

Introduction to Systems Engineering

Chapter 6

Construction, Production and Utilization

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Objectives of construction and/or production in system engineering

The primary goals of production and/or construction

- Meeting customer requirements
- Optimizing resource utilization
- Ensuring quality control
- Managing risks
- Adhering to schedules
- Enhancing efficiency

INTRODUCTION

- Construction, production, and utilization are three interconnected processes that are essential in various industries such as manufacturing, engineering, and construction. These processes involve the creation of products or structures, their manufacturing or assembly, and their use or deployment.
- **Construction**
involves the physical creation of buildings, infrastructure, and other structures. It includes activities such as site preparation, foundation laying, framing, roofing, and finishing. Construction projects require careful planning, skilled labor, and the use of various materials and equipment.

- **Production**

refers to the manufacturing or assembly of goods or products. This process involves converting raw materials or components into finished products through various manufacturing techniques such as machining, molding, welding, and assembly. Production facilities often require specialized machinery and skilled workers to ensure efficient and high-quality output.

- **Utilization**

involves the deployment or use of products or structures for their intended purpose. This can include using buildings for residential or commercial purposes, deploying infrastructure for transportation or utilities, or utilizing manufactured goods in various applications. The effective utilization of products often requires proper maintenance and management to ensure longevity and functionality.

CONSTRUCTION AND/OR PRODUCTION

- At the end of Detailed Design and Development, the PBL has been established and the production process is in place and has been proven (most likely with the trial production of selected system elements). The system can now move into Construction and/or Production.
- Some system development projects are aimed at producing only one copy of the system.

Examples:-

- high-rise buildings
- large ships (cruise liners)

Construction and production are closely related processes that often go hand in hand in many industries. In the construction industry, production is essential for creating building materials such as concrete blocks, steel beams, roofing materials, and plumbing fixtures. These materials are then used in the construction process to build structures such as houses, commercial buildings, bridges, and roads.

Similarly, in manufacturing industries such as automotive, aerospace, electronics, and consumer goods production facilities are constructed to manufacture products on a large scale.

With other system developments, many copies of the system may be produced once one or two prototypes have been proven
Example: aircraft system

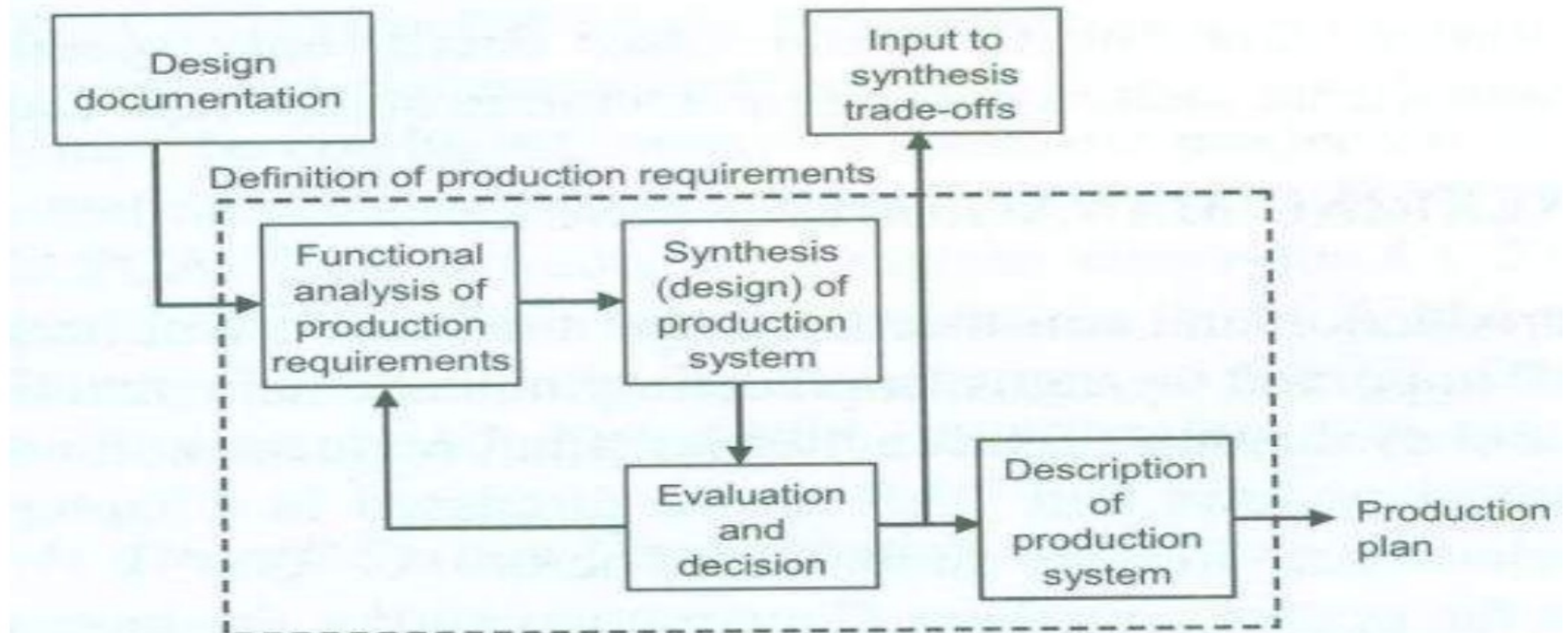
PRODUCTION REQUIREMENTS

- Production requirements need to be considered early in the Acquisition Phase to ensure that production risks are identified and addressed as early as possible.
- As with all other technical requirements, the earlier that production issues are identified in the acquisition, the easier they can be addressed
- In short, the systems engineering effort must make sure that the design that flows out of the preceding stages is able to be produced.

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- Production risks are mitigated by involving production specialists in the design team and as part of the documentation review process.
 - Typical construction and production issues that need to be addressed and monitored throughout the entire systems engineering process include:-
 - material availability (lead times), ordering, and handling
 - availability of skill sets (including any training)
 - availability of production tools and equipment
 - fabrication requirements including production requirement, assembly drawings and instructions
 - processing and process control
 - assembly, inspection and test and
 - packaging, storage, and handling.

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- Construction and/or Production could be considered a specialty program that supports the systems engineering processes.
 - The systems engineering processes can be used before and during Construction and/or Production to support the construction and production planning activities.
 - The analysis-synthesis-evaluation process is drawn upon again to support the determination of the construction and production plan.
 - The production planning process also shows that production may limit or constrain the system design

The figure below shows how Systems engineering applied to planning for Construction and/or Production



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- The content of the Production Plan varies widely with the specific characteristics of the system, but should include the following considerations:-
 - **Resources**-The plan needs to consider the type and size of any plant required to produce and construct the system.
 - **Production engineering considerations**-Production and construction schedules are required and manufacturing methods and processes detailed.
 - **Materials and purchased parts**-A complete bill of materials should be compiled and listed.
 - **Management** -should include details of process control , production testing procedures, subcontractor control, and problem prevention.
 - **Logistics**- The plan should also detail any special logistics requirements such as packaging, handling and storage requirements.

Engineering Management Issues

- During the production and construction stage, the system will be subjected to a number of important systems engineering management activities. These include test and evaluation (T &E) activities, final reviews, and configuration audits.
- Before the system completes Construction and/or Production, it should be subjected to a range of acceptance tests.
- Acceptance testing, alone, is insufficient. Audits should be conducted during production and/or construction to ensure that the system has been built in accordance with the approved specifications and project documentation.

Major Audits

- There are two main types of configuration audit
 - 1. Functional configuration audit** - FCA is used to verify and certify that the performance of the CI meets the specified requirements. FCAs for all CIs should be complete prior to releasing the design to full-scale production.
 - 2. Physical configuration audit** The objective of the PCA is to provide confidence that the as-built CIs match the low-level specifications such as the Product Specifications, assembly specifications, drawings and technical data

Example for FCA and PCA for Aircraft System Configuration Audits

- ❖ When constructing our aircraft, we will have the perfect opportunity to confirm CI-level compliance with relevant PBL documentation.
- ❖ For example, we will be able to confirm that the wiring looms, fuel lines, and flight control connections are all installed in accordance with the layouts contained in the relevant engineering drawings.
- ❖ It is essential that we do this now because, once each aircraft has been completely assembled, it will not be possible to confirm that the looms, lines and connections are installed in accordance with the drawings since they will be obscured from sight by the aircraft structure and skin.

Major Reviews

1. Test Readiness Review (TRR)

- Testing is an expensive and time-consuming exercise involving highly trained personnel, expensive facilities, and specialized test equipment.
- Test Readiness Reviews (TRR) are sometimes contractually required by the customer to demonstrate that the system CIs are ready to enter formal test and evaluation.
- Test and Evaluation Master Plan (TEMP)
- Test plans
- Formal and informal test results
- Supporting documentation
- Support, test equipment, and facilities

2. Formal Qualification Review

- The Formal Qualification Review (FQR) may be required to verify that the performance of each of the CIs meets all the functional requirements when integrated together into the system.
- The FQR will demonstrate that the integrated system complies with all the specifications generated as part of the project including SyRS , hardware and software Development Specifications, and interface requirement specifications.
- From this point of view, the FQR could be considered a 'system-level' configuration audit

Configuration Management

- Is crucial for successful project execution. It involves leadership, communication and decision-making to ensure that the project meets its objectives within the specified constraints.

OPERATIONAL USE AND SYSTEM SUPPORT IN SYSTEM ENGINEERING

MAJOR ACTIVITIES DURING UTILIZATION PHASE

- Operational use
- System support and
- Modifications

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- Differences between system documentation and the physical system tend to result when systems are operated and maintained in an environment void of configuration management practices
- Accurate documentation supports the need to understand the design and capability of the system especially if there are slight differences in configuration across a fleet of systems (for example, an aircraft fleet).

Modification

- Modifications may be required to ensure that the system continues to meet operational and support requirements
- Modifications made in accordance with configuration management practices enhance supportability and operations, BUT unmanaged modifications adversely impact training, support, safety and operations in the long run

Use of Modifications

- Modifications may be required to rectify discrepancies with the performance of the system that were not identified during the Acquisition Phase
- Failures identified as part of the Failure Reporting, Analysis and Corrective Action System (FRACAS) process
- Modifications may also become necessary due to changing system-level requirements
- Opportunities may arise to increase the efficiency of the system, or perhaps reduce maintenance costs, through the replacement of system elements

Impacts of Modifications

- system performance and functionality
- original system; the degree of impact depends on the size and significance of the modification

System Support

- It commences during the Utilization Phase to ensure that the system is maintained in operational order
- The system support will be conducted in accordance with the approved logistics concept

Failure Reporting, Analysis and Corrective Action System

- A failure reporting, analysis, and corrective action system is a closed-loop system designed to continually maintain visibility into system operation and support

The FRACAS process typically includes the following key steps

1. Failure Reporting:

- Accurately documenting and reporting all failures and incidents that occur within the system.

2. Data Collection:

- Gathering comprehensive data on failure occurrences, including their nature, frequency, and impact on the system.

3. Failure Analysis:

- Conducting thorough investigations to identify the root causes of failures using systematic analytical methods.

4. Corrective Action Planning:

- Developing and planning corrective actions based on the findings from the failure analysis phase.

5. Corrective Action Implementation:

- Executing the planned corrective actions to address the identified root causes and prevent recurrence of similar failures.

6. Monitoring and Feedback:

- Monitoring the effectiveness of implemented corrective actions and incorporating feedback into the FRACAS process

Retirement

- The Retirement Phase is the final stage of a system's life cycle, involving phase-out and disposal functions. It's crucial to develop a Retirement Concept during the early stage of Acquisition Phase, considering disposal and phase-out issues.
- Designing for retirement, also known as "design for disposability," involves considering disposal and phase-out issues as criteria for system design.

Three key tasks to undertake during the retirement design

1. Identify the reasons for potential retirement

- The system may have reached the end of its usable and supportable life
- Critical components of the system may be damaged or no longer supportable
- The system may still be useful, but the business need for it has disappeared or the business owner is forced to retire it due to various issues
- The system or its critical components may be damaged beyond repair

2. Identify potential retirement methods for the system

- Sold as a second-hand item
- Traded in on a replacement system
- Re-deployed as a training aid
- Destroyed and disposed as waste

Retirement.....

- Disassembled-that is, broken up and sold as working sub-systems
- Scrapped-that is, broken up and sold as sub-systems, assemblies
- Placed in storage-that is, mothballed because none of the other methods are currently acceptable or tenable

3. Identify design issues that arise

- observance of recycling regulations
- avoidance of the use of potentially hazardous/toxic materials
- environmental impact
- cost of disposal/destruction/uninstallation
- cost of refurbishment for resale or trade-in
- desirability of salvage or material recovery for resale
- cost of transportation for disposal
- need for specialized personnel/equipment required for disposal