CHAPTER II

LITERATURE REVIEW

Literature has been reviewed from three perspectives (Figure 2.1) namely production system life cycle models, activities of production system life cycle and applications of select multi-criteria decision making approaches.

Figure 2.1: Classification of literature survey
2.1 LITERATURE REVIEW ON PRODUCTION SYSTEM LIFE CYCLE MODELS

(i) Nakano et al., (2008) discussed the following four stages in production system life cycle (Figure 2.2):

- **Start-up stage** – Product design, Process planning, Plant (equipment) design, Layout design, Evaluation of productivity and cost, Operation.

- **Volume change mix change stage** – Adaptation planning, Reconfiguration, Evaluation

- **Product change stage** - Product re-design, Process re-planning, Plant (equipment) change, Layout change, Evaluation of productivity and cost, Operation change

- **Discarding**

Figure 2.2: Model of production system life cycle proposed by Nakano et al., (2008)
(ii) Bellgran et al., (2002) reported the following stages in production system life cycle (Figure 2.3):

- Project & system concept
- System requirement
- Preliminary design
- Quotation & Choice of sub-contractors
- Detailed design
- Component & system testing
- System integration, personnel training
- Production ramp-up
- Operation
- Analyses
- Identification of need for change

Figure 2.3: Model of production system life cycle proposed by Bellgran et al., (2002)

(iii) Chase and Aquilano, (1977) listed the following eight distinct phases in the life cycle of production system (Figure 2.4):

- Birth of production system
- Product design and process selection
• Design of system
• Manning of system
• Start-up of system
• System in steady state
• Revision of system
• Termination of system

Figure 2.4: Model of production system life cycle proposed by Chase and Aquilano, (1977)

The model proposed by Chase and Aquilano, (1977) was also adopted by Shankar, (2009).

(iv) Wiktorsson, (2000) listed the following seven stages in life cycle of production system (Figure 2.5):

• Planning
• Design
• Realisation
• Start-up
• Operation
• Operation refinement
• Termination/Re-use
(v) Preiss et al., (2001) reported the following three stages in life cycle of production system (Figure 2.6):

- Engineering
- Commissioning
- Operation & service

Figure 2.6: Model of production system life cycle proposed by Preiss et al., (2001)

(vi) Kosturiak and Gregor, (1999) stated the following four stages in life cycle of production system (Figure 2.7):

- **System Analysis** – Feasibility study, Alternatives, Strategies, Concepts, Production programme
- **Planning** – Dimensioning, Machinery planning, Control concept, Evaluation of planning parameters, Layout planning
- **Implementation** – System takeover, Simulated test operation, Labour training
- **Operation** – Monitoring, Forecasting, Scheduling, Emergency operations strategies
2.2 LITERATURE REVIEW ON ACTIVITIES OF PRODUCTION SYSTEM LIFE CYCLE

This section presents the review of literature on the different activities of production system life cycle.

2.2.1 Product Idea Generation and Selection

For organizations to thrive and survive in an increasingly competitive environment needs to harness and support the idea generation and implementation (Roth and Sneader, 2006; Tellis et al., 2009). The adoption of new ideas is required for the performance and effectiveness of the organization (Damanpour, 1991). Ozer, (2005) illustrated that average market rate for the success of new product idea ranges from 53 to 61%.


Ozer, (2004) developed a holistic guideline for managing the selection process of new product ideas. Gutiérrez et al., (2009) have developed a methodology for the
evaluation and selection of new product ideas. Badizadeh and Khanmohammadi, (2011) have developed a fuzzy model for the assessment and selection of best idea for the new product development. Rebernik and Bradač, (2008) have enlisted various idea evaluation methods and techniques.

2.2.2 Product Design

In the present competitive scenario, low manufacturing cost, short manufacture time and higher quality of product are the essential requirements for the organizations to survive (Lau et al., 2003). The quality of a product greatly exists in its design (Magrab, 1997). In the increased global environmental concern and promptly fluctuating economic conditions, design must display its enactment in quality, productivity and life cycle matters (Finger et al., 2000; Chin and Wong, 1999; Zhou et al., 2003). Product design is the most difficult and important of all decisions that the multinational manufacturing organizations are facing. Product design leads to development of specification for the different components of the product.

The main objective of product design process is to generate a comprehensive procedure for the manufacturing of a product that will fulfil the necessities of manufacturing, consumer and business (Smith and Ierapeiritou, 2011). The product design process comprises of various decisions such as selection of material, tolerances, shape, sizes, surface roughness, manufacturing techniques etc. (Weustink et al., 2000). Reverse engineering, value engineering, Taguchi method and Quality Function Deployment (QFD) are the main methodologies for product design and development (Liu, 2011).

Derelöv, (2009) have described the design process in terms of iterating divergent and convergent phases. The divergent phase is creative phase in which problem is analyzed and solutions are generated, while in convergent phase, solutions are assessed & evaluated, and solutions are selected and further refined. Liu and Boyle, (2009) have described the different perceptions, challenges and latest developments of engineering design.

Choi et al., (2008) have proposed an AHP based framework for selection of designs. Wei and Chang, (2008) have developed integrated analytical network process (ANP) and goal programming model for the selection of optimal product design solution.
Derelöv, (2002) have presented an approach for the verification and evaluation of initial conceptual design solutions. López-Mesa and Chakrabarti, (2007) have developed a systematic model for the effective decision making in conceptual design phase. Grantham et al., (2012) have proposed web based software solution for identifying the risks in conceptual product design phase.

Matsatsinis and Siskos, (1999); Tay and Gu, (2003) have presented different methodologies for the development of new product. Several authors e.g. Maddulapalli and Azarm, (2006); Hsiao, (1998); Vanegas and Labib, (2005); Parameswaran et al., (2001); Choi et al., (2004); Balakrishnan and Jacob, (1996); Besharati et al., (2006); Paramasivam and Senthil (2009) have presented different methods for product design selection or evaluation. Hsiao and Chou, (2004) presented a creativity based design process for innovative product design.

2.2.3 Process Design

Manufacturing process planning is the process of choosing and sequencing the manufacturing processes in order to attain one or more goals (e.g., lower cost, shorter processing time, etc.) and to fulfil a set of domain limits (Shen, 2006). The selection of an appropriate manufacturing process encompasses the consideration of intricate combination between features of design, material and process (Shercliff and Lovatt, 2001). Manufacturing process selection necessitates the consideration of several factors such as type of material; shape and cost of component (Djassemi, 2008). The benefits of a good manufacturing process are quality products, reduced labour rate, great employee confidence, optimistic image and higher revenues.

An organization with a tremendous manufacturing process yields a quality product which passes rigorous checks and gains consumer acceptance (Singh et al., 2011). The manufacturing process should endure low cost, low scrap and quick so as to be economical (Jahazi and Hossein-Nejad, 2004). So, it is very essential to cultivate suitable designing aids to help the design managers in the selection of manufacturing processes (Perzyk and Mefta, 1998).

In literature, several authors have developed various methods to assist the manufacturing or design managers to decide and choose the right manufacturing process for a product. Singh et al., (2011) have applied GTA methodology for
selection of manufacturing process. Perzyk and Mefta, (1998) have developed a module known as “Evaluation System” for the selection of manufacturing processes. This module uses the prevailing data on process capabilities, design for manufacturability rules and materials processing. Hambali et al., (2009) have used AHP approach for the selection of composite manufacturing process at the early stage of product development process. Esawi and Ashby, (1998a) have developed a systematic computer based procedure for the selection of process steps to manufacture a product or component.

Desai et al., (2012) have developed a material and process selection engine (MPSE) based on AHP approach for selection of material and process in the design of a product. Esawi and Ashby, (1998b) have proposed a resource consumption cost model for the ranking of manufacturing process in order to assist the decision makers in selection of process. Giachetti, (1998) developed a decision support system for the selection of material and manufacturing process. Giess et al., (2009) have proposed the application of faceted classification to assist the engineering designers to select the manufacturing process. Ashby et al., (2004) have advocated various strategies for the selection of materials and processes. Lovatt and Shercliff (1998a; b) presented a single frame-work model for the selection of manufacturing process in the engineering design.

In literature, limited number of authors has proposed different ways for improving the quality of manufacturing processes. Antony and Roy, (1998) have applied statistical design of experiments for the improvement of process quality. Antony, (2000) have used the experimental design for improving the quality of manufacturing process. Antony, (2001) have utilized the design of experiments (DOE) for improving the manufacturing process. Nestic et al., (2015) have developed a model based on the fuzzy sets and genetic algorithm approach for the assessment and optimisation of production process quality.

2.2.4 Facility Location

Facility location decisions are perceived to be of enormous significance in the long-term planning for the manufacturing organizations (Athawale and Chakraborty, 2010). Selection of appropriate facility location is an imperative problem in all types
of businesses (manufacturing and service organisations). Selection of location for a new organisation or enlargement of a prevailing facility is a critical component in the ultimate success or failure of the organization (Athawale et al., 2012). The optimum facility locations may result in competitive advantage and success of the organization (MacCarthy and Atthirawong, 2003). Facility location decisions also have long-term effect on the profitability and competitive location of the organization (Current et al., 1997; Goetschalckx, 2002; Lorentz, 2008).

In literature, a number of authors have discussed enormous number of factors which affects the selection of facility location. MacCarthy and Atthirawong, (2003) have identified 13 major factors affecting the facility location. These factors are (a) cost; (b) proximity to market; (c) proximity to suppliers; (d) infrastructure; (e) labour characteristics; (f) social and cultural factors; (g) economic factors; (h) quality of life; (i) government and political factors; (j) proximity to competition; (k) legal and regulatory framework; (l) proximity to parent company’s facilities; and (m) characteristics of a specific location. Badri, (2007) identified transportation, raw materials, labour, markets, utilities, government attitude, climate, community, tax structure, and industrial sites as the key factors affecting the facility location. Farahani et al., (2010) have performed exhaustive review analysis on the facility location and found that cost, environmental risks, coverage, service level and effectiveness, profit, resource accessibility, social and political risks are the critical factors of facility location selection problem.

Safari et al., (2012) have identified favourable labour climate, proximity to markets, community considerations, quality of life and proximity to suppliers and resources as the key factors for facility location. Bhatnagar and Sohal, (2005) have identified labour, business environment, proximity to markets, political stability, infrastructure, key competitor’s location and proximity to suppliers etc. as the main factors of facility location. Karakaya and Canel, (1998) have identified accessibility, cost, resources, living, business environment, and existing buildings as the key factors of facility location. The literature on facility location reveals that the firm's decision makers needs to cultivate better identification, exploration and assessment of these critical factors. This will lead to the development of facility location decision making process which in turn results into effective long term performance for the organization (Miller and Starr, 1968; Walker, 1975).
Barovick and Steele, (2001) have suggested the three step methodology for the selection of facility location. These steps are (i) Define the recent state and business requirement; (ii) Identify and evaluate qualified locations; and (iii) Field verification, negotiations and implementation.

Several authors e.g. Yong, (2006); Ertuğrul and Karakaşoğlu, (2008); Athawale and Chakraborty (2010); Klose and Drex, (2005); Farahani and Asgari, (2007); Chen and Yu, (2001); Lorentz, (2008); Önüt and Soner, (2008); Amiri et al., (2009); Özdağoğlu, (2012); Mousavi et al., (2013); Wu and Wu, (1984); Athawale et al., (2012) have applied different MCDM approaches for selection of facility location. Selection of the appropriate facility location needs concern of numerous alternate locations and assessment of various contradictory tangible and intangible evaluation criteria. Thus, MCDM approaches have been found to be a powerful and suitable tool for solving the facility location problems.

### 2.2.5 Facility Layout

The fundamental integration stage in the design of production system is the layout of production facilities. A facility layout may be defined as the organization of machines and movement of materials from one facility to another, which reduces the material handling cost while considering any physical limitations on the organization (Khoshnevisan and Bhattacharya, 2003). Determining the physical arrangement of a production system constitutes the facility layout problem (Meller and Gau, 1996).

Facility layout procedures defines the arrangement of various machines and departments in order to achieve minimization of total production time, turnover maximization of work-in-process, and firm output maximization (Djassemi, 2007). Facility layout plays a significant role in the business success of an organization (Johnston, 1995; Huertas et al., 2007). A good facility layout subsidizes the overall operations efficiency and can condense fifty percent of the operational expenditures (Tompkins et al., 1996; Drira et al., 2007). Processing necessities, cost, safety, equipment’s availability, plant structure, procedures, etc. are the important factors that affect the facility layout design (Tugnoli et al., 2008).

In literature, various procedures, layout models, algorithms (distance based, adjacency based, stochastic based) and MCDM approaches are available to assist the facilities
planners or manufacturing managers to effectively design the new layouts or refining the existing layouts. Chakraborty and Banik, (2007) have discussed that selection of the optimal facility layout design alternative is an iterative process and decision makers always face the difficulties to select optimal facility layout design alternative. Several authors e.g. Díaz-Ovalle et al., (2010); Maniya and Bhatt, (2011a); Rao and Singh, (2012); Cruz and Martinez, (2011); Ku et al., (2011); Taghavi and Murat (2011); McKendall and Hakobyan (2010); Gonzalez-Cruz and Gomez-Senent Martinez, (2011); Mohamadghasemi and Hadi-Vencheh, (2012); Hadi-Vencheh and Mohamadghasemi, (2013); Shokri et al., (2013); Jabal-Ameli et al. (2013); Karande and Chakraborty, (2014) have used different MCDM approaches and algorithm for solving the facility layout problems.

2.2.6 Quality Control

Quality Management (QM) systems are very necessary for the manufacturing organizations to improve the level of performance (Al-Ani and Al-Adhmawi, 2011). QM has been distributed into four phases namely (i) quality inspection; (ii) quality control; (iii) quality assurance; and (iv) total quality management (James, 1996; Dale et al., 2007; Heras et al., 2011). The fruitful employment of QM entails an effective and appropriate application of different tools and techniques (Ahmed and Hassan, 2003; Longenecker et al., 2008; Barnes, 2008; Mahadevan, 2010; Evans, 2011; Jafari and Setak, 2010). Tools are the implements which are applied to accomplish the functions while techniques are the approaches used for the accomplishment of functions (Grover et al., 2004).

Grover and Singh, (2007) have classified quality tool and techniques into different categories such as problem identification tools; data analysis tools; graphical tools; creativity tools; company-wide techniques; productivity improvement tools and decision making tools. Bunney and Dale, (1997) categorized the quality tool and techniques in two different ways (a) on the basis of application (data collection, problem solving, application customer or supplier relationship, new product introduction, quality awareness); and (b) on the basis of operations of organization (purchasing, production, sales, customer service, marketing, engineering, company-wide). Schuermann et al., (1997) classified the quality tools into two broad
categories namely qualitative tools (involves subjective inputs) and quantitative tools (involves analysis of objective data).

Ahmed and Hassan, (2003) classified quality tools as graphical tools (histogram, line charts, pie charts, stem and leaf diagrams, control charts, bar charts, run or time series charts, and pareto diagrams) and flow diagrams (process flow charts, cause and effect diagrams, and tree diagrams). Dale, (2003) listed seven management (M7) tools namely affinity diagram, systematic diagram, relation diagrams, systematic diagrams, matrix data analysis, PDPCs, and arrow diagram. These tools are also known as seven new quality management tools. Salegna and Fazel, (1996) categorized the quality tools and techniques into six parts namely customer based, employee based, management based, product based, process based and supplier based.

The persistent quality improvement is an imperative for the persistence of an organization. It involves the institution of a proper process measuring system. In order to decide the likelihoods for refining the process effectiveness and efficiency, measurement data have to be organized, managed and examined by using the proper methods and techniques (Vukelić et al., 2008). The application of quality tools and techniques is a dynamic element for effective improvement of process. These quality tools and techniques can be effectively helpful to any manufacturing organization after the appropriate training of their employees (Singh et al., 2012).

2.2.7 Production Planning

Production planning and control system plays an imperative part in a manufacturing organization. Each stage of transformation, raw materials into finished products, requires a meticulous production planning like scheduling, dispatching, inspection, and inventory management, to confirm that the organization attains the requisite production target and optimize the resources utilization (Muhammad and JengFeng, 2014). The decisions made in the production planning system involve the determination of best way for achieving the forecasted demand by altering production rates, workforce levels, inventory levels, and all other manageable variables (Heizer and Render, 2004).

Production planning is also known as aggregate planning. The objective of aggregate planning is to define the aggregate levels of production, inventory, and workforce to
counter the inconsistent demand of next 6-18 months (Swamidass, 2000). Nowak, (2013) described that it deals with determining and timing of production for the intermediate future i.e. from 3 to 18 months. The aggregate production planning aims at better utilization of available resources for the enhanced and cost-effective production of different products (Iqbal et al., 2014a). Chinguwa et al., (2013) have described the various characteristics of aggregate planning and its strategy (level strategy, chase strategy and hybrid strategy) and techniques (informal techniques, trial and error methods, mathematical techniques, linear programming, goal programming, linear decision rule, heuristic techniques, management coefficients approach, parametric production planning and simulation search procedures).

In literature, various optimization techniques such as linear programming, mixed integer programming, and dynamic programming are often employed in aggregate planning in order to obtain the lowest cost plan e.g. Novak and Ragsdale, (2003); Urli and Nadeau, (2004); Kumar and Haq, (2005); da Silva, (2006); Benyoucef et al., (2007); Mezghani et al., (2009); Ramezanian et al., (2012); Chinguwa et al., (2013); Nowak, (2013); Brahimi, (2014); Gajpal and Nourelfath, (2014).

2.2.8 Scheduling

Scheduling includes determining the distribution of facility resources. Tasks must be allocated to the process units, duration and extent of processed material associated to those allotted tasks must be determined (Verderame and Floudas, 2008). Scheduling is an imperative tool for the manufacturing system as it can have great effect on the efficiency of a production process (Gen and Lin, 2012).

Scheduling deals with the distribution of resources to tasks along with time (Framinan et al., 2014). It is a decision making process whose goal is to optimize one or more objectives (Pinedo, 1995). These objectives are minimisation of job completion time, mean flow time, delay of job and its processing cost, etc. (Ouelhadj and Petrovic, 2009). Production scheduling regulates the organizational performance (Mapokgole, 2014). Sawik, (2002); Betts and Mahmoud, (1989); Kays et al., (2014) have discussed that the production scheduling and line balancing are similar type of method that aids to increase the production rate by reducing the idle time or completion time.
Scheduling is of two types (a) predictive scheduling; and (b) dynamic scheduling. Predictive scheduling involves the generation of production plans by supposing the static operating conditions during the entire scheduling period. But, the real environment of the organization is dynamic in which unanticipated event occurs normally such as arrival of new order, annulment or modification of order, equipment failure, alterations in batch handling or setup time, late delivery of raw material, etc. These events interrupt the in-progress schedule (Novas and Henning, 2010).

Ouelhadj and Petrovic, (2009); Vieira et al., (2003); Mehta and Uzsoy, (1999); Aytug et al., (2005); Vieira et al., (2000); Leus and Herroelen, (2005) have categorized the dynamic scheduling into different groups namely (a) completely reactive scheduling; (b) predictive reactive scheduling; (c) robust predictive reactive scheduling; and (d) robust pro-active scheduling. Fujimura, (2014) has developed a reference model for the development of production scheduling systems.

In literature, several dynamic scheduling approaches such as dispatching rules (Geiger et al., 2006), neural networks (Chen and Huang, 2001), meta-heuristics (Loukil et al., 2005), Petri nets (Kim et al., 2007), knowledge-based systems (Noronha and Sarma, 1991), hybrid techniques (Das and Acharyya, 2013), fuzzy logic (Ling et al., 2011), heuristics (Stanimirović et al., 2009), and multi-agent systems (Wei and Dongmei, 2012) are available for the development of production schedules.

2.2.9 Inventory Control

In the current competitive environment, the organizations are continuously expanding their production portfolio. This expansion of portfolio has increased the complexity of their production process. Deshpande, (2010) emphasized that large number of components makes the system more complex. Moreover, the customers are demanding more variability in the product. These issues have made the production and inventory management more difficult (Ferenčíková, 2014). The main objective of inventory management is to confirm that organizations are having adequate inventories at the lowest possible cost (Thogori and Gathenya, 2014).

Hillier and Lieberman, (1995) have defined inventory as stock of goods or items being preserved for future use or sale. Inventory are used to decrease the lead time to counter customer demand in order to streamline the production rate when demand
variation occurs, and to guard the organization from misjudges of demand (forecasting inaccuracies) or deficiency of raw material supply (Iqbal et al., 2014b). Bhausaheb and Routroy, (2010) have emphasized on the effective management of inventory for reduction of cost, improvement of service quality, enhancement of product availability and customer satisfaction. Koumanakos, (2008) has illustrated the effect of inventory management on the organizational performance.

In literature, a number of control methods such as ABC (Always Better Control) analysis, SDE (Scarce, Difficult, Easy) analysis, VED (Vital, Essential, Desirable) analysis, HML (High, Medium, Slow) analysis and FSN (Fast, Slow moving, Non-moving) analysis are available for adequate control of inventory items. Moreover, a number of inventory control models are available based on simulation (Georgiadis et al., 2005; Schwartz et al., 2006; Huang et al., 2007; Bolarin et al., 2008); forecasting (Zhao et al., 2007; Levi et al., 2007; Rawata and Altokb, 2008; Rodrigues et al., 2008; Inaba, 2009); base-stock (Shang and Song, 2003; Vecchio and Paschalidis, 2003; Daniel and Rajendran, 2005a; 2005b); optimization (Biswas et al., 2004; Chung and Wee, 2006; Anli et al., 2007; Prasertwattana et al., 2007; Kadirapasaoglu et al., 2008) for effective management of inventory.

2.2.10 Work-system Design

Work-system design includes the job design, worker compensation and work study. Job design is an amalgamation of job content and work method for the performance of a particular job (Durai, 2010). Job design comprises three major categories namely job enlargement, job rotation, and job enrichment (Maxwell, 2008). Job enlargement basically involves the rotation of workforce position and assignment of extra duties along with their daily routine works (Dessler, 2013). It affects the motivation, satisfaction and commitment of employees (Hellgren and Sverke, 2001) and leads in improvement of employee’s scope and workload (Raza and Nawaz, 2011).

Job rotation allows the employees to rotate from one job to other in a prearranged way (Durai, 2010; Mbadou and Mbohwa, 2013). Job rotation leads to productivity improvement, increased employees retention, career enhancement of employees (Jorgensen et al., 2005) and better understanding of organisation’s operations (Ali and Aroosiya, 2012; Belias and Sklikas, 2013). Involving the work-force to the
managerial functions of higher positions is called job enrichment. It allows the workforce to execute additional tasks at the same position. It results in growth of self-actualization, self-control and self-respect of the workers (Saleem et al., 2012). Job enrichment is one of the precious objectives to attain individual performance (Vijay and Indradevi, 2015). Job enrichment is prerequisite for inherent motivation and is a constant management process. The commonly used wage payment system in organization is either based on work-time or work-output (Chase and Aquilano, 1977). Klein, (1965) developed optimal schemes related to incentive payment system.

Work study thoroughly deals with the determination of time standards and contribution to the enhancement of work efficiency. Developing and setting of performance standards for a given job in an organization enables the management to fix the standard for determining the workforce requirement, time required and production output (Elnekave and Gilad, 2006). Work study analysis aims to refine the work efficiency through the method study which aims at minimization of production time and operator stress (Gilad and Elnekave, 2006). Work study involves method study and work measurement. Method study refers to the identification of redundant movements and abolishes unproductive time by way of product or process inadequacy while work measurement is the application of procedures intended to institute the time for an employee to accomplish a job at a defined rate of working (Yee et al., 2014).

2.3 LITERATURE REVIEW ON APPLICATIONS OF SELECT MULTI-CRITERIA DECISION MAKING APPROACHES

The present section provides the review of literature on the applications of select multi-criteria decision making (MCDM) approaches which have been utilized in this research work.

2.3.1 Interpretive Structural Modelling (ISM) Approach

Parameshwaran et al., (2015) have developed an integrated framework for mechatronics product development. For the conceptual design of Mechatronics system, various tools like Fuzzy Delphi Method (FDM), Fuzzy Interpretive Structural Modelling (FISM), Fuzzy Analytical Network Process (FANP) and Fuzzy Quality Function Deployment (FQFD) have been used. Hsu et al., (2015) have applied FDM,
ISM, and ANP to identify the relative importance among the critical drivers affecting the performance of university technology transfer. Zhang et al., (2015) used ISM approach for analyzing the relationship between the factors affecting the network reconfiguration. Dubey et al., (2015a) developed a truck freight model using ISM and MICMAC analysis. Mahajan et al., (2015) have developed an integrated ISM based framework to analyse the interactions among the winners and qualifiers for management institutes.

Dubey et al., (2015b) have analysed the inter-relationship among the antecedents of innovation by the use of ISM approach. Katiyar and Barua, (2014) have modelled the barriers of supply chain performance measurement by using ISM approach. Mehregan et al., (2014) have analyzed the factors that drive suppliers to implement sustainable practices in the supply chain by ISM approach. Jolhe and Babu, (2014a) developed an ISM based methodology for the effective management of product quality. Mangla et al., (2014) provided an ISM based approach to implement green activities in supply chains.

### 2.3.2 Analytical Hierarchy Process (AHP) Approach

Sarfaraz et al., (2015) have applied interval based analytical hierarchy process (AHP) approach for the development of personnel for a technical manager or technical team leader. Asif, (2015) has developed an AHP based framework for determining the improvement needs in higher education. Ouyang et al., (2015) have utilized the AHP approach for the selection of natural waste water treatment alternatives. Luthra et al., (2015) have used AHP method for ranking the barriers inhibiting the adoption of renewable or sustainable technologies. Jakhar, (2015) has developed an AHP based decision model for the performance evaluation and flow allocation in a sustainable supply chain.

Abbaspour et al., (2015) have performed AHP based hierarchal assessment of noise pollution in urban areas. Mosadeghi et al., (2015) have compared the applications of Fuzzy AHP and AHP in urban land-use planning. Georgiou et al., (2015) have utilized AHP approach for the selection of RE powered RO units on the basis of different attributes. Podgórski, (2015) measured the operational performance of OSH
management system by using AHP approach. Franco et al., (2015) applied AHP approach for the selection of suitable locations for biogas plants.

2.3.3 Graph Theoretic Approach (GTA)

Rajesh et al., (2014) have used the digraph and matrix approach for the selection of risk mitigation strategy in electronic supply chains. Gupta et al., (2014) have developed a GTA based framework for the estimation of annual maintenance budget for a plant. Mishra (2014) developed an integrated system model based on Graph theoretic approach (GTA) for structural modelling and analysis of world-class maintenance system. Atri et al., (2014a) have utilized GTA approach for evaluating the intensity of barriers in the implementation of total productive maintenance. Dev et al., (2014a) have analyzed the reliability of combined cycle power plant by using the GTA approach.

Dev et al., (2014b) have analysed the reliability of cogeneration cycle power plant by digraph and matrix method. Jain and Raj, (2014) used GTA approach for the modelling and analysis of FMS productivity variables. Chahal et al., (2014) have evaluated the machinability dies steel H-11 with CNC Milling by using digraph and matrix method. Gurumurthy et al., (2013) have used graph theoretic approach for analysing the readiness of an organisation for adapting lean thinking. Singh and Singru, (2013) have developed a graph theoretic model for analysis of restructuring a manufacturing system.

2.3.4 MOORA Approach

Liu et al., (2015) have evaluated the health care waste treatment technologies using the hybrid DEMATEL and fuzzy MULTIMOORA approach. Seema et al., (2014) have designed a MOORA based decision support system to evaluate and select the supplier. Ozcelik et al., (2014) have applied hybrid MOORA and fuzzy algorithm for the development of special education and rehabilitation centre. Sahu et al., (2014a) have selected best alternative by using grey MOORA approach from the available alternative supply chains. Sahu et al., (2014b) have developed a machine tool evaluation index for selecting the best CNC machine tool.
Liu et al., (2014) have evaluated the risk of failure moods by using the extended MULTIMOORA approach. Kracka and Zavadskas, (2013) have applied MOORA and MULTIMOORA approach for the selection of effective panel building refurbishment elements. Das et al., (2013) have applied combined SOWIA-MOORA approach for the evaluation of performance of Indian technical institutions. Datta et al., (2013) utilized the grey MULTIMOORA approach for the selection of robots. Chakraborty and Karande, (2012) have used MOORA approach for the selection of suppliers.

2.3.5 PSI Method

Singh et al., (2015) have utilized Preference Selection Index (PSI) method to rank the friction materials based on the different attributes. Akyüz and Akha, (2015) have developed a PSI based frame-work for the measurement of manufacturing performance. Attri et al., (2014b) have used PSI method for selection of cutting fluids. Almomania et al., (2013) have developed a systematic procedure based on AHP, TOPSIS and PSI method for selecting the best setup technique. Maniya and Bhatt, (2013) have applied integrated AHP-PSI method for selection of optimal electrical energy equipment. Maniya and Bhatt, (2011a) applied PSI approach for the selection of optimal facility layout design.

Vahdani et al., (2011) have solved the problem of alternative fuel buses selection by using the PSI method. Maniya and Bhatt, (2011b) have solved the problem of flexible manufacturing system selection by using PSI method. Joseph and Sridharan, (2011) have ranked the scheduling rule combinations in a flexible manufacturing system by using PSI method. Maniya and Bhatt, (2010) used PSI method for the selection of materials.

2.4 COMPARISON OF EXISTING PRODUCTION SYSTEM LIFE CYCLE MODELS

In this section, the comparison of existing production system life cycle models has been done in terms of distinctive features and limitations as illustrated in Table 2.1.
Table 2.1: Comparison of existing production system life cycle models

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<td>• Volume change mix</td>
<td>• System requirement</td>
<td>• Product design and process selection</td>
<td>• Design</td>
<td>• Planning</td>
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<td>• Product change</td>
<td>• Preliminary design</td>
<td>• Design of system</td>
<td>• Realisation</td>
<td>• Implementation</td>
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<td>• Discarding</td>
<td>• Quotation &amp; Choice of sub-contractors</td>
<td>• Manning of system</td>
<td>• Start-up</td>
<td>• Operation</td>
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<td>• Detailed design</td>
<td>• Start-up of system</td>
<td>• Operation</td>
<td>• Operation refinement</td>
<td>• &amp; service</td>
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<td>• Component &amp; system testing</td>
<td>• System in steady state</td>
<td>• Revision</td>
<td>• Termination/Re-use</td>
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<td>• System integration, personnel training</td>
<td>• Analyses</td>
<td>• of system</td>
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<td>• Production ramp-up</td>
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<td>• Identification of need for change</td>
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<td>Applicable to projects</td>
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<td>Limitations</td>
<td>Not applicable to service organizations</td>
<td>Termination stage has not been included</td>
<td>No emphasis on the facility location stage</td>
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<td>Start-up planning stage has not been included</td>
<td>Not applicable to manufacturing and service organizations</td>
<td>Limited to operation refinement besides the technology, market and product refinement</td>
<td>No scope for revision of system in light of environment change</td>
<td>Termination stage has not been included</td>
<td>No scope for revision of system in light of environment change</td>
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<td>Termination stage has not been included</td>
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</table>
2.5 GAPS IDENTIFIED FROM LITERATURE ANALYSIS

An extensive review of literature brings out the following gaps in the context of production system life cycle:

- The researcher has not come across any literature on comparison of existing models of production system life cycle.

- Limited number of production system life cycle models is available absolutely for the manufacturing organizations.

- The researcher has not come across any literature on the exploration of different stages of production system life cycle in detail.

- In literature, identification of parameters such as key activities, department involved in performing these activities and barriers in different stages of production system life cycle has not been carried out.

- In literature, quality enabled factors for each stage of production system life cycle has not been enlisted and analyzed.

- The researcher has not come across any literature on prioritization and quantification of quality enabled factors for the different stages of production system life cycle.

- The researcher has not come across any literature on the availability of methodology which can be effectively utilized for the selection of decision in different stages of production system life cycle.