Chapter 5

DEVELOPMENT OF FRAMEWORK OF IMPM AND HYPOTHESES FORMULATION

5.1 Introduction

The literature on manufacturing performance improvement has revealed the importance of achieving multiple capabilities in the era of a cutthroat global competition. Implementation of individual paradigm certainly helps in improving performance. But, it would not be possible to attain multiple capabilities with limited tools and techniques. Various combinations of synergistic implementation have been suggested to realize cumulative capabilities. Integrated and overlapping practices provide the foundation for pursuing superior performance in manufacturing. Joint implementation of JIT, TQM, TPM, SCM and ERP is advantageous due to complementary strategies, inducement of side-effects, mutual stimulation and exploitation of shared concepts to create synergy among them. As discussed in Chapter 4, mapping of the practices provides the linkages among them, which show that the paradigms are mutually supportive. Though, literature provides the usefulness of several combinations in improving performance, holistic perspective is needed to achieve Manufacturing Capability Index of 10.

The holistic perspective is consistent with the systems framework. It supports the use of an integrated approach in examining the interrelated building blocks of an organization. The aim is to set up a comprehensive consolidation of requirements related to the manufacturing (Cua et al., 2001; Messaadia et al. 2006). All required properties and functions of the system should be the outcome of interaction among the components of the system and not from the actions of individual component taken separately.

The techniques such as JIT, TQM, TPM, SCM and ERP represent alternate approaches to improve the effectiveness and efficiency of an operations function. The set of tools and techniques of these improvement initiatives addresses the specific portion of the entire value chain. The systems framework suggests that these manufacturing programs should be modeled within a single framework. These programs are strongly interrelated in terms of their goals, practices and implementation and are synergistic in
nature. The synergistic implementation of these practices should lead to achieve multiple capabilities in terms of improved overall performance. Figure 5.1 shows the possible mutual reinforcement effect among JIT, TQM, TPM, SCM and ERP which can be helpful in improving the overall performance of the manufacturing system. The proposed model is named as Integrated Manufacturing Practices Model (IMPM). The details of IMPM are presented in the following sections.

![Diagram](image)

**Fig. 5.1 Possible mutual reinforcement effect among JIT, TQM, TPM, SCM and ERP**

### 5.2 Integrated Manufacturing Practices Model (IMPM)

JIT, TQM, TPM, SCM and ERP consist of a comprehensive set of practices involving both the social and technical or process-oriented aspects of manufacturing. In chapter 4, unique practices of individual paradigm and shared practice between/among them have been identified. Strategic and human oriented practices are common practices which are required for successful implementation. These paradigms have a similar objective of reducing waste in the production process to increase production efficiency and effectiveness. The synergistic implementation of practices from JIT, TQM, TPM,
SCM and ERP along with strategic and human oriented practices is termed as Integrated Manufacturing Practices Model (IMPM). The objective is to examine the relationship of these practices within a single framework. Consistent implementation of a group of interrelated practices from these paradigms should enhance the performance of the manufacturing plant. IMPM seeks to satisfy the customer through the efficient production of quality goods by emphasizing the elimination of waste and continuous improvement of the work force and production process.

5.2.1 Elements of Integrated Manufacturing Practices Model

Table 5.1 shows the elements of IMPM. The following are the definitions of the basic techniques of IMPM elements considered in the framework.

JIT Basic Techniques:
1. Setup Time Reduction: efforts for continually lowering production setup time
2. Pull System Production: production of needed parts at the needed time through Kanban controls and the use of small lot sizes
3. JIT Delivery by Suppliers: suppliers are integrated into the production system and deliver the raw material frequently in small lots as per the production schedule
4. Equipment layout: use of machine and process layout that facilitate production, easy movement and layout changes.
5. Daily Schedule Adherence: ability to meet daily production expectations as scheduled

TQM Basic Techniques:
1. Process Management: use of statistical and other systematic techniques for monitoring and controlling process variance
2. Cross-functional Product Design: involvement of different entities concerned with the design of product for manufacturability (DFX) and customer satisfaction
3. Supplier Quality Management: cooperative interaction with suppliers regarding quality concerns
4. Customer Involvement: focus on knowing and meeting customer requirements through customer involvement and feedback
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<td>Equipment Layout</td>
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Common Strategic and Human Resource Oriented Practices

- Committed Leadership (COMM_LEAD),
- Strategic Planning (STRAT_PLAN),
- Cross Functional Training (X_TRAIN),
- Employee Involvement (EMP_INVOL),
- Information and Feedback (INFO_FEED),
- Information Quality (INFO_QULT)

* Elements of the final model only are shown in the table.
TPM Basic Techniques:

1. Autonomous Maintenance: involvement of operators in daily equipment maintenance
2. Preventive Maintenance: scheduled maintenance to ensure continuous and smooth operation of equipment
3. Proprietary Equipment Development: design or selection of new equipment and improvement of existing equipment to allow minimal or easier maintenance and meet the production needs

SCM Basic Techniques:

1. Strategic Partnership: an ongoing, long-term inter-organizational relationship for achieving mutually beneficial goals
2. Information Sharing with Trading Partners: information supply chain to coordinate material flow for synchronized and integrated operation
3. Distribution and Material Handling: plan, implement and control the efficient and effective movement of goods from the origin to the point of consumption

5.2.2 Common Strategic and Human Resource Oriented Practices:

Taylor’s Scientific Management focused on the mechanics of management and organization and tended to ignore the human side of manufacturing (Angelis and Johnson, 2010). To fully exploit technology, one also has to address the human and organizational workplace aspects. Technology can be copied, but the level of which it is exploited depends on the less replicable organizational and human resource related practices. Hence, working purely towards technology excellence does not guarantee success in the long run. So, emphasizing socio-technical aspects should result in better performance (Skjelstad, 2009). ‘Socio-Technical System’, thus highlights that social and technical aspects are strongly interlinked. Cua et al. (2001) considered it impossible to optimize overall performance without pursuing joint optimization of social and technical systems which are correlated but still independent.

Many researchers (Crawford et al., 1988; Safayeni et al., 1991; Lakhe and Mohanty, 1994; Power and Sohal, 1997; Salaheldin, 2005; Garg and Deshmukh, 2006;
Ahuja and Khamba, 2008) have cited common problems in the implementation of manufacturing programs. These are related to cultural resistance to change, lack of training and education, lack of coordination of the different departments, confusion on the relationship between manufacturing subsystems and absence of senior management commitment and support. Jayaram et al. (1999) has analyzed the impact of human resource management related practices on manufacturing performance. They have found that the top management commitment, communication of goals, employee training, cross functional teams and cross training are associated with a specific manufacturing performance like quality, flexibility, cost and time. These studies provide substantial evidence of the importance of common organizational and human resource related practices that will facilitate the successful implementation of JIT, TQM, TPM, SCM and ERP programs.

Common strategic and human resource oriented practices have already been identified in Chapter 4. The common practices provide a supporting mechanism for the implementation of basic techniques of the programs under consideration. Both the social and technical subsystems should be jointly optimized to achieve the best possible performance. Definitions of the common practices of IMPM elements considered in the framework are given below.

1. Committed Leadership: firm, long-term commitment by the top management to continuous improvement through communication and support for the implementation of program practices
2. Strategic Planning: formalization of manufacturing plans and policies and communication of these plans and policies to the employees
3. Cross Functional Training: training and education of employees to increase the breadth of employees’ skill
4. Employee Involvement: inclusion of employees in the problem-solving process through teamwork and decentralization of decision making responsibility
5. Information and Feedback: availability of timely information and feedback on related area of decision making
6. Information Quality: accurate, precise, concise, updated and timely information
7. When the sets of basic practices from each of the paradigms are added to the common practices, an exhaustive group of improvement initiatives is formed. This comprehensive set of practices constitutes Integrated Manufacturing Practices Model (IMPM).

5.2.3 Manufacturing Performance

The objective of the present research work is to relate the implementation of the integrated manufacturing practices to the performance of a manufacturing plant. Traditional performance measures are based on management accounting and are primarily concerned with cost and financial performance. But in today’s manufacturing environment, cost-based measures are no longer sufficient (Digalwar and Metri, 2005). A number of dimensions have been used to measure the manufacturing performance. In a comprehensive review of the literature, Leong et al. (1990) contend that five dimensions i.e. quality, delivery, cost, flexibility and innovativeness are the most critical. In one of the earliest empirical studies of manufacturing competitive dimensions, Ferdows and DeMeyer (1990) focuses on cost efficiency, quality, dependability and flexibility as four generic manufacturing capabilities. Kasul and Motwani (1996) have identified nine performance measures namely, management commitment, quality, customer service, vendor and material management, advanced technology, facility control, flexibility, price/cost leadership and global competitiveness. Digalwar and Metri (2005) have added two more performance measures namely, speed and environment, health and safety to the list given by Kasul and Motwani (1996). While there are many performance measures, it is important to note that some ‘order-winning criteria’ are not within the responsibility of manufacturing (Ferdows and DeMeyer, 1990). For example, Vickery et al. (1996) indicate that while manufacturing had the lion’s share of responsibility for delivery, quality, cost, and flexibility, it had a much smaller degree of responsibility for innovation. Therefore, the performance outcomes that are relevant at the plant level within manufacturing domain are more representative.

The dominant approach found in the literature is to use cost, quality, delivery and flexibility as the four basic dimensions of manufacturing performance (Jayaram et al., 1999; Cua et al., 2001; Corbett and Campbell-Hunt, 2002; Tan and Wisner, 2003; Li et
al., 2005; Laugen et al., 2005; Tan et al., 2007, Bayraktar et al., 2007; Das and Jayaram, 2007; Vanichchinchai and Igel, 2010; Konecny and Thun, 2011, Green et al., 2013). So, more common performance measures within the dimensions of cost, quality, delivery and flexibility that are primary responsibilities of manufacturing are considered in this research. The dimensions of the cost efficiency include low unit cost and inventory, quality dimension is conformance quality, delivery is on-time delivery and cycle time, and flexibility includes flexibility of product mix and volume.

Cost can be directly considered in terms of unit cost of production and also the economic cost of holding the inventory. Reduction in inventory will eventually be reflected in reduced working capital, reduced storage, and reduced material handling. Reduction in this inventory related cost will lower manufacturing overhead cost. Inventory cost can be measured in terms of inventory turnover ratio and a high turnover ratio indicates lower cost.

It is clear from the literature that quality of conformance refers to the consistency of product in meeting product specifications. From the viewpoint of the manufacturing, quality also can be considered in terms of product durability and reliability. At the minimum, a product should be capable of performing its intended function, whenever necessary.

Delivery may be considered in terms of delivery time, delivery reliability and cycle time. At the minimum, deliveries are expected to be made on time. Reliable delivery may be considered as consistent delivery on time or before time. Manufacturing cycle time can be defined in terms of the ‘time required for a product to move through the entire manufacturing processes’. It is the time spent from receipt of raw material for production to shipment of the product.

Product mix, volume, new product development and delivery time are the four basic types of flexibility. Delivery performance has already been considered as a separate performance measure while new product development depends on the involvement of other functional areas such as marketing and R & D. Some of the departments may be outside the control of the plant. Therefore, product mix and volume flexibility are being considered in this study. Product mix flexibility indicates the ability to change product

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type and production quantities while volume flexibility refers to the ability to change the production volume.

5.3 Relationship Building among JIT, TQM, TPM, SCM and ERP

JIT, TQM, TPM, SCM and ERP have practices which show a considerable overlap. This overlap among these paradigms was evident as shown in Chapter 4. The manufacturing improvement initiatives have the common objective of making a production system more efficient and effective through continuous improvement and elimination of waste. TQM is focused on the elimination of defects and rework. JIT primarily emphasizes on reduction of waste in inventory and flow time. TPM targets waste caused by equipment problems such as failure, unnecessary setup and adjustment time, idling and minor stoppages, reduced speed, process defects and reduced yield. SCM reduces waste along the supply chain activities in the form of raw material and finished goods inventory, stock-out, inventory in transit, material handling, damaged goods, longer lead times, late deliveries, inefficient transport, or moving parts in and out of storage facility. By providing seamless information, ERP reduces wastages which may be caused by delayed or inaccurate decisions. It is evident that all the techniques emphases on waste reduction and elimination are complementary to each other. In Japan, it is said that in order to be strong enough in manufacturing one has to have good brains (which require TQM), but one also needs to have strong muscles (in other words, strong manufacturing capability which require TPM). Moreover, one has to have a good nervous system to connect brain with muscles, which means JIT production. The industry has to interact with the upstream for getting healthy and timely ration while it has to supply finished goods to the downstream. To fulfill this interaction with outside world, it requires SCM. ERP provides a system of communication within the organization and among trading partners. So, for being competitive in manufacturing, one needs to have TQM, JIT, TPM, SCM and ERP.

5.3.1 Effect of Implementation of Basic Techniques

This section examines the effects of the implementation of basic techniques / practices on the manufacturing performance. Quality of the manufactured products is an
important attribute since the ultimate goal is to satisfy the customer. Defects found on the shop floor need to be reworked or discarded. But, handling of the defects will add cost and not value to the product. Rejection of the final product not meeting specifications is perhaps the worst form of production waste.

The basic TQM practices seek to eliminate waste of defects and rework. Process management and availability of information and feedback provides timely means for controlling process variability that can reduce production of parts that do not meet product specifications. Designing the products by incorporating the suggestions (Design for Manufacturing and Assembly) of the different functional areas helps to ensure that the product can be easily manufactured, assembled and can meet the customer satisfaction. This practice is more important since the greatest source of failure often lies in design weakness. The cost becomes vital when the defects are discovered by customers. The involvement of customers provides continuous feedback regarding customer expectations and supports product design (Quality Function Deployment). The quality of raw material often determines the quality of the finished product. Suppliers should be made aware of the quality expectations and should be involved in the production processes.

Organized and simple to monitor production system will facilitate the timely identification and correction of process defects. The practices of JIT and TQM can complement each other in ensuring the production of quality products. The use of pull production system where production lot size is significantly reduced and production and delivery are controlled by Kanban reduces work-in-process inventory. Detection of defects is easier and less costly when there is a low level of inventory. This becomes possible due to pull system of production wherein the production stages are tightly coupled. This relationship between small lot size, work-in-process and quality is consistent with effects of joint implementation of JIT and TQM as discussed in Section 2.2.1.

The reduction of setup time and use of efficient equipment layout also facilitate immediate response to quality problems. Low setup time enables frequent changeover to accommodate small lot sizes. It also facilitates quick processing of rework. Efficient equipment layout simplifies the identification of the process step and equipment involved
in the occurrence of defects. JIT delivery by suppliers also enables suppliers to quickly respond to quality problems as and when they occur.

Other than creating a better environment for the production of quality products, JIT practices enable on-time and fast delivery of products. Setup time reduction by using SMED techniques and use of small lot sizes reduce cycle time and allow the production system to respond more quickly. The use of efficient layout also reduces cycle time by eliminating unnecessary time spent in moving work-in-process. Adherence to daily production schedule is an important practice because time and inventory buffers are minimal or do not exist.

The basic practices of TPM also facilitate the production of quality products. Monitoring and maintaining the condition of equipment reduces performance variation. When machines are well maintained and work areas are well kept using ‘5S’ principles, sources of quality problems can be easily detected. Efforts in improving the design of machine can reduce time to repair.

Implementation of TQM and JIT basic practices also increases the attention given to maintaining the equipment since quality and JIT production requires reliable machines. The use of pull system necessitates lot size reduction and demands frequent changeovers. To reduce the time required for each change over, setup time and equipment efficiency should be improved. Thus, the equipment improvement is important in JIT environment. In a pull system, unplanned stoppages can pileup WIP. Furthermore, an equipment failure causes quality problems and increases cycle time. The benefits of joint implementation of JIT-TPM, TQM-TPM and JIT-TQM-TPM are reviewed in Section 2.2.

For the successful implementation of JIT, the role of suppliers is also very important. The quality of the supplied parts determines the quality of the finished goods. In JIT, it is expected to supply parts directly at the point of use. Only when the suppliers will supply the right quality of parts in right quantity at the point of use with highest reliability, JIT can be successful. This demands the strategic partnership with the vendors which will ensure defect free material reaching the JIT line on time. The benefits of joint implementation of JIT and SCM are discussed in Section 2.2.5. TQM also has underlined the important role of suppliers in quality management. It emphasizes on supportive relationships between members of the supply chain. Inventory is a function of
manufacturing, supply and delivery cycle time which is improved through variance reduction.

The above examination of the interrelationship of the basic techniques of JIT, TQM, TPM and SCM provides the insight that the joint implementation of these techniques will help reduce waste in production, non-value added activities and process variability. If these practices are implemented successfully, the production flow would become more uniform and faster. The manufacturing processes would be more efficient, effective and more responsive to demand.

5.3.2 Effect of Implementation of Common Strategic and Human Resource Oriented Practices

The successful implementation of JIT, TQM, TPM, SCM and ERP is dependent on the manufacturing environment and employees. As discussed in Section 2.1, piecemeal approach to the implementation of these programs has led to failure. The commonly cited problems are related to cultural resistance to change, lack of training and education, poor quality, lack of co-ordination among different departments and confusion about the relationship between manufacturing subsystems. Along with other authors like Crawford et al. (1988), Safayeni et al. (1991), Lakhe and Mohanty (1994), Power and Sohal (1997), Jayaram et al. (1999), Salaheldin (2005), Garg and Deshmukh (2006) and others, Hayes and Wheelright (1984) also identified the root cause of ‘manufacturing crises’ to be the incompatibility among manufacturing policies, people, facilities and technology. Thus, common practices are vital to facilitate the successful implementation of the basic practices.

The common strategic and human resource oriented practices identified are committed leadership, strategic planning, cross functional training, employee involvement, information and feedback and information quality. The top management should be personally involved in the implementation of manufacturing practices and serve as a role model. A formal strategy allows everyone in the organization to have a common vision and to work towards a common goal. A good strategic plan also ensures
the implementation of practices that are consistent with the existing structure and practices.

Moreover, it is essential to involve the employees and seek their help in fulfilling the strategic plan. Cross-functional training to the employees provides opportunity to acquire new skills, take more responsibility and grow professionally. Foundation of teamwork can support the development of multifunctional employees. The concept of teamwork if implemented properly can enhance involvement of employees. Investment in the workforce, such as cross-functional training and development of problem solving teams enrich the human capital of an organization. Implementation of proper information system to provide the information related to various aspects of decision making and feedback can greatly improve the communication within the organization. It helps in harmonizing interdepartmental processes and interdisciplinary matters. It also helps in sustaining a shared image on organizational work across different levels of the organization and results in the increased work efficiency.

The foundation and proper execution of the common practices should provide the required environment and motivation for creating a learning organization. As stated by Flynn et al. (1995) and Jayaram et al. (1999), the implementation of infrastructural and human related practices is significantly related to manufacturing performance. Based on the above discussion and supporting literature review, it can be concluded that the common strategic and human resource oriented practices provide an important foundation for the implementation of manufacturing improvement programs. Therefore, the common practices along with basic techniques of JIT, TQM, TPM and SCM are likely to have a positive effect on manufacturing performance.

5.3.3 Effect of Implementation of Integrated Manufacturing Practices

As discussed in Section 2.1, the implementation of individual practices has a positive effect on manufacturing performance. But, empirical studies on joint implementation of various combinations of JIT, TQM, TPM, SCM and ERP has provided the evidence that these programs are interrelated and results in substantial improvement in performance as compared to the individual improvement. The detailed discussion has
been given in Section 2.2 and Section 2.3. In line with systems framework, the implementation of all these paradigms within a single framework can be examined through a holistic perspective. Moreover, according to the socio-technical systems theory, the joint optimization of technical and social elements of manufacturing system should result in the improved performance. The practices included in the Integrated Manufacturing Practices Model (IMPM) are compatible with socio-technical systems and should lead to enhanced manufacturing performance. The relationship between manufacturing practices and performance is depicted in Figure 5.2.

Since there is a lot of overlap in the practices, the effect of joint implementation can be analyzed appropriately only when one practice is considered only once within these programs. This prevents redundancy in accounting for the impact of some practices. The separation of common practices helps in avoiding this redundancy. Further, this separation highlights the existence of socially and technically oriented practices which is consistent with socio-technical theory of systems.

Many firms may have implemented a few practices in some form or combination of selected practices from JIT, TQM, TPM and SCM. Literature shows that there are cases of partial implementation of manufacturing paradigms. The complete implementation of IMPM is considered rare. Many manufacturing firms may not have the appropriate environment and commitment for the implementation of such practices.

As discussed in Section 1.3.1, various researchers, from Hayes and Wheelwright (1984) to Prester (2013), have proposed different set of best practices. The practices identified as a part of Integrated Manufacturing Practices Model are also consistent with the practices that other researchers have considered. The practices of the model are also consistent with the socio-technical systems theory. On providing the strong background and empirical evidences, it can be concluded that the simultaneous and higher level of implementation of basic practices of JIT, TQM, TPM and SCM and common strategic and human resource oriented practices will lead to the higher level of manufacturing.

It is also important to note that in closed systems, a direct cause-and-effect relationship exists between the initial condition and the final state. However, open systems operate quite differently. The socio-technical systems theory is linked to idea of
Fig. 5.2 Initial framework of the effect of Integrated Manufacturing Practices
open systems. The concept of ‘equifinality’ suggests that there is no one right way to accomplish important results in an open system. Equifinality means that the same or similar results can be achieved by using a variety of different processes (Payne, 2006). According to Jimenez et al. (2008), paths to competitiveness may be different for manufacturing plants due to plant context and manufacturing practice relationships. Machuca et al. (2011) also contended that each company is unique and the process of constructing a sustainable high performance will differ from company to company. The company should choose the advanced production practices (APPs) with which it aims to achieve high performance manufacturing and adapt them to its own circumstances, which might vary from country to country, industry to industry or depend on the size of the company. They advise that the existing advanced production practices should be integrated appropriately when drawing up this design to produce a synergistic effect that results in improvement of performance and the achievement of the company’s objectives. Hence, it would be difficult to claim that Integrated Manufacturing Practices Model (IMPM) is the only way to achieve better manufacturing performance. For example, it is possible for manufacturing plants to carry high inventory levels and have a long cycle times in order to maximize labor efficiency and higher utilization of equipment.

However, the past studies recognized that the highest level of manufacturing capability is demonstrated when the organization reaches the idealized JIT. Karr (2010), Parry-Jones (2011), and OSD Manufacturing Technology Program (2011) called it as ‘Manufacturing Readiness Level’ (MRL). According to them, the utmost MRL of 10 is established when full rate of production is demonstrated, JIT production practices are in place and continuous process improvements are on-going, and the manufacturing capability is globally deployable. The road map for competitiveness developed by Confederation of Indian Industry (CII) (Jha and Joshi, 2007) also shows that JIT demonstrates the highest level of manufacturing competitiveness and will be in a position to achieve cumulative capabilities. The supporting and infrastructural practices need to be developed for successful implementation of JIT. TQM, TPM, SCM and ERP can provide support to JIT. So, it can be argued that the implementation of basic practices together with common practices will provide a strong impact on manufacturing performance since
both the technical and social subsystems should be jointly optimized to achieve the best performance.

5.3.4 Other Supporting Theories

Beside the previous research attempts on various combinations of joint implementation, need for holistic approach, socio-technical systems theory and the need to achieve multiple capabilities, another theories such as the Theory of Swift and Even Flow, a Theory of Internal Variability of Production System and Theory of Performance Frontiers can be used to provide the insights into the effects of JIT, TQM, TPM and SCM implementation. Schmenner and Swink (1998) proposed the Theory of Swift and Even Flow (SEF) and the theory of Performance Frontiers (PF). The Theory of Swift and Even Flow addresses the issues related to difference in cross-factory production. The theory holds that the production process is more productive when the flow of material is faster and more uniform. Material can move swiftly when non-value added steps or waste of production is either eliminated or reduced and when there are no bottlenecks or impediments in the production process. The flow of material can be made more uniform when the variability associated with demand or production processes is reduced (Schmenner and Swink, 1998; Schmenner, 2001; Stratton, 2008).

This theory supports the importance of good quality of products and reliable and consistent processes. Product and process quality problems such as rework, scrap, and machine downtime creates interruptions in the flow of operations, generate variants and introduce bottlenecks. Therefore, quality problems will lower the output of the production process. The theory also favors the reduction of WIP as they deter the flow of materials and increase the throughput time. A pull system assures a smoother flow than a push system by not allowing the subsequent operations to flood with WIP.

In general, the Theory of Swift and Even Flow favors the implementation of practices that help in increasing the speed and reducing the variation. Some of these practices include quicker changeovers, small batch production, regular preventive maintenance and cross-functional workers. Schmenner and Swink (1998) argued that this theory is very much in tune with JIT philosophy. Practices associated with TQM, TPM
and SCM also address the issue of variability reduction and smoother workflow and are therefore consistent with this theory as well.

A Theory of Internal Variability of Production System is proposed by Wacker (1987) to understand the complementary nature of manufacturing goals by their relationship to throughput time. He argues that the major manufacturing goals are demand responsiveness, production efficiency and high quality. These goals are closely related to internal throughput time. Wacker (1987) and Duimering (1993) showed that effective preventive maintenance programs improve quality that in turn can lead to improvement in internal throughput time. On-time delivery and unit cost improve as throughput time is reduced. Thus, improvement in quality and throughput time can lead to better performance. Internal variability of throughput time is also caused by variability in move times and processing times. These times can be reduced by using short move distance; high speed automated moving and frequent deliveries. These practices are associated with JIT and can be accomplished with effective SCM. On the other hand, processing time variability can be reduced by lower rework time and lower down time. So, processing time variability can be reduced through systematic implementation of TQM and TPM practices.

The two theories discussed above are supportive to each other since practices that enable a reduction of variability in lead time also allow for faster and smoother production flows and leads to higher productivity.

Further, Wacker’s (1987) argument that manufacturing goals are complementary and can be cumulatively achieved through control of lead time variability is consistent with the second theory proposed by Schmenner and Swink (1998). The theory of Performance Frontiers (PF) stresses that if all plants are far from their structural (asset) frontier, a plant can achieve different manufacturing goals simultaneously by focusing on infrastructural (operating) frontier by successful implementation of manufacturing policies within given set of assets. Schmenner and Swink argue that the distance between the asset frontier and operating frontier determines whether the trade-off or the cumulative model (Ferdows and DeMeyer, 1990) is used. As the two frontiers move closer to each other, the cumulative capability model is replaced by the trade-off model. JIT, TQM and TPM related improvements are aimed at enhancing operating performance.
by emphasizing infrastructural frontier. Thus increasing the distance between asset and operating frontier leads to achieve multiple capabilities. Vastag (2000) extended the within-firm theory to study between-firm issues.

Together, the three theories discussed above emphases on the development of human and strategic practices and the implementation of JIT, TQM, TPM and SCM basic techniques and suggest that implementation of IMPM can positively affect multiple dimensions of manufacturing performance.

5.4 Hypotheses Formulation

The earlier discussion supports the need for holistic perspective to consider the interrelated practices of JIT, TQM, TPM, SCM and ERP within a single framework. In this section the hypotheses are formulated which can be verified empirically.

5.4.1 Effect of IMPM on Manufacturing Performance

The different emphases of JIT, TQM, TPM, SCM and ERP on waste reduction and elimination are complementary. Together the practices should help in reducing non-value added activities. It also helps in reducing variability in product, people, procedures and equipment. Therefore, it can be expected that successful implementation of these practices will lead to good performance. Certain practices may contribute more towards the improvement of specific manufacturing performance indicators such as low cost, quality, delivery and flexibility. Better performance could be the outcome of combined higher level of implementation of more number of these practices. It could also be expected that the firms having higher performance may have implemented basic and common practices at a higher level as compared to low performers.

Thus, following hypotheses can be formulated to test the effect of these practices on manufacturing performance.

**Hypothesis H1:** The practices of JIT, TQM, TPM, and SCM are positively associated with manufacturing performance.

**Hypothesis H2:** High performers have higher levels of implementation of both common and basic practices of JIT, TQM, TPM, and SCM than low performers.
Hypothesis H1 can be empirically tested by adopting a confirmatory approach using Structural Equation Modeling (SEM). Based on the model fit indices, the iterative approach built on theoretical background was followed to reach the final acceptable model. In order to test hypothesis H2, the Discriminant Analysis (DA) was used to differentiate the high performing industries from low performing one.

5.4.2 Effect of Contextual Factors

The manufacturing plants that have been surveyed belong to different scale of operation and sectors. The contextual factors affect the implementation and impact of manufacturing practices. Various contextual factors such as product type, industry competitiveness, market type, suppliers, ownership, leadership and management style, organizational culture, technology intensity, industry efficiency level, labor productivity, labor intensity, communication, history, social values, company size, scope of operations, number of employees, unionization status, capacity utilization, process-type and practice implementation level are some of the factors mentioned in the literature (McKone et al., 1999; Cua et al. 2001; Shah and Ward, 2003; Sila, 2007, Zhang et al., 2012; Lo et al. 2013). Lo et al. (2013) classified these contextual factors into firm level and industry-level factors while Mckone et al. (1999) classified them into environmental, organizational, and managerial contextual factors. These contextual factors play an important role in determining the possible impact on the manufacturing plant.

The manufacturing performance may differ from country to country. Some studies that investigate manufacturing performance differences across country conclude that variation in emphases in practices, and cultural differences affect performance. Studies that compare manufacturing performance across industries find that factors such as the product complexity, production technologies, and capital structure may affect the performance. Organizational size is also one of the most critical contextual factors. The number of employees and asset value can be the measure of size. Large organizations have an advantage in terms of more financial and human resources which may be used to experiment with manufacturing program. Larger organizations may be more formalized and centralized as compared to the small ones. Several hierarchies may pose difficulties in communication and immediate involvement of employees. The type of production
process such as job shop, batch, mass and continuous type also affect the manufacturing performance. A technology used for low volume and high variety is different than high volume low variety. It affects the organization's capability of standardization of products and processes and flexibility. Manufacturing resources such as plant capacity can also affect performance. Unionization and employee culture are the factors which may influence the cross-functional training and team building.

The above discussion suggests that a number of contextual factors should be investigated in this research. But, it may not be possible to capture all the possible contextual factors in a single study. However, the factors such as leadership and management style, organizational culture, labor intensity, communication, social values, unionization status are related to strategic and human resource oriented practices. They are likely to be captured by the level of implementation of common practices. The firm level factors such as technology, capacity utilization, supplier, process-type and practice implementation level are also likely to be captured by the survey instrument. It will be interesting to know about the applicability of Integrated Manufacturing Practices Model (IMPM) in different industry type and different scales of operation. It will also help in capturing contextual factors such as product type, industry competitiveness, market type and industry size. So, the scale of operation (size) and industry type are two contextual factors which have been considered in this study. Extending the empirical investigation of the effect of IMPM on manufacturing performance to include contextual factors, the following hypothesis is formulated.

**Hypothesis H3:** The practices of IMPM explain a significant portion of the variation in manufacturing performance after considering contextual variables.

Discriminant Analysis (DA) was used to differentiate the performance of the companies scalewise and sectorwise to assess the effect of contextual factors.

### 5.5 Conclusion

The Integrated Manufacturing Practices Model (IMPM) is developed considering the holistic perspective of the systems framework. The integrated and overlapping practices of JIT, TQM, TPM, SCM and ERP allowed considering them within a single framework. It highlights that the socially and technically oriented practices which are
consistent with socio-technical theory of systems can be optimized for pursuing superior performance in manufacturing. The Theory of Swift and Even Flow, a Theory of Internal Variability of Production System and Theory of Performance Frontiers also provide the basis for considering these practices in a single framework. The elements of the IMPM and the basis for their inclusion are discussed. The interrelationship of the basic techniques helps in reducing waste in production, non-value added activities and process variability. Implementation of common strategic and human resource oriented practices provides an important foundation for the implementation of manufacturing improvement programs and is included in the IMPM framework. The selection of cost, quality, delivery and flexibility as a performance measure is justified as it represents the primary responsibility of manufacturing. To analyze the effect of implementation of integrated manufacturing practices on manufacturing the framework of IMPM is presented. Two hypotheses are formulated to study the effect of integrated practices on performance. The first one relates the integrated manufacturing practices to the manufacturing performance while second one discriminates between high and low performers based on the level of practice implementation. The contextual factors are introduced and the hypothesis is formulated to examine the effect scale and sector as a contextual factors.

The next chapter presents the empirical verification of formulated hypotheses using Structural Equation Modeling (SEM) and Discriminant Analysis (DA).