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REVIEW ARTICLE

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A comparison of production system life cycle models

Abstract Companies today need to keep up with the rapidly changing market conditions to stay competitive. The main issues in this paper are related to a company's market and its competitors. The prediction of market behavior is helpful for a manufacturing enterprise to build efficient production systems. However, these predictions are usually not reliable. A production system is required to adapt to changing markets, but such requirement entails higher cost. Hence, analyzing different life cycle models of the production system is necessary. In this paper, different life cycle models of the production system are compared to evaluate the distinctive features and the limitations of each model. Furthermore, the difference between product life cycle and production life cycle is summarized, and the effect of product life cycle on production life cycle is explained. Finally, a production system life cycle model, along with key activities to be performed in each stage, is proposed specifically for the manufacturing sector.

Keywords production system, life cycle, model, product

1 Introduction

The objective of an enterprise is to provide goods or services and to earn profit. Today, many firms focus on continuous improvement and customer satisfaction. A continuous search for areas of improvement in the production system is needed. Hence, a clear understanding of recent developments in the production system is necessary. To achieve these objectives, firms need to convert particular inputs, such as human resources, materials, money, energy, information, and so on, to useful outputs like finished products and services with the required quality and quantity. The transformation of inputs into pre-specified outputs is achieved through the production process [1].

Production systems are collections of people, equipment, and procedures organized to accomplish the manufacturing operations of a company [2,3]. Encyclopedia Britannica [4] defined the production system as "any of the methods used in industry to create goods and services from various resources." A production system can be described as an assembly of production subsystems carrying the company's value streams that form the entire production flow, from raw materials or components to product delivery to the customer [5,6]. The transformed resources in a production system include labor, capital (e.g., machines and materials, etc.), and space, all of which are labeled as "men, machines, methods, materials, and money" [4]. The function of a production system can be described as a transformation system that converts input to output. Figure 1 shows a simplified model of the transformation system.

In the product life cycle, the product goes through several distinct stages: introduction, growth, maturity, decline, and death. Marketing decisions at each stage of the product life cycle are typical. The same concept is extended to the production system as a whole. During the introduction stage of the production, the product and its design are selected. Facilities must be provided for the manufacture of the product. All these decisions are major strategic decisions initiated by promoters of an industry. Immediately thereafter, the production system becomes steady as most on-going organizations are. At this stage, decisions are short-term tactical decisions, and the system is slightly influenced by internal and external environmental changes. When radical changes occur in the external environment, and the production system experiences difficulty in adapting to these changes, the system comes to an end. This end is either in the form of liquidation or sale or merger. Sometimes, the system is intentionally phased out over a period of time [9].

The main objective of this paper is to compare the existing models of the production system life cycle in literature to evaluate the distinctive features and limitations

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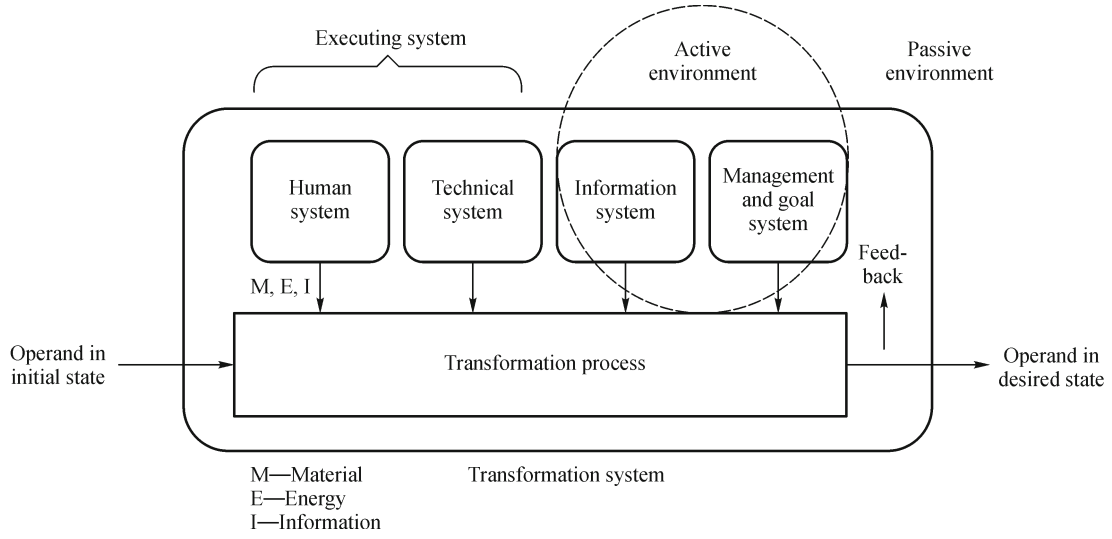

Fig. 1 Simplified model of the transformation system [7,8]

of each model and to propose an improved model specifically for the manufacturing sector.

2 Difference between product life cycle and production system life cycle

2.1 Product life cycle

According to Kotler and Keller [10], most product life cycle curves are bell shaped. As shown in Fig. 2, this curve is divided into four stages: introduction, growth, maturity, and decline.

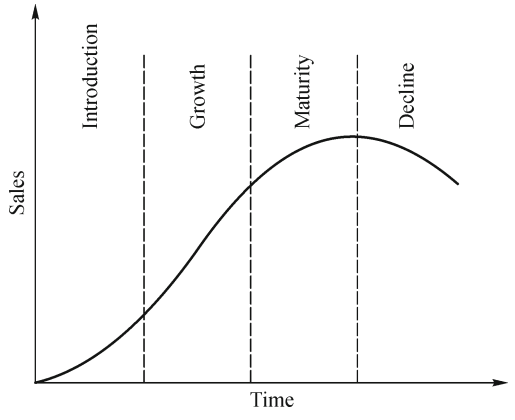

Fig. 2 Product life cycle [10]

1) Introduction: A period of sales growth is observed at this stage as the product is introduced in the market. Profits are non-existent because of heavy expenses during product introduction.

2) Growth: This stage is characterized by rapid market acceptance and substantial profit improvement.

3) Maturity: A slowdown in sales growth is observed at this stage because the product has been accepted by most potential buyers. Profits stabilize or decline because of increased competition.

4) Decline: Sales show a downward trend, and profits decrease.

2.2 Production system life cycle

According to Chase and Aquilano [11], the production/productive system life cycle (Fig. 3) has four general phases: design, start up, steady state, and termination.

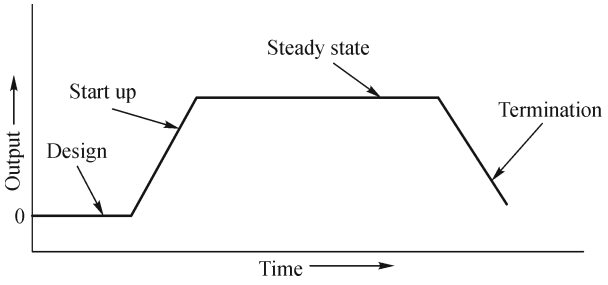

Fig. 3 Production system life cycle [11]

1) Design stage: This stage generally comprises product and design selection, process selection, location of facility, layout design, quality control, production planning, scheduling, inventory system, and job design and its evaluation methods.

2) Start-up stage: This stage includes start-up planning. That is, organizing the implementation of the system and developing the start-up schedule as well as stating predictions for the start-up progress.

3) Steady-state stage: The steady-state period is the

longest phase of a typical systems life cycle. The job of the production manager during this period consists of maintaining the adequate performance of the system and searching ways to improve performance.

4) Termination stage: In this stage, the production system is terminated based on production when it permanently ceases or when a system is so greatly modified that a major portion of the original design is no longer relevant to subsequent operations.

2.3 Effect of the product life cycle on the production system life cycle

In actual conditions, the production life cycle depends on the product life cycle. Such dependency varies according to the stages of the product life cycle. When the product and the production system life cycles are combined in a hypothetical one-product firm, the following graph on the combination is obtained (Fig. 4).

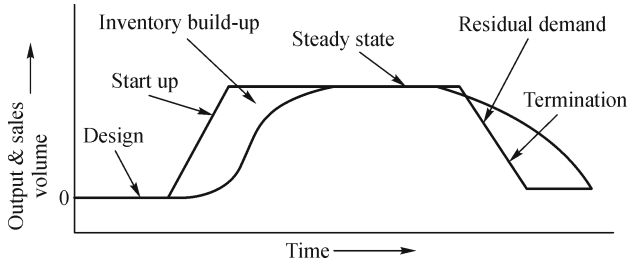

Fig. 4 Product and production system life cycles [11]

Chase and Aquilano [11] examined these combined cycles and observed that the initial phases of the product life cycle continue after the production system has achieved steady output levels. The difference between output and sales represents the inventory that accumulated because the output exceeds demand. During steady-state operations at the product maturity stage, the supply and demand for a product reaches equilibrium, such that items sold are immediately replenished. When product sales begin to decline, excess inventory is accumulated, but is then eliminated as the system cuts back production. During the final stage of the system's life cycle, the residual demand for the product finally exceeds production.

3 Production system life cycle models

Based on the extent of the literature review, the following models of production system life cycle were found:

(1) Nakano et al. [12] reported the following three stages in the life cycle of the production system (Fig. 5):

1) Start-up stage — product design, process planning, plant (equipment) design, layout design, evaluation of productivity and cost, operational procedure;

2) Volume-change and mix-change stage — adaptation planning, reconfiguration, evaluation;

3) Product change stage — product re-design, process re-planning, plant (equipment) change, layout change, evaluation of productivity and cost, operational change, discarding.

(2) Bellgran et al. [13] listed the following stages in the life cycle of the production system (Fig. 6):

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

(3) Chase and Aquilano [11] stated that the production system consists of the following eight distinct phases:

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

(4) Wiktorsson [14] divided the production system life cycle into seven stages (Fig. 8):

- Planning
- Design
- Realization
- Start-up
- Operation
- Operational refinement
- Termination/Re-use

(5) Kosturiak and Gregor [15] listed four stages in the life cycle of the production system (Fig. 9):

- System analysis — feasibility study, alternatives, strategies, concepts, production program
- Planning — dimensioning, machinery planning, control concept, evaluation of planning parameters, layout planning
- Implementation — system take-over, simulated test operation, labor training
- Operation — monitoring, forecasting, scheduling, and emergency operations strategies

(6) Preiss et al. [16] listed three stages in the production system life cycle (Fig. 10):

- Engineering
- Commissioning
- Operation and service

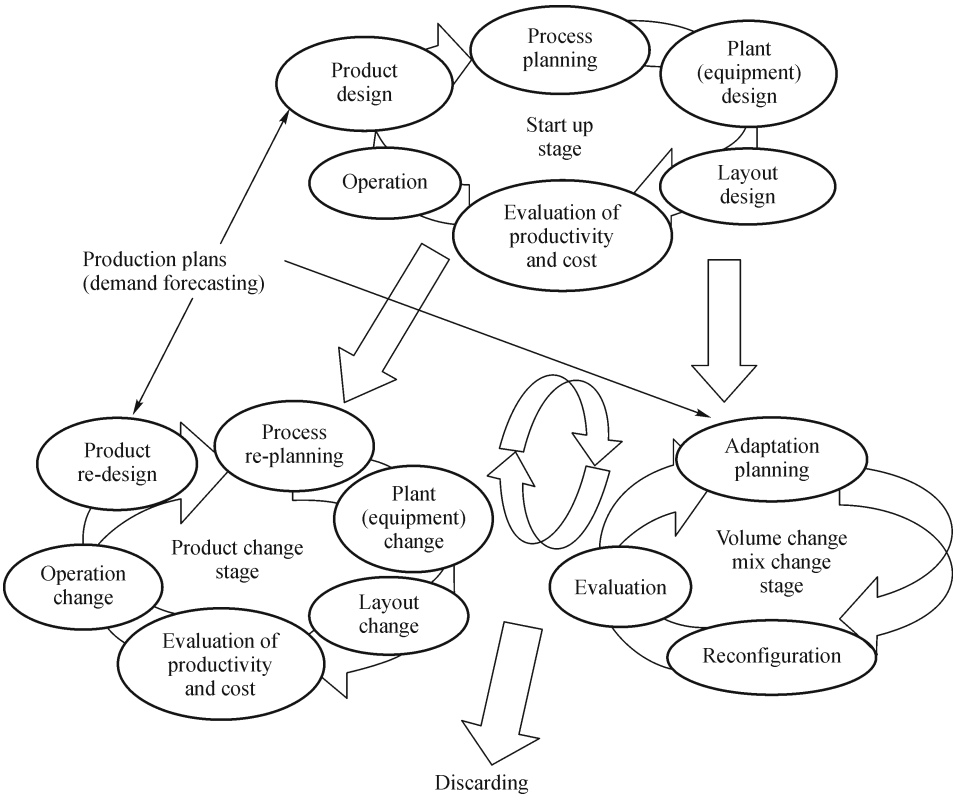

Fig. 5 Production system life cycle model proposed by Nakano et al. [12]

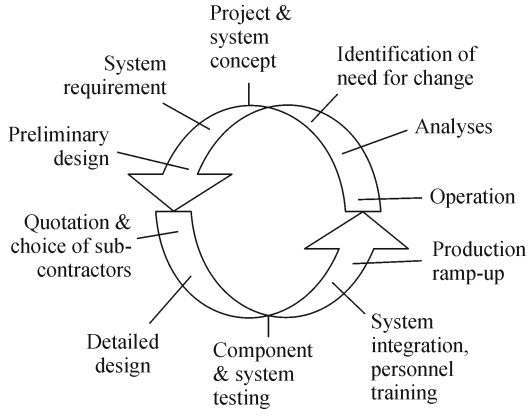

Fig. 6 Production system life cycle model proposed by Bellgran et al. [13]

4 Comparison of existing models

In this section, existing production system life cycle models are compared in terms of distinctive features and limitations, as illustrated in Table 1.

5 Proposed model of the production system life cycle

The life cycle of the production system shows the progress of the production system from inception to termination. The proposed model, along with key activities to be performed in each stage, is shown in Fig. 11. This model is specifically for the manufacturing sector.

The production system life cycle starts from the selection of the product, which is examined in terms of marketability and producibility. After selection, the product is designed in terms of shape, size, and other requirements. Process planning is then performed to select the processes that will be used in manufacturing the product. Subsequently, plant/organization location is determined. The layout design is prepared following the results of the process planning. The required machines are purchased, and the machines are installed according to the designed layout. Requirements for manpower are decided, and recruitment is conducted for the initiation of the production system. Once the production system begins to operate, daily problems are identified and rectified. During operation, the production system can be influenced by the external environment, which may involve new launched products in the market and new technological developments. To adjust to these changes, certain adjustments/revisions have to be made in the system. These changes may be repeated depending on environment change. If the production system cannot adjust according to the changes in the environment, market sale will be reduced. The system then has to be terminated if the changes become too costly as compared with profit or if the system cannot be changed.

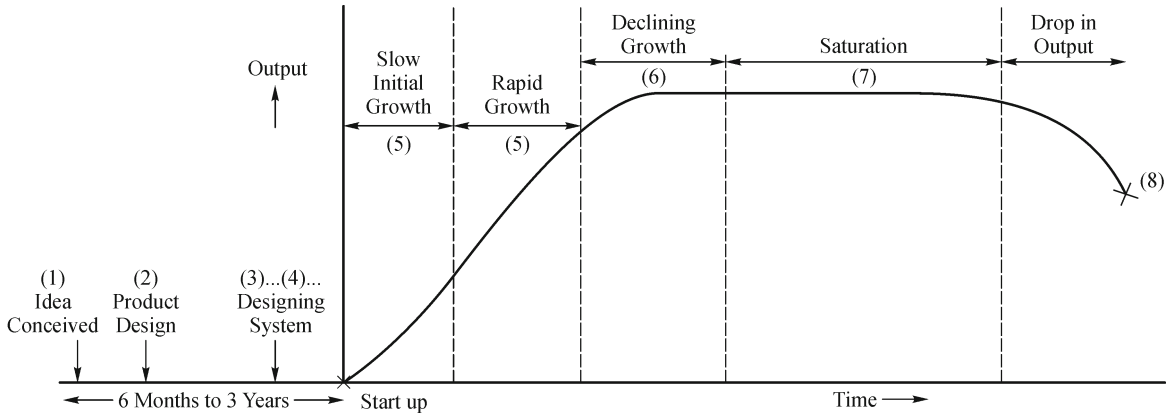

Fig. 7 Production system life cycle model proposed by Chase and Aquilano [11]

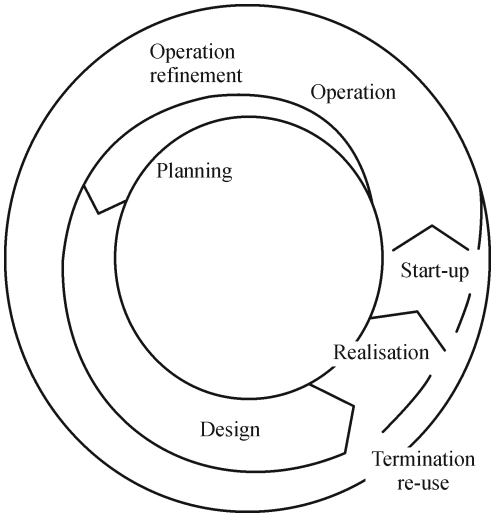

Fig. 8 Production system life cycle model proposed by Wiktorsson [14]

To build an efficient production system, proper and correct decisions have to be made in each stage of the life cycle. For example, while designing the plant layout, sufficient flexibility has to be maintained so that any change in the environment during system operation may be accommodated when required.

The main advantage of this model is that it consists of

Fig. 10 Production system life cycle model proposed by Preiss et al. [16]

the revision stage, wherein changes are facilitated whenever required. During this stage, market behavior has to be predicted at regular intervals to adapt to turbulent and fast-changing markets and to cope with the increasing competition. Moreover, correct revisions/changes in the system must be made at the onset of environmental change to maintain competitiveness in the market.

6 Conclusions

The production system life cycle has shortened because of increasing competition, market globalization, strict quality standards, low costs, short throughput times, availability of new technology, increased environmental problems, and because of the availability of multiple choices of products. These factors drove organizations to adopt a production system with a longer life to achieve organizational objectives. For the purpose of analysis, this paper attempts to compare the different production system cycle models in terms of their distinctive features and limitations. The

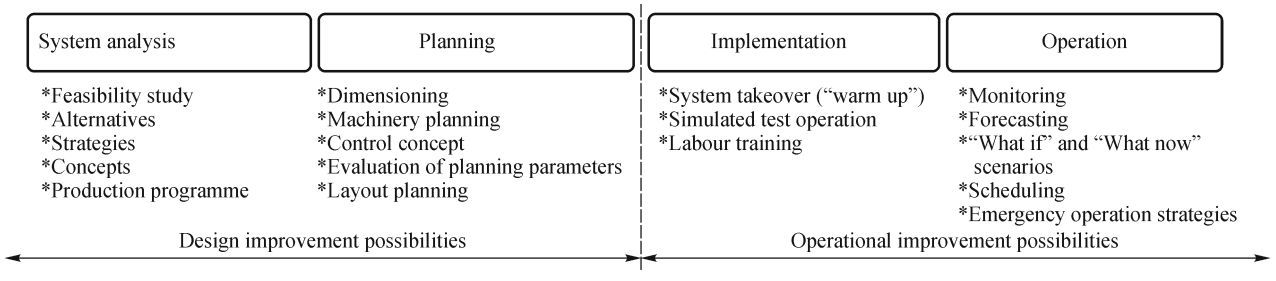

Fig. 9 Production system life cycle model proposed by Kosturiak and Gregor [15]

Table 1 Comparison of different production system lifecycles

Author's Name	Nakano et al. [12]	Bellgran et al. [13]	Chase and Aquilano [11]	Wiktorsson [14]	Kosturiak and Gregor [15]	Preiss et al. [16]
No. of stages	3	11	8	7	4	3
Name of stages	• Start-up stage—product design, process planning, plant (equipment) design, payout design, evaluation of productivity and cost, operational procedure • Volume-change and 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	• Project and system concept • System requirement • Preliminary design • Quotation and Selection of sub-contractors • Detailed design • Component and system testing • System integration and personnel training • Production ramp-up • Operation • Analyses • Identification of need for change	• Birth of the production system • Product design and process selection • Design of the system • Manning of the system • Start-up of the system • System in steady state • Revision of the system • Termination of the system	• Planning • Design • Realization • Start-up • Operation • Operational refinement • Termination/Re-use	• System analysis—feasibility study, alternatives, strategies, concepts, production program • Planning—dimensioning, machinery planning, control concept, evaluation of planning parameters, layout planning • Implementation—system take-over, simulated test operation, labor training • Operation—monitoring, forecasting, scheduling, emergency operations strategies	• Engineering • Commissioning • Operation and service
Distinctive features	• Specific to the manufacturing sectors	• Applicable to projects as well as manufacturing organizations	• Applicable to both manufacturing and service industries	• Specific to the manufacturing sectors	• Specific to the manufacturing sectors	• Specific to the manufacturing sectors
Limitations	• Not applicable to service industries • Manning stage is not included	• Termination stage is not included • Not applicable to service industries		• Not applicable to service industries • Limited to operational refinement besides technology, market, and product refinement	• Not applicable to service industries • No scope for revision of the system due to external environment • Termination stage is not included	• Not applicable to service industries • No scope for revision of the system due to external environment • Termination stage is not included

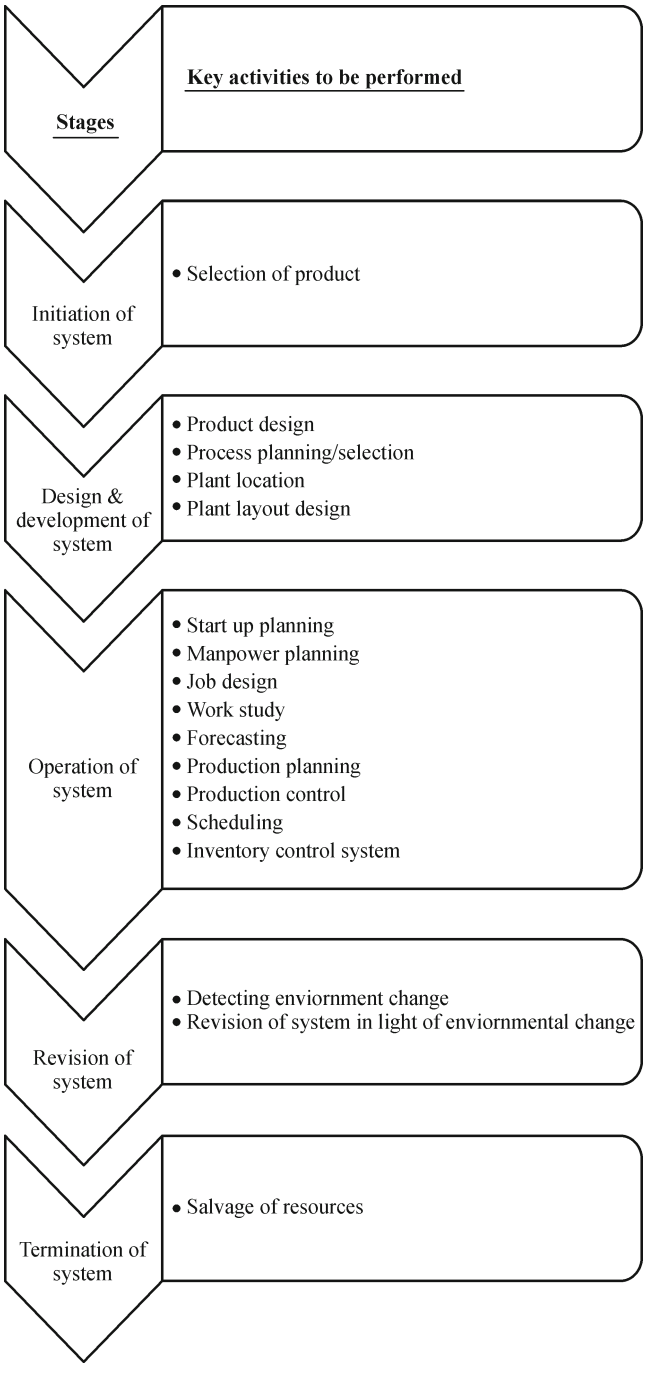

Fig. 11 Proposed model of the production system life cycle

difference between product life cycle and production system life cycle is also summarized. Furthermore, the effect of the product life cycle on the production system life cycle is likewise illustrated. A new model of a production system life cycle is proposed specifically for the manufacturing sector. The proposed model includes the key activities to be performed in each stage of the life cycle. While designing a new production system, management must make correct decisions to lengthen the life of the production system. During the operation of the system, market behavior must be analyzed at regular intervals to detect any environmental change in the market. These revisions are necessary to remain in the competition, as daily competition is also increasing.

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