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Formation of Virtual Manufacturing Cells by Incorporating Flexibility

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Abstract

In recent years, there has been a tremendous growth in the number of cell formation methods. The surge of interest in the area has been fueled by the substantial industry interest in implementing cellular manufacturing (CM) system to reduce set-up times, material handling and lead times. In this paper, a new approach for cell formation has been presented with main focus on flexibility in regrouping of operations. The procedure includes three phases. In phase 1, primary cells are formed by dividing operations into three ranges (high, medium and low). The frequency of flow occurring between the operations has been taken as a measure for dividing flows into three ranges. Phase 2, involves decomposition of individual primary cells into sub-cells by employing phase 1 again on individual primary cells until further division into sub-cells becomes impossible. Phase 3, involves shifting of operations based upon machine utilization in cells. The formulation forms a formal framework for further research for the development of multi-criteria models by incorporating various flexibilities.

Keywords : flexibility, intercell flow, intracell flow, material handling, operations regrouping, utilization, virtual manufacturing cells

Introduction

Manufacturing firms are under constant and intense pressure to quickly and continuously improve their operations by enhancing productivity, quality and responsiveness. Driven by the need to reduce manufacturing costs, and improve flexibility, there has been a major shift in the design of manufacturing planning and control systems by applying flexible manufacturing systems (FMS), cellular manufacturing (CM), and group technology (GT) principles. CM has received considerable interest from both practitioners and academicians because it allows small, batch-type, production to gain an economic advantage similar to that of mass production and still retaining the high degree of flexibility associated with the job-shop production.

A survey conducted on the impact of CM on Australian industries, with over $10 million annual turnover, showed that about 209 companies accounting for 52 per cent of the companies surveyed are already using or are in process of implementing CM, with a further 28 per cent indicating their future plans to introduce CM to some parts of their operations. Of the companies already using CM, more than 70 per cent reported improvements in one or more aspects of lead times, lot sizes, labour productivity, set-up times, on-time delivery, flexibility and quality (Kaebernick and Bazargan-Lari, 1996).

The conventional definition of a manufacturing cell is somewhat restrictive (Henry and Abdelaziz, 1988). The requirements that each cell functions as a modified flow shop, and that parts within the family must go from raw material to finished parts, within a single cell, makes the manufacturing cells configuration problem very complex. The presence of alternate process plans, duplication of machines, and subcontracting may not always eliminate the problem of 'inter-cell' flows. Hence, there is a need to relax the restriction by allowing jobs to move between cells. Virtual cells allow the time sharing of machines among different cells producing different part families, but having overlapping resource requirement (Irani et al., 1993). Thus, the restriction of confining a part to only one cell is relaxed. Machines retained in a functional layout can be dedicated to a family without physically disturbing those shared machines among two or more cells, by simply assigning different tools and fixtures to a machine, it can be dedicated to different part families in successive production periods. In this way, machine and routing flexibilities of the job shop can be maintained in the cellular manufacturing system.

The rest of the paper is organized as follows. In section two, a brief review of literature is presented. The need for formation of virtual cells by incorporating flexibility in operations regrouping is presented in section three. A three-phase methodology used in formation of virtual cells is explained in section four. Through an illustrative example, the capability of the proposed methodology with advantages and limitations is presented in section five. This is followed by conclusions in the last section.

Literature Review

The design of a CM system is quite challenging because so many strategic issues, e.g. the selection of parts suitable for manufacturing on a group of machines, the level of machine and routing flexibilities, the layout of cells, the types of material handling equipment, and the types and numbers of tools and fixtures, must be considered during design. The purpose here is to document some significant developments in cell formation methods and to understand the issues involved in identifying the links between them.

Steudel and Ballakur (1987) introduced a two-stage dynamic programming heuristic model for the machine grouping problem in flexible manufacturing systems. The authors introduced a new similarity coefficient measure called cell bond strengths (CBS). CBS captures relationship between machines with respect to the parts incident on them. The measure is based on the processing times of the parts on the machines.

Kusiak (1988) introduced a two-stage model based on expert systems and optimization technologies for solving the generalised GT problem. The objective of the model is to minimise material handling costs for the part family having maximum production costs subjected to limitations on machine capacity, cell size, material handling system capabilities, machines dimensions and technological requirements.

Tam's (1990) density linkage clustering technique known as kth-nearest neighbour cluster method is used for forming groups of parts. The study also defines similarity coefficient that incorporates both machine resource requirements and operations sequences of parts. The main advantage of this model is that part families resulting from it allow machines to "interleave between identical operations of different parts", thereby minimizing setup times and intra-cell travels.

Shafer and Rogers (1991) proposed goal programming model combined with the p-median (for identifying part families) and travelling salesman problem (to determine the optimal sequence of parts). The criteria considered by the authors include minimizing set-up times (through parts sequencing), minimizing intercellular movements, minimising the investment in new equipment, and maintaining an acceptable machine utilisation level.

Dahel and Smith (1993) developed a 0-1 integer model and a multi-objective model for designing flexibility into cellular manufacturing systems. 0-1 integer model minimises inter-cell moves and multi-objective model forms cells which are flexible with the constraint of minimum interactions. They measure routing flexibility of a cell based on number of different parts, which could be handled by the cell.

Liang and Taboun (1995) use a heuristic weighted approach to achieve a compromise solution between flow-line efficiency and job-shop flexibility. The objectives of the model are to maximize system flexibility (measure based on the number of part types accommodated into the focused cells), and to maximize system efficiency (measure based on the degree of part similarities).

Machine and routing flexibilities of the job shop can be maintained in the cellular manufacturing system.

Rajamani et al. (1996) developed a mixed integer programming model with the objective function of minimizing the sum of investment, process and material handling costs as a weighted sum of the three different cost functions. Weighted approach is used for three factors. To solve the relaxed linear model the author makes use of a column generation scheme and the branch and bound technique.

Lee and Chen (1997) developed a weighted three-phase approach, which not only forms machine cells and part families, but also allows machine duplication wherever necessary. Phase 1 determines the workload balances for duplicated machines. Phase 2 constructs machine cells and part families by employing heuristic algorithm. Phase 3 improves the solution quality using heuristics. The two criteria considered are: minimizing inter-cell movement of parts and maximizing workload balance among duplicated machines.

Su and Hsu (1998) consider three objectives in their model. The objectives are: minimizing the total cost of inter-cell transportation, intra-cell transportation and machine investment; minimizing intra-cell machine (in cell) load unbalance; and minimising inter-cell machine (in plant) load unbalance. The authors unified these objectives through weighting and solved the model by means of parallel simulated annealing.

In the pioneering work of Hollier (1963), Carrie (1975) and Carrie and Mannion (1976) on unidirectional flow line design, the flows have been classified as (a) in-sequence, (b) bypass, or (c) backtrack. This classification is sufficient since they considered the optimum layout of a single group of machines only, thus encouraging duplication among cells. However, if inter-cell layout must be incorporated with intra-cell layout, an additional type of flow is created as the cells have common machine requirements. Such type of inter-cell flows is known as cross flows. This type of flow reduces number of machines available within a cell for duplication. But they pose problems like higher queuing delays for parts involved and machine utilisation.

Creating independent cells, i.e. cells with no linkages to other cells in the factory, is a common goal of the traditional cell formation approach (Burbridge, 1977). This approach discourages machine sharing and intercell flows and also fails to capture the information about the flow of material. However, with the advances in material handling systems, machine duplication is being discouraged. Part families with overlapping machine requirements are assumed to be merged to eliminate the need to duplicate shared machines among competing cells. When intercell flow exists, it is more important to eliminate these flows by machine duplication since these will have even higher queuing delays. Material handling cost and time are dependant on the volume of intercell moves, so there is a need to minimize the volume of intercell moves leading to reduced material handling (Venugopal and Narendran, 1992).

Most of the CM approaches and techniques available in the literature fail to address other important issues, such as (1) feasibility of non-independent cells having intercell flows and machine sharing among them (Wemmerlov and Hyer, 1989), (2) concentration on machine grouping and part family and neglecting flow directions and flow volumes (Irani et al., 1993), and (3) the effect of sequence of operations on material handling costs and time (Harhalkis et al., 1990). These issues have received relatively little attention in the literature so far. Hence, there is a need to develop an algorithm to address the above mentioned issues. For this purpose, a flow based approach is suggested for the formation of virtual manufacturing cells which integrates machine grouping and intercell flow handling. Also, the motivation to incorporate flexibility in operations regrouping as the main criteria to solve part-machine grouping problem is based on the following:

A virtual cell was defined as a logical grouping of products and resources within a controller.

- Inclusion of operation sequence into part-machine grouping leads to formation of flow line, which with their streamlined work flows, achieve complete realization of benefits of cellular manufacturing, with lesser backtracking and material handling, improved control of cell activities, and easier use of conveyors within the cell. Also operation overlapping can be achieved, which leads to further reduction in lead-time and work-in-process inventory (Suresh et al., 1999).
- Part-machine grouping does not consider two of the most fundamental elements in cellular manufacturing, the facility layout and the material handling strategies (Irani et al., 1993).

Formation of Virtual Manufacturing Cells by Incorporating Flexibility

The virtual manufacturing concept was first developed at National Bureau of Standards to address specific control problems encountered in the design phase of the automated manufacturing of small batches of machined parts (McLean et al., 1982). A virtual cell was defined as a *logical grouping* of products and resources within a controller. It allows time sharing of workstations with other cells by virtue of overlapping resource requirements. The job shop based upon virtual manufacturing cells provides greater flexibility due to time sharing of machines. Machines are at all times under the control of either a particular virtual cell or a pool of idle machines. Basically, the shop control system schedules cell activation and allocate machine and other resources to these cells.

The approach of virtual cells may help to minimize the load balancing problems, which are due to the sharing of machines by various part families (Irani *et al.*, 1993). Further, the authors argue that the machine groups can be 'virtual', i.e. parts of several families can be loaded on a particular machine shared by several cells. They developed a two- stage flow based approach for the formation of virtual manufacturing cells with an objective to minimize intercell flow distances. The issues of their study include machine grouping, machine sharing, intracell layout and intercell layout by neglecting part family formation.

Slomp, Chowdary and Suresh (2005) addressed virtual cells as temporary groupings of machines, jobs and workers to realize the benefits of CM. The virtual cells are created periodically depending on changes in demand volumes and mix, as new jobs accumulate during a planning period. Factors such as capacity constraints, cell size restrictions, minimization of load imbalances, minimization of inter-cell movements of parts, provision of flexibility, etc. are considered. In this paper, a multi-objective procedure was developed for designing virtual cells that includes not only job-machine grouping, but also labor grouping. To help the readers to understand various operational definitions of virtual manufacturing cells a review of definitions is presented in Table 1.

Table 1 : Definitions of Virtual Manufacturing Cells

Author(s)	Definition
McLean, Bloom, and Hopp (1982)	A virtual cell is a logical grouping of resources with in a controller and is not identifiable as a fixed physical grouping of workstations, but as data files and processes in a controller.
Irani, Cavalier, and Cohen (1993)	The virtual cell is no longer identifiable as a fixed physical group of machines and defines only in the system control software. It allows the time sharing of workstations with other virtual cells that produce different part families.
Rheault, Drolet, and Abdulnour, (1995)	A virtual cell is a logical grouping of workstations that are not necessary transposed into physical proximity
Kannan and Ghosh (1996)	Virtual cellular manufacturing (VCM) as formation of temporary virtual cells where family-based scheduling rules are used to form logical cells within a shop using a process layout.
Marcoux, Drolet, and Abdulnour (1997)	Virtual cell is a logical grouping of machines under a control of computer system
Hyer and Brown (1999)	Virtual cells are referred to as 'dedication of machines without rearrangement' and have been known as logical cells
Vakharia, Moily, and Huang (1999)	A virtual cell is simply the dedication of specific machines within the current departments to a prespecified set of part families
Ko and Egbelu (2000)	Virtual cell is defined as a logical grouping of machines and its basic configuration is recognized and stored by a computer.
Thomalla (2000)	Formation of logical cells without changing the physical layout.
Slomp, Chowdary, and Suresh (2005)	Virtual cell is defined as temporary groupings of machines, jobs and workers to realize the benefits of CM. The virtual cells are created periodically depending on changes in demand volumes and mix, as new jobs accumulate during a planning period.

This paper addresses the problem of virtual cell formation through a three phase flexible methodology based on operations sequence of the parts. Often there are operations in the cells, which contribute more towards intercell flow than to intracell flows. So these types of operations needs to be identified and shifted to a cell in which they contribute maximum towards intracell flow, provided they do not increase the overall processing cost for the whole manufacturing system. The work uses the utilization of machines within the cell as an evaluation criterion for determining the fairness of the various solutions generated. Also the methodology cross checks the utilization criterion by evaluating material handling cost and time. These measures judge the operations contribution towards intracell flows. We treat the restriction of complete processing within a single cell as a desirable goal, but not a constraint. The virtual cellular system proposed here is a new cell design concept, which enables a company to limit machines grouping and machine duplication by having a semi-functional layout and allowing some intercell flows.

> ***The job shop based upon virtual manufacturing cells provides greater flexibility due to time sharing of machines.***

Methodology

Phase 1: Formation of Primary Cells

a) Divide operations into three ranges (high, medium and low) based on GT philosophy by employing frequency of flow occurring between operations in the part routings for the various parts.

b) Shift operations causing only intercell flows to its respective cells.

Phase 2: Decomposition of Individual Primary Cells into Sub-cells

a) Employ phase 1 again on individual primary cells until further division into sub-cells becomes impossible.

b) Find maximum number of operations in a cell out of newly formed sub-cells.

Phase 3: Evaluation of Cells and Shifting of Operations

a) Evaluate percentage utilization for all machines in the cell by using the following:

$$(U_i)_{net} = \sum_{k=1}^{n_s} v_k \sum_{l=1}^{m_k} \left[x_{(k,l)} * t_{(k,l)}\right]$$

$$(U_i)_{net} = \sum_{k=1}^{n_s} v_k \sum_{l=1}^{m_k} \left[x_{(k,l)} * t_{(k,l)}\right]$$

where

$$x_{(k,l)} = 1, \forall m_{(k,l)} = i$$

$$x_{(k,l)} = 0, \forall m_{(k,l)} \neq i$$

where

U_{ij} = Utilization of i^{th} machine in the j^{th} cell

$(U_i)_{net}$ = Utilization i[th] machine in the system assuming no cells

v_k = batch quantity for k^{th} part

n_j = number of parts assigned to j^{th} cell

n_s = total number of parts produced by the system

m_k = number of machines involved in manufacturing of k^{th} part

$t_{(k,l)}$ = time required to complete l^{th} operation of k^{th} part

b) Start shifting machines having least utilization in the cell where it provides maximum utilization subjected to condition of least material handling cost and time. Evaluate the material handling cost and time using the following.

$$M_{ij} = e(M_{ij})_t + f(M_{ij})_c$$

where,

$$(M_{ij})_t = \sum_{k=1}^{n_s} v_k \sum_{l=1}^{(m_k-1)} x_{[k,(l,l+1)]} * d\left[\mu_{(l,l+1)}\right] * t_{av}$$

$$(M_{ij})_c = \sum_{k=1}^{n} \sum_{l=1}^{n_f} d\left[\mu_{(l,l+1)}\right] * c_{av}$$

$$f = g * t_c$$

$$x_{[k,(l,l+1)]} = 1, \forall m_{(k,l)} = i \bigcup m_{(k,l+1)} \notin cell\ j$$

$$, \forall m_{(k,l+1)} = i \bigcup m_{(k,l)} \in cell\ j$$

$$, \forall m_{(k,l)} \neq i \bigcup m_{(k,l+1)} \neq i$$

$$x_{[k,(l,l+1)]} = 0, \forall m_{(k,l)} = i \bigcup m_{(k,l+1)} \in cell\ j$$

$$, \forall m_{(k,l+1)} = i \bigcup m_{(k,l)} \in cell\ j$$

where

$(M_{ij})_t$ = net material handling time

$(M_{ij})_c$ = net material handling cost

$d[m_{(l,l+1)}]$ = , if cross flow, i.e. for i^{th} flow, number of arcs m_{ij} required for connecting two nodes

a = y, if cross flow, i.e. node $l+1$ is reachable from node l vertically by a path m_{ij} containing y arcs,

b = z, if cross flow, i.e. node j is reachable from node $j+1$ horizontally by a path m_{ij} containing z arcs

n_f = number of non repeating intercell flows because of i^{th} machine placed in j^{th} cell

t_{av} = average material handling time

c_{av} = average material handling cost

g = constant for material handling flexibility

t_c = conversion factor for converting cost into equivalent time

We treat the restriction of complete processing within a single cell as a desirable goal, but not a constraint. This relaxed definition of manufacturing cell results in the complete partition of machinery.

Illustrative Example

In order to show the capability of the integrated approach in generating multiple cell design solutions, an example is introduced and solved using the integrated flow based approach described above.

The proposed method will be explained by using an example obtained from the literature (Huang and Irani, 1999). The problem concerns a system having 12 machines and 19 parts. The information regarding the part routing is given in the Table 2.

Table 2 : Operation Sequences for the System of Parts

Part Number	Operation Sequence	Time	Parts per Batch
1	1,4,8,9	96-36-36-72	2
2	1,4,7,4,8,7	36-120-20-120-24-20	3
3	1,2,4,7,8,9	96-48-36-120-36-72	1
4	1,4,7,9	96-36-120-72	3
5	1,6,10,7,9	96-72-200-120-72	2
6	6,10,7,8,9	36-120-60-24-36	1
7	6,4,8,9	72-36-48-48	2
8	3,5,2,6,4,8,9	144-120-48-72-36-48-48	1
9	3,5,6,4,8,9	144-120-72-36-48-48	1
10	4,7,4,8	120-20-120-24	2
11	6	72	3
12	11,7,12	192-150-80	1
13	11,12	192-60	1
14	11,7,10	288-180-360	3
15	1,7,11,10,11,12	15-70-54-45-54-30	1
16	1,7,11,10,11,12	15-70-54-45-54-30	2
17	11,7,12	192-150-80	1
18	6,7,10	108-180-360	3
19	12	60	2

Phase 1 : Formation of primary cells by dividing flow into three ranges. Table 3(a) presents the actual flow that is occurring between various machines in the manufacturing system prepared by using the part routings given in the Table 2 (Huang and Irani, 1999). Table 3(b) presents the flows by summing of similar flows under one machine head, which is prepared by using the Table 3(a). This step converts the frequency matrix in to a lower triangular matrix.

Table 3(a) : Frequency Chart for all Machines

	1	2	3	4	5	6	7	8	9	10	11	12
1	-	1	-	3	-	1	2	-	-	-	-	-
2	-	-	-	1	-	1	-	-	-	-	-	-
3	-	-	-	-	2	-	-	-	-	-	-	-
4	-	-	-	-	-	-	4	6	-	-	-	-
5	-	1	-	-	-	1	-	-	-	-	-	-
6	-	-	-	3	-	-	1	-	-	2	-	-
7	-	-	-	2	-	-	-	2	2	2	2	2
8	-	-	-	-	-	-	1	-	6	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	2	-	-	-	2	-
11	-	-	-	-	-	-	3	-	-	2	-	3
12	-	-	-	-	-	-	-	-	-	-	-	-

Table 3(b) : Summation Frequency Chart for all Machines

	1	2	3	4	5	6	7	8	9	10	11	12
1	-	-	-	-	-	-	-	-	-	-	-	-
2	1	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	3	1	-	-	-	-	-	-	-	-	-	-
5	-	1	2	-	-	-	-	-	-	-	-	-
6	1	1	-	3	1	-	-	-	-	-	-	-
7	2	-	-	6	-	1	-	-	-	-	-	-
8	-	-	-	6	-	-	3	-	-	-	-	-
9	-	-	-	-	-	-	2	6	-	-	-	-
10	-	-	-	-	-	2	4	-	-	-	-	-
11	-	-	-	-	-	-	5	-	-	4	-	-
12	-	-	-	-	-	-	2	-	-	-	3	-

Table 3(c) : Primary Cells Obtained by Dividing into three Equal Ranges

Cell Type	Operations Assigned to Each Cell
Low frequency	2, 3, 5
Medium frequency	1, 6 , 10
High frequency	4, 7, 8 , 9, 11, 12

The maximum frequency as obtained from Table 3(b) is 6. So dividing the maximum frequency in three parts based on GT philosophy, the primary cells obtained are shown in Table 3(c).

> ***The virtual cells are created periodically depending on changes in demand volumes and mix, as new jobs accumulate during a planning period.***

Phase 2 : Redesign the primary cells to minimize the intercell travels. The primary cells obtained after redesigning might have some operations which may be contributing more to intercell flows as compared to intracell flows. So the type of machines needs to be relocated to proper cells to minimize the intercell travels. Operations assigned to cells need to be re-adjusted among themselves to minimize the intercell travel distances. But the shifted operation is contributing more towards intercell flow. Hence, its needs to be shifted to medium frequency cell. Table 3(d) shows the primary cells obtained after redesign of the primitive cells to minimize the intercell travels.

Table 3(d): Primary Cells Obtained after Redesign of the Primitive Cells

Cell Type	Operations Assigned to Each Cell
Low frequency	3, 5
Medium frequency	2, 1, 6 , 10
High frequency	4, 9, 8, 7, 11, 12

Phase 3: Shifting of operations based upon utilization of machines in cell. All the operations, which are having less utilization in a cell needs to be shifted to cell where they have a better utilization. Utilization calculated for all machines in the system and results are tabulated in Table 4.

Table 4: Utilization, Material Handling Time and Cost Values

Machine No.	Utilization	Material Handling Time	Material Handling Cost	Maximum Utilization	Percentage Utilization
1	0921	18.022	3.650	0921	100.00
2	0048	02.414	2.414	0096	050.00
3	0288	00.000	0.000	0288	100.00
4	0480	21.260	4.650	1560	030.77
5	0240	02.828	2.828	0240	100.00
6	0864	13.187	5.064	1008	085.71
7	0880	15.708	4.650	2530	034.78
8	0048	00.000	0.000	0444	010.81
9	0000	00.000	0.000	0804	000.00
10	1735	13.243	2.414	2815	061.63
11	1440	04.242	1.414	1764	81.633
12	0340	00.000	0.000	0430	79.070

From Table 4, it can be clearly seen that machine 9 has least utilization. Hence, it needs to be shifted to medium frequency cell. Material handling cost and time has been calculated for various combinations of cells. The results show that there is an overall increase in material handling time by 68 per cent and material handling cost by 37 per cent. As shifting caused an increase in material handling cost and time, hence the shifting is discouraged. Multiple cell designs are formed by forcing certain operations to other cells based on the criteria of utilization of machines in a cell. Various results obtained by shifting various machines are shown in Table 5. In this way, the strength of the proposed approach can be demonstrated.

The virtual cellular system proposed here is a new cell design concept, which enables a company to limit machines grouping and machine duplication by having a semi-functional layout and allowing some intercell flows.

Table 5: Various Cell Designs Due to Shifting of Operations Based on the Machine Utilization, Material Handling Cost and Time

Cell Design	Cell formed: Cell #	Cell formed: Machines Assigned	Material Handling Time (MHT)	% Increase or Decrease in MHT	Material Handling Cost (MHC)	% Increase or Decrease in MHC
1	I	3, 5	090.90	-	27.085	-
	II	2, 1, 6, 10				
	III	4, 9, 8, 7,11, 12				
2	I	3, 5	152.80	+ 68.087	37.058	+36.82
	II	2, 9, 1, 6, 10				
	III	4, 8, 7, 11, 12				
3	I	3, 5	146.75	+ 61.432	33.770	+ 24.68
	II	2, 8, 1, 6, 10				
	III	4, 9, 7, 11, 12				
4	I	3, 5	112.87	+ 24.168	25.086	- 07.38
	II	2, 1, 4, 6, 10				
	III	9, 8, 7, 11, 12				
5	I	3, 5	118.63	+ 30.505	32.732	+ 20.84
	II	8, 4, 6, 10, 1, 2				
	III	9, 11, 7, 12				
6	I	3, 5	138.66	+ 52.535	35.560	+ 31.28
	II	9, 4, 6, 10, 1, 2				
	III	8, 11, 7, 12				
7	I	3, 5	120.77	+ 32.090	31.077	+ 14.73
	II	2, 1, 4, 7, 6, 10				
	III	9, 8, 12, 11				

Advantages

i) The proposed methodology is extremely useful when the system has large number of operations.

ii) Provides the decision- maker with multiple cell designs according to maximum number of machines cell, which offers flexibility to evaluate each alternative against tangible and intangible benefits.

Limitation

The performance of the proposed methodology is dependent on phase 1. A poor division criterion will in turn increase the computational effort and the time for convergence will be increased drastically.

Conclusions

CM is a major innovation in the design of production systems. But the restrictive nature of traditional manufacturing cell makes it almost impossible to achieve higher efficiencies from the CM system. The added flexibility through operational regrouping of virtual cellular system provides balanced utilization of machines and faster response to short-term fluctuations in demand. Also this flexibility provides a premium competitive value in the current production environment, which is characterised by ever changing demands.

This paper presents a three-phase approach for formation of virtual manufacturing cells with flexibility in operations regrouping as a main issue. Phase 1, is responsible for formation of primary cells. Phase 2 tries to decompose the individual primary cells into sub-cells. Shifting of operations based upon machine utilization in cell is done in Phase 3. The approach generates multiple cell designs, identifies flowline layout for each group and minimizes intercell distances and travels. It offers the flexibility to assess each alternative against tangible and intangible benefits and criteria. The capability of the model was demonstrated by applying it to an illustrative example. This formulation provides a formal framework and starting point for the development of solution methods and heuristics by incorporating various flexibilities in the formation of virtual cells.

Future Research Directions

The design of virtual manufacturing cells with respect to multiple criteria has been an attractive research. The multi-criteria models should include labor grouping considerations in addition to part-machine grouping. Factors such as capacity constraints, cell size restrictions, minimization of load imbalances, minimization of inter-cell movements of parts, and provision for adequate levels of labor flexibility need to be considered in the future research.

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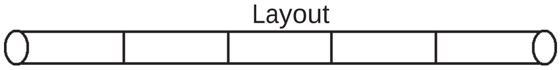
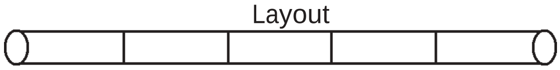
Flexibility Mapping : Practitioner's Perspective

1. Which variants of flexibility do you envision in a practical situation of identifying "virtual cell formation" on the following planes:
   - Flexibility in terms of "options"
   - Flexibility in terms of "change mechanisms"
   - Flexibility in terms of "freedom of choice" to participating actors.
2. Identify and delineate the types of flexibilities that are relevant for your own organization. On which dimensions, flexibility should be enhanced?
3. Try to map your own organization on the following continua. (Please tick mark the appropriate box(es)).

Layout

Functional  Traditional Cellular

Layout

Functional  Virtual Cellular

Flexibility

Machine Flexibility  Sequence Flexibility

3. Develop a SAP-LAP (Situation Actor Process- Learning Action Performance) model of virtual cell formation relevant to your organization.

Reflecting Applicability in Real Life

1. How your organization will benefit using the proposed virtual cell formation?

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Simulation

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Performance Analysis of Partial Flexible Manufacturing Systems

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Abstract

The importance of manufacturing flexibility has gained momentum in recent times due to product variety and faster response time required by the customers. The application of partial flexibility applied in shop floor control has shown that many benefits of total flexible systems can be obtained by less flexible systems. The levels of routing flexibility are utilized to distinguish between different types of flexible systems. In particular, routing flexibility allows system resources to process parts based on some control logic. Partial flexible system is an intermediate configuration between a total flexible system (where each part can be processed on all the available resources) and a non-flexible system (where each part has dedicated resources). A simulation study is carried out to measure the make-span performance of different systems. In this study, different variables considered are routing flexibility, sequencing rules, buffer size, system load, setup time, pallets, and part mix. Simulation results show that partial flexible system performs almost at par with total flexible system under different system variables. A sensitivity analysis is done to see the impact of different sequencing rule and system load on the system performance.

Keywords : flexibility, make-span, pallets, routing flexibility, system performance

Introduction

To fulfill customer requirements in terms of variable demand, variety, cost and quality has forced many manufacturing companies to adopt flexible systems. In particular, a large number of products variables have to be provided, without neglecting cost. Gilmore and Pine II(1997) state that flexibility has to be pursued together with scale of economies, as stated by mass customization. It follows that greater variety of parts requires more frequent changeovers and setups of the manufacturing system. Every changeover disrupts the production and thus incurs plenty of time and cost. Flexibility can help in production of variety of products at lower time and cost (Wadhwa and Rao, 2000).

The searches for system flexibility, agility and versatility on the one hand, and of high volumes and low costs on the other, have led to modifications in the planning and control of production activities. From the operations management point of view, batch production systems are among the most interesting in the search for a competitive trade-off between cost and flexibility. According to Jensen et al. (1996), under turbulent manufacturing environment management adopts flexible manufacturing system, which can deal with uncertainty in a better way. Partial flexibility may be seen as a given level of flexibility in a system (that is flexible to a certain extent but not to it's full potential (Wadhwa and Aggarwal 2000). In partial flexible system, parts and resources are linked in such a manner that it provides many typical benefits of total flexible system. This link can provide many typical benefits of a total flexible system (where every resource can process every family, as in a job shop) and of a non-flexible system (where every resource is dedicated to just one family). Simulation study is carried out to measure system performance in terms of make-span time for different system configurations. In particular, the comparisons between the non-flexible, partial flexible and total flexible configurations are studied. Wadhwa and Browne (1990) and Wadhwa and Rao (2000) have discussed the evolution of such concepts at the discrete event level and at the operational levels respectively.

This study is motivated by the works of partial flexibility in FMS/CIMS contexts, as discussed by Wadhwa and Aggarwal (2000). The model chosen for our study involves different variables, such as Routing Flexibility (RF=3 levels, i.e. no-flexibility, partial flexibility and total flexibility), Sequencing Rules (SR=2 levels, i.e. SPT and MBPT), Buffer Size (BS=2 levels, i.e. 3 and 10), System Load (SL=2 levels, i.e. 600 and 900), Setup Time (ST=2 levels, i.e. 0 and 0.25), Number of Pallets (NP=4 levels, i.e. 24, 36, 48, and 60) and part mix. However, solving uncertainty problems with the help of routing flexibility involves some disadvantages, as it has been shown by Ang and Willey (1984). First, extra costs of material handling are incurred; second, workflow simplicity is lost and the costs of production planning and scheduling are increased; third, the number of components being processed by a particular resource is reduced. A judicious decision has to be taken to implement the right level of flexibility to get the maximum benefit from the system as has been shown by Wadhwa and Bhagwat (1998) for a deterministic model of a semi-computerized flexible system

(SCFM). In this study, an attempt has been made to show that such partial flexible systems can perform at par with the total flexible system thereby reducing the role of issues indicated by Ang and Willey (1984). The work extends efforts of Wadhwa and Browne (1990) by covering many scenarios.

The paper is organized as follows. In Section two, literature review is presented. Section three describes the simulation methodology, simulation language selection criteria and brief description of ARENA – 7 software package. Simulation model is discussed in Section four. Section five discusses the simulation results followed by sensitivity analysis in Section six. Section seven presents conclusions.

Literature Review

The literature review is done keeping in mind the parameters considered in this study. The parameters include routing flexibility, control strategies, performance measures etc. The routing flexibility measures the ability to perform operations by more than one machining center in order to tackle bottleneck machines or to handle machine breakdowns. Exploiting the routing flexibility in the discrete part manufacturing systems involving variety production towards the make-span performance by using on line control strategies is represented by key works of Wadhwa and Browne (1990), Lin and Solberg (1991), Benjaafar (1994), Paulli (1995), Caprihan and Wadhwa (1997), Wadhwa and Bhagwat (1998) and Wadhwa and Aggarwal (2000). Das et al. (1997) point out that routing flexibility responds effectively to changing environment, hence reducing the negative impact of variability on the system performance. Barad et al. (2003) state that routing flexibility is the capability of processing a part through varying routes, or in other words by using alternative machines.

Partial flexibility is a given level of flexibility in a system (Wadhwa and Aggarwal 2000) that is flexible to a certain extent but not to it's full potential.

Wadhwa and Browne (1990) indicate that flexibility may be viewed to offer various decision points that guide the discrete events to evolve the system towards directions that may lead to system performance improvements. According to them decision choices on entity flows are typically exercised using different control strategies, which manifest themselves as dispatching and sequencing rules. Ovacik and Uzsoy (1994) explain that in practice, job shop scheduling has been approached mainly by using sequencing and dispatching rules. Many authors have used different sequencing rules. Some of these are earliest due date (Mohammed 1995, Sukran et al.1999), shortest processing time (Denzler et al.1987, Wadhwa and Bhagwat 1998, Elmekkawy et al. 2003), and balance processing time (Wadhwa and Bhagwat, 1998). All these rules are used in combination with different dispatching rules and performance measures. Stecke and Solberg (1981) have carried out a simulation study for machine loading and part sequencing in flexible manufacturing system. The study showed that the system performance is highly dependent on the control strategies applied. The benefit of flexibility can be obtained by using good scheduling strategies.

Many studies (for instance Wemmerlok and Hyer 1987, Morris and Tersine 1995, Chan 2001, Wadhwa and Rao 2004) have addressed the benefits of flexible and non-flexible system in different scenarios, for instance, depending on the performance analyzed (e.g. make-span and system utilization, lead time) and on the ranges assumed by various parameters (e.g., product volume and part mix, setup time buffer size, number of pallets type of pallets and control strategies).

It is seen from the literature review that very few studies are reported that deal with the impact of partial routing flexibility, under different variables, such as number of pallets, sequencing rule, dispatching rule, setup times etc., on the system performance. In this paper, the concept of partial flexibility, which is synonymous to limited flexibility, proposed in the literature in a multi-plant production-planning context (Jordan and Graves 1995, Garavelli 2001), is applied to the shop floor management. Partial flexibility is considered here as a particular level of routing flexibility allowing some resources to process some parts according to a given logic. Our view of partial flexibility is similar to the levels of flexibility described by Wadhwa and Browne (1990) for FMS and Wadhwa and Rao (2004) for manufacturing and supply chains.

Simulation Methodology / Simulation Language Selection Criteria / ARENA - 7

Development of the simulation model proceeded through various stages, such as setting of scope and objectives, gathering of data, building, verifying, and validating the model, and analyzing its output. Each of these steps is essential for simulation project success (Robinson and Bhatia, 1995). Simulation modeling is useful to analyze complex systems such as flexible systems. Alternative routing flexibility options can be studied as partial flexible systems using simulation models. The experience of the various manufacturers of these systems clearly demonstrates the value of simulation in analyzing system design. For most companies, the benefits of using simulation go beyond just providing a look into the future. However, developing simulation models for Industry requires cost-effective simulation packages. The important criteria for selection of simulation package includes ability to handle discrete event changes, adequate documentation, must have well developed diagnostic aids, must make efficient use of memory, be compatible with other software, must be capable of easy modification and extension and should have a well-established support group. Many simulation software packages require special modeling efforts to effectively model flexibility and its exploitation in manufacturing enterprises. Most packages lack features to model flexibility explicitly, but this feature is increasingly needed by Industry.

Special modeling efforts are needed to develop flexibility options. Simulation packages that offer in-built flexibility modeling will be preferable to Industry. ARENA - 7, a simulation package (simulator) used for this study needed some added efforts to model different levels of flexibility. Simulators can be used in wide variety of application areas such as call centers, business processes, and manufacturing systems. It has an extensive document in hard copy as well as electronic. Model development is done using templates and modules. Building a model in this software is similar to creating a flowchart model. Since flowcharts are the predominant mechanism to describe processes, the ARENA - 7 methodologies for building models is based upon the creation of flowcharts. Most importantly, ARENA - 7 retains the natural flowchart-style model building regardless of detail or complexity. ARENA - 7 is a discrete change language and is transaction flow oriented developed by Rockwell Software. Modules are dragged and dropped to the model layout window. Data are fed in dialog boxes and spreadsheet interface. Modeling is done most of the time visually. Coding can be done using SIMAN. For model development, ARENA - 7 has nice features, such as hierarchical modeling, application based templates, visual coding, integration with external programming languages (VB, C and Fortran), import CAD and Vision drawing, and conditional routing. ARENA - 7 contains most of the standard distributions. It also has the ability to let the user create a new distribution. It can handle time dependent distributions (Non-stationary Poisson process). It also has input data distribution-fitting tool. It has run setup, warm up period, replication specifications, and reset capability. It has a good 2D animation. The package also has a good debugging tool. Tracing output and other information can be extracted. Its breakpoints feature has ability to stop the model based on time, entity, and other conditions.

The Simulation Model

The impact of different flexible systems is investigated by a simulation study. According to Law & McComas (1990), simulation provides a ground for study of the design of new systems or to evaluate and compare the performance of existing complex system in 'what if' analysis. The study analyzes the behavior of a production system characterized by three different levels of flexibility (no-flexibility, partial flexibility and total flexibility), each corresponding to a different system configuration. These configurations are investigated by varying the operating level (i.e. total number of pallets) of the production system. Each system configuration is made up of similar and same number of machines and parts. A scheme of the three different system configurations is shown in Figure 1, with six parts and six machines. The parts have unequal number of operations to be performed on the machines, i.e. (P1=P4=4 operations, P2=P5=5 operations and P3=P6=6 operations). In case 'a', each machine can process one operation of the part (no-flexibility). In case 'b', (partial flexibility) an operation of the part can be assigned only to a limited number of machines (in this case only to two machines). Finally, total flexibility is shown in 'c' allows every operation to be processed on any machine (i.e. total routing flexibility). Tables 1, 2 and 3 show the sequence of operation and processing time of the parts for all the three configurations of flexible systems. The number in the brackets indicates the processing time in minutes. These values are same for the all the three systems. However, when setup time is considered then 25 per cent of the processing time is added to each value of the processing time.

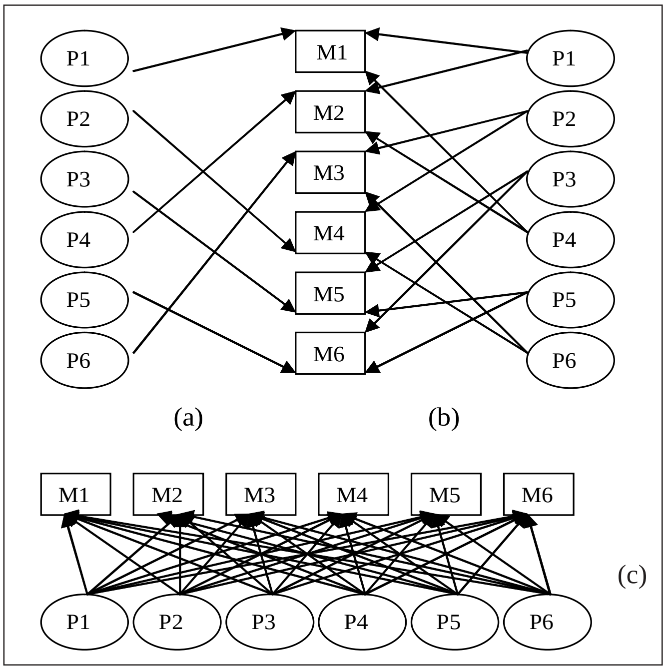


Figure 1: Production System Model
(Source: Wadhwa and Rao 2004)

The flexibility model used is based on the views of Wadhwa and Rao (2004). There are six machines with finite buffers and a central buffer of infinite capacity that can store the parts temporarily till the input machine buffers become vacant.

Flexibility may be viewed to offer various decision points (Wadhwa and Browne 1990) that may guide the discrete events to evolve the system towards system performance improvements.

The use of centralized buffer helps to prevent the blocking of the system. The assumptions regarding the nature of simulation and simulation parameters include the following: (a) Nature of simulation: The studies used a terminating simulation approach. All parts involve deterministic operation times. The simulation starts with an initial condition of the manufacturing system being empty, and specified number of parts, i.e. 600 (100 of each part) are processed. The simulation terminates when all the parts are manufactured. In this simulation model of the production system, parts are generated every minute. The processing time is assumed to be deterministic and transportation time is considered to be one time unit for all parts movements. When an operation of the part is assigned to a machine that can process different operation, a deterministic setup time is added. Since we are working in deterministic environment, the output in the form of make-span time is collected for one run of the simulation. (b) Dependent variables: The dependent variable in this study is the performance of the manufacturing system as represented through the manufacturing make-span time. (c) Independent variables: The independent variables include three modes of routing flexibility, viz. no-flexibility, partial flexibility and total flexibility, four levels of number of pallets, viz. 24, 36, 48, and 60, two level of setup time viz., 0% and 25% of the processing time and two levels of buffer size, viz. 3 and 10. (d) State of nature: The operations of the manufacturing systems are affected by number of variations in its internal and external environment. This is referred to as state of nature. Two important states of nature are considered in this study. The first one is the pattern of arrival of different parts, and the second is the processing time. The parts arrive every minute in the following sequence P1, P2, P3, P4, P5, and P6. The processing time is deterministic, i.e. the processing time of each operation of the parts is known in advance. With the view to enable an easy comparison of results obtained through the experiments, the same set of data has been used for all the experiments of a particular study.

Simulation modeling is useful to analyze complex systems such as flexible systems. Alternative routing flexibility options can be studied as partial flexible systems using simulation models.

The sequencing rule adopted by a machine to prioritize parts in queue is the Shortest Processing Time (SPT) and Maximum Balance Processing Time (MBPT). One of the critical aspects of the system is the dispatching rule adopted to select the machine for the next operation. In general, the dispatching and sequencing decisions on parts will impact the system performance. The material flow in flexible systems is complex. This material flow complexity is further increased by different levels of flexibility, setup times and number of parts in the system. The parts sequencing and dispatching to the various flexible machines can significantly impact the performance due to setup and other factors. We need simulation modeling to compare the relative impacts in these complex material flow situations.

Table 1: The Operation Sequences of Different Parts (no-flexibility)

Parts	O1	O2	O3	O4	O5	O6
P1	M1(40)	M3(24)	M4(12)	M6(18)	#	#
P2	M4(08)	M2(39)	M3(11)	M5(11)	M1(17)	#
P3	M5(39)	M1(68)	M3(16)	M2(49)	M4(94)	M6(70)
P4	M2(25)	M5(38)	M6(92)	M3(92)	#	#
P5	M6(15)	M4(05)	M2(20)	M5(94)	M1(67)	#
P6	M3(03)	M5(63)	M4(26)	M1(64)	M6(49)	M2(52)

Table 2: Routing for Sequence of Operation for Routing Flexibility (partial flexibility)

Parts	O1	O2	O3	O4	O5	O6
P1	M1M2	M3M5	M4M1	M6M3	#	#
P2	M4M3	M2M1	M3M4	M5M2	M1M5	#
P3	M5M6	M1M4	M3M5	M2M1	M4M6	M6M1
P4	M2M1	M5M3	M6M2	M3M6	#	#
P5	M6M5	M4M6	M2M3	M5M4	M1M2	#
P6	M3M4	M5M2	M4M6	M1M5	M6M3	M2M4

Table 3: Routing for Sequence of Operation for Routing Flexibility (total flexibility)

Parts	O1	O2	O3	O4	O5	O6
P1	M1M2 M4M5 M6M3	M3M5 M2M1 M4M6	M4M1 M5M2 M6M3	M6M3 M1M2 M5M4	#	#
P2	M4M3 M5M6 M1M2	M2M1 M3M4 M5M6	M3M4 M2M1 M6M5	M5M2 M4M3 M6M1	M1M5 M6M4 M3M2	#
P3	M5M6 M2M1 M4M3	M1M4 M6M5 M2M3	M3M5 M4M6 M1M2	M2M1 M6M5 M4M3	M4M6 M1M2 M3M5	M6M1 M2M5 M4M3
P4	M2M1 M3M4 M6M5	M5M3 M4M6 M1M2	M6M2 M1M3 M4M5	M3M6 M5M4 M1M2	#	#
P5	M6M5 M1M3 M2M4	M4M6 M5M2 M3M1	M2M3 M6M4 M5M1	M5M4 M3M1 M2M6	M1M2 M3M6 M5M4	#
P6	M3M4 M6M2 M5M1	M5M2 M1M3 M4M6	M4M6 M3M5 M2M1	M1M5 M2M6 M3M4	M6M3 M4M1 M2M5	M2M4 M5M3 M1M6

The operation is not performed on the part

To make a fair comparison among the different system configurations, flexibility should then be driven by more appropriate dispatching rules, in order to limit the negative effect of setups on system performance. To this aim, the following dispatching rule is considered. A dedicated machine is set for the first operation so that a part entering the system is assigned to its dedicated machine, unless the queue of that machine exceeds a given value of the input buffer of the machine. If the buffer is full it is sent to the next available machine (depending on the system configuration as shown in Figure 1 a, b, c). If the input buffer is full, the parts are directed to the central buffer where it is stored till vacancy exists in the input buffer of the required machine. To show the effect of this dispatching rule on system performance, two values of the Buffer Size (BS) are considered, i.e. BS=3 and BS=10. The effect of the dispatching rule (i.e. of the two buffer values) has been analyzed first, with setup times (ST=0%). Then, the influence of the setup time is investigated, referring to the value of ST=25% of the processing time. The impact of part mix is analyzed. Finally, sensitivity analysis is done by changing the sequencing rule and system load.

System Performance: The Effect of the Dispatching Rule

In this section, we study the effect of dispatching rule on the performance of the flexible system. We first perform simulation with ST=0% and BS=3 and BS=10. In the next section, the setup time is taken into consideration which is equal to 25% of the processing time. The BS value in this case is also 3 and 10 respectively. The results of both these studies are discussed in the following sections.

When Setup Time is Equal to Zero (ST=0%)

> ***Special modeling efforts are needed to develop flexibility options. Simulation Packages that offer in-built flexibility modeling will be preferable to Industry.***

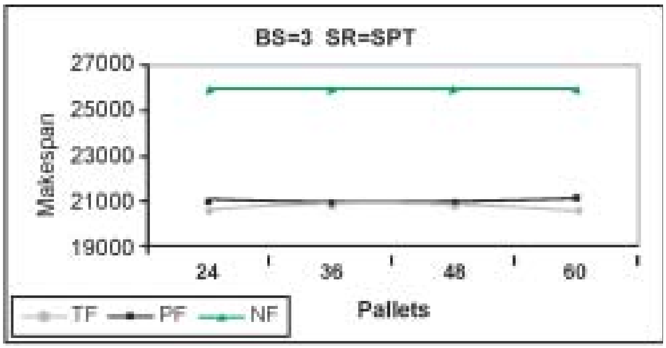
If all the machines of a production system could process any operation of the part with no penalty in terms of setup times then total flexible system, would be the best option (Garavelli 2001). In this case, however, flexible systems are penalized by the fact that, to exploit the benefits of flexibility, the products in the queues waiting to be processed by different machines have to reach at least the upper value of the buffer size (in this case BS=3 and BS=10), to let the new parts entering the system to be assigned to other less loaded machines. In Figure 2, the make-span time for 600 parts is reported for different values of pallets for Non-Flexible (NF) system, Partial Flexible (PF) system and Total Flexible (TF) system.

As we can see from Figure 2, the three configurations behave differently at different value of pallets and buffer size. At BS=3 we can see that the performance of partial flexible system is almost same as compared to total flexible system. This is due to the fact that the system is unable to exploit the potential flexibility. The parts have to reach the upper value of the buffer size in order to be routed to the alternate machine. If alternate machine is not available then the parts are sent to central buffer. In particular, the performance of the non-flexible system is the worst one, due to the absence of possible assignments of the parts to non-dedicated machines, which does not allow a dynamic redistribution of the workload. If BS=3, SR=SPT and ST=0%, then it is better to implement partial flexible system than the total flexible system as the performance of both these system is almost same.

As the value of buffer size is increased to 10 we observe that the make-span time increases as compared to BS=3. This phenomenon is visible for both partial and total flexible system but not for non-flexible system. This is due to the fact that more parts wait in the input buffer of the machine thereby increasing the make-span time. We can see that when the pallets in the system are increased there is decrease in make-span time for both the flexible systems in the same proportion (Figure 2). This is because when pallets are increased more parts are able to exploit the potential flexibility as a result decreasing the make-span time. In this case also, we see that partial flexible system performs almost at par with total flexible system. The differences in percentage of the make-span time between different system configuration and buffers are reported in the Table 4. The values show how benefits of flexibility are affected when the number of pallets is increased. In particular, the results show that there is marginal difference between partial and total flexibility levels under different scenarios of pallets allowed in the system. Further, lower buffer capacity situation gives improved performance more consistently. In addition, it can be seen that at buffer size (BS=10) partial flexible system performance improves with the increase in number of pallets as compared with non-flexible system. However, when compared with total flexible system it is seen that performance variation is not very much.

When Setup Time is Equal to 25% of the Processing Time

The condition of ST=0% is not ideal in many cases. In Figure 3, the performance of the three manufacturing systems is reported for different number of pallets in the system, with setup time equal to



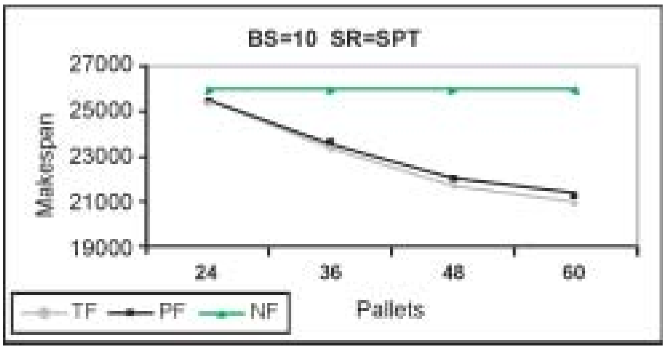


Figure 2: System Performance at ST=0% and SR=SPT

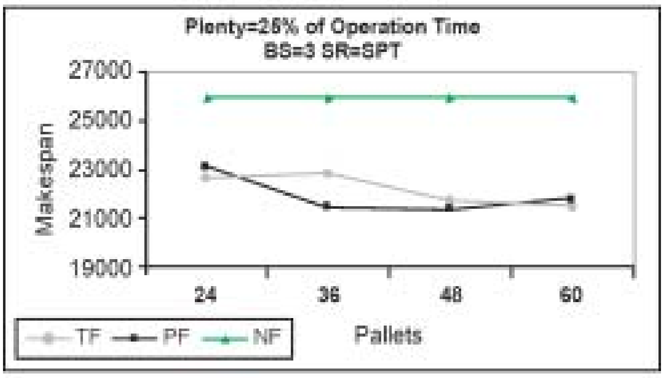
Table 4: Comparison of Make-span Performance of the TF, PF and NF System Configuration with ST=0%

	Number of Pallets			
	24	36	48	60
BS=3 TF VS PF PF VS NF	 (-) 2 % (-) 24%	 (+) 0.8% (-) 25%	 (-) 0.6% (-) 25%	 (-) 1% (-) 23%
BS=10 TF VS PF PF VS NF	 0% (-) 2%	 (- (- (+) 0.8% (-) 10%	 (-) 0.7% (-) 18%	 (-) 0.9% (-) 22%
BS=3 VS BS=10 TF PF	 (-) 24% (-) 22%	 (-) 14% (-) 14%	 (-) 6% (-) 6%	 (-) 2% (-) 2%

25% of the processing time. In this case also, buffer size is equal to 3 and 10. We observe from Figure 3 that the performance of the non-flexible system, due to its completely dedicated resources, is not affected by the setup time. Let us consider first the system performance at the lower value of the dispatching rule, i.e. BS=3. As it can be observed from the comparison with Figure 2, the setup time decreases the performance of flexible system (in Table 5 the make-span comparison is reported). There is significant difference in the performance of partial flexible system and total flexible system when the number of pallets is equal to 36. We observe that performance of partial and total flexible system is almost same when the number of pallets is at 24, 48 and 60. A similar result is reported in Figure 2 where relative performance changes are minimum. This is due to plenty incurred in exploiting routing flexibility in the form of setup time.

The flexibility model is based on Wadhwa and Rao (2004) views. The modeled system has six flexible machines with finite input buffers and a centralized buffer.

The variation of performance of both the systems is less when the number of pallets is increased. It can be again observed that the relative performance between partial and total flexibility cases is nearly same. The marginal difference may occur occasionally at certain buffer level and pallet in system cases. We also observe that the partial flexible system shows a very good reaction to the increase in operating levels. The partial flexible system performance is very close to that of the total flexible system (Table 5).



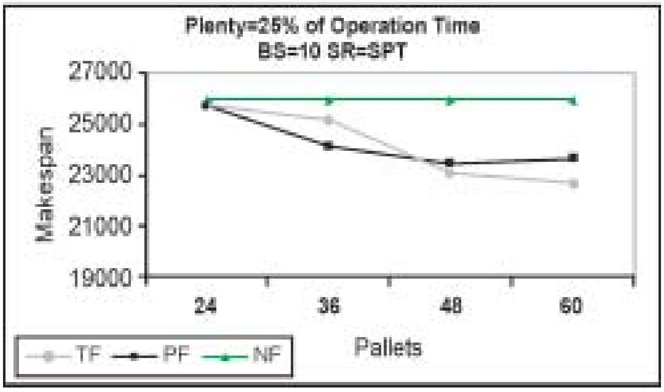


Figure 3: System Performance at Setup=25 % of Processing Time

When BS=10, we observe that the performance of the system shows somewhat same trend with little improvement as reported earlier with BS=3, but with higher value of make-span. This is due to the plenty imposed in exploiting flexibility. At this value of the buffer, we see that the performance of partial flexible system improves initially but deteriorates as the number of pallets increases. This is because initially with the increase of pallets in the system, more pallets are able to seize the buffers and processed faster rather than waiting in the central buffer.

Table 5: Comparison of Make-span Performance of the TF, PF and NF System Configuration with ST=25% of Processing Time

	Number of Pallets			
	24	36	48	60
BS=3 TF VS PF PF VS NF	 (-) 2 % (-) 11%	 (+) 5.5% (-) 20%	 (+) 1% (-) 20%	 (-) 0.9% (-) 18%
BS=10 TF VS PF PF VS NF	 0% (-) 1%	 (- (+) 4% (-) 8%	 (-) 1% (-) 11%	 (-) 4% (-) 10%
BS=3 VS BS=10 TF PF	 (-) 13% (-) 11%	 (-) 9% (-) 11%	 (-) 6% (-) 9%	 (-) 5% (-) 8%

For higher value of pallets, there is decrease in the performance of partial flexible system due to the impact of setup time. Besides, with the setup penalties and increase in pallets the performance of partial flexible system is almost equal to total flexible system. However, with the value of pallets at 60 we see that the performance of total flexible system is better than partial flexible system. The comparison of make-span at different level of set up time is shown in Table 6.

However, total flexible system performs better with higher value of the buffer size, because by limiting the flexibility degree of the system, it also reduces the number of setups and consequent system congestion. When we compare this result with the result in Figure 2, we observe that in the former case there is gradual decrease in the make-span performance

Table 6: Comparison of Make-span Performance of the TF, PF System at ST=0 and ST=25% of Processing Time

	Number of Pallets			
ST=0 vs. ST=0.25	24	36	48	60
BS=3 TF PF	 (-) 11 % (-) 11%	 (-) 11% (-) 11%	 (-) 6% (-) 9%	 (-) 5% (-) 8%
BS=10 TF PF	 (-) 0.7% (-) 0.7	 (- (-) 6% (-) 1%	 (-) 5% (-) 6%	 (-) 7% (-) 11%

for both the flexible systems with the increase of pallets. In the latter case, we see that total flexible system performs slightly better than partial flexible system. From these two studies we can see that the partial flexibility shows a very good reaction to the increase in the number of pallets in the system than total flexible system. If we look at the system performance in correspondence of a higher value of the pallets, partial flexibility shows similar performance as total flexibility even though setup times are significantly changes. However, under some situations of higher buffer sizes, the relative performance may marginally vary.

The simulation starts with an initial condition of the manufacturing system being empty, and terminates when all the specified parts are manufactured.

The Effect of Part Mix

The simulation results reported in Figure 4 are obtained by changing the part mix but keeping the total volume constant with setup time equal to 25% of the processing time. The results confirm most of the considerations made in the previous cases. In particular, the results confirm that the partial flexible system provides a very close performance to that of the total flexible system. This configuration performs at par when the number of pallets in the system is 36. On the contrary, in correspondence of higher value of pallets, the total flexible system performs slightly better. As in the previous sections, the non-flexible system provides a reference for the performance, which is usually worse than in the other flexible system.

The result provided by the total flexible system with a low value of the buffer size (BS=3), is slightly better as compared to partial flexible system. This is similar to the result obtained in Figures 2 and 3. However, when the buffer size is increased to BS=10 we see that the performance of both partial and total flexible systems are almost same initially but starts deteriorating as the number of pallets in the system are increased (Table 7). This can be justified by the increased congestion generated by flexible system, which provides more opportunities for the pallets to find less loaded machines, thus increasing the setup penalties for the system. This consideration points out that as the part mix is changed, the flexibility degree of the system has to change in order to exploit the flexibility benefits for a wide range of parts mix. The differences in percentage of the make-span time between the different system configurations and for different values of the buffer size are reported in Table 7.

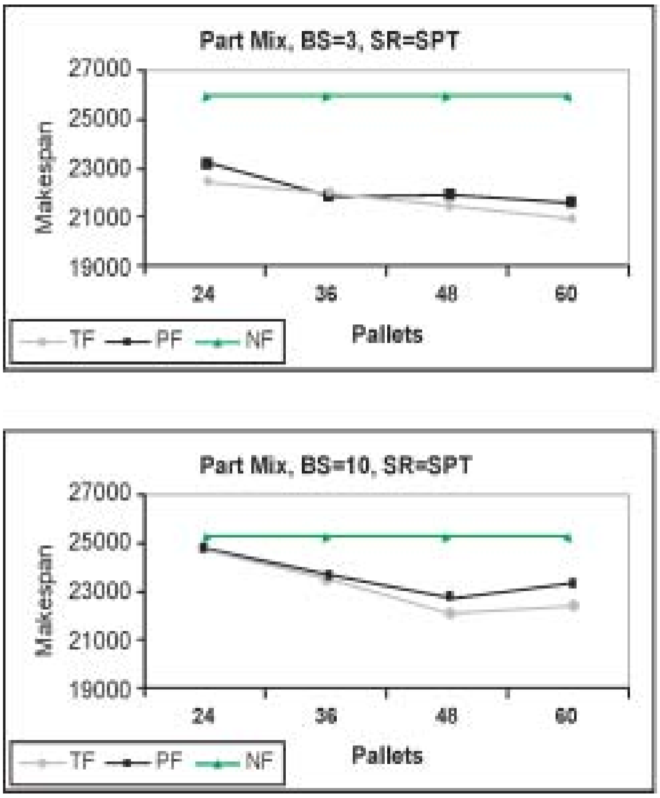


Figure 4: Effect of Part Mix on the System Performance

Table 7: Comparison of Make-span Performance of the TF, PF and NF System Configuration with Part Mix at ST=25% of PT

	Number of Pallets			
	24	36	48	60
BS=3 TF VS PF PF VS NF	(-) 3% (-) 9%	(+) 0.9% (-) 16%	(-) 3% (-) 15%	(-) 3% (-) 16%
BS=10 TF VS PF PF VS NF	0% (-) 0.3%	(- (-) 0.6% (-) 11%	(-) 3% (-) 18%	(-) 4% (-) 24%
BS=3 VS BS=10 TF PF	(-) 12% (-) 8%	(-) 9% (-) 11%	(-) 5% (-) 6%	(-) 9% (-) 10%

Sensitivity Analysis

In the previous section, we have analyzed system performance for the three types of system configurations i.e. non-flexible system, partial flexible system and total flexible system under various experimental conditions. In this section, we lighten up some earlier assumptions and analyze the sensitivity of the make-span time results.

Sensitivity to Sequencing Rule

Sabuncuoglu et al. (2003) have used sequencing rule for sensitivity analysis. In earlier study, we used SPT as the sequencing rule to load parts from the queue on the machines. In fact, it is generally agreed that SPT minimizes the make-span time. In this section, we test the system with Maximum Balance Processing Time (MBPT), a rule that is considered dynamic, which changes from machine to machine. We examine this rule under similar condition in which SPT rule is used. The result is shown in the Figure 5.

The differences in percentage of the make-span time between the different configurations and for different values of the buffer size are reported in Table 8. Table 9 shows the comparison of make-span performance for different

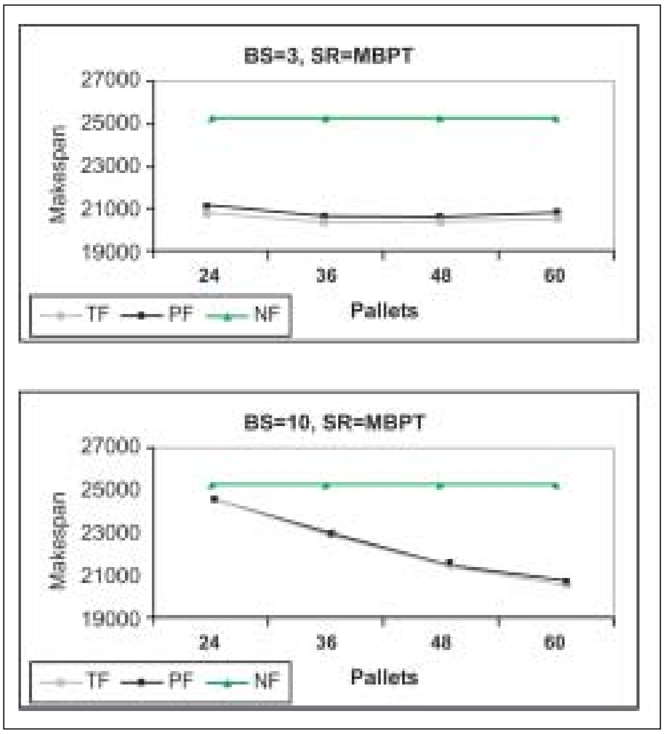


Figure 5: System Performance at ST=0 and SR=MBPT

sequencing rules. From this table we conclude that in the presence of flexibility, the machine sequencing rules play a minor role in affecting make-span performance. If we compare this result with Figure 2, we observe that both the sequencing rules give almost similar results. However, when the number of pallets is kept at the highest level we see that there is some deterioration in the performances of both the flexible systems. However, this deterioration is minimal.

The parts sequencing and dispatching to the various flexible machines can significantly impact the performance due to setup and other factors. We need to do simulation to compare the relative impacts in these complex material flow situations.

Sensitivity to System Load

The simulation result reported in Figure 6 is obtained in correspondence to an increase in the system load from 600 to 900 (i.e 150 parts of each types). The result shows that with the increase of system load there is increase in the make-span time for all the three types of the systems. In particular, the results shows that the partial flexible system provides very close performance to that of total flexible system at different value of pallets and buffer size. This configuration always performs better with the lower value of buffer size than with the higher value of the buffer size, since it allows better exploitation of flexibility benefits, without considerably increasing the system congestion. On the other hand, in correspondence to higher value of the pallets, the total flexible system needs a higher value of the buffer size to contrast the increasing number of setups. As in the previous sections, the non-flexible system provides a reference for the performance, which is usually worse than in the other flexible system.

Table 8: Comparison of Make-span Performance of the TF, PF and NF System Configuration with ST=0

	Number of Pallets			
	24	36	48	60
BS=3 TF VS PF PF VS NF	(-) 2 % (-) 21%	(+) 0.8% (-) 24%	(-) 0.7% (-) 24%	(-) 2% (-) 23%
BS=10 TF VS PF PF VS NF	0% (-) 3%	(- (-) 0.5% (-) 11%	(-) 0.2% (-) 18%	(-) 0.8% (-) 24%
BS=3 VS BS=10 TF PF	(-) 20% (-) 18%	(-) 14% (-) 12%	(-) 5% (-) 5%	(+) 0.1% (+) 0.7%

Table 9: Comparison of Make-span Performance of the TF, PF at SR= SPT and MBPT

	Number of Pallets			
	24	36	48	60
BS=3 TF PF	(-) 0.9 % (-) 0.7%	(+) 2% (+) 0.6%	(+) 0.9% (+) 0.8%	(+) 0.9% (+) 0.9%
BS=10 TF PF	(+) 2% (+) 2%	(- (+) 1% (+) 3%	(+) 2% (+) 2%	(+) 3% (+) 3%

In particular, for the non-flexible system the variation of the pallets does not involve any performance variation due to the absence of routing flexibility. The differences in percentage of the make-span time between the different configurations and for different values of the buffer size are reported in Table 10. If we compare Figure 6 with Figure 3 we observe that with the increase of system load the partial flexible system provides very close performance to that of total flexible system at different values of pallets and buffer size. This is also visible in Table 11. From Table 11, we can see that with the increase in system load from 600 to 900 there is increase in make-span time. There is no impact of increase in pallets and buffer size on the

Table 10: Comparison of Make-span Performance of the TF, PF and NF System Configuration with ST=25% of PT, System Load=900

	Number of Pallets			
	24	36	48	60
BS=3 TF VS PF PF VS NF	(-) 3 % (-) 10%	(+) 4% (-) 19%	(+) 1% (-) 20%	(-) 1% (-) 19%
BS=10 TF VS PF PF VS NF	0% (-) 1%	(- (-) 0.5% (-) 8%	(-) 2% (-) 12%	(-) 4% (-) 10%
BS=3 VS BS=10 TF PF	(-) 12% (-) 9%	(-) 10% (-) 8%	(-) 5% (-) 8%	(-) 5% (-) 8%

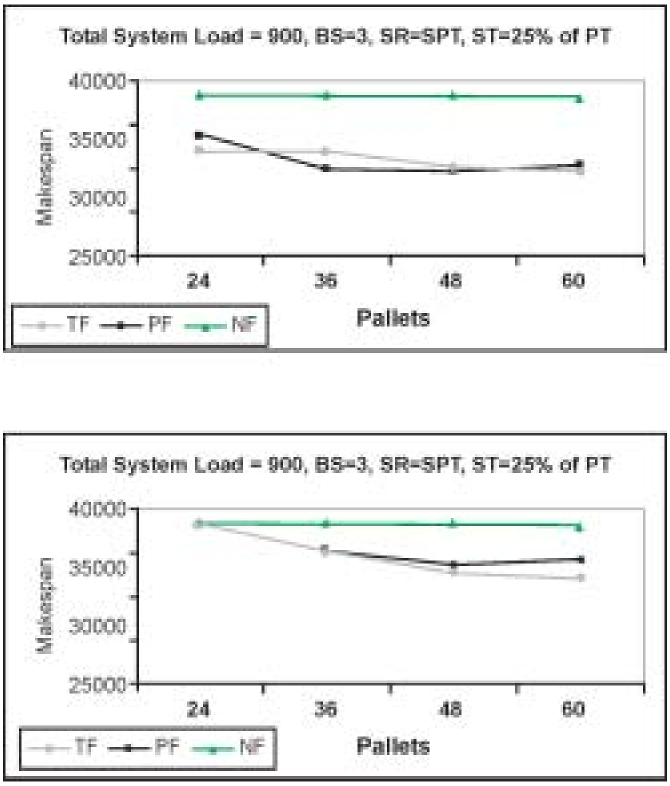


Figure 6: System Performance at System Load=900

performance of both the flexible systems. Hence, we conclude that system load does not have an impact on the performance of partial flexible and total flexible systems much. Therefore, the system is able to perform adequately when demand changes.

Table 11: Comparison of Make-span Performance of the TF, PF at SL=600 and SL=900

	Number of Pallets			
	24	36	48	60
BS=3 TF PF	 (-) 49 % (-) 51%	 (-) 48% (-) 50%	 (-) 49% (-) 50%	 (-) 49% (-) 50%
BS=10 TF PF	 (-) 49% (-) 49%	 (- (-) 43% (-) 50%	 (-) 48% (-) 50%	 (-) 49% (-) 49%

Conclusion

A simulation study has been carried out to evaluate the behavior of a production system characterized by different flexibility options. In particular, three flexibility system configurations have been considered: no-flexibility, partial flexibility and total flexibility. The make-span performance has been investigated for different system operating levels, dispatching rules, sequencing rules, setup times, system load and part mix. The simulation results have shown that the partial flexible system can provide nearly same performance as the total flexible system under many situations. The partial system can sometimes be even better where more flexible systems are penalized due to higher setup times. It may also be nearly suitable when setup times are negligible, or system is under-loaded. The partial flexible system can exploit the benefits of flexibility by maintaining lower system congestion compared to the no-flexibility case. It may be often advantageous in terms of investments to have partial flexibility compared to full flexibility as also shown by Wadhwa and Bhagwat (1998) for a different system modeled. The total flexible system is able to distribute the workload among a larger number of resources. Thus, it may provide better performance than the other two system configurations, if the setup times are negligible. On the other hand, the non-flexible system can mostly provide the worst performance. The results also show that the performance of the flexible system is sensitive to machine sequencing rule although its effect becomes less significant in the presence of routing flexibility. The system modeled is also sensitive to the system load as make-span increases.. Even though this work provides us with interesting observations and insights about the impact of pallets on flexible system performance, the results of this study should be interpreted with respect to the considered assumptions and experimental conditions. It is useful to conduct further research to determine the best factor combinations that can offer greater improvements to the flexible system performance.

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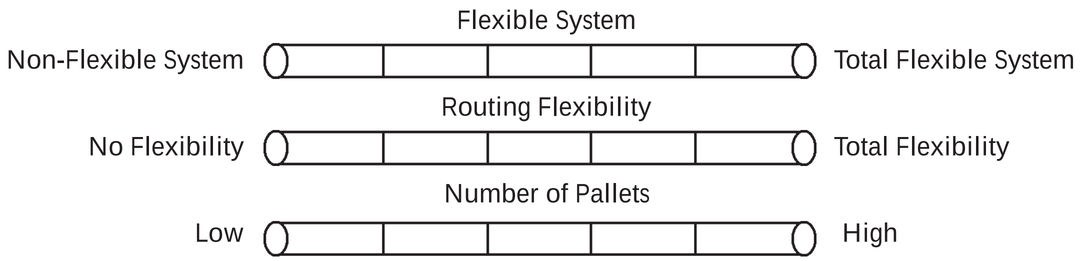
Flexibility Mapping : Practitioner's Perspective

1. What types of flexibilities you see in the practical situation of "Partial Flexible System" on the following points:
   - Flexibility in terms of "options"
   - Flexibility in terms of "change mechanisms"
   - Flexibility 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))



4. Develop a SAP-LAP (Situation Actor Process-Learning Action Performance) model of "Partial Flexible System" relevant to your organization

Reflecting Applicability in Real Life

1. How do you find the case study presented in this paper relevant to your organization? Critically examine and use the relevant issues.
2. Based on the research process in this paper, is it possible to use it for benchmarking purposes?
3. To what extent the findings of this paper are relevant for the technological capability development of your organization?

Prof. Subhash. Wadhwa (Eur.Ing., C.Eng.,Ph.D (Ireland)) worked in Europe for several years on prestigious European projects and a US Multinational before joining IIT Delhi. He extensively contributed to the development of generic simulators and expert systems for flexible systems. He is currently a permanent Professor in Industrial Engineering at the Indian Institute of Technology, Delhi. He has originated novel research themes: Decision-Information Synchronization (DIS) in Enterprise Systems and Flexible Supply Chains; Dynamic Reconfiguration with Integrated Scheduling (DRIS) for Agile Enterprise; SAMIN Architecture for Intelligent Manufacturing System in flexibility contexts, etc. He is an active contributor to Global projects in the IT domain and has coordinated several workshops. He has been consultant /Contributor/National-Expert to many prestigious International bodies. He has over 100 publications and has reviewed papers for renowned journals. He has also been chief consultant on several Industrial projects. His interest include Flexible Systems, SCM, TQM, BPR, Knowledge Management, Simulation, Intelligent Systems,e-Biz/e-Goverance/e-education/e-healthcare etc. he is dedicated to the goal of bringing synergy between Academics, Industry and Research.

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Empirical Study

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A Cross-impact Analysis of the External Situation and Culture on Factors of IT-enabled Business Transformation

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Abstract

The objective of the study is to identify the effect of cultural and environmental pressures on factors of IT-enabled business transformation, based on the experience and perception of chief information officers in India and the U.S. The findings suggest that, in both countries, environmental pressures and cultural factors are found to have a significant influence on the factors of IT-enabled business transformation. In this study, culture is measured by using variables power distance, uncertainty avoidance, individualism, and masculinity. The environmental pressures are measured using variables frequency of changes in marketing practices, rate of product obsolescence, prediction of competitors' actions, prediction of consumer test/product demand, and frequency of changes in mode of production/services. The factors of IT-enabled business transformation were identified as follows: localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), business scope redefinition (Phase V), IT induced reconfiguration, and degree of business transformation/degree of potential benefits.

Keywords : business transformation, cross-impact analysis, culture, environmental pressures

Introduction

The worldwide spread of IT is well documented, with diffusion from developed to developing countries and newly industrialized economies (NIEs) in Asia (Mody and Dahlman, 1992). Most businesses in the industrial world could not compete, and many could not even survive without continuous IT-enabled business transformation (Jones 1994, Luftman et. al. 2004); however, IT is now an integral part of the products and services delivered to customers (Henderson and Lentz 1995/1996, Luftman et. al. 2004).

Today, multinational corporations and governments increasingly use IT for international business and commerce. While advanced countries have made use of this technology for years, IT has also started to make inroads into lesser-developed countries (Palvia and Palvia, 1992). Businesses are generally regulated by a government policy in India (Palvia and Palvia, 1992); however, beginning with the New Computer Policy of 1984 (Dhir 1992, Menon 1990), the Government of India has aggressively promoted the increased use of IT and transformation of the business for reaping the maximum benefits from IT applications. The United States remains the world leader in IT (Westwood, 1995).

Computer related technology or any other technology is essentially neutral; hence, whether IT's application succeeds or fails depends entirely on the decisions regarding how it shall be used (Bostrom and Heines, 1977). Also, the impact of IT in less developed countries depends on its adaptation to the local environment (Montealegre, 1998). Effective implementation of IT depends on the organization's vision of change, either by deliberate design or as an emergent phenomenon. Agrawal and Haleem (2003) argued that environmental and cultural factors play an important role in developing a positive mindset for successful implementation of IT applications. Cultural studies utilize Hofstede's cultural parameters for cross-impact analyses (Frucot and Shearon 1991, Harrison 1992, 1993 and Harrison and McKinnon 1999). In this study, the authors have used the same parameters for cross-comparison.

This study deals with the development of a model for identifying the effect of environmental pressures and cultural factors on the factors of IT-enabled business transformation addressing four interrelated questions upon which the entire analysis centered: (1) What are the cultural factors and environmental pressures that facilitate and inhibit the factors of IT-enabled business transformation? (2) What are the cultural factors and environmental pressures that facilitate and inhibit growth in IT-induced reconfiguration? (3) What are the cultural factors and environmental pressures that facilitate and inhibit the growth in degree of business transformation/

degree of potential benefits? and (4) How can trends in the United States organizations help Indian organizations formulate their IT related strategies regarding the promotion of IT applications and business transformation to survive/ grow in a competitive environment?

The present work is confined to manufacturing, telecommunication (hardware), computer hardware, banking, hotels, computer software, and airlines. The quantitative and qualitative data were collected through a survey of chief information officers in India and the United States.

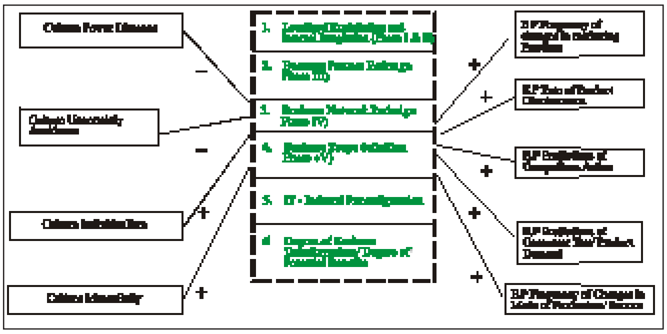
The next section discusses the theoretical background and the model and hypothesis formulation, followed by discussion of the methodology used and implementation of research methodology. The paper then discusses the results obtained, along with limitations of the study and suggestions for future work, concluding with the authors' summary of the findings and concluding remarks.

Background and Development of Research Model

Venkatraman has argued that enterprise pass through levels of IT-enabled transformation (in Scott-Morton, 1991), which range from localized automation (exploitation), internal integration, business process redesign, and business network redesign, to business scope redefinition. Organizations proceed to higher levels as the demands of competition and value creation for customer increases. Venkatraman (in Scott-Morton 1991) defined five levels; the first two levels are evolutionary, requiring relatively incremental changes in the existing organizational processes. In contrast, the other three levels are conceptualized as revolutionary, requiring fundamental changes in the nature of business processes. As the organizations proceed to higher levels, the amount of benefits and degree of business transformation increases exponentially (Agrawal et al., 2003). Using these five levels and the critical response activities (Turban et al., 2001), Agrawal et al. (2003) identified the following factors of IT-enabled business transformation: localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), business scope redefinition (Phase V), IT induced reconfiguration, and degree of business transformation/degree of potential benefits. The enterprise passes through levels of IT-enabled transformation (from Phase I to Phase V). As the organization goes to a higher level of transformation, it will reap a higher level of benefits. This study is focused on identifying the effect of environmental and cultural factors on these factors of which a brief description is given below:

- *Localized exploitation and internal integration (Phases I and II):* IT's role in making better and more effective decisions, increasing productivity (reduced costs and increased effectiveness), change management, and total quality management.
- *Business process redesign (Phase III):* IT's role in responding quickly to customer needs and to changing the business or its environment, just-in-time, and reorganize and reengineer.
- *Business network redesign (Phase IV):* IT's role comprises electronic commerce and business alliances (joint venture/virtual corporation).
- *Business scope redefinition (Phase V):* contribution of IT in creating a competitive advantage, attaining a company's strategy, and improving creativity and innovation.
- *IT-induced reconfiguration:* empirical formula is used to compute the value based on the input values of Phases I through V.
- *Degree of business transformation/degree of potential benefits:* empirical formula is used to compute the value based on the input values of Phases I through V.

The overall conceptual model with the research constructs and proposed relationships is presented in Figure 1. Each of the constructs, along with the expected relationships and hypotheses, are discussed in two parts: environmental pressures and culture/use of computers.



EP: Environmental Pressures

Figure 1: Conceptual Model–Environmental Pressures, Culture and Factors of IT-enabled Business Transformation

Environmental and cultural factors play an important role in developing a positive mindset for successful implementation of IT applications.

Environmental Pressures: With blurring national boundaries, the numbers of competing organizations and knowledge workers have been increasing. Additionally, since the environment is turbulent, changes rapidly, and in unpredictable manner (Scott-Morton 1991, Turban et al. 2001), it generally changes much faster than organizations. The characteristics of the environment include time compression–amazing short product life cycle, strategic discontinuity –competition in uncertainties, blurring organizational boundaries–increased collaboration, knowledge intensity, increased returns to the scale, and customer focused (El Sawy et al, 1999). New technology, new products, and changing public tastes and values (many of which result in new government regulations) put strains on any organization's culture, policies, and people (Schein, 1985). Sutcliffe (1997) stated that the U.S. industries, with their backs against the wall from increased foreign

Table 1: Implications of Not Keeping Pace with Technology

Loss of Competitive Edge	58%
Increased Cost of Production	16%
Would not be in Business	13%
Lack of Control in Running the Business	7%
Other	3%
Would Not Happen	3%

Source : A.T. Kearney Survey 1998

competition, fought in the past decade to regain their position as global leader using information technology. Thus, for successful implementation of computer-based information systems/business process reengineering, the environmental pressures play an important role in converting the mindset of the organization's employees (Agrawal et al., 2003).

The organizations are under a constant pressure to master the new technology brought on by the change of pace in the industry and the rate of adoption of the new innovation (Luftman et al., 2004). They further stated that information technology has the ability to provide the organizations a needed dynamic stability–flexible (mass customized) products via fixed business processes. A delay in adoption of what may become a disruptive technology (one which greatly alter the business model, ex. the Internet), can result in a major setback for an organization (Luftman et al., 2004). Table 1 indicates for the organizations the devastating consequences of not keeping pace with the technology. The effect of environmental pressures can be transcribed in terms of frequency of changes in marketing practices, rate of product obsolescence, difficulties in the prediction of competitors' actions, difficulties in the prediction of consumer test/product demand, and frequency of changes in mode of production/services (Agrawal et al. 2005).

> ***Organizations proceed to higher levels of business transformation as the demands of competition and value creation for customer increases.***

- **H1:** The severity in environmental pressures (frequency of changes in marketing practices, rate of product obsolescence, prediction of competitors' actions, prediction of consumer test/ product demand, and frequency of changes in mode of production/services) positively correlates with factors of IT-enabled business transformation (localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), and business scope redefinition (Phase V)).

- **H2:** The severity in environmental pressures (frequency of changes in marketing practices, rate of product obsolescence, prediction of competitors' actions, prediction of consumer test/product demand, and frequency of changes in mode of production/services) positively correlates with IT induced reconfiguration and degree of business transformation/degree of potential benefits.

Culture/Use of Computer: A socio-technical systems approach views a work system as an open system, made up of technical and social subsystems (Schoderbek, Schoderbek, and Kefalas, 1986), with the output of the work systems depending on the interaction between its subsystems.

The technical system deals with the processes, tasks, and technology needed to transfer inputs to outputs (Bostrom, 1980), whereas the social system is concerned with attributes of people (e.g., attitudes, skills, and values), the roles they enact, the reward systems, and the authority structure. To optimize the entire work system, the interaction of both subsystems must be jointly optimized (Huse and Cummings, 1985). The social system is heavily influenced by the societal culture and plays an important role in adoption of innovation and usage of information technology.

Theories in sociology, psychology, and organizational behavior suggest that a theory applicable to one culture does not necessarily apply, in total, to other cultures (Hofstede and Bond, 1988). Haire, Ghiselli and Porter (1966) determined that national differences make a consistent and substantial contribution to the differences in a manager's attitude: two-thirds national and one third individual, while Herbig and Day (1990) indicate that certain sociocultural conditions have to be in place for innovation to occur.

Leach-López et al. (2004) stated that the concept of culture used by most researchers is based on Hofstede's work (1984). Hofstede (1984) identified four basic dimensions accounting for variations in culture that we have used in this study for measurement of culture: ***Individualism versus Collectivism:*** The extent to which the individual expects personal freedom versus the acceptance of the responsibility to family, tribal, or national groups. More individualism will result in more innovation. ***Power Distance:*** The degree of tolerance and inequality in wealth and power indicated by the extent to which centralization and autocratic power are permitted. Higher innovation capacity is more available in societies with less power structure or little difference in power status within organizations. ***Risk (Uncertainty) Avoidance:*** The extent to which a society avoids risks and creates security by emphasizing technology and buildings, laws and rules, and religion. A high-risk avoidance environment is not conducive to entrepreneurship and hence, dampens innovations. ***Masculinity versus Femininity:*** The extent to which the society differentiates roles between the sexes and places emphasis on masculine values of performance and visible achievements. Masculinity refers to assertive, competitive, and firm, whereas femininity culture refers to soft, yielding, dependent, intuitive, etc. Consequently, radical innovation thrives in more masculine societies.

The cultural factors that facilitate innovation will in turn result in an acute competitive, turbulent, and dynamic environment.

- **H3:** Power distance and uncertainty avoidance are negatively correlated with factors of IT-enabled business transformation (localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), and business scope redefinition (Phase V)).
- **H4:** Power distance and uncertainty avoidance negatively correlate with IT induced reconfiguration and degree of business transformation/degree of potential benefits.
- **H5:** Individualism and masculinity positively correlate with factors of IT-enabled business transformation (localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), and business scope redefinition (Phase V)).
- **H6:** Individualism and Masculinity positively correlate with IT induced reconfiguration and degree of business transformation/degree of potential benefits.

> ***As organizations proceed to higher levels of IT-enabled business transformation, the amount of benefits and degree of business transformation increases exponentially.***

Methodology

This study has been confined to manufacturing, telecommunication (hardware), computer hardware, banking, hotels, computer software, and airlines. This particular study has been defined as an exploratory and descriptive "survey" approach in order to achieve more generalizability and additional richness. The study is divided into three phases:

Phase 1–Exploratory Study

In the first phase a literature search, which is an obvious first step in an exploratory study, was conducted, followed by interviews. The data gathered from a literature search and interviews were analyzed, and a revised version of the problem list and a questionnaire were developed.

Phase 2–Survey, Construct Validity, and Data Analyses

In the second phase, a questionnaire survey was used to answer the research questions. The data are qualitative and quantitative in nature and were then used to test the hypotheses using correlation analysis. Principal component factor analysis, along with Varimax rotation, were performed to test the construct validity of the questionnaire.

Phase 3–Computation of Discriminant Functions

To determine if statistical differences exist between the average score of manufacturing and service sectors within Indian organizations, discriminant analysis using stepwise variable selection method was implemented. The discriminant analysis was also utilized out for manufacturing and service sectors in the United States.

Implementation of Research Methodology

Questionnaire Design: The questionnaire uses the Likert scale with nine intervals, from low to high, with equal weights. Because of the difficulties in measurement, open-ended questions were avoided, and the questions were mutually exclusive.

Questionnaire Validation and Testing: The questionnaire validation exercise was divided into four parts: face validity, criterion validity, content validity, and construct validity. In construct validity, to determine the number of factors for each construct, an eigenvalue greater than one rule was employed. While 0.30 has been suggested as sufficient, only loadings greater than 0.32 in absolute value were used in this study (Churchill, 1979). The questionnaire items were found significantly loaded {Appendix I(a)} and grouped under the variables they ought to measure. There are variables loaded on more than one factor, but there was no variable found not loaded significantly on any of the factors — possible association of variables is one reason, which could be attributed to loading more than one construct on the same factor. The construct validity is not more or less than a scientific process (Baussel, 1986); therefore, it is difficult to assert that construct validity of a measure is established. An instrument may need several administrations before its construct validity can be ensured. Further, due to multiple variations and combinations in each study, a general model as proposed in Figure 1 is considered uniformly to facilitate the needed comparison between organizations in India and the United States. In spite of seeming limitations, this ensures that the questionnaire administered had enough construct validity. After field-testing, the questionnaires were mailed for survey research. A list of data items included in the questionnaire is placed in Appendix I(b). Further, the list of variables, along with the data items used for measurement, are placed in Appendix I(c).

Administering the Instrument: The questionnaire survey was administered following the guidelines suggested by Dillman (1978, 2000). For the United States, stratified sampling was used; whereas in India, a judgment sampling was used.

A total of 423 questionnaires in India and 384 in the United States were mailed. After about three weeks a follow up letter was mailed, requesting that the completed questionnaires be returned at the respondents' earliest convenience. Of the questionnaires received, the total usable responses were 112 from India and 89 from the United States, resulting in a response rate of 26.48 per cent in India and 23.18 per cent in the United States. This rate compares favorably to mail surveys reported in the IS literature, many of which have less than a 25 per cent response rate (Jeong, 1995).

Data Processing and Results

The results of statistical analysis are presented to show the degree of association among the variables and examine the statistical significance of the model presented. The significance level of 0.01 and 0.05 are very common in a larger sample size. In our case, the sample size is 112 (India) and 89 (U.S.A.); thus, the significance level of 0.1 is considered appropriate. Further, for generalization of model and considering the number of combinations of options in the study, the significance level of 0.1 is justified. Software package SPSS version.12.0 has been used for statistical analysis to validate the hypotheses.

US industries, with their backs against the wall from increased foreign competition, fought in the past decade to regain their position as global leader using information technology.

This part is divided into six sub-parts: environmental pressures, culture, descriptive statistics of variables, results and analysis, validation of hypotheses, and comparison of manufacturing sector and service sector (results of stepwise–statistical–discriminant function analysis).

Environmental Pressures: The effect of environmental pressures is measured using frequency of changes in marketing practices (V101), rate of product obsolescence (V102), difficulties in the prediction of competitors' actions (V103), difficulties in the prediction of consumer test/product demand (V104), and frequency of changes in mode of production/services (V105). The mean values for both countries are depicted in Figure 2. In comparison with the values in India, organizations in the United States exhibited a significant difference in frequent changes in marketing practices to keep pace with its market and competitors. Furthermore, within moderate range the organizations in the United States have value for predictions of competitors' actions closer to the upper limit, while in India, it is near the lower end of the range. These environmental pressures in United States organizations seem to be contributing significantly in building an innovative culture in the organizations and acting as enabler (Figure 1) to factors of IT-enabled business transformation.

Culture: For cross comparison, the culture is measured using power distance (V201), risk avoidance (V202), individualism (V203), and masculinity (V204). The mean values for both countries are plotted in Figure 3. In comparison with the values in India, organizations in the United States have moderate values for power distance and uncertainty avoidance. Additionally, within moderate range, organizations in the United States have values for individualism, and masculinity closer to the upper limit, while in India, it is at the lower end of the range. These attitudes in United States organizations seem to be contributing significantly in building the innovative culture in the organizations and acting as enablers/inhibitors (Figure 1) to factors of IT-enabled business transformation.

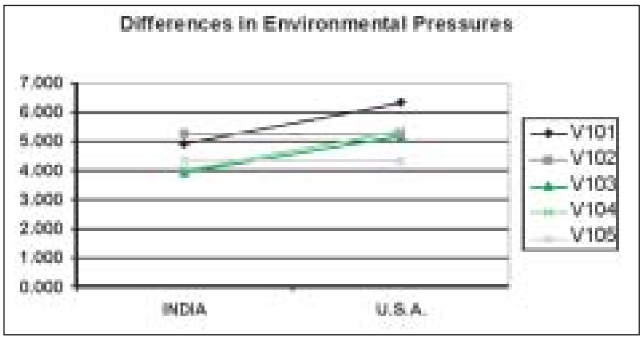


Figure 2: Differences in Environmental Pressures

Descriptive Statistics of Variables: Table 2 contains the perception of the respondents about the future role of IT in supporting the critical response activities of business, the ranking of variables, and mean values (descriptive statistics of variables). The perception of Indian organizations can be argued, considering economic and competitive conditions in the country. The organizations appear to be trying to become effective and efficient by network redesign, supported by process redesign, which accounts for tremendous pressures leading to radical change. The perception seems to be the effect of domestic and international competition. In contrast, United States organizations are looking for distributed processing and avenues to generate revenue from IT applications. Their perception can be argued considering the maturity level of the country in IT applications and their

Table 2: Descriptive Statistics of Variables–All Industries

			INDIA		USA	
Sr. No.	Code	Description	Mean Values	Ranking	Mean Values	Ranking
1	V301	Localized Exploitation and Internal Integration (Phases I & II)	7.366	4	7.705	1
2	V302	Business Process Redesign (Phase III)	7.607	2	7.03	4
3	V303	Business Network Redesign (Phase IV)	7.83	1	7.225	3
4	V304	Business Scope Redefinition (Phase V)	7.434	3	7.678	2
5	V305	IT-induced Reconfiguration	83.67	NA	82.11	NA
6	V306	Degree of Business Transformation/ Degree of Potential Benefits	230.6	NA	235.5	NA

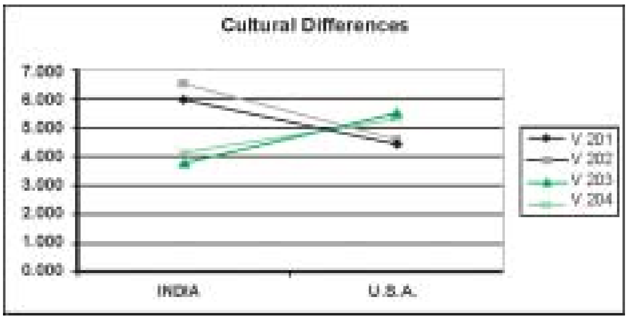


Figure 3: Cultural Difference

prevailing severe competitive environment. The respondents of both countries perceived identical levels of IT-induced reconfiguration and degree of business transformation/degree of potential benefits.

Results and Analysis

The results of correlations are placed in Appendix II. The interpretation of the results is given below:

• *Frequent Changes in Marketing Practice (V101)*

India: A positive correlation between frequent changes in marketing practice and factors of business transformation (business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits) support the argument that the organizations will continue transforming their businesses and identify ways of earning revenues through technology to justify IT's cost in gaining a competitive advantage. The positive correlation can be argued considering the increasing competitive pressures in the country.

U.S.A.: A positive correlation between frequent changes in marketing practice and factors of business transformation (localized exploitation and internal integration–Phases I & II, business process redesign–Phase III, business network redesign–Phase IV, business scope redefinition–Phase V, IT-induced reconfiguration and degree of business transformation/degree of potential benefits) support the argument that the organizations will try to reduce IT's cost by generating revenues from integrated and networked IT applications. This variable induces the innovative culture, which will result in a competitive advantage through frequent adoption of new technology/processes and business transformation in the organizations; thus, the positive correlation can be argued considering the severe competitive pressures in the country.

> ***A delay in adoption of what may become a disruptive technology (one which greatly alter the business model, ex. the Internet), can result in a major setback for an organization.***

• *Rate of Obsolescence of the Product (V102)*

India: A positive correlation between rate of obsolescence of product and factors of business transformation (localized exploitation and internal integration–Phases I & II, business process redesign–Phase III, business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits) support the argument that the organizations will try to reduce IT's cost by generating revenues from integrated and networked IT applications. This variable induces the innovative culture, which will result in developing new product/process for competitive advantage and frequent adoption of new technology/processes along with business transformation in the organizations. The positive correlation can be argued considering the increasing shrinkage in product life cycle (El Sawy et. al., 1999) in the economy.

U.S.A.: A positive correlation between rate of obsolescence of product and factors of business transformation (localized exploitation and internal integration–Phases I & II, business process redesign–Phase III, business network redesign–Phase IV, business scope redefinition–Phase V, IT-induced reconfiguration and degree of business transformation/degree of potential benefits) supports the argument that the organizations will try to reduce IT's cost by generating revenues from integrated and networked IT applications. This variable induces the innovative culture, which will result in developing new product/ process for competitive advantage and frequent adoption of new technology/processes, along with business transformation in the organizations. The positive correlation can be argued considering the increasing shrinkage in product life cycle (El Sawy et. al., 1999) in the economy.

• *Prediction of Competitors' Actions (V103)*

India: A positive correlation between the prediction of competitors' actions and factors of business transformation (business scope redefinition–Phase V and degree of business transformation/degree of potential benefits) supports the argument that as the competitors' actions become unpredictable, the need will arise to frequently upgrade technological solutions, along with business transformation to improve creativity and innovation and to attain company's strategy, which in turn will create a competitive advantage for the firm.

U.S.A.: There are no statistically significant results obtained.

• *Prediction of Consumer Test/Product Demand (V104)*

India: There are no statistically significant results obtained.

U.S.A.: A positive correlation between the prediction of consumer test/product demands and business process redesign (Phase III) supports the argument that as prediction of consumer test/product demand becomes difficult, the corporations would reengineer their processes to respond quickly to customer needs and to changes in business or its environment and rely more on customization and technological solutions to reduce manufacturing cycle time/time to market their products/ services.

• *Frequency of Changes in Mode of Production/ Services (V105)*

India: A negative correlation between the frequency of changes in mode of production/services and business network redesign (Phase IV) supports the argument that the rapid changes in mode of production/services will lead corporations to rely more on customization, increase their dependencies on their human resources, and decrease their dependencies on integrated, networked technological solutions.

U.S.A.: A negative correlation between the frequency of changes in mode of production/services and localized exploitation/internal integration (Phases I & II) supports the argument that the rapid changes in mode of production/ services will lead corporations to rely more on customization, increase their dependencies on their human resources for internal decision-making, and decrease their dependencies on technological solutions. Further, the positive correlation between the frequency of changes in mode of production/ services and business network redesign (Phase IV) can be argued considering that organizations need an efficient and effective connectivity with its business partners and a better interaction with customers, which can help in developing the customized products/ services.

- **Power Distance (V201)**

India: A negative correlation between power distance and factors of business transformation (business network redesign–Phase IV, business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits) supports the argument that higher values of power distance will obstruct organizations in adopting revolutionary IT applications (business network redesign and business scope redefinition) and will limit their scope to a lower degree of business transformation.

U.S.A.: The control of information systems departments on their manpower and IT budget has been decreasing and shifted to end-users (Edberg and Bowman 1996, He et al. 1998, Lucas 2000), which is primarily attributed to the availability of knowledgeable end-users and extensive company support to EUC (Turban et al., 1999). The percentage of knowledge and information work constitutes 60% of America's GNP and 55% of their labor force (Laudon and Laudon, 1999). The knowledge workers will extensively use the latest technological solutions while working independently in fulfilling their functional obligations, creating a very limited reliance on higher management. These arguments are supported by the positive correlation between power distance and localized exploitation and internal integration (Phases I & II).

Socio-technical systems are made up of technical and social subsystems. To optimize the entire work system, the interaction of both subsystems must be jointly optimized.

- **Uncertainty Avoidance (V202)**

India: A negative correlation between uncertainty avoidance and business process redesign (Phase III) supports the argument that a higher value of uncertainty avoidance will create more resistance for radical changes, and thus, organizations will not be able to undertake business process redesign projects.

U.S.A.: There are no statistically significant results obtained.

- **Individualism (V203)**

India: The India organizations are at operational level, as classified by the United Nations (Palvia and Palvia, 1992). Agrawal and Haleem (2003) argued that the increasing competitive pressures are helping Indian organizations in developing a positive mindset for successful implementation of IT applications. Further, knowledge workers and End-users Computing are growing fast in Indian organizations. The positive correlation between individualism and factors of business transformation (business process redesign–Phase III and IT-induced reconfiguration) may be a symptom of initiation of business process redesign projects, along with IT-induced reconfiguration in Indian organizations due to growth in End-users Computing.

U.S.A.: The control of information systems departments on their manpower and IT budget has been decreasing and shifted to end-users (Edberg and Bowman, 1996; He et al., 1998; Lucas, 2000). The main reason for this shift is attributed to the availability of knowledgeable end-users and extensive company support to EUC (Turban et al., 2001). The percentage of knowledge and information work constitutes 60% of America's GNP and 55% of their labor force (Laudon and Laudon, 1999). The knowledge workers will extensively use the latest technological solutions while working independently in fulfilling their functional obligations, creating a very limited reliance on higher management. These arguments are supported by the positive correlation between individualism and localized exploitation/ internal integration (Phases I & II).

- **Masculinity (V204)**

India: The India organizations are at operational level, as classified by the United Nations (Palvia and Palvia, 1992). Agrawal and Haleem (2003) argued that the increasing competitive pressure is helping Indian organizations develop a positive mindset for successful implementation of IT applications. Further, the knowledge workers and End-users Computing is growing rapidly in Indian organizations. However, being at a lower level of capability maturity model (Whitten et. al., 2004) and lacking team spirit, the higher value of masculinity will lead to an obstruction in undertaking IT application projects at various phases (Phase I, II, and V), along with business transformation. These arguments are supported by a negative correlation between masculinity and factors of business transformation (localized exploitation & internal integration–Phases I & II, business scope redefinition–Phase V, and degree of business transformation/degree of potential benefits).

U.S.A.: There are no statistically significant results obtained.

Validation of Hypotheses: Based on the results and above interpretation, the hypotheses can be concluded as given in Appendix III.

Comparison of Manufacturing Sector and Service Sector (Results of Stepwise–Statistical– Discriminant Function Analysis)

The results of stepwise (statistical) discriminant function analyses reveal that there are significant differences in the values of the manufacturing sector and service sector in the number of variables, as given in Table 3. The classification procedure, classifying substantially more than the number of cases, should be correct by chance. The results tabulated in

Table 3: Results of Discriminant Analysis: Summary of Comparison between Manufacturing and Service Sectors

Independent Variables (Predictors)	Significant higher values in MS (manufacturing sector) or SS (service sector) as indicated in the applicable columns below	
	India	U.S.A.
V301: Localized exploitation and internal integration–Phase I & II	MS	SS
V302: Business process redesign–Phase III		MS
V303: Business network redesign–Phase IV	SS	
V304: Business scope redefinition–Phase V.		SS
V102: The rate of obsolescence of your product.	MS	MS
V103: Prediction of competitor's actions (fairly easy to very unpredictable).	SS	
V105: The mode of production/services (well established to subject to very much change).		MS
V203: Individualism (degree to which people in a culture prefer to act as individuals rather than members of groups).		SS
V204: Masculinity–degree to which value like assertiveness, performance, success, and competitiveness prevails among people of a culture over gentle values like quality of life, maintaining warm personal relationships, service, care of the weak, etc	SS	

Table 3 can be argued as:

• India:

- Earlier, the major emphasis was on improving the productivity; hence, the major concentration was in the manufacturing sector. Subsequently, the service sector is also considered by the organizations for further improvements. Additionally, in manufacturing, the products could be produced with local automation using standard processes, while in service sector, the processes used are integrated and have a substantial scope of redesign.
- The faster rate of obsolescence of products seems to be causing an excessive pressure on manufacturing sector to create facilities for developing and manufacturing customized products.
- Because of non-standard processes in service sector, it is very difficult to predict competitors' actions. Therefore, the higher amount of masculinity in the labor force can help organizations with survival and growth.

• U.S.A. :

- The major emphasis in the competitive market is on improving the productivity; therefore, the major concentration seems to be in the manufacturing sector. The availability of user-friendly packages is suited more to blue-collar workers where the available packages have best practices in-built and the implementation requires process redesign. Further, the usage of decision support systems in service sector requires customized packaged solution. Therefore, localized exploitation and internal integration seem to be more significant in service sector. The higher cost of non-standard packages in service sector will pressure organizations to identify sources of revenue from IT applications to make their IT related investments cost-effective.
- The faster rate of obsolescence of products seems to be causing an excessive pressure on manufacturing sector to create facilities for developing and manufacturing customized products. The problem of frequent changes in the mode of production/ services in manufacturing sector also can be addressed, to an extent, by manufacturing customized products using extensive automation.
- Considering the job requirements in service sector, the higher amount of individualism in the culture of human resources can have substantial benefits to the organizations.

> ***National differences make a consistent and substantial contribution to the differences in a manager's attitude: two-thirds national and one third individual. Certain socio-cultural conditions have to be in place for innovation to occur.***

Limitations of the Study

As with any other study, this research also has several limitations that need to be discussed. First, the list of variables pertaining to IT related issues might reflect some biases. Although the literature was thoroughly reviewed and additional perspectives were obtained form IS academicians and managers, we do not claim that these are the only variables that could be included. Thus, it must be stressed that any interpretation of the findings be made in lieu of the selected set of variables, issues, and categories. Availability of literature in the area of information technology in the context of developing countries was found to be scarce and limited. Any research that uses data gathered for inferential statistics assumes that the data are collected randomly from the population, which was the case with U.S. organizations, while stratified judgment sampling was used in the case of Indian organizations. Since the questionnaire survey involved people from various departments, such as information systems, administration, accounting/ finance, production, etc., a balance among the number of respondents from each department could not be achieved. Secondly, with organizations in India, multiple samples have been collected because the executives of these firms showed keen interest in this study, and in India there are a limited number of organizations with experience of IT applications for more than five years. As well, the choice of firms for the questionnaire survey in India was restricted to technological hubs located in northern, southern, and western parts of the country. Additionally, there is a base of firms scattered in other parts of the country, which could not be included in the sample. Furthermore, samples were collected from the manufacturing sector (telecommunication hardware, computer hardware, and other manufacturing industries) and service sector (banking, hotels, computer software, and airlines). Other types of organizations like insurance, financial institutions, etc., are not included in the sample. Thus, any inferences based on the results might be restricted to the companies listed in the directory.

Suggestions for Further Work

The findings from this study — in the area of culture, environmental pressures, and factors of business transformation — provide several study opportunities for future research, and the results suggest that it might be useful to develop a number of comprehensive models. Therefore, future research can extend this study to include additional factors, such as organizational maturity, IS sophistication, etc., to test a variety of such factors. In studying this, future research is recommended utilizing more rigorous methodologies that employ longitudinal approaches and non-linear relationships. Hence, with a broader sample and number of variables, a more generalized model can be developed.

Concluding Remarks

The main objective of this study was to arrive at a better understanding of the number of issues pertaining to implications of environmental pressures and cultural factors on the factors of IT-enabled business transformation in India and learning from the experience of the United States, the world leader in IT applications. This research has allowed us to investigate a number of issues in United States organizations: (1) The statistical correlation analyses resulted in: (a) a positive correlation between frequent changes in marketing practice and factors of business transformation (localized exploitation and internal integration–Phases I & II, business process redesign–Phase III, business network redesign–Phase IV, business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits), (b) a positive correlation between rate of obsolescence of product and factors of business transformation (localized exploitation and internal integration–Phases I & II, business process redesign–Phase III, business network redesign–Phase IV, business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits), (c) a positive correlation between the prediction of consumer test/product demands and business process redesign (Phase III), (d) a negative correlation between the frequency of changes in mode of production/services and localized exploitation/internal integration (Phases I & II), (e) a positive correlation between power distance and localized exploitation and internal integration (Phases I & II), and a positive correlation between individualism and localized exploitation and internal integration (Phases I & II), and (f) a positive correlation between the frequency of changes in mode of production/services and business network redesign (Phase IV). (2) The discriminant analysis resulted in significant higher values for: (a) the variables localized exploitation and internal integration (Phases I & II), business scope redefinition (Phase V) and individualism in service sector, and (b) the variables business process redesign (Phase III), rate of obsolescence of the products, and frequency of changes in the mode of production/services in manufacturing sector. (3) The above results could be argued as: (a) the organizations will try to reduce IT's cost by generating revenues from integrated and networked IT applications, (b) the induction of innovative culture will result in development of new product/process for competitive advantage and frequent adoption of new technology/processes, along with IT-enabled business transformation in the organizations, (c) as the prediction of consumer test/product demand becomes difficult, the corporations would reengineer their processes to respond quickly to customer needs and to changes in business or its environment and rely more on customization and technological solutions to reduce manufacturing cycle time/ time to market their products/services, (d) the rapid changes in mode of production/services will lead corporations to rely more on customization, increase their dependencies on their human resources for internal decision making, and decrease their dependencies on technological solutions, (e) the networking will help in meeting organizations' needs for an efficient and effective connectivity with its business partners and a better interaction with customers and can help them in developing customized products/services, and (f) the knowledge workers will extensively use the latest technological solutions while working independently in fulfilling their functional obligations, creating a very limited reliance on higher management.

The significance level of 0.01 and 0.05 are very common in a larger sample size. For smaller sample size and generalization of model the significance level of 0.1 is justified.

However, in the case of Indian organizations the findings are: (1) The statistical correlation analyses resulted in: (a) a positive correlation between frequent changes in marketing practice and factors of business transformation (business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits), (b) a positive correlation between rate of obsolescence of product and factors of business transformation (localized exploitation and internal integration–Phases I & II, business process redesign–Phase III, business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits), (c) a positive correlation between the prediction of competitors' actions and factors of business transformation (business scope redefinition–Phase V and degree of business transformation/degree of potential benefits), (d) a negative correlation between the frequency of changes in mode of production/services and business network redesign (Phase IV), (e) a negative correlation between power distance and factors of business transformation (business network redesign–Phase IV, business scope redefinition–Phase V, IT-induced reconfiguration, and degree of business transformation/degree of potential benefits), (f) a negative correlation between uncertainty avoidance and business process redesign (Phase III), (g) a positive correlation between individualism and factors of business transformation (business process redesign–Phase III and IT-induced reconfiguration), and (h) a negative correlation between masculinity and factors of business transformation (localized exploitation & internal integration–Phases I & II, business scope redefinition–Phase V, and degree of business transformation/degree of potential benefits). (2) The discriminant analysis resulted in significant higher values for: (a) the variables business network redesign (Phase IV), prediction of competitors' actions, and masculinity in service sector, and (b) the variables localized exploitation and internal integration (Phases I & II), and rate of obsolescence of the products in manufacturing sector (3) The above results could be argued as: (a) the organizations will continue transforming their businesses and identify ways of earning revenues through technology to justify IT's cost for a competitive advantage, (b) the organizations will try to reduce IT's cost by generating revenues from integrated and networked IT applications, (c) the induction of innovative culture, will result in development of new product/process for a competitive advantage and frequent adoption of new technology/processes, along with IT-enabled business transformation in the organizations, (d) the need will arise to frequently upgrade technological solutions, along with business transformation, to improve creativity and innovation and to attain company's strategy, (e) the rapid changes in mode of production/services will lead corporations to rely more on customization, increase their dependencies on their human resources, and decrease their dependencies on integrated, networked technological solutions, (f) a higher value of power distance will obstruct organizations in adopting revolutionary IT applications (business network redesign and business scope redefinition) and will limit their scope to a lower degree of business transformations, (g) a higher value of uncertainty avoidance will create more resistance for radical changes, and consequently, organizations will not be able to undertake business process redesign projects, (h) there seem to be symptoms of initiation of business process redesign projects and IT-induced reconfiguration in Indian organizations because of growth in End-users Computing, and (i) being at a lower level of capability maturity model (Whitten et. al., 2004) and lacking team spirit, the higher value of masculinity will lead to an obstruction in undertaking the projects of IT applications at various phases (Phase I, II, and V), in addition to business transformation.

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Appendix I

(a) Factor Analysis: Factors and Variables through the Construct of Items Loaded

ORGANIZATIONS IN **INDIA**				
Factor	EIGEN VALUE	% Variances	Cumulative %	Variable Construct Loaded
1	5.099	39.219	39.219	B(1**, 2**, 4, 8, 9, 10, 11)
2	1.427	10.979	50.198	B(1, 2, 3, 12, 13)
3	1.1	8.463	58.662	B(5, 6, 7)
ORGANIZATIONS IN **USA**				
Factor	EIGEN VALUE	% Variances	Cumulative %	Variable Construct Loaded
1	4.591	35.314	35.314	B(1**, 3, 8, 9, 12, 13)
2	2.097	16.133	51.448	B(4, 5, 6, 9**, 10)
3	1.28	9.845	61.293	B(3**, 7, 11, 13)
4	1.029	7.918	69.211	B(1, 2)

** Items loaded on multiple factors, but having relatively lower significance and are above the cut-off value of 0.32 (absolute value).

(b) List of Data Items

Code	Description
B1	Create competitive advantage
B2	Attain company's strategy.
B3	Make better and more effective decisions.
B4	Increases productivity (reduce cost, increase effectiveness)
B5	Managing information and knowledge.
B6	Change management
B7	Improve creativity and innovation
B8	Respond quickly to customer needs and to changes in business or its environment
B9	Just-in-Time
B10	Total Quality Management
B11	Reorganize and reengineer
B12	Electronic Commerce
B13	Business Alliances (Joint Ventures, Virtual Corporations).

(c) List of Variables along with Corresponding Data Items used for Measurement

Variable Description	Variable Code	Code Numbers of Data Items
Localized Exploitation and Internal Integration (Phases I & II)	V301	B3, B4, B5, B6, B10
Business Process Redesign (Phase III)	V302	B8, B9, B11
Business Network Redesign (Phase IV)	V303	B12, B13
Business Scope Redefinition (Phase V)	V304	B1, B2, B7
IT-induced Reconfiguration	V305	Computed using empirical equation
Degree of Business Transformation/ Degree of Potential Benefits	V306	Computed using empirical equation

Appendix II : Results of Correlation Analysis

		V301	V302	V303	V304	V305	V306
INDIA							
V101	Pearson Correlation	0.099	0.110	0.096	**0.262**	**0.217**	**0.262**
	Sig. (2-tailed)	0.303	0.257	0.317	**0.006**	**0.024**	**0.006**
	N	110	107	110	109	108	108
V102	Pearson Correlation	**0.275**	**0.356**	-0.017	**0.426**	**0.357**	**0.406**
	Sig. (2-tailed)	**0.004**	**0.000**	0.863	**0.000**	**0.000**	**0.000**
	N	109	106	109	108	107	107
V103	Pearson Correlation	-0.036	0.154	0.001	**0.228**	0.133	**0.217**
	Sig. (2-tailed)	0.711	0.116	0.992	**0.018**	0.175	**0.026**
	N	108	106	108	107	106	106
V104	Pearson Correlation	-0.097	0.087	-0.046	0.037	-0.005	0.029
	Sig. (2-tailed)	0.319	0.374	0.639	0.703	0.959	0.764
	N	108	106	108	107	106	106
V105	Pearson Correlation	-0.125	-0.021	**-0.227**	0.038	-0.035	0.010
	Sig. (2-tailed)	0.197	0.829	**0.018**	0.695	0.719	0.920
	N	108	105	108	107	106	106
V201	Pearson Correlation	-0.072	-0.140	**-0.189**	**-0.167**	**-0.203**	**-0.181**
	Sig. (2-tailed)	0.457	0.151	**0.050**	**0.086**	**0.037**	**0.063**
	N	108	106	108	107	106	106
V202	Pearson Correlation	-0.005	**-0.244**	-0.014	-0.070	-0.113	-0.069
	Sig. (2-tailed)	0.959	**0.011**	0.888	0.475	0.246	0.480
	N	109	108	109	108	107	107
V203	Pearson Correlation	0.148	**0.197**	0.102	0.103	**0.161**	0.109
	Sig. (2-tailed)	0.122	**0.041**	0.289	0.288	**0.096**	0.261
	N	110	107	110	109	108	108
V204	Pearson Correlation	**-0.209**	-0.105	0.098	**-0.236**	-0.133	**-0.213**
	Sig. (2-tailed)	**0.029**	0.283	0.311	**0.014**	0.172	**0.028**
	N	109	107	109	108	107	107
USA							
		V301	V302	V303	V304	V305	V306
V101	Pearson Correlation	**0.219**	**0.278**	**0.427**	**0.230**	**0.374**	**0.278**
	Sig. (2-tailed)	**0.041**	**0.010**	**0.000**	**0.032**	**0.000**	**0.009**
	N	87	86	87	87	87	87
V102	Pearson Correlation	**0.175**	**0.344**	**0.419**	**0.284**	**0.404**	**0.329**
	Sig. (2-tailed)	**0.106**	**0.001**	**0.000**	**0.008**	**0.000**	**0.002**
	N	86	86	86	86	86	86
V103	Pearson Correlation	-0.037	0.087	-0.027	-0.108	0.011	-0.101
	Sig. (2-tailed)	0.733	0.421	0.806	0.314	0.920	0.350
	N	88	87	88	88	88	88
V104	Pearson Correlation	-0.013	**0.206**	0.059	-0.004	0.070	0.008
	Sig. (2-tailed)	0.906	**0.055**	0.583	0.972	0.517	0.944
	N	88	87	88	88	88	88
V105	Pearson Correlation	**-0.252**	0.160	**0.216**	-0.077	0.072	-0.033
	Sig. (2-tailed)	**0.019**	0.142	**0.044**	0.480	0.509	0.761
	N	87	86	87	87	87	87
V201	Pearson Correlation	**0.210**	0.103	0.015	0.086	0.137	0.083
	Sig. (2-tailed)	**0.052**	0.347	0.894	0.432	0.208	0.448
	N	86	85	86	86	86	86
V202	Pearson Correlation	-0.142	-0.165	-0.074	-0.164	-0.123	-0.161
	Sig. (2-tailed)	0.191	0.132	0.496	0.132	0.257	0.138
	N	86	85	86	86	86	86
V203	Pearson Correlation	**0.221**	0.091	0.071	0.153	0.133	0.151
	Sig. (2-tailed)	**0.039**	0.407	0.512	0.157	0.218	0.163
	N	87	86	87	87	87	87
V204	Pearson Correlation	0.017	-0.086	-0.112	0.057	-0.058	0.033
	Sig. (2-tailed)	0.878	0.433	0.305	0.603	0.594	0.761
	N	86	86	86	86	86	86

Appendix III : Conclusion of Hypotheses

H1: The severity in environmental pressures (frequency of changes in marketing practices, rate of product obsolescence, prediction of competitors' actions, prediction of consumer test/product demand, and frequency of changes in mode of production/services) positively correlate with factors of IT-enabled business transformation (localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), and business scope redefinition (Phase V)).

	INDIA	U.S.A.	COMMENTS
Frequency of changes in marketing practices is positively correlated with localized exploitation and internal integration (Phases I & II).		Accept	
Frequency of changes in marketing practices is positively correlated with business process redesign (Phase III).		Accept	
Frequency of changes in marketing practices is positively correlated with business network redesign (Phase IV)		Accept	
Frequency of changes in marketing practices is positively correlated with business scope redefinition (Phase V)	Accept	Accept	
Rate of product obsolescence is positively correlated with localized exploitation and internal integration (Phases I & II).	Accept	Accept	
Rate of product obsolescence is positively correlated with business process redesign (Phase III).	Accept	Accept	
Rate of product obsolescence is positively correlated with business network redesign (Phase IV).		Accept	
Rate of product obsolescence is positively correlated with business scope redefinition (Phase V).	Accept	Accept	
Prediction of competitors' actions is positively correlated with business scope redefinition (Phase V).	Accept		
Prediction of consumer test/product is positively correlated with business process redesign (Phase III).		Accept	
Frequency of changes in mode of production/services is positively correlation with localized exploitationand internal integration (Phases I & II).		Do Not Accept**	** Significant negative correlated
Frequency of changes in mode of production/services is positively correlation with business network redesign (Phase IV).	Do Not Accept**	Accept	** Significant negative correlated

H2: The severity in environmental pressures (frequency of changes in marketing practices, rate of product obsolescence, prediction of competitors' actions, prediction of consumer test/product demand, and frequency of changes in mode of production/services) is positively correlated with IT induced reconfiguration, and degree of business transformation/degree of potential benefits.

	INDIA	U.S.A.	COMMENTS
Frequency of changes in marketing practices is positively correlated with IT-inducedreconfiguration.	Accept	Accept	
Frequency of changes in marketing practices is positively correlated with degree of business transformation/degree of potential benefits.	Accept	Accept	
Rate of product obsolescence is positively correlated with IT-induced reconfiguration.	Accept	Accept	
Rate of product obsolescence is positively correlated with degree of business transformation/degree of potential benefits.	Accept	Accept	
Prediction of competitors' actions is positively correlated with degree of business transformation/degree of potential benefits.	Accept		

H3: Power distance and uncertainty avoidance are negatively correlated with factors of IT-enabled business transformation (localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), and business scope redefinition (Phase V)).

	INDIA	U.S.A.	COMMENTS
Power distance is negatively correlated with localized correlation exploitation and internal integration (Phases I & II).		Do Not Accept**	** Significant positive
Power distance is negatively correlated with business network redesign (Phase IV).	Accept		
Power distance is negatively correlated with business scope redefinition (Phase V)	Accept		
Uncertainty avoidance is negatively correlated with business process redesign (Phase III)	Accept		

H4: Power distance and uncertainty avoidance are negatively correlated with IT induced reconfiguration, and degree of business transformation/degree of potential benefits.

	INDIA	U.S.A.	COMMENTS
Power distance is negatively correlated with IT induced reconfiguration.	Accept		
Power distance is negatively correlated with degree of business transformation/degree of potential benefits.	Accept		

H5: Individualism and masculinity are positively correlated with factors of IT-enabled business transformation (localized exploitation and internal integration (Phases I & II), business process redesign (Phase III), business network redesign (Phase IV), and business scope redefinition (Phase V)).

	INDIA	U.S.A.	COMMENTS
Individualism is positivelycorrelated with localized exploitation and internal integration (Phases I & II).		Accept	
Individualism is positively correlated with business process redesign (Phase III).	Accept		
Masculinity is positively correlated with localized exploitation and internal integration (Phases I & II).	Do Not Accept**		** Significant negative correlation
Masculinity is positively correlated with business scope redefinition (Phase V)	Do Not Accept**		** Significant negative correlation

H6: Individualism and Masculinity are positively correlated with IT induced reconfiguration, and degree of business transformation/degree of potential benefits.

	INDIA	U.S.A.	COMMENTS
Individualism is positively correlated with IT induced reconfiguration	Accept		
Masculinity is positively correlated with degree of business transformation/degree of potential benefits.	Do Not Accept**		** Significant negative correlation
NOTE : In all remaining blank cells : Do Not Accept because of insignificant statistical results.			

Flexibility Mapping : Practitioner's Perspective

1. What types of flexibilities you see in the practical situation of "IT- enabled business transformation" on the following points:
   - Flexibility in terms of "options"
   - Flexibility in terms of "change mechanisms"
   - Flexibility in terms of "freedom of choice" to participating actors.

   Identify and describe the types of flexibilities that are relevant for your own organizational IT- enabled business transformation? On which dimensions, flexibility should be enhanced?
2. Try to map your own organization on following continua of IT- enabled business transformation issues. (Please tick mark in the appropriate box(es))

Strategy

Focus on Current | | | | | | Robust for Future

Decision Process

Centralized | | | | | | Decentralized

Level of Automation

Limited Range of Product/ Services | | | | | | Customized Product Services

Creativity/ Innovation

Low | | | | | | High

Transformation

Continuous Improvements | | | | | | Big Push or Radical Change

3. Develop a SAP-LAP (Situation Actor Process-Learning Action performance) model of "IT- enabled business transformation" relevant to your organization.

Key Questions Reflecting the Applicability in Real Life:

1. How are the objectives of your organization oriented in terms of socio-political and economic spectrum? How will you utilize the findings of this study to focus them?
2. What is the level of centralization, formalization and standardization in your organization? Can you redesign the organizational processes involving above-mentioned parameters, which can help you in focusing organizational orientation and also in achieving organizational effectiveness?

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A Management Information System for Team Productivity Improvement

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Abstract

This paper presents a case study, where a Management Information System (MIS) for Team Productivity Improvement Group (TPIG) called, MIS-TPIG, is designed, developed and commissioned in a manufacturing organisation. The system's primary responsibility is to organize and administer team building and productivity improvement events and functions for its employees. The MIS replaces the existing tedious manual paper base system and helps streamline the TPIG administration of such events. The new system is intended to help in bridging the gap between top management and the factory floor through the organizing these potentially valuable events to enhance idea exchange, sharing of information and communication at all levels.

Keywords : communication, flexibility, information, MIS, team productivity

Introduction

Today's organizations have emphasized on team based environments, to combat the existing hostile and competitive market place. Most organizations believe that through teams, information sharing, idea generation and communication through all levels of the organization can be achieved. As a result, organizations find that their hierarchical structure they once had often transform to a more flattened structure.

Many organizations have responded by becoming decentralized, team based and dispersed (DeSanctis, 1994). An important reason for the implementation of a Management Information System (MIS) is that the people can meet together to generate ideas, share information and to improve communication through all levels of the organization. Little research has been completed to examine the effectiveness of teams in sharing information (Mennecke, et al. 1995). Yet, information sharing and idea generation can potentially be quite important in influencing a groups success, in solving problems and making decisions.

According to Orlikowski (1992), "Nothing is more central to an organisation's effectiveness than its ability to transmit accurate, relevant, understandable information amongst its employees. All of the advantages of an organization's economy of scale, financial and technical resources, diverse talents, and contacts are of no practical value if the organization's employees are unaware of what other employees require of them".

This paper presents a case study, where a real life problem was identified for a large manufacturing company to design, develop and commission a management information system for team productivity improvement group. The primary responsibility was to organize and administer team building and productivity improvement event and function for its employees. The MIS was to replace the existing tedious manual paper based system and help streamline the administration of such events. The new system would ultimately help in bridging the gap between top management and the factory floor through the organizing these potentially valuable events to enhance idea exchange, sharing of information and communication through all levels of the organization.

Role of Flexibility in MIS

Management Information systems can support a company's competitive positioning. All successful companies have one or two business functions that they do better than the competition. These are called core competencies. For a core competency to become a sustainable competitive advantage it must be difficult to mimic, unique, sustainable, superior to the competition, and applicable to multiple situations. Examples of company characteristics that could constitute a sustainable competitive advantage include: strategic flexibility, superior product quality, extensive distribution contracts, accumulated brand equity and positive company reputation, low cost production techniques, government protected monopoly, and superior employees and management relations. However, there are some studies that claim that in a fast changing competitive world, none of these advantages can be sustained in the long run. They claim that the only truly sustainable competitive advantage is to build an organization that is so agile and flexible that it will always be able to find an advantage, no matter what changes occur.

Management Information Systems often support and occasionally constitute these competitive advantages. The rapid speed of change has made access to timely and current information critical in a competitive environment. Information systems, like business environmental scanning systems, support almost all sustainable competitive advantages. Occasionally, the information system itself is the competitive advantage.

While flexibility is normally considered as an adaptive response to environmental uncertainty, it is important to realize that a firm may use its strategic flexibility to re-define market uncertainties and make it the cornerstone of its ability to compete (Gupta and Goyal, 1989). Flexibility can help in successful implementation of an MIS if the following factors are taken into account:

- Recording and storing inventory data, work in process data, equipment repair and maintenance data, supply chain data, and other production/operations records
- Processing these operations records into production schedules, production controllers, inventory systems, and production monitoring systems
- Recording and storing personnel data, salary data, employment histories, and other human resources records
- Processing these human resources records into employee expense reports, and performance based reports
- Recording and storing market data, customer profiles, customer purchase histories, marketing research data, advertizing data, and other marketing records
- Processing these marketing records into advertizing elasticity reports, marketing plans, and sales activity reports
- Recording and storing business intelligence data, competitor analysis data, industry data, corporate objectives, and other strategic management records
- Processing these strategic management records into industry trends reports, market share reports, mission statements, and portfolio models
- Use of all the above to implement, control, and monitor plans, strategies, tactics, new products, new business models or new business ventures.

The Case Study Overview

An increasing number of manufacturing companies are undertaking broad based programs of change, in pursuit of international competitiveness and improving business performance. ABC Pty Ltd is a tale of such an organization that has undergone radical change. Change that was necessary in order to survive adverse economic conditions and in order to become “World Leaders” in the glass manufacturing around the world.

Typically some of these programs encompass a range of management philosophies aimed at improving product quality, customer service, manufacturing, distribution flexibility and total productivity improvement. Principal among these philosophies are Just In Time (JIT), Total Quality Management (TQM), World Best Practice (WBP), Business Process Re-engineering (BPR), Computer Integrated Manufacture (CIM-SAP R/3) and Team in Manufacturing. A major objective was to develop within the organization, a new customer focused, team-based culture or ethics, with fewer levels of management and supervision, and a higher degree of empowerment for front-line workers. This new style of organization is often built around self-managing or self-directing work teams.

Using teams as a way of managing the business has become part of the every day management language - some would say it's a "buzz word" around the site. A recent industry report found that over 80 per cent of sizeable businesses have team structures in place. The trend is towards the establishment of permanent teams responsible for ongoing development and improvement of business processes. Developing responsive team culture is a lengthy and complex process requiring planning and long-term commitment from top management.

The keys to a successful implementation of a MIS are as follows:

- A clear articulated vision and strategy for the business
- Strong support from senior management
- Long-term commitment and flexibility
- Sharing of information through all levels of the business
- Idea generation and employee participation for decision-making
- Transfer of real decision-making power
- Skills training to support new ideas and roles
- Improved communication channels through all levels of the business
- Continued coaching from team leaders
- System to support teams.

To successfully bring about changes to a team based culture and to develop new leadership role is a difficult process and must be gradual. However, the benefits are compelling. It is not that traditional planning, organization, leading and controlling have gone out of style. Instead, organizations under pressure are realising that they can no longer pay the price of layer upon layers of management. Some companies are reaping huge operational benefits by shifting traditional hierarchical management duties to self-managing teams, frequently of non-managerial staff and operators. Close to the action, employees often know more than distant managers ever could. That is the reason why these self-managing teams often perform "management work" in three improved ways - better, faster and cheaper than any manager ever did. One team leader, described the organisation as having gained efficiency and productivity levels. He quoted, "We are a more effectively organized work force that is inspired, motivated and forward thinking employees with fewer grievances. It enabled us to spend more time focusing on the customer and the competition - and less on the internal issues". The company reports dramatic quality and productivity gains from successfully implementing team-based structures. The company has found to be more flexible and has lowered their response time to customer demands to such a degree that they are well on their way to achieving world class status as being leaders in the float glass operation.

The Team Productivity Improvements Group (TPIG) was set up around fifteen years ago and is administered by a team of six employees. It's primary function is to bridge the gap between top management and the factory floor, so that it can improve communication, idea generation and information flow through all levels of the organization. This would improve quality, efficiency, productivity and world best practice results as world leaders in the float glass operation. The TPIG can achieve this by organizing team building exercises, communication programs, inter plant transfers, guest speakers, total quality management, seminars, quality circles etc. Each event is organized by the TPIG and could take anywhere between three to six months to be successfully arranged.

At present, most of the activities of the association, including managing and event organizing are performed manually. This inevitably requires time and resource from the ABC company, the TPIG and its employees, and could include up to forty people to manage, organize and participate in various team building activities in a single year. Therefore, development of an MIS will improve the present tedious "paper dragon" manual system and would reduce the workload and streamline the activities of the TPIG activities.

It is anticipated that this new system would enable the TPIG to serve its teams better by readily making available the information necessary for important decision-making and management of team events and functions.

The new MIS provides a simple graphical user interface (GUI) which was developed using Microsoft Access with a Visual Basic front end. It was implemented on an IBM compatible PC under the Windows 95 operating environment and is compatible with the Groups Hewlett Packard (HP) Laser printer.

The Team Productivity Improvement Group

The major objectives of the Team Productivity Improvements Group (TPIG) are as follows:

- Involve employees in decision-making.
- To Improve communication, idea generation, information sharing and flow-through to all levels of the organization.
- Team building exercises for quality, efficiency, flexibility and productivity improvement.
- To flatten the structure of the organization by bridging the gap between top management and factory floor personnel.
- To encourage, promote and motivate teams within ABC.
- To provide opportunities for the team to get involved in a variety of enjoyable and team building activities as part of self training, development and improvement.
- To provide a balance between working and social life at ABC.
- To publicize the Interactive Group activities and events within ABC.
- Making the support and running of events more efficient, thereby reducing the workload of the TPIG committee and its volunteers.
- Improving the level of service to its employees and teams.
- Increasing information available to the TPIG committee about its team membership and thereby facilitate decision-making and management of the organization.

In order to achieve these objectives, the company has embarked on a number of such team building events and activities. The TPIG keeps its team members up to date by circulating newsletters which contains details about upcoming team events that are planned for the year. The mentioned difficulties and problems, have necessitated the TPIG to develop an MIS that will help stream line the operations and maximize the groups resource utilization by providing a quality and efficient service to its teams and employees.

This was achieved by designing the MIS for TPIG, called MIS-TPIG, with the following requirements:

- A simple GUI to facilitate its use by the TPIG who would have differing computer literacy levels.
- Team information on a full-featured Database Management System (DMS) format.
- To facilitate the updating of teams and employees information for ease of administration of team events and activities.
- Ad-hoc querying and report generating facilities for decision-making within the organization.
- Facilities for printing mailing labels needed for newsletter distribution and other mailing requirements.
- Back up facilities for system information protection.
- Provision of hardware and software necessary for the implementation of the system.

The MIS-TPIG reduced the workload of volunteers by automating the above mentioned functions. This new system has enabled the TPIG to serve its team and employees better, by readily making available the information necessary for a wide variety of decision-making, idea exchanges and improved communication through all levels within the organization.

The Benefits of MIS-TPIG

From various studies carried out by MIS developers and researchers, a compromise of a "before MIS" and "after MIS"' picture is presented for the MIS-TPIG system.

Before the MIS-TPIG was installed, the following situation was typical at the organization.

1. The organisation was departmentalised by function.
2. Communication was primarily up and down the hierarchy structure of the organization with no commitment for any integration.
3. Management style tends to be autocratic or paternalistic in nature.
4. Leadership was based more on power than on professional competence.
5. The role of the manager was very important because of ambiguity of situations caused by lack of information. The emphasis was on managers who can drive ahead in ignorance using low levels of conceptualization and management sophistication.
6. Non-managers are limited in scope of action because of ambiguity of objectives and lack of information about the business system as a whole.
7. Aspirations and motivations of non-managers are heavily influenced by goals set for them by their managers.
8. Motivation of non-managers was directed more towards filling social needs on the job than toward self fulfilment through control of one's own work.
9. Group conformity, group norms, and group cohesion are sought above individual job performance.

After the MIS-TPIG was installed, the following changes were observed in the organization:

1. The organization became more sophisticated in structure as a complex cross-functional structure, or a product investment inter functional geographical structure developed.
2. Communication was more formalised into networks represented by the MIS. Emphasis was on getting information directly to the individual responsible for a task rather than through his or her manager.
3. Management style became flexible and participative or else it fails.
4. Leadership was based more on competence than power. Those managers who lack technical competence become very insecure.
5. The old role of the manager changed. Emphasis was on analytical skills and a high level of conceptualization.

Discussion

Can information systems "flatten" organizations by reducing their number of levels? Will MIS allow organizations to operate with fewer middle managers and clerical workers? Can MIS reduce paperwork? Can they be used to "re-engineer" organizations so they become lean, efficient, and hard hitting? Can organizations use MIS technology to decentralize power down to lower-level workers, thereby unleashing the creative talents of millions of employees? These are among today's leading management questions.

The issues raised by contemporary information systems; efficiency, creativity, flexibility, bureaucracy, employment, quality of work life, are long standing issues of industrial society, and they pre-date computers. No one can deny that MIS has contributed to organizational efficiency, effectiveness and ultimately improving an organization's productivity and strategic flexibility. Yet social and behavioural scientists, who have studied organizations over long periods of time, argue that no radical transformation of organisations has occurred except in isolated cases. Exactly what can MIS do for organisations?

A MIS must be aligned with the organization to provide information needed by important groups within the organization. At the same time, the organisation must be aware and open itself to the influences of MIS, to benefit from new technologies.

It is very convenient for journalists, scholars and managers to think about the impact of computers on organizations. But the actual effect is much more complex. These include the organization's surrounding culture, organizational structure, standard operating procedures, politics, and management decisions (Orlikowski 1992, Orlikowski and Baroudi 1991). Managers, after all, decide what systems will be built, what they will do, how they will be implemented, and so forth.

Conclusions

The MIS-TPIG system described in this work has satisfied the requirements of the company. The primary driving forces for the company in deciding to implement the MIS-TPIG was to eliminate the antiquated paper based system and streamline its operations and administration. The MIS-TPIG will inevitably save time and resources for the company, the TPIG and its team volunteered members.

The MIS-TPIG through time, will ultimately bridge the gap between top management and the factory floor through the efficient sharing of information and communication through various levels of the business organization. Time alone will tell if theory will become practice.

A comprehensive information system for use by the top management in making strategic decisions is theoretically possible with the MIS-TPIG development. The management of the company can have a quick snap shot of the TPIG and very quickly arrive at financial decisions for the group. This re-emphasizes the point of quick information flow, idea exchange, flexible information sharing and communication through a flatter ABC organizational structure.

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Technology Innovation as an Evolutionary Process

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Innovation= theoretical concept + technical invention + commercial exploitation

U.S Department of Commerce

Innovation is integration of a new idea, invention of a new device, and development of a market all combined together.

Myers and Marquis (1969)

Abstract

Both Biological and Technology development processes have evolutionary nature and have some similarities. This paper examines the extent of similarities between the two and concludes that the similarity does not go very far. The Technological processes are controlled by the concurrent knowledge base of the development team, whereas biological processes depend upon the internal cell mutations, which depend upon the available environment. The working legacy of the organization controls its strengths, weaknesses and the entrepreneurial spirit, thus profoundly influencing its growth aspirations. Unlike biological processes, though the process of technological innovations is recursive in nature and continuous improvements in both product and processes occur. The biological evolutionary process however yields information for better understanding of the parts played by legacy of the organization and exploitation of available growth potentialities.

Keywords : Innovation, Innovation Management, Genotype, Phenotype, Evolutionary processes, and Industrial innovation

Introduction

HP calls itself as an innovative firm and has included the word 'invent' in its LOGO. 3M aims at earning its 30% of its revenue from new products developments. SAP invests all the maintenance revenues it receives into ERP product development.

Technological processes are similar to biological processes in many respects and are evolutionary in nature. The technology evolution is carried out through scientific research and developing working and operating procedures and services for developing new products and services. This methodology involves defining working processes and operating procedures for delivering products and services and also simplifications in prevalent working procedures within the constraints of time and available resources. The result appears in the form of development of some product or introduction of some new product or simplified procedure. In this age of industrial revolution, innovation in industrial activities has acquired utmost importance and no enterprise can survive without innovating its products and services.

Innovation is a dynamic process[1] and its application to business greatly influences the enterprise behavior-pattern and market deliverables in terms of products, processes, materials, and services. It depends on the enterprises' dynamics controlled by enterprise' resources, its market economics, employees, and the consuming society. Organization's technology development policies, its culture, structure and practices can effectively enhance the innovativeness of an existing enterprise.

Biological v/s Technological Evolutionary Processes

The biological evolutionary process is explained by the conceptual foundation of gene, which

Living systems have built in regenerative systems, whereas non-livings need to be specially equipped with such systems.

was laid down by Wilhelm Johannsen[9]. Johannsen defined two types of genes - the *genotypes* and *phenotypes*. The genetic information about a particular part of an organism is called its *genotype*. The appearance of organism due to presence of these genes is called the *phenotype*. The phenotype depend on the way that the alleles of the genotype interact with each other. Thus genotypes may be considered to represent heritable potentialities and phenotypes, which make these potentialities realized. If mapped for physical systems, genotypes carry information about the potential growth characteristics of an individual or organization and phenotypes help the individual or the organization in availing of the opportunities during their realization of full growth potential. Since the living and nonliving systems have different characteristics, the analogy cannot be expected to go far – as the non living systems having only partial characteristics of living systems.

Technological evolutions lead to *Innovations* in industrial processes that have many characteristics similar to biological evolutionary process. Scientific discoveries generate new concepts, which when applied to physical systems lead to development of new products and improvement in the existing ones. Technology is the application of scientific knowledge to working processes in systems developed and conceived by humans. The modification in old systems and developing new systems using concurrent technologies is *technology development*. The process of Technology Development derives inputs from human knowledge about products, processes, services and market needs.

Involvement of human brains makes technology development process a live process *with evolutionary nature.*

Three elements contribute to technological development[9] - artifacts, knowledge and organizational attributes. Development process may be individualistic, design driven, collaborative, discovery driven or their combination depending upon the task. The pool of knowledge accumulated through experience by both individuals and design teams helps in understanding the operational principles, technology and technological processes involved and provides a base for the product design and manufacturing process development. The related manufacturing techniques also get continuously improved resulting in betterment of the product size, shape and performance.

Technology development requires input from design tools, manufacturing processes, and accumulated pool of product knowledge possessed by experts.

It has been attempted to structure the technology development process[4] by recognizing various stages of development cycle. All processes, of *design* and *manufacturing process* innovations, have elements requiring judgments, which are subjective and can be either individualistic or collaborative. The end result does not provide a unique solution; instead, many solutions are plausible through individuals and groups following an interactive approach and charged with the depth and width of multidisciplinary knowledge. The new solution is an improved version and is characterized by either simplification of working processes or amplification of product functions. As pointed out earlier biological and technological processes have many common characteristics. Following characteristics describe the similarities and differences.

Characteristics of Biological and Technological Processes

Technological innovation is primarily driven by a need, whereas biological evolution is mandatory.

A comparison of processes of technological evolution with biological processes[9] leads to following deductions:

a) Technological innovation differs from biological evolutionary process as the former is almost always motivated by some need or opportunity and the solution is always constrained by some boundary conditions. On the other hand the biological evolutionary process is caused by random cell mutations, which is their inherent characteristic and dependents on the characteristics of participating cells and environment. There are, however, some striking similarities between the two. Just as most of the information contained in a biological DNA is junk and do not affect the selection criterion till a suitable environment is created and calls for adaptation; most of the human knowledge is also junk and does not directly contribute to development process of chosen product or service. In the evolutionary process of both cases, only some of the enormous information contained in the cells or the knowledge contained in the human brains becomes useful; that too if it gets right environment.

b) In the evolutionary processes of biology, the artifacts are generated randomly and their final form remains unpredicted and un-visualized till they take a physical shape. On the contrary, the results of technological processes can be visualized in product form before the product is given final shape. The technological evolutionary processes may also lead to a product, which may or may not take a physical shape but essentially *require* pre-conceptualization of the ultimate product. This is true with software products or system design processes; the designs of which may culminate into a well-thought out assemblage of processes chosen to serve some predefined objective.

Technological innovation may not always culminate into a physical product, like software design or preconceptualization of a product.

c) The biological evolution requires that there can be no more than two parents for a new entity; the technological evolution does not have any such restriction as a product may involve large number of independent processes or may be developed as a combination of many independent products. It also uses multidisciplinary knowledge dimensions and interactive approach of the developers.

Only limited control can be exercised on biological products till the process of cell mutation is not fully understood.

d) Unlike biological processes, which are progressive, the process of technological innovations is recursive in nature. The development of technological products is predominantly dependent on designers experience, his knowledge base and working environment. The products therefore, are the results of conscientious design effort done almost always to accomplish a well-thought out need. The variations in the physical shape, size and performance of a product designed by different design teams, for serving same ultimate aim, are natural because of difference of their experience, knowledge base and working environment and are also subject to conscientious control of team members. For biological mutations no such conscientious control is possible. Products of Technology can have pre-defined physical shape and size though necessarily they may not a physical shape.

The figure 1 shows the factors affecting technological evolutionary processes. The similarities between evolution of biological systems and technology systems suggests criterion for the development and growth of an innovative enterprise. First it is important to recognize the equivalents of genotypes and phenotypes of biological evolution in the enterprise's technological evolution processes.

The above enterprise' characteristics can be classified into *Genotypes and Phenotypes*. Following is a tentative classification.

Enterprise Technology Development Capability (ETDC) represents heritable characteristics and genotypes potentialities. They depend on the legacy and cultural builtup.

a) Genotypes potentialities: *Enterprise Technological Development Capability (ETDC) is the potential of the enterprise to grow.* The knowledge accumulated from in-house developments and out sourced technologies develops heritable characteristics giving the enterprise capability to develop better quality products and also increases its capability to widen its product range. Therefore the enterprise scientific and technological base and its resourcefulness showing *Enterprise Technological Development Capability (ETDC)* represent heritable characteristics and *genotypes potentialities*.

b) Phenotype potentialities: The product physical appearance, enterprise' service quality, maintainability of its products and services and other realizable characteristics of organization's products and their market value represents phenotype potentialities. The enterprise work culture and willingness of its management to experiment and learn helps the enterprise to realize and exploit its inherited technological potentialities for developing products with better aesthetic

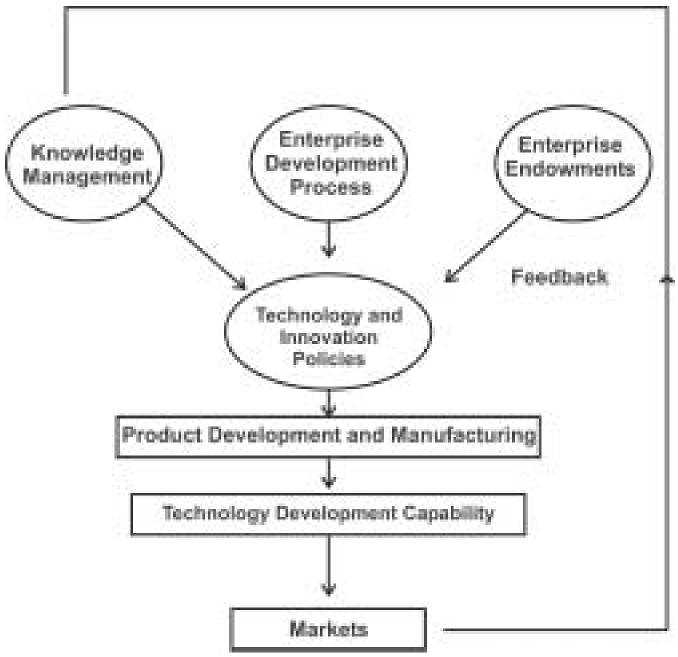

Figure1: Technology Development and Innovation Process

appearance and quality. They form *Enterprise Technology Exploitation Capability (ETEC) and represent phenotype potentialities*.

The recognition of the equivalence of genes in a technological process may guide us in planning the organizational setup and the policies for promoting innovation in the firm. As discussed earlier, unlike biological processes, the process of technological innovations is recursive in nature and continuous improvements in both product and processes occur *Enterprise Technology*

Table 1: Factors Influencing Innovativeness and Myths and Misconceptions

Factors influencing innovativeness	*Myths and misconceptions*
• Technology requires a broad range of tools, from mathematical to trial and error practice to reverse engineering.	• Technology is just applied science
• Continuous redesigning of products and building up knowledge base for improving products.	• More technology is always good
• Technologists are engineering or science graduates in a variety technology of fields and must be trained to have multidisciplinary knowledge.	• Technological self-reliance is key to break out of dependency
• Tacit and local knowledge is key to technological innovation. Since tacit knowledge is experiential, it is not as easy to transfer as blueprints.	• High tech is the best technology
• 'On-the-ground' industrial and non-laboratory situations and production bases are good sources for gaining technological knowledge	• Technology is well understood and easily transferred
• The knowledge built up from local production allows for continuous innovation 'on the job'.	• R&D is key to innovation and is led by R

Enterprise Technology Exploitation Capability (ETEC) represents phenotype potentialities. They depend upon management's strategies for enterprise growth pursued by the management.

Exploitation Capability (ETEC) represents phenotype potentialities. They depend upon management's strategies for enterprise growth pursued by the management. over time. But in order to affectively realize the improvements, the adopted policies have to follow enterprise growth model by implementing practices, which conform to the prevailing technological processes in the enterprise and are in line with its vision.

Enterprises strive to build their *Technological Capabilities, which increase their* innovativeness. This results in their continuous technological evolution. *Technological Capabilities* of companies are influenced by factors, which help in accelerating their innovativeness. The key factors promoting innovation in the process of technology development and some common myths[3] are given in table 1. These are true for all enterprises irrespective of their size and specialty.

In process innovation, it is established that most of the technology innovations are done on the shop floor. Similarly the design innovations are mostly done on the basis of market feedback. The above findings have been amply proved by methodology adopted by South Asian countries for their technological development.

The South Asian experience of product development teaches that mostly innovations are done on the shop floor and are not dependent on basic research.

A common parameter for measuring innovativeness is number of patents registered by a company during a particular period. On this basis, to day Samsung, a Korean company is amongst the first few in registering the number of patents [after few American companies like IBM and HP in similar fields]. These companies did not concentrate on basic research; instead they developed the technological processes for their work[5]. They also did not blindly follow the prevalent industrial practices of the west [as applied to manufacturing and management]. Instead they tailored them to suit their working environment and culture and further innovated them for better performance both for products and processes.

In biological systems, the interaction of genotype genes representing heritable potentialities and phenotype genes representing growth potentialities [with respect to working environment] decide the pattern of growth. Therefore exact analogy of growth pattern of biological systems with physical systems may not hold good as,the two systems have only few similarities.. The comparision, therefore, has to be seen with caution. Each identified group activity needs to be seen in the light of its functions and,growth potential (equalent to *genotypes* for direction of growth and, *phenotypes* for potntial realisable growth in the environment of working). In general depending on the enterprise functions, following resources activities affect the enterprise growth.

In physical systems, since most of the activities are interdependent, each is a combination of different proportions of genotype and phenotype functions.

1. Physical Resources

These are defined in terms of (i) infrastructure facilities for manufacturing, servicing and testing, (ii) financial resources, and (iii) marketing network.

Manufacturing, servicing and testing facilities in the company form the core operations without which no production or service operations are possible. A company without these facilities will loose its manufacturing company status. Similarly without credit worthiness the company will not be able to sustain itself against the market forces and it will always be fighting for its survival. Without marketing of its products the existence of the company comes in danger.

The importance of activities dealing with manufacturing, servicing and testing, finances and marketing network will vary for different companies dealing with different types of activities. The importance given to genotype and phenotype activities will therefore vary considerably.

2. Enterprise Technological Development Capability (ETDC)

This consists of (i) Internal information flow within the enterprise and access to outside information, (ii) scientific and technological Knowledge base and in-built information sharing mechanism and (iii) competencies of employees- their education, training and experience.

All the above factors influence the growth rate and the direction of growth for the company. R&D facilities help in finding innovative solutions for improvements in existing product and processes and in new product development; the information sharing amongst experienced and trained employees provide a broader vision for finding alternative economic solutions and help the company to face the competition better. Their contribution to innovation activities depends upon the level of R&D activities. For example a manufacturing company may have different sets of requirement than a continuous flow production, marketing or service company. These facilities make the company to realize its full potential for growth and therefore they correspond mainly to to *phenotype* functions. Since realization of company growth also depends company resources, this activity is influenced by genotype functions also.

3. Management Policy for in-house technology development through (R&D) and import and adoption of new technology:

For a progressive organization, it is essential to remain live in the areas of its working and develop newer applications of the presently known and incoming technologies. Potential for growth of a company is a direct function of company policies and company resources. Therefore management policies for the enterprise through its policies, affect both *genotype* and *phenotype* activities in varying proportions.

Enterprise Growth policy

Enterprise's solely devoted to manufacturing in general have growth policies[1, 6] dependent on three basic parameters (business development may have different parameters):

- Science policy,
- Technology Policy and,
- Innovation Policy.

Enterprise resources and activities, as detailed earlier, constitute basic inputs. The features and importance of each vary from industry to industry. For example small, medium and big industries will attach different importance to science policy and many of them may not have one. The experiences from developing strategies of South Asian countries amply justify this deduction. Forbes[3] in his six myths suggests that often gaining scientific knowledge is unimportant for industrial innovation, which largely takes place on shop floor. Promotion of scientific research in medium and small-scale industries is therefore not considered an important factor for technology innovation. However, the quality manpower, which is important for new product design, may hardly contribute to shop floor innovation. The other policies related to *technology* and *innovation* deserves consideration.

All enterprises have their self-developed growth pattern; accordingly they develop their own Indigenous Technological Capabilities (ITCP) and Innovation Policy (IP). Fig.1 gives the interplay of enterprise resources, its activities and policies in organization's development. The technology policy of an enterprise encourages support for creation of strategic or generic technologies, facilitating diffusion of technology, encouraging transfer of concurrent technology (particularly, advanced manufacturing technology), and focus on small and medium industry. In general, the strength of the enterprise depends on flowing factors:

The activities mentioned are regrouped to assess the relative importance of genotype and phenotype activities of the enterprise.

Knowledge Management in the Enterprise

It deals with generation, acquisition, storing and retrieval of (i) knowledge generated within the organization and that (ii) acquired from outside the organization.

Enterprise Development Process

It depends on learning of the organization through (i) its own experience, (ii) through training programs, seminars, and training at the sites of other equipment suppliers, (iii) by critical analysis of failures of own products and others products and policies, (iv) by doing field jobs and (v) through R&D

Enterprise Endowments

These are (i) the cultural factors, which depend upon the local culture, and work habits, (ii) entrepreneurship of the persons working in enterprise and (iii) local educational environment.

Different companies may attach different importance to the above parameters. The importance attached to each coupled with resources and external working environment, decides the enterprise growth rate. These factors may show interdependent as changes in one, may influence the others. For example, a software company has to give considerably large emphasis to Knowledge Management (KM) whereas KM may be of lesser significance for conventional manufacturing companies. In general whatever may be the relative importance of each, the three show interdependent, the extent of which, varies from case to case.

Our discussion here is limited to Technology development and manufacturing companies. Companies purely dealing with business development, planning and execution of projects attach different importance to the parameters influencing their growth accordingly importance of associated processes may also differ.

These factors are also responsible for technology and innovation policies of an enterprise. Many of them strongly influence the enterprise from within [inhibiting mainly genotype characteristics] while the others try to influence the enterprise through environmental variables [inhibiting mainly phenotype characteristics].

Enterprise Innovativeness

An important consideration in evaluating innovativeness is that the results are not influenced the size and trade of companies (e.g. software, production, design and consultancy, services and marketing). As discussed earlier, the organizations develop their own innovation strategy and adopt policies for promoting innovativeness among its employees. Zairi[8] has made a study of some innovating enterprises and the policies adopted by three consistently highly innovating enterprises are given in Table 2.

Table 2: Factors Recognized by Companies for Promoting Innovation

IBM (UK) Ltd	*3M*	*Hewlett Packard*
Teamwork, TQM, Tools and Techniques, Supplier Partnerships, Technology, Integrated Product Development Process	Teamwork, Ideas, Innovation Steering Committee, Recognition for innovation and corporate dependence on innovation, and Technological Exploitation	Teamwork, TQM, Quality Innovation and delivery chain, Product generation team

A study of innovation strategies of above three organizations reveals that importance to team work for both product and process development, TQM, technology exploitation and recognition of contribution of individuals are most commonly recognized innovation promotion strategies.

There are some variations also. Importance is given to other criterion like supplier involvement, for getting feed back from the market for continuously improving the products.

As mentioned earlier, the factors affecting enterprise innovativeness have both *genotype* and *phenotype* characteristics in varying degrees. Table 3 gives predominant component weightage of these factors for each of the processes mentioned above. The classification given is tentative and only suggestive, as actual type will depend on enterprise functions. Here G = Genotype, P = Phenotype.

Table3: Predominance of Genotype and Phenotype Activities in Various Innovation Promotion Activities of Organizations

Characteristics	*Genotype/ Phenotype Content*
1. Knowledge generated within the organization	G
2. Knowledge from outside the organization	P
3. Its own experience	G
4. Knowledge acquired through training programs, seminars, and training at the sites of other equipment suppliers	G
5. Knowledge generated by critical analysis of failures of own products and others products and policies	G
6. Knowledge generated through field jobs	G
7. Knowledge generated through R&D	G
8. Effect of cultural factors, which depend upon the local culture, and work habits	P
9. Entrepreneurship of the persons working in enterprise	G
10. Education of the people employed and local and environment	G+P
Total	**8G+3P**

Here the internal strength of an enterprise is considered to control the *Genotype activity* and the external environment the *Phenotype activity.* The above analysis shows that subject to some variations, internally controllable variables exercise about 70 per cent control and external environment exercise only 30 per cent control on the enterprise on the enterprise functions. Thus the internal strength of the company plays the dominant role in developing its Technological Capability.

Example of two Indian companies is worthy of mention. The Birla Group and Reliance. Till 1960, Birlas were a leading group. But during the fast development phase of the country, it failed to keep up with the times and today there a business houses which have become far bigger than the Birla group. If we peek into the development of the Birla group in pre and early post development era, the group focused on importing technology and deploying the same for product delivery. However the group did not develop the technology imported further and it can be said that the Enterprise Technology Development Capability (ETDC) were severely lacking. ETDC as stated above represents heritable characteristics and genotypes potentialities. The genotypes aspects of enabling innovation were never a strength with the company or its culture, which had been founded on usage and exploitation of imported technology. As times moved the organization saw reduced growth and stagnancy with the genotype attributes failing to deliver and while the phenotypes attributes of Enterprise Technology exploitation not being a focus for the organization. Reliance on the other hand started from a scratch as a trading company but the man behind it realized the potential of growth through technology exploitation. The company, which started from a trading business, had a very strong focus on phenotype aspects because of the nature of the trading activities. Its consistent focus on the same stimulated the growth of the company around these aspects. The growth of the company was on account of by rapid furor into new technological areas, exploitation of technology and rapid adoption of knowledge from outside the company. The company saw unprecedented growth and is now one of the largest industrial empires of the world.

Conclusions

i. Development of enterprise technological capability (ETC) can be compared to Genotype activities of biological systems. ETC is mainly dependent on organization's internal strengths. The innovativeness in a company can be promoted by enhancing its ETC through information exchange and knowledge base among its employees, quality of manpower employed, in house technology development and import of essential technologies. Management can achieve these by remaining responsive to developments in technology.

ii. Product physical appearance, enterprise' service quality, maintainability of its products and services and other realizable characteristics of organization's products and their market value represents *phenotype potentialities*. The enterprise work culture and willingness of its management to experiment and change its products as per market need helps the enterprise to exploit its inherited technological potentialities for developing products with better aesthetic appearance and quality.

iii. The effect of genotypes is about three times (8/11) that of phenotypes.

CASE 1 Research Design and Standards Organization of Indian Railways

The primarily design organization of Indian Railways is the epitome for technological innovations for railways technology in India. The organization is multidisciplinary and address all aspects of railway Research and Development. The manifestations of genotype and phenotype characteristics for the organization are detailed out below to arrive at the technological innovation

Characteristics	*Genotype/ Phenotype Content*	*Manifestation of Characterscics*
1. Knowledge generated within the organization	G	Research reports are regularly published by the organization and the standards made the organization are Indian Industry Standards for quality and railway products.
2. Knowledge from outside the organization	P	The organization is a party to all technological collaborations and import of technologies by the Indian Railways be it higher horse power locomotives, new design coaches , signalling equipments etc. However, organized framework is not in place for the same.
3. Its own experience	G	A permanent research cadre of the organization enables the organization to maintain its experiences within the organization.
4. Knowledge acquired through training programs, seminars, and training at the sites of other equipment suppliers	G	Regular training sessions for in house staff and vendor product awareness programs are held to build up staff capabilities and knowledge levels.
5. Knowledge generated by critical analysis of failures of own products and others products and policies	G	All failures statistics for critical railway equipment are monitored by the organization for building up knowledge base and initiating changes in the design or improvement in the product quality
6. Knowledge generated through field jobs	G	The large complement of the organizations manpower are personnel who have worked in the filed and are posted for tenure in the organization to bring filed level knowledge to the design organization.
7. Knowledge generated through R&D	G	The research wings have well equipped laboratories where research activities are an ongoing process to evaluate new technologies or evaluate field observations.
8. Effect of cultural factors, which depend upon the local culture, and work habits	P	With the organization having its own complete campus , the organization allows for a true research environment.
9. Entrepreneurship of the persons working in enterprise	G	No framework for the same exists.
10. Education of the people employed and local environment	G+P	Officers posted attend higher education programs with recognized academic educations and now even research chairs have been sponsored in leading technological institutions of the country. A recent trend.
Total	**8G+3P**	

characteristics of the organization.

From the above we see that the organization is well equipped and has framework in place for addressing most of its genotype characteristics which give the organization a strong technological innovation capability. This characteristic is particularly strong with respect to design refinements and standardization, where the organizations response has been significant and not in aspects of core railway design.

The phenotype characteristics of the organization, which enable it to adapt to new technologies, are however weak due no clear frameworks in place or are recent in nature resulting in poor adaptability to adopt new technologies and hence adoption of technology or manifestations of technological innovation, are few in number for the organization of its potential and capability.

Case II Diesel Locomotive Works, Varanasi, Indian Railways

A premier and only production unit for diesel locomotives in India with an integrated unit manufacturing almost all parts of the engine and locomotive chassis and assembling the same. Initially setup as a technological transfer project with ALCO, USA and has now gown in for a technological transfer project with General Motors of USA. The organization has manifested many characteristics because of past history and these are primarily classified into *genotype and phenotypes.* An illustration of the same is given below.

The organizations genotype characteristics are not very strong; hence the organizations' inherent capabilities to innovate are required to be enabled through positive enablement of

Manifestations of the Genotype and Phenotype Characteristics

Characteristics	*Genotype/ Phenotype Content*	*Manifestation of Characterscis*
1. Knowledge generated within the organization	G	No structured framework in place for documentations and preserving knowledge generated inhouse.
2. Knowledge from outside the organization	P	Technology transfer documentations as source of acquiring knowledge from outside.
3. Its own experience	G	Its own shop floor experiences, trail runs and failure statistics enable it to use its inhouse design capability to refine manufacturing level processes.
4. Knowledge acquired through training programs, seminars, and training at the sites of other equipment suppliers	G	Training sessions for staff in manufacturing technology and through vendor product awareness programs are held to build up staff capabilities and knowledge levels.
5. Knowledge generated by critical analysis of failures of own products and others products and policies	G	All failures statistics for critical railway equipment are monitored by the organization for building up knowledge base and initiating changes in the design or improvement in the product quality. Vendor databases are maintained and vendor certifications is done by the design wing to monitor product quality.
6. Knowledge generated through field jobs	G	The small complement of the organizations manpower are personnel who have worked in the field and are posted for tenure in the organization to bring field level knowledge to the design organization.
7. Knowledge generated through R&D	G	Inhouse design setup is more of a manufacturing process improvement and introduction of new subcomponents
8. Effect of cultural factors, which depend upon the local culture, and work habits	P	An Eastern UP establishment near to Bihar and
9. Entrepreneurship of the persons working in enterprise	G	Protected job environment with fixed channels of promotion do not give a place for entrepreneurial spirit.
10. Education of the people employed and local environment	G+P	The only large enterprise in the area and most employees are local who have not taken up education subsequent to initial education. The only significant exposure has been through the technological transfer project.
Total	**8G+3P**	

phenotype characteristic. This has been achieved through the numerous transfers of technological projects and these are main source of technological innovation in the organization.

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S. B. L. Garg After graduating and post graduating in Mechanical Engineering from IT Roorkee (University) in 1962, he joined MNNIT (earlier MNREC) as a faculty member. He did doctoral work at Liverpool University in 1971. He continued to teach at the institute with research in Engineering Design. He headed the Department of Mechanical Engineering and later became Principal of the college. After retirement from the college, he headed the Management Department of ABV-Indian Institute of Information Technology and Management (ABV-IIITM), Gwalior. Post retirement he took up AICTE Emeritus Fellowship with ABV-IITM. Presently, he is living in Delhi with a consulting assignment in ASET.

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The following candidates have been certified Level 1 through the process conducted at Godrej and Boyce, Mumbai (Batch 105).

1. Ms. Nalini Kala
2. Ms. Poonam Sharma
3. Mr. Darshan Kamat
4. Ms. Harpreet Kaur
5. Ms. Kanchan Kathuria
6. Ms. Shubdha Raina
7. Mr. Anil Verma

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Table 5: Various Cell Designs Due to Shifting of Operations Based on the Machine Utilization, Material Handling Cost and Time

Cell Design	Cell formed		Material Handling Time (MHT)	% Increase or Decrease in MHT	Material Handling Cost (MHC)	% Increase or Decrease in MHC
	Cell #	Machines Assigned				
1	I	3, 5	090.90	-	27.085	-
	II	2, 1, 6, 10				
	III	4, 9, 8, 7,11, 12				
2	I	3, 5	152.80	+ 68.087	37.058	+36.82
	II	2, 9, 1, 6, 10				
	III	4, 8, 7, 11, 12				
3	I	3, 5	146.75	+ 61.432	33.770	+ 24.68
	II	2, 8, 1, 6, 10				
	III	4, 9, 7, 11, 12				
4	I	3, 5	112.87	+ 24.168	25.086	- 07.38
	II	2, 1, 4, 6, 10				
	III	9, 8, 7, 11, 12				
5	I	3, 5	118.63	+ 30.505	32.732	+ 20.84
	II	8, 4, 6, 10, 1, 2				
	III	9, 11, 7, 12				
6	I	3, 5	138.66	+ 52.535	35.560	+ 31.28
	I	9, 4, 6, 10, 1, 2				
	III	8, 11, 7, 12				
7	I	3, 5	120.77	+ 32.090	31.077	+ 14.73
	II	2, 1, 4, 7, 6, 10				
	III	9, 8, 12, 11				

Table 1: Implications of Not Keeping Pace with Technology (Source: Strategic Information Technology and the CEO Agenda, "A.T. Kearney Survey of 213 CEOs and Senior Executives," 1998

Loss of Competitive Edge	58%
Increased Cost of Production	16%
Would not be in Business	13%
Lack of Control in Running the Business	7%
Other	3%
Would Not Happen	3%

Table 5: Descriptive Statistics of Variables–All Industries

			INDIA		USA	
Sr. No.	Code	Description	Mean Values	Ranking	Mean Values	Ranking
1	V301	Localized Exploitation and Internal Integration (Phases I & II)	7.366	4	7.705	1
2	V302	Business Process Redesign (Phase III)	7.607	2	7.03	4
3	V303	Business Network Redesign (Phase IV)	7.83	1	7.225	3
4	V304	Business Scope Redefinition (Phase V)	7.434	3	7.678	2
5	V305	IT-induced Reconfiguration	83.67	82.11		
6	V306	Degree of Business Transformation/ Degree of Potential Benefits	230.6	235.5		

Table 1: Factors Influencing Innovativeness and Myths and Misconceptions

Factors influencing innovativeness	*Myths and misconceptions*
• Technology requires a broad range of tools, from mathematical to trial and error practice to reverse engineering.	• Technology is just applied science building up knowledge
• Continuous redesigning of products and base for improving products.	• More technology is always good
• Technologists are engineering or science graduates in a variety of fields and must be trained to have multidisciplinary knowledge.	• Technological self-reliance is key to break out of technology dependency
• Tacit and local knowledge is key to technological innovation. Since tacit knowledge is experiential, it is not as easy to transfer as blueprints.	• High tech is the best technology
• 'On-the-ground' industrial and non-laboratory situations and production bases are good sources for gaining technological knowledge.	• Technology is well understood and easily transferred, and
• The knowledge built up from local production allows for continuous innovation 'on the job'.	• R&D is key to innovation and is led by R

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IBM (UK) Ltd	***3M***	**Hewlett Packard**
Teamwork, TQM, Tools and Techniques, Supplier Partnerships, Technology, Integrated Product Development Process	Teamwork, Ideas, Innovation Steering Committee, Recognition for innovation and corporate dependence on innovation, and Technological Exploitation	Teamwork, TQM, Quality Innovation delivery chain, and Product generation team

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5. Knowledge generated by critical analysis of failures of own products and others products and policies	G
6. Knowledge generated through field jobs	G
7. Knowledge generated through R&D	G
8. Effect of cultural factors, which depend upon the local culture, and work habits	P
9. Entrepreneurship of the persons working in enterprise	G
10. Education of the people employed and local and environment	G+P
Total	**8G+3P**

Table 8: Results of Discriminant Analysis: Summary of Comparison between Manufacturing and Service Sectors

Independent Variables (Predictors)	Significant higher values in MS (manufacturing sector) or SS (service sector) as indicated in the applicable columns below	
	India	U.S.A.
V301: Localized exploitation and internal integration–Phase I & II	MS	SS
V302: Business process redesign–Phase III		MS
V303: Business network redesign–Phase IV	SS	
V304: Business scope redefinition–Phase V.		SS
V102: The rate of obsolescence of your product.	MS	MS
V103: Prediction of competitor's actions (fairly easy to very unpredictable).	SS	
V105: The mode of production/services (well established to subject to very much change).		MS
V203: Individualism (degree to which people in a culture prefer to act as individuals rather than members of groups).		SS
V204: Masculinity–degree to which value like assertiveness, performance, success, and competitiveness prevails among people of a culture over gentle values like quality of life, maintaining warm personal relationships, service, care of the weak, etc	SS	

Factors influencing innovativeness	*Myths and misconceptions*
• Technology requires a broad range of tools, from mathematical to trial and error practice to reverse engineering.	• Technology is just applied science
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INDIA

		V301	V302	V303	V304	V305	V306
V101	Pearson Correlation	0.099	0.110	0.096	**0.262**	**0.217**	**0.262**
	Sig. (2-tailed)	0.303	0.257	0.317	**0.006**	**0.024**	**0.006**
	N	110	107	110	109	108	108
V102	Pearson Correlation	**0.275**	**0.356**	-0.017	**0.426**	**0.357**	**0.406**
	Sig. (2-tailed)	**0.004**	**0.000**	0.863	**0.000**	**0.000**	**0.000**
	N	109	106	109	108	107	107
V103	Pearson Correlation	-0.036	0.154	0.001	**0.228**	0.133	**0.217**
	Sig. (2-tailed)	0.711	0.116	0.992	**0.018**	0.175	**0.026**
	N	108	106	108	107	106	106
V104	Pearson Correlation	-0.097	0.087	-0.046	0.037	-0.005	0.029
	Sig. (2-tailed)	0.319	0.374	0.639	0.703	0.959	0.764
	N	108	106	108	107	106	106
V105	Pearson Correlation	-0.125	-0.021	**-0.227**	0.038	-0.035	0.010
	Sig. (2-tailed)	0.197	0.829	**0.018**	0.695	0.719	0.920
	N	108	105	108	107	106	106
V201	Pearson Correlation	-0.072	-0.140	**-0.189**	**-0.167**	**-0.203**	**-0.181**
	Sig. (2-tailed)	0.457	0.151	**0.050**	**0.086**	**0.037**	**0.063**
	N	108	106	108	107	106	106
V202	Pearson Correlation	-0.005	**-0.244**	-0.014	-0.070	-0.113	-0.069
	Sig. (2-tailed)	0.959	**0.011**	0.888	0.475	0.246	0.480
	N	109	108	109	108	107	107
V203	Pearson Correlation	0.148	**0.197**	0.102	0.103	**0.161**	0.109
	Sig. (2-tailed)	0.122	**0.041**	0.289	0.288	**0.096**	0.261
	N	110	107	110	109	108	108
V204	Pearson Correlation	**-0.209**	-0.105	0.098	**-0.236**	-0.133	**-0.213**
	Sig. (2-tailed)	**0.029**	0.283	0.311	**0.014**	0.172	**0.028**
	N	109	107	109	108	107	107

USA

		V301	V302	V303	V304	V305	V306
V101	Pearson Correlation	**0.219**	**0.278**	**0.427**	**0.230**	**0.374**	**0.278**
	Sig. (2-tailed)	**0.041**	**0.010**	**0.000**	**0.032**	**0.000**	**0.009**
	N	87	86	87	87	87	87
V102	Pearson Correlation	**0.175**	**0.344**	**0.419**	**0.284**	**0.404**	**0.329**
	Sig. (2-tailed)	**0.106**	**0.001**	**0.000**	**0.008**	**0.000**	**0.002**
	N	86	86	86	86	86	86
V103	Pearson Correlation	-0.037	0.087	-0.027	-0.108	0.011	-0.101
	Sig. (2-tailed)	0.733	0.421	0.806	0.314	0.920	0.350
	N	88	87	88	88	88	88
V104	Pearson Correlation	-0.013	**0.206**	0.059	-0.004	0.070	0.008
	Sig. (2-tailed)	0.906	**0.055**	0.583	0.972	0.517	0.944
	N	88	87	88	88	88	88
V105	Pearson Correlation	**-0.252**	0.160	**0.216**	-0.077	0.072	-0.033
	Sig. (2-tailed)	**0.019**	0.142	**0.044**	0.480	0.509	0.761
	N	87	86	87	87	87	87
V201	Pearson Correlation	**0.210**	0.103	0.015	0.086	0.137	0.083
	Sig. (2-tailed)	**0.052**	0.347	0.894	0.432	0.208	0.448
	N	86	85	86	86	86	86
V202	Pearson Correlation	-0.142	-0.165	-0.074	-0.164	-0.123	-0.161
	Sig. (2-tailed)	0.191	0.132	0.496	0.132	0.257	0.138
	N	86	85	86	86	86	86
V203	Pearson Correlation	**0.221**	0.091	0.071	0.153	0.133	0.151
	Sig. (2-tailed)	**0.039**	0.407	0.512	0.157	0.218	0.163
	N	87	86	87	87	87	87
V204	Pearson Correlation	0.017	-0.086	-0.112	0.057	-0.058	0.033
	Sig. (2-tailed)	0.878	0.433	0.305	0.603	0.594	0.761
	N	86	86	86	86	86	86