	9
11. Lighting System	5	1	16
12. Paint Appearance	15	3	10
13. Restraints	6	2	18
14. Seating	8	1	12
15. Sheet Metal	12	3	10
16. Steering	18	2	17
17. Transmission	17	3	18
18. Wiper	2	1	8

In addition to the information given in the tables we also need to know organizational constraints, availability of resources and corporate imperatives for TGW warranty and repairs. This additional information is given as follows:

Resources = 200 man months

Corporate imperative for TGW = 500 IPTV (incidents per thousand vehicles) for 12 months in service (12 MIS)

Corporate imperative for repairs = 700 IPTV for 12 MIS

Corporate imperative for warranty = $ 45 per unit sold

Corporate imperative for customer satisfaction = 75 (total of 18 systems based on an 0-10 scale for each system)

Any system with CDI greater than 15 needs at least minor improvement

Systems with market position 3 should have major or significant improvement

Systems with time '3' should not be selected for significant improvement

For resource calculations, we will multiply level of improvement by efforts required for improvement. We will use a scale of 0,1, 2, and 3, to represent four levels of improvement.

Based on the information provided here and general model described in earlier sections we construct a Goal Programming (GP) model. The details of the GP model are given in the Appendix II. Things Gone Wrong, Repairs, Warranty and Customer Satisfaction are considered as objectives.

Solution of GP Model for Case Study

To solve this model, we need to decide the weights for each objective to establish the priorities. To start with, we are assuming all the objectives to be equally important, therefore, we will assume weights as (1.5, 1, 15, 10) respectively for TGW, Warranty, Repairs and Customer Satisfaction. This model was solved using Non-Linear GP techniques with the help of a spreadsheet (Microsoft Excel 7.0) optimization macro (Solver). This Macro solves NLP problems with the GRG (Generalized Reduced Gradient) method as implemented in Lasdon and Waren's GRG2 code (1978, 1992). This method and specific implementation have been proven in use over many years as one of the most robust and reliable approaches to solving NLP problems (Frontline Systems Inc. 1996).

There exists flexibility in the selection of tools and techniques. A flexible approach will lead to a proper integration of quantitative and qualitative techniques to suit the decision of prioritization.

Table 3 summarizes the solution obtained by the integrated approach for prioritization in PD. Solution recommends no changes for 3 systems, for 2 systems it is recommended to have significant changes, and for remaining systems minor and major changes are suggested. Based on the recommended solution it is expected that TGWs will reduce from 1105 to 848, that is a 23 % improvement. On warranty, repairs and customer satisfaction we may expect 26%, 27% and 38% improvements, respectively. For better understanding of this solution we solved the GP Model for different values of resources constraint. Figures 6 and 7 graphically show these results.

Table 3: Prioritization Results Based on Goal Programming Model

System	Improvement	TGW (per 1000)	Repairs (per 1000)	Warranty per Unit	Customer Satisfaction
1. Braking System	Minor	57	76	4	4
2. Chassis	Minor	19	30	2	3
3. Climate Control	Minor	76	68	5	5
4. Electrical System	No (Carry over system)	40	50	3	3
5. Engine	Minor	76	95	14	4
6. Entertainment	Significant	14	11	1	9
7. Glass	Major	13	32	1	8
8. Instruments	Major	39	81	3	6
9. Interior Trim	Major	64	55	2	3
10. Instrument Panel	Minor	38	45	3	3
11. Lighting System	Minor	23	34	1	4
12. Paint Appearance	No (Carry over system)	120	90	1	4
13. Restraints	Minor	23	15	0	4
14. Seating	Major	29	16	1	3
15. Sheet Metal	No (Carry over system)	105	75	5	4
16. Steering	Major	23	58	4	3
17. Transmission	Major	64	93	16	2
18. Wiper	Significant	26	40	0	5
Total		**848**	**965**	**64**	**76**

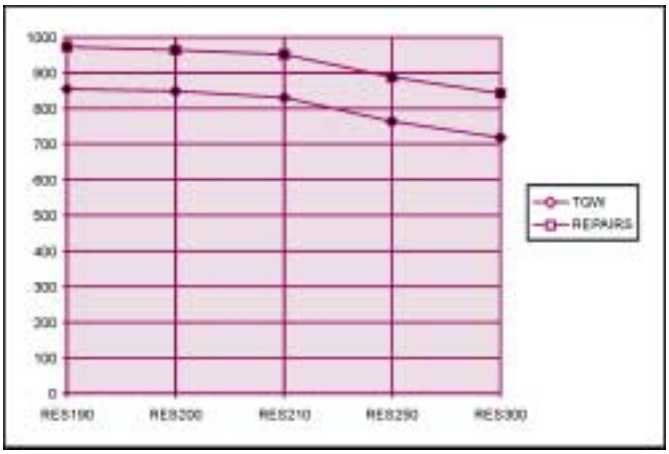

Figure 6 : Expected TGW and Repairs Based on Charges in Resources

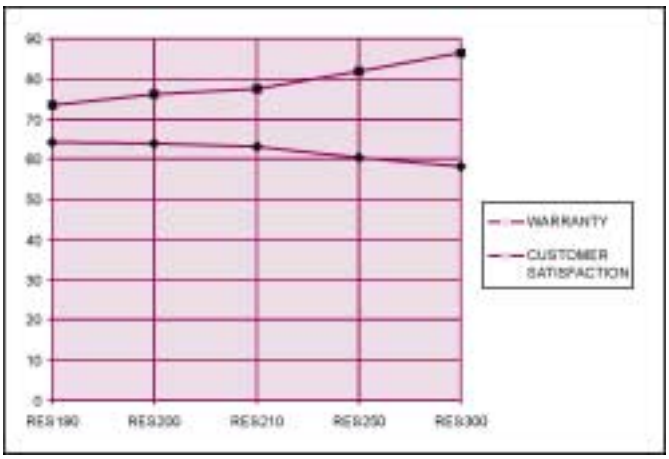

Figure 7 : Expected Warranty and Customer Satisfaction Based on Charges in Resources

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Appendix I : General Goal Programming Model

Minimize Z:

$$Z=\sum_{i=1}^{n}\sum_{j=1}^{m_i} P_i\{W_{ij}d_{ij}^{+}+W_{ij}d_{ij}^{-}\} \qquad (1)$$

Subject to :

$$f_{ij}(x_1,\ldots x_k,\ldots x_p)-d_{ij}^{+}+d_{ij}^{-}=G_{ij} \qquad \forall i \ \ and\ j \qquad (2)$$

$$\psi_{ij}(x_1,\ldots x_k,\ldots x_p)\geq a_{ij} \qquad \forall i \ \ and\ j \qquad (3)$$

$$\xi_{ij}(x_1,\ldots x_k,\ldots x_p)\leq b_{ij} \qquad \forall i \ \ and\ j \qquad (4)$$

$$\zeta_{ij}(x_1,\ldots x_k,\ldots x_p)=c_{ij} \qquad \forall i \ \ and\ j \qquad (5)$$

$$x_1,\ldots x_k,\ldots x_p;d_{ij}^{+},d_{ij}^{-}\geq 0 \qquad (6)$$

We have n different products, and each product has m_i distinct objectives to be optimized by deciding the level of p systems. Variables x_k represent the controllable decision parameters for the prioritization problem. G_{ij} is the jth goal of the ith product; d^{-}_{ij} and d^{+}_{ij} represent under- and over-achievement of the corresponding goals. P_i represents the priority for the ith product. W_{ij} is the weight associated with over-or under-achievement of G_{ij}.

Appendix II: Goal Programming Model for the Case Study

Based on the information available for the case study and general model described in Appendix I we constructed a Goal Programming (GP) model. The GP model will consider following factors as objectives:

Things Gone Wrong

Repairs

Warranty

Customer Satisfaction

Objective of the GP model is to minimize the weighted sum of the deviations from the Goals (Corporate Imperatives) of these factors. GP Model objective is represented by Equation (7). Equations (8) to (16) represent various constraints of the model.

$$Z = M_T(d_T^+ - d_T^-) + M_R(d_R^+ - d_R^-) + M_W(d_W^+ - d_W^-) + M_C(d_C^- - d_C^+) \quad (7)$$

Subject to:

$$\sum_{i=1}^{n}\left(\frac{T_i}{(S_i+1)^{0.4}}\right) - d_T^+ + d_T^- = G_T \quad (8)$$

$$\sum_{i=1}^{n}\left(\frac{R_i}{(S_i+1)^{0.4}}\right) - d_R^+ + d_R^- = G_R \quad (9)$$

$$\sum_{i=1}^{n}\left(\frac{W_i}{(S_i+1)^{0.4}}\right) - d_W^+ + d_W^- = G_W \quad (10)$$

$$\sum_{i=1}^{n} C_i(S_i+1)^{0.4} - d_C^+ + d_C^- = G_C \quad (11)$$

$$\sum_{i=1}^{n} S_i E_i \le U_E \quad (12)$$

$$S_i \le 3 \quad \forall i \quad (13)$$

$$S_j \ge 1 \qquad for\ CDI \ge 15 \quad (14)$$

$$S_k \ge 2 \qquad for\ MP = 3 \quad (15)$$

$$S_l \le 2 \qquad for\ Time = 3 \quad (16)$$

$$S_i, d_T^+, d_T^-, d_W^+, d_W^-, d_R^+, d_R^-, d_C^+, d_C^- \ge 0 \text{ and } S_i \text{ are integer}$$

where:

S_i = Decision variable indicating level of improvement selected for i^{th} system

n = Number of systems in our case it is 18

M_T, $M_{R,\ MW}$, and M_C = Weights to represent the priority of respective objective

T_i = Things Gone Wrong for i^{th} system, values are given in Table 1

G_T = Things Gone Wrong (TGW) Goal, in our case it is 500

R_i = Repairs for i^{th} system, values are given in Table 1

G_R = Repair Goal in our case it is 700

W_i = Warranty Cost for i^{th} system values are given in Table 1

G_W = Warranty Cost Goal, in our case it is 45

C_i = Customer Satisfaction, for i^{th} system values are given in Table 1

G_C = Customer Satisfaction Improvement Goal, in our case it is 25

E_i = Efforts for i^{th} system, values are given in Table 2

U_E = Upper Limit of Efforts, in our case it is 150

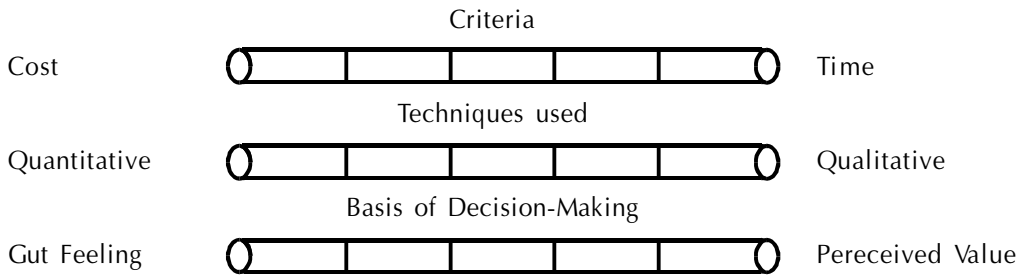
$d_T^+, d_T^-, d_W^+, d_W^-, d_R^+, d_R^-, d_C^+, d_C^-$ = Over and under achievement of respective goals

i, j, k, l = Indexes for decision variable on level of improvement

Equations (8) to (11) represent the four objective functions, adjusted with deviations and equated to their respective goals. Equation (8) is for Things Gone Wrong and it assumes that with minor improvements we can reduce TGWs by 24%, with major improvements TGWs can be reduced by 36% and with significant improvements these can be reduced by 43%. Similar improvements are assumed for warranty, and repair. Improvements for customer satisfaction are assumed to be 32%, 55% and 74% respectively for minor, major and significant changes. Equation (12) ensures the constraint of available resources and Equation (13) ensures the proper selection of the level of improvement. Equation (14) ensures that any system with CDI more than 15 will have at least minor improvement. Equation (15) ensures that systems with market position '3' will have major or significant improvement. Equation (16) ensures that systems with time '3' will not be selected for significant improvement. In the end, we have stated the non-negativity constraint for all the variables and integer constraint for S_i.

Flexibility Mapping : Practitioner's Perspective

1. What types of flexibilities you see in the practical situation of *"Intergrated Product Development Strategy"* on the following points:
   - Flexibility in terms of *"options"*
   - Flexibility in terms of *"change mechanisms"*
   - Flexbility in terms of *"freedom of choice"* to participating actors.
2. Identify and describe the types of flexibilities that are relevant for Product Development Stategy for your own organizational context? On which dimensions, flexibility should be enhanced?
3. Try to map your own organization's product development strategy on following continua. (Please tick mark in the appropriate box(es)).



4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Intergrated Product Development Strategy"*.

Reflecting Applicability in Real Life

1. Identitify important factors in Intergrated Product Development Strategy of your organization and develop an Interrelationship digraph.
2. Develop a flexible methodology for Intergrated Product Development Strategy of your organization based on this paper.

Case Study

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Incorporating Flexibility in Manufacturing and Operations – A Case Study in the Indian Context

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Abstract

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

Keywords: automation, computerization, flexible manufacturing systems, flexible manufacturing technology, organization, production, strategic factors

Introduction

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

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

The manufacturing sector, which is–and is likely to remain–the core of any economic activity, is no exception and changes have taken place in this sector also, characterized by the concept and evolution of advancements in manufacturing technologies. The flexible manufacturing technology (FMT), incorporating the flexible manufacturing systems (FMSs) as its major constituents, is one of these. Other elements constituting the FMT are: CNC machine tools, robots, transfer mechanisms, automated guided vehicles (AGVs), automated storage and retrieval systems (ASRSs), computer-aided design and computer-aided manufacturing (CAD/CAM) systems, flexible manufacturing cells (FMCs), and general flexible manufacturing systems (GFMSs). When these physical elements of FMT are completely integrated using computers and different networks, they result in computer-integrated manufacturing (CIM) systems, which are considered to be quite complex and highly advanced manufacturing facilities. The state of diffusion and level of operations of the elements of these advanced manufacturing

systems in various countries have been reported by different authors (Margirier 1986, De Meyer et al 1987, Ranta and Tchijov 1990, Roller and Tombak 1991, Carlsson 1992, Hill 1995, Upton 1995, Sharma and Sharma 1997). In India, the earliest recorded adoption of flexibility in manufacturing is credited to the Rail Coach Factory (RCF), Kapurthala, Punjab in 1987 and the first unit of FMS was installed at the Heavy Alloy Penetrator Project (HAPP) at Tiruchirappalli in South India, around 1989. A part of the supply and installation of equipment for this project was undertaken by the CIM Division of Hindustan Machine Tools Limited (HMT), a Government of India undertaking. However, both these units were set up by the Government of India, meaning thereby that Indian manufacturers in the private sector did not evince much interest in FMSs around this point of time. This was due not only to the high capital investment incumbent upon these systems, but also because they did not feel threatened. But after the advent of globalization of the Indian economy in 1991, a number of flexible manufacturing cells have been set up by manufacturers in different parts of the country. The author has attempted to study the current and the likely future pattern and mode of diffusion of FMT in Indian industry (with a focus on the automobile and the engineering sectors) and the paper is a part of this exhaustive study. The research effort covered several aspects and employed the methodologies of the Empirical Study or the Questionnaire Method (to explore the current state and practices); the Delphi Methodology (to generate the likely future scenario); the System Dynamics (SD) Modelling (to construct a mathematical model to predict the future behaviour of the static and dynamic systems involved); and the Case Studies (to explore in-depth the actual operating modes and experiences of the users of FMT in varying degrees, i.e. from those utilising bare essentials to those incorporating fully operative FMSs in their manufacturing units).

In the manufacturing sector, which is – and is likely to remain – the core of any economic activity, revolutionary changes have taken place characterized by the concept and evolution of flexible manufacturing technology (FMT).

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

The focus of this exercise has been to find out:

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

The four companies studied for the purpose were: New Holland Tractors, located at Greater Noida, U.P. in Northern India; Tata Engineering and Locomotive Company Limited (TELCO), located at Pune, Maharashtra in Western India; Rail Coach Factory (RCF), Kapurthala, Punjab, in Northern India; and Bharat Heavy Electricals Limited Limited (BHEL), having its manufacturing plants at 14 locations in different parts of India. But due to the space limitations, only the case of BHEL is presented in this paper. This organization, which is the largest heavy engineering company under the public sector operating in India, was selected for conducting a case study because it incorporates features which are unique in many ways.

Methodology Used

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

Historical Background of BHEL

Incorporated as Heavy Electricals (Pvt.) Limited in August 1956, the first unit was established at Bhopal, in Central India, to manufacture electrical equipment required for generation, transmission and utilization of electrical power. The Bhopal unit was inaugurated by the then Prime Minister of India, Late Pandit Jawahar Lal Nehru on 6th November, 1960 and the name of the company was changed to Heavy Electricals (India) Limited during 1961. Subsequently three more plants, one each at Hardwar (North India), Hyderabad (South India) and Tiruchirapalli (South India), were set up under the control of another company, Bharat Heavy Electricals Limited (BHEL). The plant at Hardwar is known as Heavy Electrical Equipment Plant, which was built in technical collaboration with erstwhile USSR (now called the Confederation of Independent Soviet States or the CIS states). The plant at Hyderabad is known as Heavy Power Equipment Plant and was built in the collaboration with Czechoslovakia (now

called the Czech states). The plant at Trichy is called High Pressure Boiler Plant and was also built in collaboration with Czechoslovakia.

The operation of all these four plants was integrated from July 1972 and Heavy Electricals (India) Limited formally merged with Bharat Heavy Electricals Limited (BHEL) in 1974, thus consolidating the activities of the two companies into a single corporate entity.

The Company Profile

Today, BHEL is one of the largest engineering and manufacturing enterprises in India and is one of the leading international companies in the field of power. With a gross annual turnover (1998-99) of INR 70 billion and a work force of 62,500, out of which over 11,000 are highly qualified engineers, BHEL has 14 manufacturing units located all over India. Bangalore has three units, Hardwar and Trichy two units each, and Bhopal, Goindwal, Hyderabad, Jagdishpur, Jhansi, Ranipet and Rudrapur have one unit each of these manufacturing facilities. The company has four power sector regional centers located at New Delhi (Northern Region), Kolkata (Eastern Region), Nagpur (Western Region) and Chennai (Southern Region). It also has nine service centres, located one each at Bangalore, Baroda, Kolkata, Chandigarh, Secunderabad, New Delhi, Nagpur, Patna, and Varanasi.

The BHEL units are decentralized, independent, and the bureaucratic structure of work-organization is almost non-existent. Flexibility, rather than red-tapism is the norm in day-to-day working.

The Product Range

BHEL offers a wide range of 180 products, under 30 major groups, for core sectors like power transmission, industry, transportation, oil and gas, and telecommunications. It also provides non-conventional energy systems and has diversified into defence and civil aviation as described below.

In the power generation sector, BHEL manufactures a wide range of products and systems for thermal, nuclear, gas and hydro based power plants. In the thermal sector, the company supplied generation sets up to 500 MW capacity, with over 245 sets already in operation. In the nuclear sector, it has supplied sets up to 235 MW with 500 MW sets under manufacture and in the gas sector, it has supplied up to 150 MW capacity. Its maximum contribution is in the hydro sector where the maximum size supplied by it is 165 MW and over 370 sets are already in operation. In this category, 250 MW units are under construction.

In the power transmission sector, high voltage direct current (HVDC) technology has been pioneered in India by BHEL. It also manufactures a vast range of transformers, instrument transformers, thyristor valves, and associated control equipment.

In the industrial equipment sector, BHEL has supplied a wide variety of electrical, electronic and mechanical equipment to a host of industries, viz. fertilisers, petro-chemicals, refineries, coal, steel, aluminium, paper, sugar, rubber, cement and mining.

In the transportation sector, the company has made rapid strides. Today, over 66% of the Indian Railways, one of the largest railways networks in the world, is equipped with traction equipment by BHEL. India's first underground metro at Kolkata is equipped with BHEL drives and controls. Other products in the sector include traction generators/ alternators, transformers, sub-station equipment, vacuum circuit breakers, locomotive bogies, smoothing tractors, exciters, converters, inverters, choppers, brake and door equipment and electronic controls. BHEL has manufactured and supplied AC and AC-DC locomotives ranging from 3900 HP to 4700 HP to the Indian Railways and diesel electric locomotives ranging from 350 HP to 2600 HP to cement, steel and fertilizer plants, coal fields, ports and other medium and large industries. The BHEL is, thus, a leading locomotive manufacturer in the country.

In the area of oil and gas, BHEL has designed, manufactured and serviced various types of on-shore deep drilling rigs, super-deep drilling rigs, heli rigs, work-over rigs, mobile rigs and desert rigs with matching draw works and hoisting equipment. Christmas tree valves and well-head assemblies (up to 10,000 psi) are other vital products supplied.

Telecommunication is another area where BHEL has made significant contributions by way of manufacturing electronic private automatic branch exchanges (PABXs) and rural automatic exchanges (RAXs) for India.

In non-conventional energy, BHEL has contributed by way of manufacturing equipment like solar water heating systems, solar photo-voltaic systems and wind electric generators.

Technology Source for Major BHEL Products

BHEL acquires technology for its products from companies based in Canada, the Confederation of Independent States (CIS) countries, France, Germany, Italy, Sweden, Switzerland, UK, and USA.

BHEL has two pronged technology strategy: one is acquiring technology and making products out of it through licensing; secondly, to develop its own technology also. Both these are done simultaneously with a thrust on the former through transfer of technology. Since the products are highly sophisticated, reverse engineering is not feasible.

Table 1 shows other details of the products for which technologies are acquired, and the countries from which acquired

Research and Development

BHEL is amongst the highest investors in Research and Development in the country with a highly talented and experienced team of engineers and scientists engaged in R&D activities as well at all its manufacturing units. The R&D efforts have made significant contributions to almost all areas of operation of BHEL; a few among them are: atmospheric bubbling fluidized bed combustion (FBC) boiler up to 100 tonne/hr, direct ignition of pulverized coal (DIPC), ceramic liners for abrasion resistance application in thermal power plants, wear resistant castings for hydro turbines and many more accomplishments in the field of non-conventional energy, AC-DC locomotives, microprocessor-based controls, switch-gears, and superconductors.

Table 1: Technology Source for Major BHEL Products

Country	Products
Canada	Francis Hydro Turbines
CIS Countries	Thermal, Hydro Sets, and Motors
France	Tube Mills, Castings and Forgings, 400 kV Transformers and Shunt Reactors, Pelton type Hydraulic Turbines
Germany	Steam Turbines, Generators and Condensers, Vacuum Circuit Breakers, Electrical Motors, Electronic Automation System for Steam Turbines and Generators, Camshaft Controllers and Traction Current Control Unit, Large Size Gas Turbines, Moisture Separator Reheaters, Dry Type Transformers, Fans for Power Stations and Industrial Applications
Italy	Centrifugal Compressors
Japan	Reversible Pump Turbines
Sweden	High Voltage Direct Current Systems, Electrostatic Precipitators
Switzerland	Bypass and Pressure Reducing Systems, Programmable Systems
UK	Boiler Feed Pumps, CW Pumps, Condensate Extraction Pumps
USA	Gas Turbines, AC Variable Control Devices, Christmas Trees and Well-head Assemblies, Steam Generating Equipment for Industrial and Utility Purposes and Coal Pulverisers, Waste Heat Boilers, Masts and Substructures

Core Competence

Design and manufacturing of heavy electrical machinery and high grade and highly accurate machining capabilities constitute the core competence of BHEL. Accuracy levels of 5 to 10 microns are being achieved at BHEL, which no one else in the industry is achieving currently. Further, the components and products made by the company are truly of a world-class quality and standards, with the focus on generators and turbines and a niche strategy in the segments of motors and switch gears.

Competitive Edge and Technological Leadership

The company's competitive edge lies in its capacity to produce heavy electrical machinery, generators, turbines and turbine blades conforming to the highest international standards at globally competitive prices. The company is a leader in the area of providing technology for these and other products, which include non-conventional energy systems, traction equipment, electric locomotive engines and bogies for railways and seamless pipes.

Integration

BHEL is more of a vertically integrated company with a captive foundry and forge plant, seamless steel type plant, and specialized facilities for 800 kV transformers are also being established. As almost all products are customized, horizontal integration is practically non-existent and is not envisaged in the near future.

Corporate Vision, Mission and Values

The vision is to be, and remain, a world-class, innovative, competitive and profitable engineering enterprise providing total business solutions. The mission is to be the leading Indian engineering enterprise providing quality products, systems and services in the field of energy, transportation, industry, infrastructure and other potential areas.

The values are: meeting commitments made to external and internal customers; foster learning, creativity and speed of response; respect for dignity and potential of individuals; loyalty and pride in the company; team playing; zeal to excel, and integrity and fairness in all matters.

Work-Culture and Philosophy

The BHEL philosophy of professional excellence through continuous striving for state-of-the-art technology is embodied by a strong team of 62,500 employees, including over 11,000 highly qualified engineers. Continuous training and re-training, a positive work culture and participative style of management have resulted in the development of a committed and motivated work force, ready to meet the challenges of tomorrow.

Workers' participation at all levels (even at the Board); encouragement to all employees to participate in cultural, sports, educational and other activities; and dedication to excel, coupled with safety habits, are other hallmarks of the BHEL culture.

The BHEL units are decentralized, independent and bureaucratic structure of work organization is almost non-existent. Flexibility, rather than red-tapism is the norm in day-to-day working.

Quality Strategy

The quality strategy at BHEL is to achieve highest international standards of quality at every stage of operation through implementation of quality management systems and procedures in consonance with international standards and practices. This is evidenced through state-of-the-art design and technology adapted from world- renowned collaborators.

BHEL has an independent corporate quality department at its corporate office in New Delhi and all its 14 plants are ISO-rated (ISO 9002 and ISO 9004). The first ISO certification for a few of its plants was acquired in 1989 and now even some of its offices are ISO-rated.

Global Presence and Joint Ventures

The presence of BHEL products and services extends to over 50 countries spread over all the five continents. Export orders range from individual products to complete power stations on turnkey basis, operation and maintenance, retrofitting and refurbishing, including life expectancy studies as well as training of manpower. This also includes consultancy services for establishing manufacturing units. BHEL has joint ventures with General Electric and Siemens for renovation and modernization of power plants.

Re-training of workers, altering the work culture and laying more stress on maintenance and preventive maintenance were the changes effected after installing FMT equipment.

Vendor Development

As already stated, vertical integration is practically non-existent in BHEL at present, but they have ancillary units in non-core areas of machining and welding of non-critical components. However, the company does have programs to develop vendors and recently a global meeting of about 200 vendors was held at Hardwar.

Manufacturing Strategy and Technologies being Used Currently

The Technology Development laboratory in the corporate research and development centre contributes to the development and application of new manufacturing technologies and processes which chiefly include flexible manufacturing systems (FMSs), automated guided vehicles (AGVs), robotics, automated storage and retrieval systems (ASRSs), computer aided design (CAD), and computer aided manufacturing (CAM). A majority of these are already in operation at several of BHEL's plants.

The manufacturing strategy of BHEL is to acquire more and more advanced machines whereby the productivity can be improved, cycle time reduced, cost of production lowered and the rate of stock removal is enhanced. Spindle speeds of up to 16,000 RPM are being achieved at BHEL. Almost all types of technologies are being used currently with a whole gamut of CNC, general purpose, and special purpose machines.

Integration of IT Elements into the System

With the thrust in the use of computers in the area of materials management, day-to-day working and financial management is also computerized. On the shop floor environment, distributed numerical control (DNC) is extensively used along with the use of computers on individual machines for data collection and integration with the system. Analysis and decision-making is getting more and more computerized with increasing utilization of the Internet. In fact, the company has its own BHEL net and all its manufacturing units and many cells are inter linked through a network of communication on this unit.

Reasons for Adopting FMT

As the company operates in a multi-project system mode, time is a critical factor in its operations. International competition, shorter delivery times, targets and commitments and other internal and external factors propelled adoption of FMT. Flexible manufacturing cells (FMCs) and flexible manufacturing systems (FMSs) were set up to enhance tool cutting and engagement time of the set-up. As a consequence of this, it was experienced that the machines are in the cutting mode for longer time, leading to higher productivity and reduced lead-time. Although the reduction in lead-time is possible by other means also, but the company managers feel that main advantage of FMT is that the idle time is reduced. For example, as the company automated tool changing, tool loading, job changing and job loading, the cutting time increased proportionately because idle time was reduced. A reduction in delivery time and levels of inventory and work in progress (WIP) was also experienced.

Technology-based Future Plans of the Company

BHEL's future plans include upgrading its product engineering and manufacturing technology base by induction of state-of-the-art technologies, upgrading equipment and facilities to maintain quality leadership, absorption of know-how from its international collaborators and integrating them with indigenous developments in its R&D facilities. The company relentlessly pursues higher levels of productivity and exemplary customer service.

Major areas of research and technology development identified for the future are: fluidized bed combustion (FBC) boilers up to 120 MW, sub-critical and super-critical once-through type boilers for ratings of 500 MW and above, 800 kV AC transmission equipment and super conductivity.

In the area of manufacturing, the future plans are to look for ways and means to perform maximum number of operations on a machine using a single set-up. Technology induction will be more in this area and this means more of FMT and other advanced manufacturing technologies, especially those incorporating high to very high cutting speeds and the appropriate tools to withstand these speeds and incumbent forces.

FMT Environment of the Company

BHEL has not only installed almost all major elements of FMT as shown in Table 2, but also is a pioneer in developing in-house, the flexible machining cells (FMCs) and flexible manufacturing systems (FMSs) by integrating its existing fleet of CNC machines and other elements. In this respect, the company is unique among the four companies studied in this work.

The manufacturing strategy of BHEL is to acquire more and more advanced machines to improve productivity, reduce cycle time, reduce cost of production, and to enhance the rate of stock removal.

The company is going for inducting more and more ASRSs of height up to 9 meters in a big way. These are chiefly used for storing steel plates. But the company has experienced that while location and storage of these plates is not a problem, their retrieval has the disadvantage of the whole bin coming out because the stored parts/plates cannot be retrieved individually. The capability of the stacker crates is organic, that is, it can be added, as the structure is built-up and developed in-house.

Just-in-time (JIT) systems are non-existent at BHEL because their critical components come from abroad. Moreover, feels the company, in areas of heavy engineering where raw materials are quite critical, the JIT systems are quite impractical. However, the company has succeeded in reducing its inventory levels from 200 days to 100 days in just 2 to 3 years. This has been achieved by developing ancillaries and doing ABC analysis and improving controls systems.

Table 2: Characteristics of FMT Elements / Systems Installed

Sl. No.	Component currently in use		Type and No. where applicable	Year of Installation or Inception	Cost in Rs. million
1.	Multi functional machining centres and number of tools		28 (all CNCs), with minimum of 8 and maximum of 64 tools with automatic tool changers (ATCs)	First acquired in 1980, added in 1999	4000
2.	NC Machine Tools with Number of tools		4	1975-76	5.0
3.	Robots	Manipulator	25	1981	4.0
		Industrial	04	1984	7.0
		Welding	02	1991	9.0
4.	Automated Storage and Retrieval Systems (ASRSs)		05	1997-98	8.0 per 8 meter of height
5.	Flexible Machining Cells (FMCs)		16	1984	20.0
6.	Flexible Manufacturing Systems (FMSs)		01	1991	Developed in-house

Other notable features of the FMT environment are:

With a total stock of installed machine tools in all its 14 manufacturing units numbering 5000 and costing around INR 13,000 million, the company has practically no conventional machining centres.

The company is engaged in jobbing type of production of heavy engineering products and, as such, the conveyor systems are not much in evidence. Exceptions are its 16 FMCs and one FMS and also its electro-porecilin plants at Jagdishpur and Bangalore, having continuous process lines.

There are more than twenty-five manipulators robots, supplied by Japan, with three or four axes. But real human like robots are four in number, two of which are working at its Hyderabad plant and one each at Bangalore and Hardwar works. These four robots are used chiefly for material handling. A welding robot was acquired in 1991 at a cost of INR 9 million and installed at its Tiruchirapally plant. Another robot is being developed in-house at the corporate R&D centre at Hyderabad, at an estimated cost of INR 6.5 million.

Normally, the automated guided vehicles (AGVs) are used only where the route is well defined and/or where the

component has to move from one machine to another. But at BHEL, the operations are not sequential because being heavy to very heavy, the machines are not laid out in sequence. Out of the two AGVs, one is working in the blade shop at Hardwar while the other is installed at the company's corporate R&D centre at Hyderabad for training and demonstration.

One fully operative flexible manufacturing system (FMS) having multi-machining centers and automated movement of materials is installed at its corporate R&D centre at Hyderabad since 1991. This was developed in-house by integrating CNC machines. The software used is interactive and developed in-house.

In addition, there are 16 flexible manufacturing cells (FMCs), which are flexible manufacturing facilities with single station, where the material is moved from the buffer to the machines through pallets. Once the component to be machined is loaded, all other operations are automated, except unloading of the component.

Out of these 16 FMCs, 4 are installed at Tiruchirapalli, 5 at Hyderabad, 3 at Bhopal and 4 at Hardwar plants. The earliest FMC station was of Mitsubishi, Japan, acquired in 1984.

Almost all the manufacturing units have computer–aided design (CAD) facilities and attempts are underway to make them updated with the latest versions of Auto-CAD.

The most motivating factors behind including FMT equipment by the company have been increasing the productivity with an underlying strategy of maximizing profits through lowering unit costs, followed by the objective of globalization with the underpinning strategy of creating world class facilities to meet the expected targets.

Computer-aided manufacturing per se is not in operation at BHEL, but programs from central computer can be transferred directly to the individual machines through a distributed numerical control (DNC) network. The programs can be downloaded from one workstation to the other.

But on an aggregate level, not all production functions and not every shop is automated. In the next section, other details of this aspect are discussed.

The company is still importing its machinery mainly from Germany, Japan, Switzerland and Italy because no company (not even the Hindustan Machine Tools Ltd., which is one of the few Indian companies manufacturing FMSs) in India manufactures the machines of the size BHEL needs.

The chief consideration in acquiring FMT was to reduce time on the shop floor and reduce work in progress (WIP). Lesser and lesser dependency on human beings is another consideration. Although, the company has no problems on the labour front on this account, but the accuracy level is still a problem. In nutshell, economies of scope are the guiding principle at BHEL.

The company did not face much difficulty in the installation of FMT elements but the maintenance remains a problem. However, re-training of workers, altering the work culture and laying more stress on maintenance and preventive maintenance, were the changes effected after installing FMT equipment.

Since the company inducted FMT only in those areas where the worker fatigue was a problem, the step was rather welcomed by the labour unions, although resistance to change on account of attitudinal aspects was experienced.

The company's FMT system managers have not attempted to measure flexibility of the systems installed because they felt no need to do so. But they have suggested that a system permitting more frequent changes can be rated as more flexible.

The components machined on the FMT set ups are turbine blades, compressors and impellers, which are critical to the company's product range.

Automation/Computerization of Production Functions

The discussions in this section relate to the extent of performing some production functions through automated facilities or modes and non-automated or conventional means on an aggregate basis.

It may be seen from Table 3 that transportation, management of production (including data base management), and transferring parts from conveyance facilities to the machines, are the least automated or computerized. Management information reporting (MIR), and monitoring and management of stock, inventory and wear and tear of the tools, are the most computerized production functions.

Table 3: Automation/Computerization of some Production Functions

Function	Extent of Automation	Extent of Non-Automation
Management of Production	5 %	95 %
Management Information Reporting (MIR)	80 %	20 %
Transportation	Zero %	100 %
Transferring Parts from the Conveyance Facility to Machines	10 %	90 %
Monitoring and Management of the Stock and Wear and Tear of the Tools	80 %	20 %

Division of Task Performance

Table 4 shows the level of operators or technical specialists performing a given task in the FMT and conventional technology environment.

Table 4 : Division of Task Performance; FMT Vs Conventional Technology

Task	Performed by	
	FMT Environment	Conventional Technology Environment
CNC Programming and Minor Adjustments	CNC Programming Groups	
Quality Control	Quality Control Groups, Area wise	The Same Group
Monitoring of Stocks, Tool, Tool Wear etc.	Engineers	Engineers
Loading / Unloading of Parts	Skilled Workers	Skilled Workers
Setting up of Fixtures, Pallets	Skilled Workers	Skilled Workers
Debugging and Tool Pre-setting	Skilled Workers	Skilled Workers
Co-ordinating and Planning	Engineers	Engineers and Supervisors
Production Scheduling	Engineers	Engineers and Supervisors
Supervision of Operators	Engineers	Supervisors
Responding to Un-anticipated deviations from Normal Operations	Highly Experienced Engineers	Engineers
System Development	Engineers	Engineers
Machine Servicing	Engineers and Supervisors	Supervisors and Skilled Workers

However, it may be mentioned here that at BHEL, by and large, the tasks listed in Table 4 are performed by the same groups because even in the conventional technology environment, the required levels of accuracy and productivity are so high that the demarcation between FMT and conventional technology gets blurred.

The company feels that in areas of heavy engineering where raw materials are quite critical, the JIT systems are quite impractical.

Strategic Factors, Objectives and Means Contributing to the Choice of FMT Elements Installed

The numerals appearing in the matrix squares of Table 5 denote the extent of contribution made by the means to achieve the listed objectives under defined strategies on a ten point scale as reported by the company.

The motivating factor behind inducting FMT equipment by the company is to increase the productivity with an underlying strategy of maximising profits through lowering unit costs. This is followed by the objective of globalization with the underpinning strategy of creating world-class facilities to meet the export targets.

The comparative contribution of the objectives listed in Table 5 in influencing the choice of FMT elements installed is shown in Table 6. The relative influence appearing in this table has been calculated by dividing the column total of an objective by grand total of all the columns and expressed as a percentage. For example, the relative percentage influence of the objective of enhancing productivity $\frac{71}{246} \times 100 = 28.86\%$

It may be noted from Table 5 that enhancing machine utilization time more extensively, improvement in the engineering aspects of the production process, and quickly tuning to the input variations, have been significant means to achieve these objectives. The level of significance of other means is also shown in Table 5, indicated by the row total of their contributions.

Benefits Actually Realized after Installation of FMT Equipment

Table 7 shows the benefits actually experienced after installing the FMT equipment at BHEL. The percentage changes appearing in the last column of this table were not calculated by us but were given by the company respondents themselves based on their own calculations and experiences. It may be observed that hallmarks of these benefits are improved machine utilization, improvement in quality of the products, reduction in unit costs, rapid response to the market changes and improvement in the controls of the manufacturing process.

In the next sections the impacts of FMT on the technological and the work and organizational systems of the company are investigated.

Impacts of FMT on the Technical System

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

Table 8, reproduced from Willenborg and Krabbendams (1987) was not shown to the respondents of the company; only their responses were collected through interviews and questionnaires.

Table 5: Strategic Factors, Objectives and Means Contributing to the Choice of Elements of FMT Installed

	Means \ Strategies	Fast Response to the Markets	Maximising Profits Through Lower Unit Costs	Acquiring the edge to beat Competitors	Acquiring flexibility for Future Needs	Creating World Class Facilities to Meet Export Targets	Total Score
	Objectives	Product Variety	Productivity	Technological Leadership	Survival & Growth	Globalization	
1.	Enhancing machine Utilization Time more Extensively	3	7	5	6	6	27
2.	Optimum Utilization during Partial Breakdown	0	3	0	0	0	03
3.	Making Machine Utilization more Intensive	2	7	4	6	5	24
4.	Making Machine more Versatile and Multifunctional	4	5	6	2	3	20
5.	Enhancing Product Quality	0	0	4	3	3	10
6.	Lowering direct Labour Costs	0	7	2	4	6	19
7.	Making the size of Labour Force Flexible	Not relevant, since the labour cannot be laid off					
8.	Making the Labour Force Multi-skilled and Multifunctional	2	4	3	2	3	14
9.	Better Sequencing and Scheduling of the Production Process	3	6	4	3	5	21
10.	Improvement in the Engg. Aspects of the Production Process	3	7	5	5	6	26
11.	Experience in the Field of CNC etc.	3	6	2	2	5	18
12.	Simultaneous Production of Various Parts / Products	4	4	0	2	0	10
13.	Smooth Launching of Newer Products	6	2	1	2	4	15
14.	Variation in the Batch Size	3	6	2	1	3	15
15.	Quickly Tuning to the Input Variations	3	7	5	4	5	24
	Total	**36**	**71**	**43**	**42**	**54**	**246**

Legend : 0= Minimum 10= Maximum

Table 6 : Objectives and their Influence on the Choice of FMT Elements Installed

Objective	% Relative Influence
To enhance Productivity	28.86
Globalization	21.95
To acquire Technological Leadership	17.48
For Survival and Growth	17.08
To have Product Variety	14.63

Table 7: Benefits Actually Realized after Installation of FMT

Element	Percentage Change
1. Reduction in Lead Time	25 to 30
2. Improved Machine Utilization	50 to 55
3. Reduction in Unit Costs	30 to 35
4. Reduction in direct Labour Hours	30
5. Rapidity of Response to Market Changes	30
6. Increase in Profits	10
7. Improvement in Quality	40
8. Improvement in Responsiveness	30
9. Reduction in Inventory	20
10. Improvement in Control	30
11. Improvement in Discipline	Not quantifiable, but better
12. Reduction in Industrial Relations (e.g. discussions regarding keeping pace with production, recruitments, layoffs etc. with labour unions)	Not applicable.
13. Reduction in Pay-back periods and Satisfactory Levels of Return on High Investment Required	15
14. Reduction in the Number of Operations	20 to 25
15. Reduction in 'Door to Door' and 'Floor to Floor' Times	20

Table 8: Features of the Technical System

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

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

The impacts of FMT operative at BHEL on its technological system as actually experienced by the company were compared against the expected ones and the reported results are shown in Table 9. It may be clarified here that although at BHEL the dominant elements of FMT are CNC machines, the company is far ahead of many others in its usage of almost all other essential components of FMT, like AGVs, ASRSs, FMCs and FMSs. Yet, it is not entirely dependent upon full FMSs and computer integrated manufacturing is only in its primitive state. Hence, in the column of expected scores (impacts) the figures have been modified to lie between those of CNC and FMS as shown in Table 9.

The experienced levels of impacts have been recorded verbatim as reported by the company and actual score have been interpreted. For example, average and medium have been interpreted to be more than low but less than high and an average score (average of 2 and 3) of 2.5 assigned to it.

Table 9: Reported Impacts of FMT on the Technical System

Features	Expected Score	Actual Score	Experienced Level of Impact
Complexity	3	2.5	Medium
Level of Automation	3	2.5	Medium
Capital Intensity	3	3	High
Product Flexibility	3	2.5	Medium
Process Flexibility	3	2.5	Medium
Production Flexibility	2	2.5	Medium

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

It has been discovered that the reported impacts on capital intensity have been on the expected lines but those for complexity, level of automation, product flexibility, process flexibility, and production flexibility fall short of the expected ones. Given the size and scale of operations of BHEL, the level of automation, if it is intended to make it at par with those of the developed countries, is still way behind. But the extent of automation should be attempted judiciously taking into account socio-economic and other factors specific to a country.

Another factor responsible for levels of automation remaining lower than expected could be that the company is not a consumer product organization and therefore, frequent changes are not needed much, although batch sizes do vary.

Impacts of FMT on the Work and Organizational Structure

In Table 10 are recorded and reproduced verbatim the experiences of the company under the column entitled 'the company responses'. Other details and parametric

Table 10 : Comparison Between Conventional and FMT Work Organizations

Features		The Work Organization		
		Conventional	**FMT**	**The Company Response**
1.	Level of Skills and Awareness Required by the Operators	Low	High	Workers had to be re-trained
2.	Level of Qualifications and Preparedness Required by the Managers	Moderate	High	Required levels of competence and involvement of engineers has increased
3.	Number of Operators Required	Moderate to large	Extremely small	Has reduced steadily
4.	Number of Specialists Required for Process Planning and Maintenance	Very small	Quite large	It has increased
5.	Critical Components of Maintenance and Preventive Maintenance	Chiefly Mechanical	Electrical Electronics and Mechanical	Chiefly electronics and electrical
6.	Division of Labour	Job specialization	Job rotation	Job rotation
7.	Training	On the job, trial and error, with low costs	Comprehensive, theory based, with high costs	Theoretical exposure, courses, hands on experience and on-the-job training. costs are not high
8.	Relations	Individual with low communication	Group with high communication	Group and high communication, lack of bureaucratic culture
9.	Culture	Lack of motivation, wage oriented	High motivation, work oriented	Very high motivation
10.	Problem Solving and Trouble Shooting	Low capabilities (lack of skills and motivation)	High capabilities and specialists	High levels of capabilities
11.	Software	Standard	Interactive	Both interactive and standard
12.	Implementation	Smooth : small differences with existing division of labour, wages and training	Radical restructuring required	Not much of restructuring affected

considerations while conducting this part of the study were the same as for other three case studies.

There are two notable deviations, marked by asterisk (*). The first is regarding the costs of training. In the company's opinion, the training costs are low, mainly due to the fact that it conducts its own in-house courses and practical training sessions, mainly at its corporate R&D Centre at Hyderabad as it has a substantial number of facilities there. In case it does not have a particular facility, it sends its team of engineers or specialists to other companies. For example, recently a team of BHEL engineers was sent to another public sector company, the Hindustan Machine Tools Ltd. (HMT) for training on Mechatronics.

The company did not face much difficulty in the installation of FMT elements but the maintenance remains a problem.

The second deviation was that not much of restructuring of the organizational structure was experienced at BHEL. This may be due to the fact that much earlier, the company went for de-centralization, making its units almost independent. Lack

of red-tapism, lack of a bureaucratic/hierarchical structure and a lot of in-built flexibility in its work and organization culture helped it to absorb the induction of FMT without much difficulties.

Other impacts of FMT on the aspects listed in this section are :

The company is considering replacing the manual mode of changing the process plans by computer-aided process planning (CAPP).

With increase in the induction of FMT and enhanced sophistication, more qualified engineers are replacing supervisors. In some cases, even CNC machines and FMCs are being operated by qualified engineers.

Preventive maintenance has assumed significance to such an extent that teams of electronics engineers, with each member carrying a pager/cell-phone/walkie-talkie, are deployed to ensure that in case of a problem, there is someone to attend within a matter of minutes.

In conclusion, it may be stated that long standing exposure (even before the on-set of liberalization in India) to world markets and international competition, where very high quality products at very competitive prices only can sustain, have shaped this largest engineering company of India in the public sector.

The Situation-Actor-Process (SAP) Analysis

The Situation

- In the early years of independent India (around mid fifties), there were colossal efforts by the Government of India to build industrial base of the country. Attention was focussed on petroleum, power and cement. In fact, power generation was very high on priority which manifested in the construction of first world-class hydro power plant at Nangal in the northern state of Punjab.
- It was felt that without facilities for indigenous production of equipment for generation, transmission and utilization of electrical power, these massive programs would not succeed.
- The country, at that time, had not much of an industrial base to speak about, more so in the core industries.
- This led to setting up of the first unit in August, 1956 when Heavy Electricals (Pvt.) Limited was incorporated at Bhopal, in the central Indian state of Madhya Pradesh, in technical collaboration with the Associated Electrical Industries (AEI), now known as General Electric (GE), of UK.

The Actors

- It was the vision of the first Prime Minister of India, Pandit Jawahar Lal Nehru, who is aptly remembered as the architect of modern India.
- The political leaders under the guidance of the then Prime Minister of India, the secretaries and technical specialists of the Government of India, and the top, middle and lower levels of technicians of the first plant set-up. Other functionaries of the state of Madhya Pradesh provided land and other basic infrastructure facilities.
- The management, engineers and technical specialists of Associated Electrical Industries (now known as General Electric) of United Kingdom (Britain). Technology providers for the first plant, erstwhile USSR (now known as the CIS Countries) and erstwhile Czechoslovakia (now known as the Czech States).
- Team of highly qualified engineers, R&D scientists and professionals, managers, technicians, and skilled, semi-skilled and unskilled workers and labourers, who helped built the subsequent plants.
- Subsequent technology providers for different products and processes are the countries of Canada, the CIS countries, France, Germany, Italy, Sweden Switzerland, UK., and USA.

The Process

- The technical know-how, design and initial support system for creation and commissioning of the first plant was acquired from Associated Electrical Industries (AEI) of the UK.
- Initial machinery and plant was imported not only from the UK as well as from Germany and the USA.
- Indian engineers and technicians were initially trained by the collaborators but eventually they became capable of coming on their own.
- Initially, the first plant was set up to cater to the domestic needs but setting of subsequent plants enabled the company to initially export to neighbouring countries like Sri Lanka, Bhutan, Thailand.
- Gradually, the company was able to bag prestigious contracts in the European countries, including Germany, against tough international players.
- The global exposure thus acquired helped it to become highly competitive and quality conscious through induction of advanced manufacturing technologies, including FMT, in substantial measures, leading to its present state and status.

The Learning Issues

- Acquiring technology and making products through licensing and developing indigenous technology base simultaneously, is the strategy to acquire competitive edge, especially for heavy engineering industries engaged in manufacturing highly sophisticated and also where reverse engineering may not be possible.
- Ploughing back money in R&D pays rich dividends by way of enhancing competitive edge which results in higher profits and other gains.

- For a company situated in a developing nation but engaged in the production of highly sophisticated and customized products, vertical integration may still remain the norm till the surrounding ambience becomes developed enough to sustain horizontal integration.
- Decentralized, autonomous units with flexibility in decision-making should be encouraged by an organization aspiring to become truly world-class.
- Separate teams of well-qualified professionals and engineers in a high technology-oriented company should handle management of quality and preventive maintenance.
- The Indian companies engaged in manufacturing should strive hard to increase productivity of the production organs by enhancing the rate of stock removal and machine engagement time. Advanced technologies and machines can help achieve this objective.
- Integration of IT elements into the operations of a company will assume even greater significance in future.
- Developing an organizational structure conducive to fostering a climate of learning, creativity, quick response, respect for dignity and capability of each individual, a sense of loyalty and pride in the organization, team spirit, zeal to excel, transparency and fairness is central to survive and grow in a highly competitive environment.
- One way to combat resistance to adoption of FMT by labour unions is to induct FMT initially only in those areas where worker fatigue is a problem.

Concluding Remarks

As demonstrated, if there is a champion for a cause, including that of incorporating FMT, the chances of success are enhanced. It has also been adequately proved that even a government-controlled organization can achieve excellence and compete globally by incorporating FMT in its production facilities, training and re-training its personnel, giving a thrust to innovation, integrating elements of IT into almost all of its functions, and integrating activities such as data management, production, finance, accounting, and human resources management systems through local area networks (LANs).

The BHEL has amply demonstrated how a heavy engineering company in the public sector of a developing nation can achieve international standards by acquiring competitive edge. A judicious mix of acquisition of advanced technologies through technology transfer, strong thrust to in-house R&D, designing a flexible organizational structure, inducting training and retraining programmes to constantly train personnel on advanced technologies, and using FMT substantially but appropriately, can really help in acquiring this competitive edge.

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Flexibility Mapping : Practitioner's Perspective

1. What types of flexibilities you see in the practical situation of *"Manufacturing Technology"* on the following points:
   - Flexibility in terms of *"options"*
   - Flexibility in terms of *"change mechanisms"*
   - Flexbility in terms of *"freedom of choice"* to participating actors.
2. Identify and describe the types of manufacturing flexibilities that are relevant for your own organizational context? On which dimensions, flexibility should be enhanced?
3. Try to map your own organization's manufacturing flexibility on following continua. (Please tick mark in the appropriate box(es)).

Current Status of Manufacturing Flexibility

Totally Dedicated ☐ ☐ ☐ ☐ ☐ Fully Automated

Investment in FMT as a Fraction of Total Investment

Zero ☐ ☐ ☐ ☐ ☐ 100%

Technology Acquisition Strategy

Acquiring form outside ☐ ☐ ☐ ☐ ☐ Devloped in-house

Extent of Integration of IT Elements in Operations

Very Low ☐ ☐ ☐ ☐ ☐ Very High

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Flexible Manufacturing"*.

Reflecting Applicability in Real Life

1. Try to work out relative influence of the objectives of product variety, productivity, technological leadership, survival and growth, and globalization, leading to the present state of installed FMT in your company, as done in this case study.
2. Attempt preparing a plan to enhance the competitive edge of your company by using a combination of SAP-LAP analysis, data based calculations of the benefits actually realized, and impacts on the technical system and work organization, after elements of FMT were installed in your company.

Case Study

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Flexibility in an Automobile Manufacturing Enterprise

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Abstract

The present manufacturing systems have become very complex. This requires the manufacturing system to rapidly adjust itself to changes, complexities, and uncertainties. Therefore, flexibility is needed. At the same time, productivity is also desired due to resource crunch and severe competition. This paper presents an approach for managing flexibility in an automobile manufacturing enterprise, keeping productivity improvement in mind. The values of various types of flexibilities have been found at various intervals of time for a tractor manufacturing enterprise. Various types of productivity have been calculated for the corresponding time intervals. The trends of flexibility and productivity have been determined. An approach has been suggested for managing flexibility in future. A hireachy of flexibility, listing the order in which various types of flexibility should be focused in future, is also given. SAP (situation-actor-process) analysis has been carried out to arrive at learning issues.

Keywords: automobile manufacturing enterprise, flexibility, productivity, SAP

Introduction

The wave of liberalization and economic reforms in India has led to drastic changes in the approach to manufacturing. These days, the emphasis is more on production of small batches due to rapid changes in product design. The manufacturing systems have become very complex as a variety of materials, machines, tooling and other inputs are being employed for production purpose. This complexity along with market uncertainties due to short product life cycles and rapid product innovations require the manufacturing system to respond quickly to uncertainties and changes. For that, flexibility is needed. Flexibility is the ability of a system to respond or react to a change with little penalty in time, effort or cost (Upton, 1994). The change may be internal (equipment breakdown, workers' absenteeism etc.) or external (change in product design, demand and product mix). Flexibility is also the ability to do things differently or do something else should the need arise (Bahrami, 1992). Flexibility is the exercise of free will or freedom of choice on the continuum to synthesize the dynamic interplay of thesis and antithesis in an interactive and innovative manner, capturing the ambiguity in systems and expanding the continuum with minimum time and efforts (Sushil, 1997). On one side, flexibility means being agile and versatile, while on the other side, it means being robust and resilient so as to withstand shocks when negatively affected by changes. There are various types of flexibilities. A comprehensive classification of flexibility is provided (Browne et al, 1984) by describing eight types of flexibilities – machine flexibility, process flexibility, product flexibility, routing flexibility, volume flexibility, expansion flexibility, process sequence flexibility, and production flexibility.

Various companies are experimenting with novel organizational structures and management processes to accommodate flexibility. Some of the prevalent developments include delayering, team-based network, alliances and partnerships.

Besides flexibility, proper utilization of resources is essential due to unprecedented competition coupled with acute resource crisis. Enhancement in productivity is the key to success. One of the method of improving productivity is to measure productivity. Productivity can be measured either as total productivity or partial productivity, i.e. material productivity, labour productivity, energy productivity, and equipment productivity. The paper presents an approach for managing flexibility in a tractor manufacturing firm, keeping productivity improvement in mind.

Methodology for Measurement of Flexibility and Productivity

The methodology involves measurement of existing levels of different types of flexibilities. For this, various parameters contributing towards a particular type of flexibility are identified. A paired comparison of these parameters is carried out by drawing a position matrix to find out their weight. Further, questions have been framed related to these parameters in a specially designed questionnaire to know the response of the manufacturing firm to these parameters. Various types of flexibilities have been measured on 0–1 scale. The trends in various types of flexibilities have been measured by comparing their values with the values of the last year and with that of five years back. At the same time, productivity values (partial as well as total) of the

manufacturing firm have been found out for the corresponding periods by finding actual output and various types of inputs in monetary terms. The trends of various types of productivities have also been determined. Correlation have been established between various types of flexibilities and productivities. Based on the past trends and existing levels of various types of flexibilities and keeping in mind the correlation between flexibilities and productivities, an approach has been suggested for managing flexibility in future. A hierarchy of flexibility, listing the order in which various types of flexibilities should be focused in future, is also given.

Flexibility is the ability of a system to respond or react to a change with little penalty in time, effort or cost.

Present Status

Swaraj Tractors division, a unit of Panjab Tractors Limited was established at S.A.S. Nagar (Panjab) in 1972 for manufacturing tractors. It is India's first large scale project based on totally indigenous design, know-how, and technology. It went into commercial production in the year 1974 with Swaraj 724, a 26.5 bhp tractor as its first model. Since then, Swaraj tractors has not only expanded its tractor manufacturing capacity but also added more products to its manufacturing range. The product range of the plant includes Swaraj 724 (a 26.5 bhp tractor), Swaraj 735 (a 39 bhp tractor), Swaraj 720 (a 19.5 bhp tractor), Swaraj 855 (a 39 bhp tractor) and various agricultulral implements like disc plough, cultivator, disc harrow, and planter.

Total revenue of the plant rose by 26% in 1995–96 as compared to that in 1994–95. Market tilt towards higher horsepower tractors was also manifest during 1995–96, when nearly 90% of the sales came from 35 HP and 55 HP engines. The growth has been equally pronounced on the export front, where billings touched INR 64 million against previous year's INR 32 million.

The comfortable order-book position for tractors indicate a sound growth for the enterprise in future. Table 1 gives the values of various flexibilities of the enterprise for the year 1991–92, 1994–95, and 1995–96 respectively. The percentage changes in these values in 1994–95 and 1995-96 as compared to that in 1991–92 are also shown. Table 2 shows values of various types of productivities along with percentage changes in the values for the year 1994–95 and 1995–96 as compared to that in 1991–92.

Table 1: Flexibility Values

Sr. No	Type of Flexibility	1991-92	1994-95	1995-96	% Change 94-95 Vs 91-92	% Change 95-96 Vs 91- 92
1	Routing	0.577	0.670	0.671	16.12	16.38
2	Volume	0.493	0.643	0.753	30.50	52.77
3	Product	0.494	0.664	0.711	34.34	43.82
4	Product mix	0.574	0.748	0.761	30.28	32.55
5	Labor	0.499	0.725	0.725	45.10	45.20
6	Design change	0.394	0.583	0.645	47.87	63.64
7	Machine	0.404	0.501	0.503	23.94	24.38
8	Planning	0.786	0.787	0.791	0.05	0.06
9	Communication	0.80	0.90	1.00	12.5	25
10	**Total**	**0.534**	**0.695**	**0.700**	**30.19**	**31.07**

Table 2: Productivity Values

Sr. No	Type of Productivity	1991-92	1994-95	1995-96	% Change 94-95 Vs 91-92	% Change 95-96 Vs 91- 92
1	Equipment	71.56	81.68	86.33	14.14	20.64
2	Labor	17.40	24.07	20.83	38.33	19.71
3	Material	1.44	1.42	1.47	- 0.76	2.56
4	Energy	156.08	146.91	147.48	- 5.87	- 5.50
5	**Total**	**1.10**	**1.12**	**1.15**	**2.26**	**4.53**

Trends of Flexibility

The changes in various types of flexibilities that have occurred in Swaraj Tractor plant in the last five years are discussed below:

Routing Flexibility

The type of machinery installed in the plant has contributed a lot towards routing flexibility. Nearly 50 percent of the machines are special purpose machines with negligible margins of changeover. Around 40 percent of the machines are purely general-purpose which allow for routing flexibility. A lot of emphasis has been given on installing CNC machines and flexible machining centres, which accounts for 10 percent of the installed machines.

In case of machine breakdown, it is possible to shift the operation to other similar type of machines. Generally, the shifting is done only if down-time is long. The rescheduling needs some effort but there is not much loss of production time. Another option is that the sequencing of operations for some products can be changed with some loss of time and efforts.

The managers of the plant, sometimes, may resist bringing changes in the process particularly if the change affects the production targets. The production lines are completely balanced. The material handling system also contributes towards routing flexibility of the system, as in case of breakdown, the material handling in the new situation results in very little loss of time and efforts.

Due to these factors, the routing flexibility of the plant increased by 16.12 percent and 16.38 percent from 1991–92 to 1994–95 and 1995–96, respectively.

Flexibility is also the ability to do things differently or do something else should the need arise.

Volume Flexibility

The plant has gone in for a lot of expansion to cope with the increasing demands from customers. The production levels increased from 14,809 in 1991–92 to 23,149 in 1994–95, and it further increased to 24,193 in 1995–96. The turnover increased from INR1908.8 million in 1991–92 to INR 3836.4 million in 1994–95, and it rose further to INR 4460.3 million in 1995–96.

The company has never faced any situation of under-demand or shortage of orders. However, in any such type of situation, the plant has the capacity to utilize its excess capacity as it has got many sister concerns like Swaraj Combine Division, Swaraj Mazda Division, and Swaraj Engines Ltd. from where orders can be received. The company is already making gears for Swaraj Mazda, and agricultural implements for Swaraj Combine Division.

To cope up with increasing demands, the company has been continuously investing by procuring new machines at various intervals of time. The total investment in machinery and equipment has been INR 5708.4 million and Rs. 8600.6 million in 1994–95 and 1995–96 respectively. The lead time for incremental investment, which used to be around one year, has decreased over a period of time and at present it is in the range of 6 months to 9 months. The plant has got a network of vendors who are providing various parts, components, and sub assemblies to the plant. At present, the plant has got around 4000 vendors, and every year 10–15 new vendors are being added. The plant has made a policy of giving incentives to employees for achieving higher production targets, which helps in increasing volume flexibility. The incentives given amounted to INR 895.7 million in 1991–92, increased to INR 1533.3 million and INR 1702.6 million in 1994–95 and 1995–96, respectively. A complete and detailed exercise is conducted to evolve a strategy to meet wide fluctuations in demand.

All these factors have led to increase in volume flexibility from 0.493 in 1991–92 to 0.643 in 1994–95, and 0.753 in 1995–96 respectively.

Product Flexibility

At present, the plant is manufacturing four models of tractors namely Swaraj 724, 735, 720, and 855. Although no new model has been introduced in the last five years, yet the product flexibility of the plant has increased due to installation of CNC machines and machining centres. Some major design changes include changes in input shaft and bull-pinion shaft. A few changes have also been made in the design of bevel pinion. The production levels have also increased from 14,809 in 1991–92 to 23,149 in 1994–95, and 24,193 in 1995–96. Recently, the plant has introduced fuel efficient versions of Swaraj 724 and Swaraj 735 models. All these factors have contributed towards improvement in the product flexibility of the plant by 34.34 percent and 43.82 percent from 1991–92 to 1994–95 and 1995–96 respectively.

Product Mix Flexibility

The variation in share of Swaraj 724 varies from 8 to 33 percent, that of Swaraj 735 from 66 to 75 percent, and for Swaraj 855 it varies from 10 to 14 percent. Most of the components that are made in the plant have large variations in size and shape. However, different sub-ranges of these components can be made on different sets of machines by changing tooling.

The time and cost for rescheduling a product mix has decreased over a period of time. The plant is presently using around 800 components which are bought from various vendors. Due to this, the product mix flexibility of the plant has increased from 0.574 in 1991–92 to 0.748 in 1994–95, and to 0.761 in 1995–96.

Labour Flexibility

The labour flexibility has increased tremendously over the last five years due to company's policy to focus on human

resources development. The number of persons employed was 1,538 in 1991–92. It increased to 1,653 in 1994–95, and rose to 1,668 in 1995–96. The workforce in various categories has been increasing but the strength of supervisors decreased from 412 in 1994–95 to 399 in 1995–96. The delayering of the work force at middle level has been done to help in better communication, and quick decision-making.

The workers' union in the enterprise plays a significant role if a worker has to be shifted from one machine to another in case of workers' absenteeism. Generally, shifting of workers is possible within the section. Despite this, more than 25 percent of the workforce is trained to work on 4–5 different types of machines. The skill levels of the workers have increased by nearly 10 percent in the last five years due to installation of machining centres, and CNC machines. The workers generally cooperate in achieving the production targets, and they do the work expected of them. A lot of attention is paid towards training of workforce for attaining production targets. The investment in staff training was INR 0.298 millon in 1991–92, and it increased to INR 0.403 million in 1995–96. A new human resources development centre has been established in 1992 for training of management staff, supervisory staff, and workers. Thus, labour flexibility of the plant increased from 0.499 in 1991–92 to 0.725 in 1994–95, and it improved further to 0.725 in 1995–96.

On one side, flexibility means being agile and versatile, while on the other side, it means being robust and resilient so as to withstand shocks when negatively affected by changes.

Design Change Flexibility

To meet the growing needs for greater research, a new research wing was established in 1992. The wing built for improving existing design of tractor includes a design office, prototype manufacturing section, assembling and testing sections. Changes are made in the tractor design, both at major and minor levels, regularly for improving productivity and quality. The plant has also established teams for getting continuous feedback from the customers regarding the problems being faced by them, and design changes proposed by them. However, a lot of time and efforts are needed for making design changes. The major changes made in the last five years include changing the design of input shaft, bull-pinion shaft, and bevel-pinion. The plant has also introduced fuel-efficient versions of Swaraj 724 and Swaraj 735 models of tractors. Other design changes include shifting of battery to the back side of the tractor, strengthening of fenders, developing water proof brake system, and developing double clutch system. Thus, the design change flexibility improved by 47.87% and 63.64% from 1991–92 to 1994–95 and 1995–96 respectively. Correspondingly, the investment in R&D has increased from INR 5.913 million in 1991–92 to INR 7.791 million in 1994–95 and INR 9.222 million in 1995–96.

Machine Flexibility

The Swaraj Tractor Division consists of a number of shops, namely, light machine shop, heavy machine shop, assembly shop, heat treatment shop, and paint shop.

The light machine shop is the largest of all the shops in the enterprise. All transmission components like shafts and gears used in tractors are manufactured in this shop. The facilities of this shop include gear manufacturing and grinding, machining of bull gears, bevel gears, cutting of all rounds parts on power hacksaws, facing and centering, all types of grinding inner and outer gears, hobbing and broaching machines, gear shavers, gear deburring machines, and drilling machines for all types of gears. The various types of machines are: cylindrical grinders, internal grinders, copying lathes, gear hobbers, radial drilling machines, drum turret lathes, honing machines, centre lathes, capstan lathes, broaching machines, centering and facing machines, vertical milling machines, horizontal milling machines, deburring machines, boring machines, bevel gear generators, gear shapers, CNC machines, power hacksaws, special purpose drilling machines, twin chuckers, and grinding machines. In view of complexity of operation and high standard of quality, this shop is manned by about 170 highly experienced operators.

In the heavy machine shop, all heavy castings of tractors like differential housing, gear box housing, rear cover, trump housing, and steering housing of tractors are machined with the help of special purpose machines. These machines have been designed to suit component requirements. In addition, facilities of this shop include general purpose turning machines, drilling machines, and milling machines. About 20 special purpose machines and 30 general purpose machines have been installed in this shop.

In the heat treatment shop, heat treatment of various tractor parts, such as axles, gears, and shafts, is carried out. The heat treatment processes include hardening, tempering, and toughening. The shop is equipped with several heating furnaces and testing machines.

In the assembly shop, assembly of all finished components for tractor models Swaraj 720, 724, 735, and 855 is done. The various sections in assembly shop are differential assembly, gearbox assembly, steering assembly, brake paddle assembly, engine preparation for assembly, and chassis painting.

The paint shop is utilized for painting of sheet metal components, chassis, rims, and other implements. The important equipment in this shop include high pressure cleaning machines, spray painting booth, paint baking oven, feeding conveyors, and pre-treatment tanks.

From 1991–92 to 1994–95, various CNC machines like hob resharpening machine, grinding machine, drilling centre, twin chucker, shaving machine have been procured in the light machine shop. While in the heavy machine shop, CNC

turning centre has been procured from year 1991–92 to 1994–95. During 1995–96, CNC vertical machining centre and CNC turning centre have been further added to the shop.

It is clear that the enterprise is emphasizing in bringing more and more machining centres, which will provide more flexibility to the equipment. As light machine shop is already having high flexibility, therefore emphasis is being laid in further reducing the change-over times in the light machine shop. The machine flexibility of the plant has increased by 23.94% and 24.38% from 1991–92 to 1994–95 and 1995–96 respectively.

Planning Flexibility

The plant is conducting a complete and detailed exercise of master production scheduling and operation scheduling. In addition, complete exercise is also done to evolve strategy to meet wide fluctuations in demands and variable production levels. A firm master production schedule is made, which is reviewed from time to time. A complete line balancing of production lines is planned. No provision of stand-by machine is made and situation is tackled as the time comes.

The paper presents an approach for managing flexibility in a tractor manufacturing firm, keeping productivity improvement in mind.

The installation of CNC machines and equipment has also contributed towards increase in planning flexibility. Planning flexibility increased from 0.786 in 1991–92 to 0.787 in 1994–95, and it further rose to 0.791 in 1995–96.

Communication Flexibility

Presently, the plant is using an integrated computer based management information system. The system is widely used in various areas like purchasing, production planning, designing, and dispatching. The delayering at the middle level has also contributed a lot to communication flexibility. Communication flexibility increased by 12.5 percent from 1991–92 to 1994–95, and increased further by 11 percent from 1994–95 to 1995-96.

Total Flexibility

Total flexibility of the plant has increased from 0.534 in 1991–92 to 0.696 in 1994–95, an increase of 30.19 percent. Its value rose to 0.700 in 1995–96, an increase of 31.07 percent as compared to that in 1991–92. The increase in total flexibility is attributed mainly to an increase in product flexibility, labour flexibility, design change flexibility, product mix flexibility, and volume flexibility.

Productivity Trends

The equipment productivity of the plant has increased by 14.14 percent in 1994–95, and by 20.64 percent in 1995–96 as compared to that in 1991–92. The labour productivity increased by 38 percent from 1991–92 to 1994–95 but it fell by 13 percent in 1995–96.

The material productivity and energy productivity show a similar trend decreasing by 0.76 percent and 5.87 percent, respectively in 1994–95 as compared to that in 1991–92, but both these productivities improved marginally in 1995–96.

Total productivity shows an increasing trend with 2.26 % and 4.53 % increase in 1994–95 and 1995–96, respectively as compared to that in 1991–92.

Keeping in mind the decrease in labour productivity and marginal increase in material productivity and energy productivity in 1995–96, there is a scope to improve labour productivity, material productivity, and energy productivity in the future.

Future Order of Flexibility Acquisition

Seeing the changes in the flexibility values in the last five years, as shown in Figure 1, it is clear that the Swaraj Tractors plant is mainly focusing on design change flexibility, product flexibility, and volume flexibility. On the productivity front, there has been a decrease in energy productivity in 1994–95 as compared to that in 1991–92, and it has not shown much improvement in 1995–96. The labour productivity has also decreased appreciably in 1995–96.

It is proposed that, in the future, the plant should focus on various types of flexibilities in the following order:

i) Design Change Flexibility
ii) Product Flexibility
iii) Volume Flexibility
iv) Product Mix Flexibility
v) Planning Flexibility
vi) Labour Flexibility
vii) Machine Flexibility
viii) Routing Flexibility
ix) Communication Flexibility

The plant should continue to increase its product flexibility, volume flexibility, and product mix flexibility, in the future, also. The plant should focus, further, on design change flexibility, in the future, which may improve labour productivity because both have a positive correlation. Higher design change flexibility may also contribute to an increase in product mix flexibility, machine flexibility, and total flexibility. Further, the plant should focus on increasing planning flexibility, which may improve energy productivity as well as material productivity. In addition, higher planning flexibility may contribute towards an improvement in routing flexibility and communication flexibility because planning flexibility has a significant positive correlation with them.

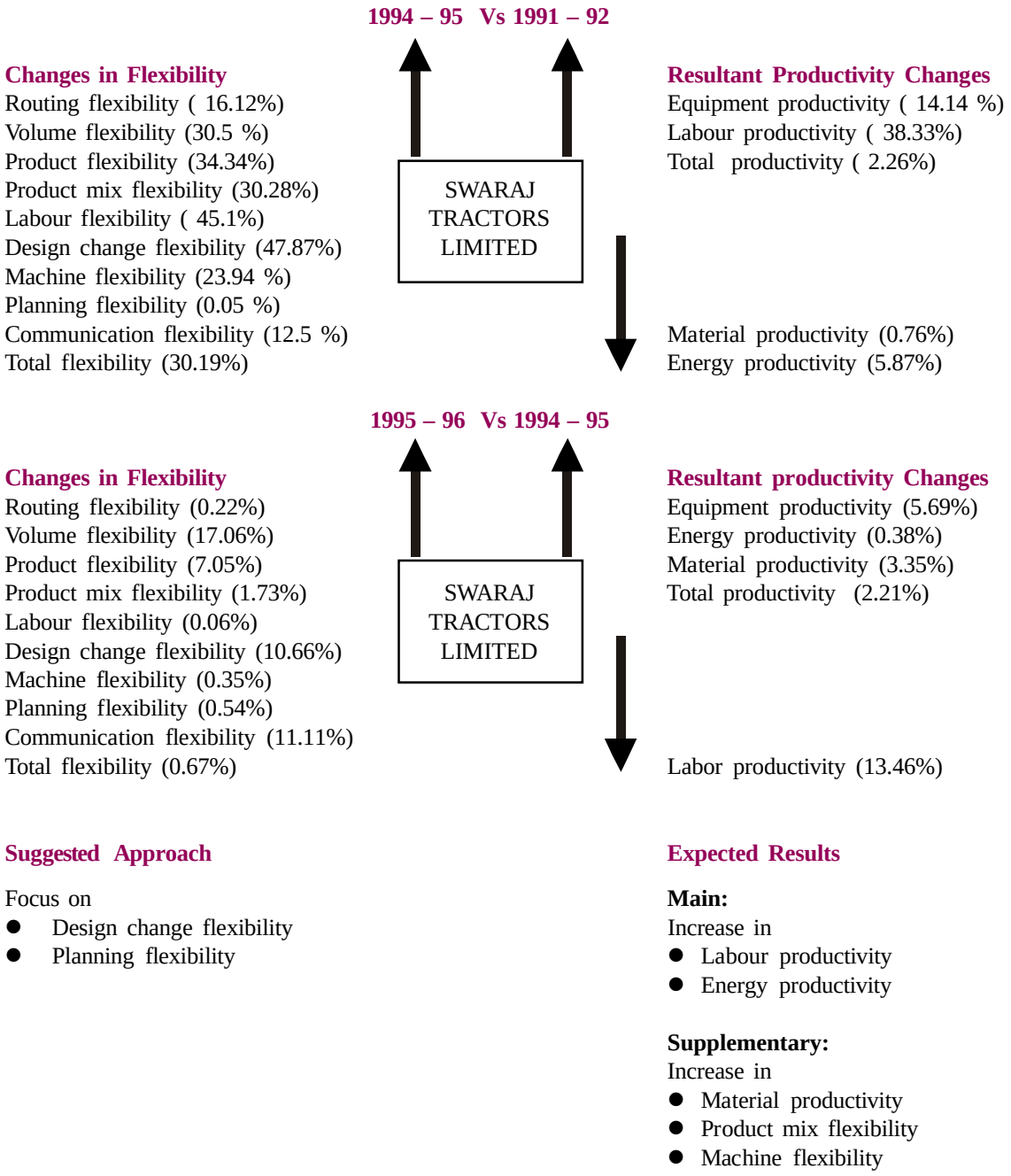

Figure 1 : Trends in Flexibility and Productivity and Suggested Approach for Managing Flexibility

SAP Analysis

SAP (situation-actor-process) analysis has been carried out to determine the approach adopted by the enterprise for managing flexibility. SAP analysis (Sushil, 1994,1997) is a method of analyzing case study. In SAP analysis, the case has been described through three basic components (situation, actor and process) that define the dynamic interplay of reality. From the analysis, learning issues have been explored.

Situation

- Swaraj Tractor Plant is India's first large scale project based on totally indigenous design, know-how, and technology.
- The plant has developed core competence in tractor manufacturing.
- Increasing demand for tractors especially in the category of higher horse-power tractors.
- Demand from customer for changes in tractor design as per their needs.

Actor

- Vice Chairman and Managing Director of the plant as the visionary leader.
- Managers and engineers of the plant as the dedicated lot.

- Employees of the plant as multi-skilled, trained, and flexible workforce.
- Customers as a source of innovative ideas.

Process

- Making a lot of investment in the area of research, design, and development.
- Acquiring state-of-art technology by installing CNC machines and flexible machining centres.
- Increasing volume flexibility by increasing the number of vendors, and stressing on vendor development.
- Establishing teams to get feedback from the customers regarding design changes and any problems faced by them while using the existing models.
- Introducing new tractor models catering to the requirements of specific region and areas.

Learning Issues

The SAP analysis helps to arrive at the following learning issues :

- Core competence helps in meeting the customers requirements, thus, increasing flexibility.
- Investment in R&D helps in building up product flexibility.
- Acquiring state-of-art technology helps the firm to have a competitive edge over others.

Concluding Remarks

Flexibility is a multi dimensional concept. Flexibility is required to respond to uncertainties and changes. There are various types of flexibility, namely, routing, volume, product, product mix, labour, design change, machine, planning, communication and total flexibility. A particular type of flexibility can be measured taking into account the weight of various parameters contributing to it and the response of an enterprise to these parameters. The paper highlights the fact that it is possible to manage flexibility keeping productivity in mind as different types of flexibility have significant relationship with various types of productivity. However, the type of flexibility to be acquired will also depend on the present levels of flexibility, cost aspects and preparedness of an enterprise to acquire flexibility.

The increase in total flexibility in the case organization is attributed mainly to an increase in product flexibility, labour flexibility, design change flexibility, product mix flexibility, and volume flexibility.

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Flexibility Mapping : Practitioner's Perspective

1. What types of flexibilities you see in the practical situation of *"Manufacturing Systems"* on the following points:
   - Flexibility in terms of *"options"*
   - Flexibility in terms of *"change mechanisms"*
   - Flexbility in terms of *"freedom of choice"* to participating actors.
2. Identify and describe the types of manufacturing flexibilities that are relevant for your own organizational context? On which dimensions, flexibility should be enhanced?
3. Try to map your own organization's manufacturing flexibility on following continua. (Please tick mark in the appropriate box(es)).

Product Flexibility

Very Low ☐ ☐ ☐ ☐ ☐ Very high

Volume Flexibility

Very Low ☐ ☐ ☐ ☐ ☐ Very high

Process Flexibility

Very Low ☐ ☐ ☐ ☐ ☐ Very high

Productivity

Very Low ☐ ☐ ☐ ☐ ☐ Very high

4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of *"Flexible Manufacturing"*.

Reflecting Applicability in Real Life

1. Assess various types of manufacturing flexibilities (as discussed in this paper) in your organization and find out critical areas of flexibility.
2. Compare the trends of manufacturing flexibility in your organization and develop and approach for managing flexibility as given us Fig. 1 of this paper.

Learning Lessons on Flexible Systems Management L2

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SAP-LAP Framework

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Introduction

In order to translate Flexible Systems Management into action, SAP-LAP framework is developed

In order to deal with complexity, chaos and contradictions of fast changing business reality, flexibility is becoming a key attribute of the evolving futuristic enterprises. The aspects of flexibility and freedom have been given due consideration in the evolving paradigm of Flexible Systems Management. Flexible Systems Management paradigm takes 'systemic flexibility' as the base which has been discussed in the Learning Lesson L1 in Vol.1 No.1. In order to translate this paradigm of management into action, a methodological construct is provided in the form of SAP-LAP (Situation Actor Process–Learning Action Performance) framework in this learning lesson. An outline of the framework is provided, supported by an application in case analysis.

SAP-LAP

In order to implement the Flexible Systems Management paradigm, a holistic framework is developed that contains the basic entities in any management context and their associated managerial functions and attributes. Basically, any managerial context consists of a "situation" to be managed, an "actor" or a group of actors to deal with the situation and a "process" or a set of processes that respond to the situation and recreate it.

Situation, Actor, Process and their interplay comprise of SAP framework

The "situation", "actor" and "process" and their interplay comprise of the SAP framework where the freedom of choice lies with the actor as shown in Figure 1. If the actors have more freedom, the processes will become flexible and adaptive to cope with the changing situation. Lack of freedom of choice to the actors will restrict their options, ultimately making the process rigid and static and thereby failing to cope with the turbulence in the situation.

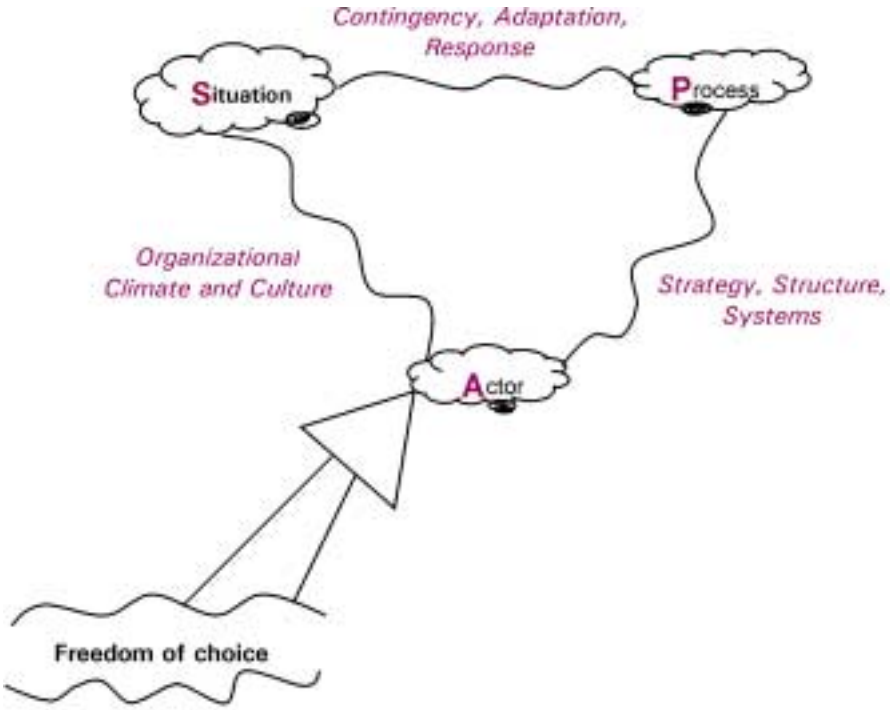

Figure 1: SAP Framework

"Situation" is external and internal environment of the organization and its performance

The "situation" is the external and internal environment of the organization and its performance. For example, some representative variables of external situation are competitive potential, economic policy, new technologies, type of supplies, infrastructure, industry performance and so on. Similarly, some important variables of the internal situation are financial performance, market share, corporate image, resources, capabilities and competencies, plant and machinery, core values, and so on. In a dynamic sense, the historical development and milestones provide the organizational situation.

"Actor" can be individual managers, groups, departments or class of actors

The "actor" can be individual managers, or groups, departments or class of actors such as suppliers, competitors, government, consultants, management, employees, etc. Some important variables in the "actor" domain are motivation, morale, attitude, actor performance, roles, capabilities, world-views, freedom of choice, communication, knowledge, skills and so on.

The interface of "actor" and "situation" defines the organizational climate and culture that is important for the evolution of the business processes.

"Process" is the overall transformation converting inputs into outputs

The "process" is the overall transformation process that converts a set of inputs into outputs to recreate the situation. The processes could be of various types, such as, supply chain process, customer interface process, performance management process, technology transfer process, innovation process, investment process, distribution process and so on. Depending upon the situation, one or more processes are to be studied and improved for higher flexibility.

The interface of "actor" and "process" defines the strategy, structure and systems that need to be transformed for organizational change.

The interface of "process" and "situation" defines the contingency to be taken care of (e.g. contingency planning) and adaptation and response of the process to the changing situation.

LAP is synthesis of SAP which includes interplay of Learning, Action and Performance

The interplay and synthesis of SAP leads to Learning-Action-Performance (LAP). We need to learn about the situation, actor and process and bring out key learning issues of interest. Based on the learnings, the action is to be taken on the fronts of situation, actor or process or the relevant interfaces. Depending upon the effectiveness of actions, performance is generated in terms of improved processes/actors and better situational parameters. In a business situation, the performance parameters could be market share, profitability, quality, productivity, competitive advantage, core competence and so on.

SAP-LAP framework can be used for case analysis, managerial inquiry and problem solving

The interplay of SAP and LAP makes the complete SAP-LAP framework as shown in Figure 2. This can be used effectively for case analysis, managerial inquiry and problem solving.

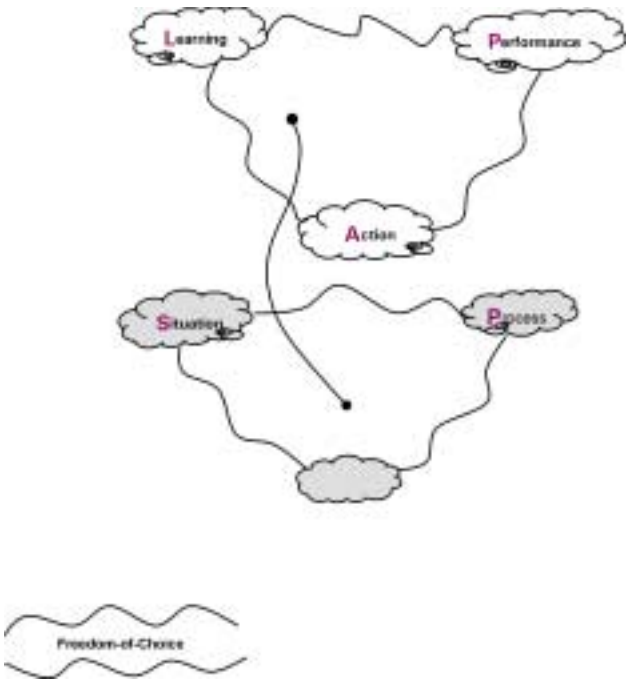

Figure 2: SAP-LAP Framework

Case Analysis

The steps for case analysis using SAP-LAP framework are: understanding situation, actors and roles, evolving process, learning issues, suggested actions, and expected performance

The SAP-LAP framework is an innovative and holistic framework for case analysis. Based on SAP-LAP framework, following generic steps can be used for analyzing any case.

i. *Understanding Situation:* In this step, we bring out key points of the emerging situation of the case in terms of historical perspective, external environment, competition, government policies, market condition, organizational performance and so on.

ii. *Major Actors and their Roles:* Identification of key actors in the case and their roles, relationships, world views and freedom of choice are to be summarized. Usually, this aspect of case analysis is not well addressed in the traditional case methods.

iii. *Evolving Process:* In this step, we critically analyze the key process(es) evolving in the case and portray their key issues. The processes could be of any type as discussed previously.

iv. *Key Learning Issues:* The analysis carried out in SAP framework leads to synthesis in terms of key learning issues for the case. These can be of two types: (i) generic, and (ii) specific. The generic issues are in terms of lessons learnt from the case that can be generalized by synthesizing the lessons from other cases.

The specific learning issues are linked directly with the case under consideration and are either expressed in terms of the problem areas or in terms of the objectives to be achieved.

v. *Suggested Actions:* Based on the specific learnings of the case, alternatives are to be generated and evaluated. Based on this, actions are to be suggested to improve/resolve the case problem.

vi. *Expected Performance:* Finally, the impact of suggested actions on performance is assessed so as to justify the actions.

The above methodology can be applied for case analysis using a variety of quantitative or qualitative tools and can be presented in a bullet form or using tabular presentation.

An illustration of SAP-LAP framework for case analysis is given in the next section using bullet–form presentation.

ILLUSTRATIVE CASE OF ABB INDIA

SAP Analysis

ABB India is developing in–house R&D for technology pioneering. SAP analysis and LAP synthesis of the case is presented here in brief

Context

Developing in-house R&D for technological pioneering. Electrical power generation and distribution technology leader in the making.

Prevailing Situation

- ABB India has very stiff competition from BHEL, KEL, and other foreign multinationals.
- Independent Power Plants (IPPs) in India and development of a power generation base have opened up opportunities for ABB India.
- The company's financial health has improved, and hence its R&D budget is also likely to go up.
- The firm has a strong technology base and keeps the emphasis on technology in its future planning.

Main Actors

- CEO of ABB, as the motivating force behind ABB all over the world.
- ABB India's management as the local policy-makers.
- ABB India's employees as the heart and soul of the company.
- Government of India and various state governments in context of IPPs.

Process of Technology Pioneering

- Emphasis on technology in business strategy and corporate philosophy.
- ABB India managing technology through mergers and acquisitions. It has taken over companies, which were supplying key technology components. The firm is consolidating its technological position in the power industry and emerging as a technology leader in many new areas. If technology development is mapped on a continuum that ranges from in-house R&D to mergers and takeovers, then ABB India's position falls in the range of 7.5 to 8.0 on a 10-point scale, as shown in Figure 3.
- A deep backward integration has been chosen as a technology strategy.
- The local ABB (within a country) enjoys the support of ABB at the global level. It is in a position to offer the best technological solution to a customer, taking into account the strengths of various national level facilities spread over the globe.

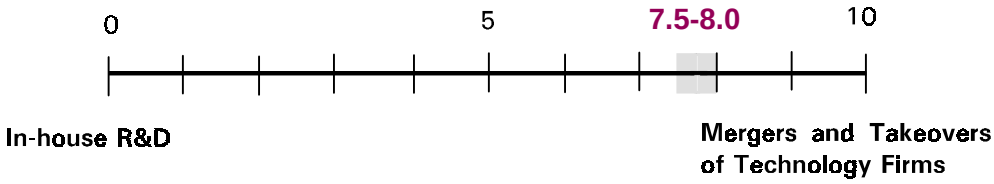

Figure 3: Technology Development Continuum

LAP Synthesis

Learning Issues

Technology Policy

- Technology policy is missing. In its absence, the company ends up as a mere manufacturing facility.
- Dependence on developed countries continues. Core competencies have not been identified.

Technology Development

- Backward integration of high-tech or key component manufacturing by way of takeovers can help in improving technological health of the company.

Innovation Culture

- Takeovers of high-tech firms affect the innovation culture adversely, and those firms' technologists lose creativity.

Technology and Competitive Advantage

- The local company draws benefit from the global image of the corporation and also can rely on corporate technological support when needed.

Technology Absorption

- The capability to cater to local customers' needs and innovate on existing technology requires technology absorption to a nearly complete level.

Suggested Actions

- Make Technology Management at par with other management functions to be accomplished more professionally by establishing a technology policy.
- Develop and deploy a core competence building agenda.
- Strengthen implementation of backward integration strategy by acquiring key component manufacturing firms.

- Develop in-house R&D for technology absorption so that further innovations can be made.

Expected Performance

- Development of sustainable competitive advantage through core competence building.
- Higher customer satisfaction by way of innovation to meet local needs.
- Dependence on imported technology will be reduced.

Concluding Remarks

SAP-LAP framework can be used in a variety of ways using dynamic, multi-level and plural models

SAP-LAP framework can be used in a variety of ways to gain insight into managerial problems and concerns. It can be used as a methodology for problem solving and decision-making rooted in the concept of learning. It is a holistic framework that synthesies the hard and soft systems thinking by taking both learning and action linked with the performance. It also blends the analytic and synthetic paradigms by incorporating both the situation and the process. The framework can be used in a variety of ways using dynamic, multi-level and plural models. Specific models can be developed using this framework using critical questioning and matrix based tools, which will be taken up in subsequent learning lessons.

Self Assessment and Reflection with Reality

- Analyze situation, actor and process in the context of your organization.
- Identify the characteristics of interfaces of situation and actor, actor and process, and process and situation.
- Choose a suitable case and carry out its SAP-LAP analysis.
- What kind of innovative applications of SAP-LAP framework can be made in real life situations? Illustrate.

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From Little Acorns Do Olive Trees Grow !

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Introduction

Paradoxes are actually truisms that force us to be flexible in our perspective. They present to us viewpoints from bipolar ends of a continuum.They also reflect managerial dilemmas and provide insights into how managers think. Acorns actually grow into Olive trees. But then that is a rigid genetic program.It is certain,it is destined. The real challenge of human endeavour is when Acorns grow into Olive trees! Or into any tree other than Oak for that matter. This is symptomatic of flexibility. Flexibility is all about the exercise of options. These options do not exist in isolation. They are like a point on a line. Existing on a continuum, separate yet dynamically interplaying.

Ranbaxy Laboratories Limited set itself on a journey to turn from an India centric company to a multinational enterprise. Responding to a global business environment it set about modifying its business processes.

Marketing

Strategy : Making presence felt in developed markets through acquisitions and tie-ups.

Position yourself as a top of the line company in emerging markets

Concept : Wherever possible obtain the advantage of speed to market.

Process : Initially wait for the time that the patent expires and then be aggressive in the speed to market.

Remote manage the market and enter at a time when enough brand and company awareness has been built.

Consolidate in the market by shifting office there (if lucrative enough) .

Once presence established – do a check on the local distributors – keep the good performers, phase out the bad

If market is doing extremely well, set up a back office also in the Head Quarters in New Delhi.

Flexibility : Marketing Flexibility, Strategic Flexibility

Process R & D

Strategy : Improve the manufacturing process of some well established generic formulations .

Aggressively come out with new molecules and establish a strong product pipeline to get ready for the post 2005 scenario.

Concept : Product quality and economies of scale of established indigenous products sustain the market share and ensure sales revenues.

Process : Focus on basic research . Invest heavily in this kind of infrastructure.

Establish state of the art pilot plants before sending to manufacturing Continuous improvement of the manufacturing process.

Flexibility : R&D Flexibility

Novel Drug Delivery Systems

Strategy : Not only make more efficacious drugs but also discover better delivery system of drugs into the human system.

Concept : Increasing incidence of disease and lesser availability of resources especially time for health care demands better management of drug administration.

Process : Lesser frequency of dosage but higher efficacy in therapy.
Out license this technology to original makers of this drug - potential to be a great source of revenue generation.

Flexibility : Usage Flexibility, Strategic Flexibility

Novel Drug Discovery Research

Strategy : New molecules and/or identifying new properties of existing molecules would enhance medical health care as well as fortify research in medicinal chemistry.

Concept : Chemistry of the human body has a direct bearing to the efficacy of drugs administered. Understanding this can hold answers to many questions.

Process : Molecular reengineering.
Build up skill capability within the workforce for this kind of work

Flexibility : R&D Flexibility

Information Technology

Strategy : Achieve superior decision-making through faster access to data across business entities, business processes and people across geographies.

Concept : IT could bring in higher synergy in a fast expanding organization, especially when there is a lag between rate of business growth and supporting processes.

Development of people through IT

Process : Implementation of enterprise wide IT system.
Establishment of an e-learning culture in the organization.
Setting and disbanding small project teams and rewarding multiskilling.

Flexibility : Information Systems Flexibility, Organizational Flexibility

LAP Reflections

Learning - Which of the above listed practises you find most relevant in the context of your organiaztion ?

Action - How will you adapt the identified critical practices to enhance flexibility of your processes/actors ? Prepare an action plan.

Performance - Which performance indicators will be affected by implementing these critical practices and in what way?

About GIFT

GIFT (Global Institute of Flexible Systems Management) is a professional society to enhance *"flexibility"* in business and management.

Mission

To evolve and enrich the flexible systems management paradigm for the new millennium.

Vision

Evolving as a global forum for interaction of all interested professionals and organizations in a truly flexible mode so as to help them create more options, faster change mechanisms and greater freedom of choice in their own settings.

Schools

The Institute comprises of various schools, which are autonomous bodies, dealing with contemporary areas at the cutting edge contributing to the flexible systems management paradigm. At any point of time, each member can opt for an association with any two of the following schools in the respective thrust areas:

* GIFT School of Global Management
* GIFT School of Technology and Innovation Management
* GIFT School of Information Technology & Knowledge Management
* GIFT School of E-Commerce and E-Governance
* GIFT School of Learning Organization and Strategic Transformation
* GIFT School of Quality, Productivity and Wastivity Management
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* GIFT School of Human Values and Management Ethos

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– Book Series on Flexible Systems Management

– Quarterly Journal - *"Global Journal of Flexible Systems Management"* giftjourn@l

– Newsletter - "Flexibility"

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All correspondence and membership applications may be addressed to the Secretary of the institute at the following address:

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Detailed about topics, deadlines, registration fee etc. will be put on web shortly.

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Global Journal of Flexible Systems Management

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Guidelines for Authors

Aim

The journal is intended to share concepts, researches and practical experiences to enable the organizations to become more flexible (adaptive, responsive, and agile) at the level of strategy, structure, systems, people, and culture. Flexibility relates to providing more options, quicker change mechanisms, and enhanced freedom-of-choice so as to respond to the changing situation with minimum time and efforts.

It is aimed to make the contributions in this direction to both the world of work and the world of knowledge so as to continuously evolve and enrich the flexible systems management paradigm at a generic level as well as specifically testing and innovating the use of SAP-LAP (Situation- Actor - Process-Learning-Action-Performance) framework in varied managerial situations to cope with the challenges of the new business models and frameworks.

Scope

The Journal will include the papers relating to: conceptual frameworks, empirical studies, case experiences, insights, strategies, organizational frameworks, applications and systems, methodologies and models, tools and techniques, innovations, comparative practices, scenarios, and reviews.

The papers may be covering one or many of the following areas: Dimensions of enterprise flexibility, Connotations of flexibility, and Emerging managerial issues/approaches generating and demanding flexibility (details can be seen on the website - www.giftsociety.org.).

Coverage

The journal will be organized into various sections to include following types of contributions: Research papers, Short notes/correspondence, Applications and case studies, Book reviews, Book summaries, Interviews and round tables, Information about relevant conferences and seminars, Educational and learning experiments, and any other relevant information related with the theme of the Journal.

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Four copies of manuscript should be submitted to the Editor-in-Chief at this address: Prof. Sushil, Department of Management Studies, Indian Institute of Technology, Hauz Khas, New Delhi - 110 016, Ph: 91-11-6591167, 91-11-6857787, Fax: 91-11-6591167, 91-11-6862620.

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Title: The title should be brief and typed on a separate sheet.

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Footnotes: should be used only when absolutely necessary and must be identified in the text by consecutive numbers placed as superscript.

Text: The main text should be more readable and mathematical models, if any, should be provided in Appendix. The ideas proposed should preferably be supported by real life case examples from business situations.

Tables and Figures: All tables and figures should be kept to a minimum and numbered consecutively using arabic numerals. Each table should have a brief title written on the top of the table, and each figure should have a brief caption written on the bottom of the figure.

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e.g. Volberda H.W. (1997) Building Flexible Organization for Fast Moving Markets, *Long Range Planning,* 30 (2), 169-183.

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Fifty offprints of each paper will be provided free of charge to the principal author. Additional copies may be purchased on an offprint order form, which will be sent to authors along with proofs.

Checklist

- The paper is original, not submitted anywhere else.
- The length of the paper is commensurate with content.
- The title and headings are brief and catchy.
- The author(s) name and affiliation are given only on cover page.
- Abstract and keywords are provided.
- The category of the paper is specified as per standard list.
- Focus on flexibility in management is kept.
- The paper incorporates innovative ideas/models in a practical framework.
- Mathematical models, if any, are given in Appendix.
- Tables/Figures are properly placed and numbered with brief titles/ captions.
- References are in standard style.
- Autobiographical notes and passport size photographs of all authors are provided (in case of final submission).

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