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Modelling Production Equipment Requirements using Function-Means Principles to Support Reconfigurable Solutions

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Aim

Modern production systems must handle a **high variety of products** and frequent changes, requiring **flexible, scalable, and modular systems**. While product requirements are well-studied, production requirements receive less attention despite their critical role. Current methods lack traceability and adaptability, often relying on supplier quotations. The aim is to develop a **structured, holistic approach** for production equipment requirements to support **long-term reconfigurability**.

Current State

- **Reconfigurable Production:** Frequent product changes demand adaptable systems. Current planning methods are costly and disruptive; reconfigurable systems aim to reduce redesign costs and improve sustainability.
- **Requirements Management:** Traditionally, requirements evolve from broad objectives to detailed specifications. In production development, requirements define desired properties for systems, lines, or stations.
- **Challenges:** Diverse stakeholders, evolving needs, and a lack of structured classification lead to ambiguity.
- **Existing Approaches:** Frameworks cluster requirements into functional, constraints, and criteria; database-driven methods enable traceability; model-based approaches link design and production requirements.
- **Function-Means Modelling:** Describes systems through **functions (what)** and **means (how)**, enabling systematic reasoning and alternative solution exploration.

Test and Evaluation

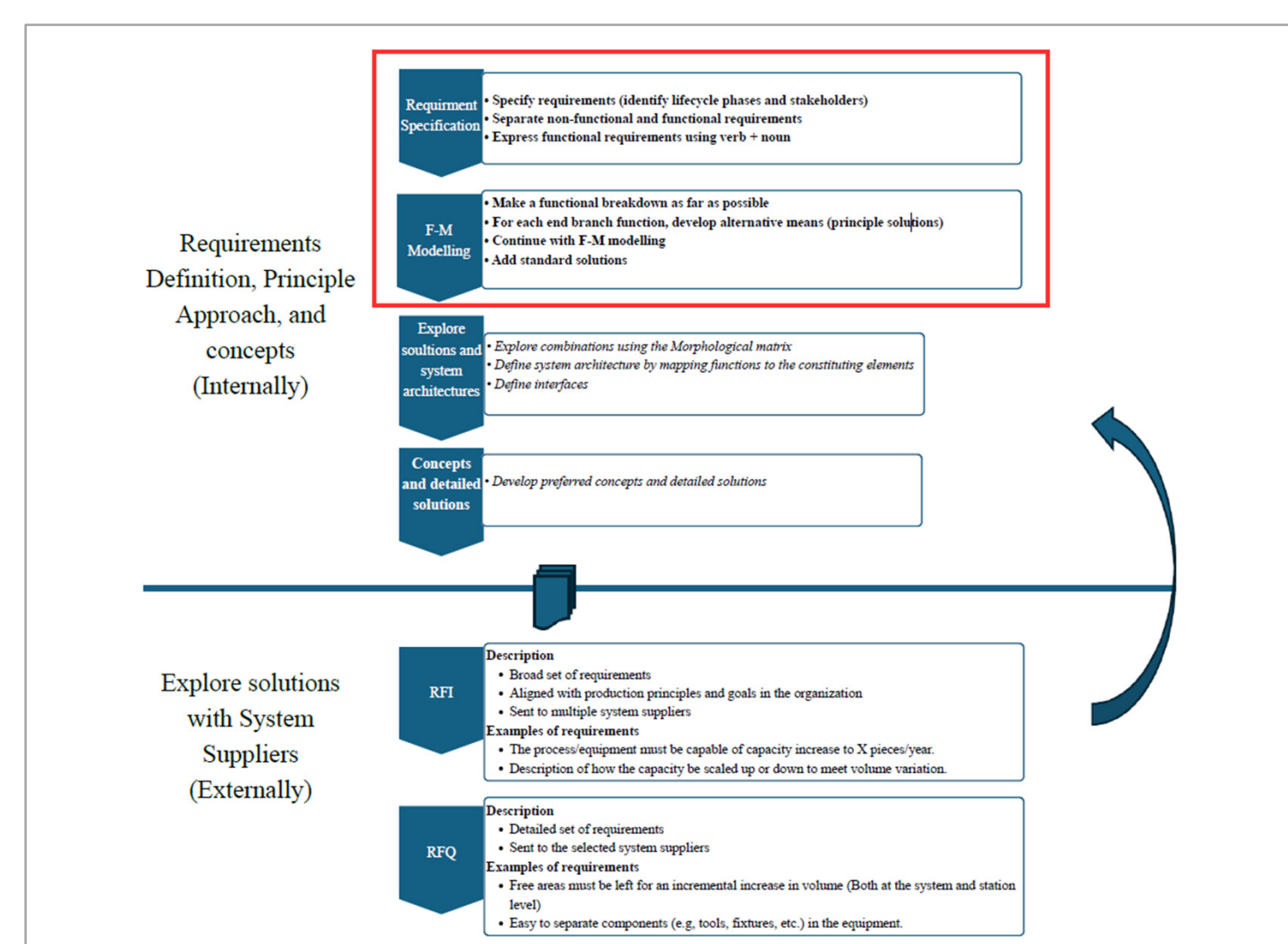
- **Reclassification:** Existing requirements were analyzed and rephrased into functional/non-functional categories.
- **Functional breakdown:** Developed hierarchical structures linking functions to technical means.
- **Workshop with experts in the industry:**
 - ✓ Functional requirements make sense in early phases; strict requirements apply later.
 - ✓ Progressive specification improves adaptability.
 - ✓ Clear functional requirements reduce miscommunication and impractical solutions

Solution and Effects

A structured approach to **production equipment requirements** using **Function-Means modelling**. **Effects:**

- Clear distinction between functional and non-functional requirements.
- Improved traceability and adaptability.
- Long-term benefits in flexibility and reuse. Although the initial effort is high, the approach offers significant advantages for sustainable and competitive production systems.

Overall principle



Approach - Main steps

1. **Specification of requirements:**
By identifying all relevant stakeholders and the lifecycle phases of the production equipment. Analysing requirements from each stakeholder and phase to ensure that a complete system context is represented.
2. **Separation of requirement types:**
Distinguish between functional and non-functional requirements.
 - Functional requirements describe the intended actions of the equipment (what it must do).
 - Non-functional requirements define constraints or qualities (how it should perform).
3. **Formulation of functional requirements:**
Express each requirement using (verb + noun) syntax. This ensures clarity and consistency in the definition of functions.
4. **Functional Decomposition:**
Decompose each high-level function into sub-functions until the required level of detail is reached. Continue the breakdown until the function can be directly linked to technical means.
5. **Exploration of alternative means:**
For each function and sub-function, identify and evaluate alternative means of realisation. This step supports flexibility and allows different possibilities before selecting a preferred solution.
6. **Function-means modelling:**
Establish explicit function-means (F-M) relationships by linking each function to one or more potential technical means that can fulfil it. This enables traceability between requirements and design solutions.
7. **Integration of standard solutions:**
Incorporate standard solutions and known technical means into the model where applicable. Standard elements should be prioritised to enhance compatibility, modularity and reusability with the production system.

Examples

