

Introduction to Systems Engineering

Chapter 3

Requirements Engineering

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Needs and Requirements Documentation

- In system engineering, needs and requirements documentation plays a vital role in capturing and documenting the desired outcomes and specifications for a system.
- It involves recording the needs and requirements of stakeholders to ensure a clear understanding of what the system should achieve and how it should function.
- ❖ The needs documentation phase typically involves the following steps:
 1. **Identify Stakeholders:** System engineers identify the key stakeholders who will be affected by or have a vested interest in the system. This includes end-users, customers, operators, and other relevant parties.
 2. **Elicitation of Needs:** System engineers engage with stakeholders to understand their needs, expectations, and desired outcomes. This is done through interviews, workshops, surveys, and other appropriate

Needs and Requirements Documentation ...

3. Categorize and Prioritize Needs: The needs are categorized and prioritized based on their importance and impact on the system. This helps in managing resources and focusing on the most critical requirements.

4. Requirements Definition: The identified needs are translated into specific requirements that describe the desired characteristics, functions, and performance of the system. Requirements should be clear, unambiguous, measurable, and traceable.

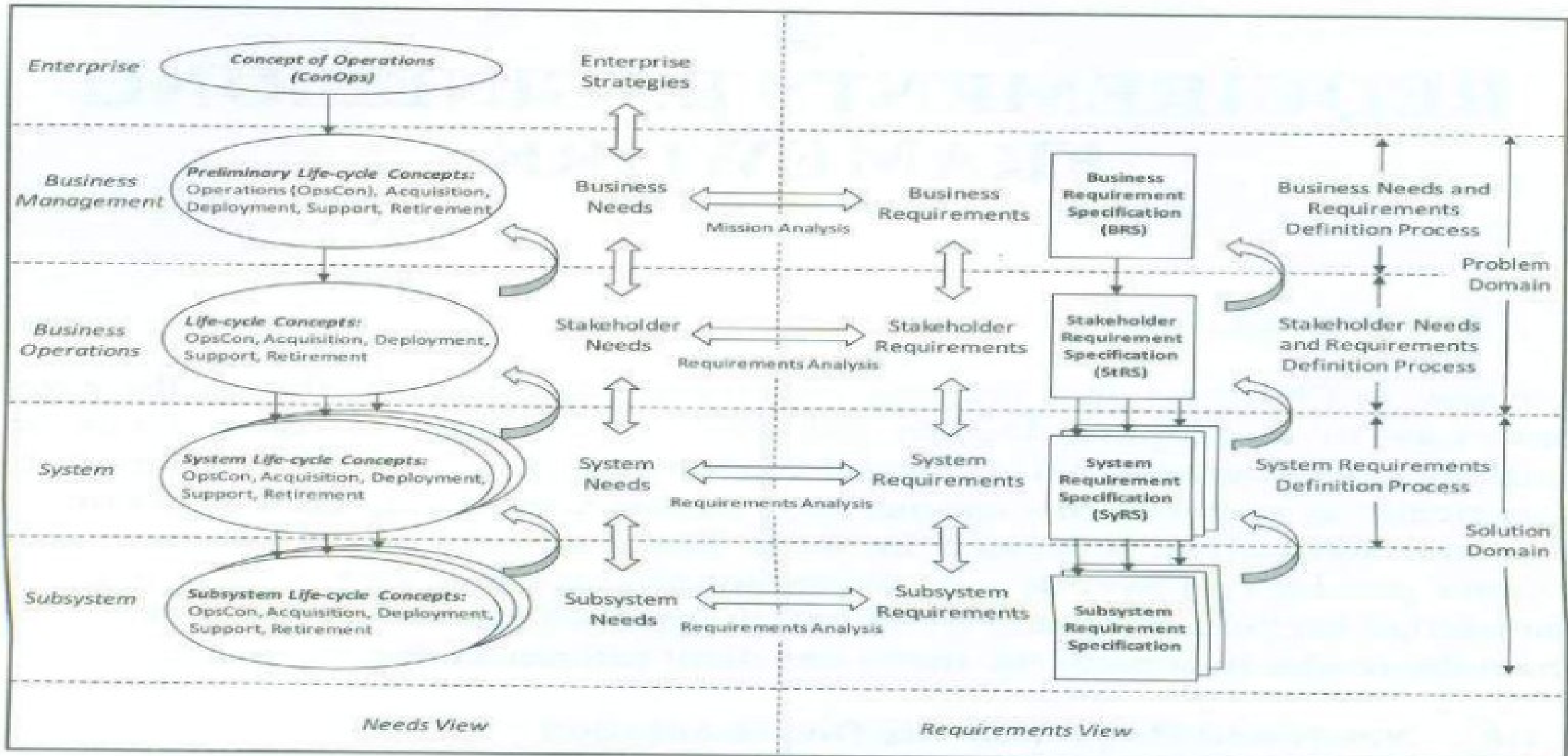
5. Requirements Documentation: The requirements are documented in a structured manner, often using a requirements specification document. This document serves as a reference for all stakeholders involved in the system development process.

6. Validation and Verification: The documented needs and requirements are reviewed and validated by stakeholders to ensure that they accurately

Needs and Requirements Documentation

- There are **needs** and **requirements** at a number of levels.
- There is an **enterprise view** (in which enterprise leadership sets the enterprise strategies and concepts of operations);
- A **business management view** (in which business management derive business needs and constraints as well as formalize their requirements); a **business operations view** (in which stakeholders define their needs and requirements); and a **systems view** (in which the system is defined in logical and physical views).
- The enterprise, business management, and business operations views are in the **problem domain**; the **system and subsystem** (and lower) views are in the solution domain.

Needs and Requirements Documentation ...



Needs and Requirements Documentation ...

- In addition to these vertical views of the process, there are two horizontal views, the **Needs View** and the **Requirements View**.
- While they tend to coexist at each level of consideration, needs and requirements are different:
 - Needs are capabilities stated in the language of the business at the business management or business operations levels.
 - Requirements are formal structured statements that can be validated-there may be more than one requirement defined for any one need.

What is Requirement?

- A requirement can be defined as a statement of a system service, an attribute or a quality of the system, or a constraint placed on the system. A requirement is therefore:
 - ✓ something that the system must do,
 - ✓ a quality or attribute that it must possess, or
 - ✓ a constraint under which it must operate or be developed.

Requirements Characteristics and Attributes

Each requirement should exhibit the following characteristics

- **Necessary.** The requirement must be necessary in that the system could not function in the desired way without this requirement. It also follows that a requirement cannot be necessary if it cannot be traced back to a higher-level requirement (and the associated need).
- **Singular.** A requirement cannot be a combination of two or more requirements-that is, the requirements set must be normalized that requirements do not overlap. This also implies that the requirement is concise and clear.
- **Correct.** That the requirement must be correct is axiomatic-an incorrect requirement will result in a system that does not

Requirements Characteristics ...

- **Unambiguous.** All readers of the requirement should come to the same understanding of what the requirement is saying—there can be only one interpretation. This is difficult when the requirement is written in natural language, particularly English, where a single statement can have more than one meaning.
- **Feasible.** A requirement must be achievable using extant design and engineering processes, extant technologies, and extant manufacturing procedures. A requirement should also be achievable within organizational constraints such as budget and schedule.

Requirements Characteristics ...

- **Implementation independent.** Each requirement must be independent of the method of implementation (process) or physical solution- that is, it should say what is required, rather than how it should be implemented.
- **Justifiable.** Every requirement must be traceable with respect to at least one higher-level requirement.
- **Verifiable.** Each requirement must be verifiable, in that it can be proved that the system meets or possesses the requirement. Verification may be by one or more means.

Requirements Attributes

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- ❖ To support analysis and management, requirements should be recorded with associated information including the following attributes:
 - ❖ Unique identifier
 - ❖ Short title
 - ❖ Priority
 - ❖ Criticality
 - ❖ Feasibility
 - ❖ Risk
 - ❖ Source
 - ❖ Type
 - ❖ Rationale
 - ❖ Relationship to other requirements

Emergent Properties

- Not all properties of a system are exhibited separately by its constituent elements.
- That is, the system may have properties that only exist when the systems are integrated-these are called the emergent properties of a term.
- Emergent properties:
 - are those that are possessed by the system as a whole;
 - only emerge after all the individual subsystems have been integrated;
 - cannot be exhibited by parts of the system in isolation; and
 - depend on interactions between components including their

Emergent Properties ...

- Example of emergent properties are the 'ilities' such as: maintainability, reliability, availability, and usability.
- Other examples include safety, security, comfort, and ease of use.
- Emergent properties must therefore be defined from the top down-they cannot be obtained by specifying requirements for individual subsystems and then hoping that the desired properties will exist on integration.

What is Requirements Engineering?

- Requirements engineering can be described most simply as the process by which we identify a problem's context, locate the business and stakeholder needs and requirements within that context, and deliver specifications that meets those needs.
- Dorfman and Thayer describe requirements engineering as the "science and discipline concerned with analysing and documenting requirements".
- Kotonya and Sommerville define requirements engineering as "the systematic process of eliciting, understanding, analysing, documenting, and managing requirements".
- ISO/IEC stands for International Organization for Standardization/International Electrotechnical Commission (ISO/IEC 29148) defines requirements engineering as the "process through which the acquirer and the suppliers of a system discover, review, articulate, understand, and document the requirements on the system and the life

Why We Need Requirements?

- Requirements are essential in the development of systems, software, products, or any solution-oriented endeavour. Here are some key reasons why requirements are necessary:
 - ❖ **Understanding Stakeholder Needs:** Requirements help in capturing and understanding the needs, expectations, and constraints of stakeholders. They provide a clear understanding of what the stakeholders want to achieve or the problems they want to solve.
 - ❖ **Guiding Development:** Requirements serve as a roadmap for the development process. They provide the basis for designing, building, and implementing a system or product that meets the intended purpose and satisfies stakeholder needs.
 - ❖ **Defining Scope:** Requirements help in clearly defining the boundaries and scope of a project. They outline what is included and what is excluded from the system or product being developed, ensuring that there is a shared understanding among stakeholders.

Why We Need Requirements? ...

- ❖ **Managing Complexity:** Requirements help in managing the complexity of a system or product by breaking it down into smaller, manageable components. They provide a structured approach to addressing various functionalities, features, and interactions within the system.
- ❖ **Facilitating Communication and Collaboration:** Requirements serve as a common language for stakeholders, facilitating effective communication and collaboration among different teams, including developers, designers, testers, and end-users. They ensure that everyone involved has a shared understanding of what needs to be achieved.
- ❖ **Managing Change:** Requirements provide a mechanism for managing changes throughout the development process. As new information emerges or stakeholder needs evolve, requirements act as a reference point for evaluating the impact of changes and making informed decisions.
- ❖ **Ensuring Customer Satisfaction:** Requirements help in aligning the

Why We Need Requirements Engineering?

❖ Requirements Engineering is a systematic and disciplined approach to managing requirements throughout the development lifecycle of a system, software, or product. Here are some reasons why Requirements Engineering is essential:

- ❖ Understanding Stakeholder Needs
- ❖ Minimizing Risks and Costs
- ❖ Enhancing Communication and Collaboration
- ❖ Improving Solution Quality
- ❖ Managing Scope and Change
- ❖ Enhancing Traceability and Accountability
- ❖ Supporting Decision Making
- ❖ Enabling Validation and Verification

Requirements Elicitation and Elaboration

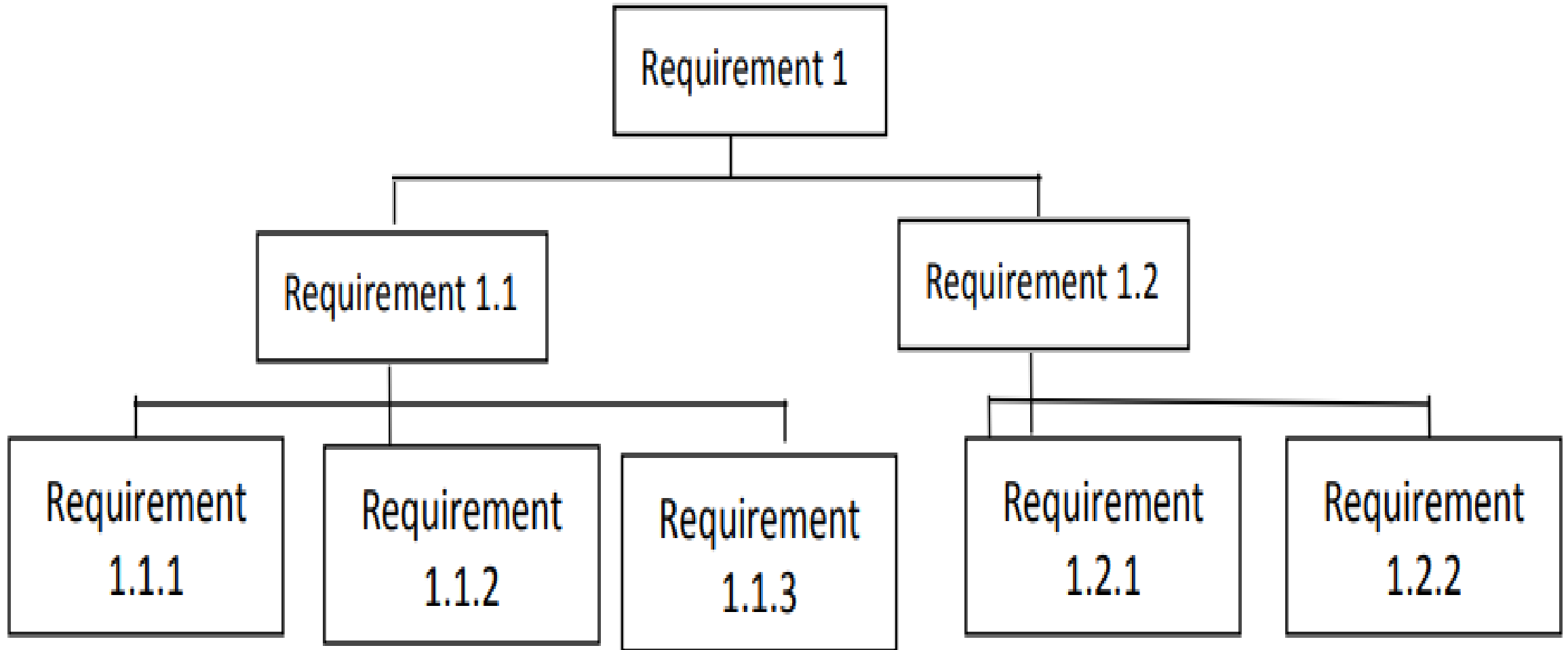
- ❖ **Requirements Elicitation:** is the process of gathering information from stakeholders to identify their needs, expectations, and requirements for a system, software, or product. The goal is to understand the problem domain, the stakeholders' perspectives, and the desired functionalities of the solution.
- During requirements elicitation, **various techniques** are used to collect information, such as:
 - Interviews: One-on-one discussions with stakeholders to gain insights into their needs and expectations.
 - Workshops: Collaborative sessions involving multiple stakeholders to gather

Requirements Elicitation and Elaboration

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- ❖ **Requirements Elaboration:** is the process of **refining** and **expanding** the initially captured requirements to provide more detail and clarity. It involves analysing, validating, and further specifying the requirements to ensure their completeness, consistency, and feasibility.
- ❖ During requirements elaboration, the following activities are typically performed:
 - ❖ **Requirements Analysis:** The elicited requirements are analysed to identify dependencies, conflicts, and inconsistencies. This helps in refining and clarifying the requirements and ensuring they align with stakeholder needs.
 - ❖ **Requirements Prioritization:** The requirements are prioritized based on factors such as their importance, urgency, feasibility, and impact on the system. This helps in planning and resource allocation during development.
 - ❖ **Requirements Specification:** The requirements are further specified and documented in a structured format, such as a requirements specification document. This includes providing more detailed

Requirements Elaboration ...



❖ Figure: The hierarchical elaboration of requirements.

Difficulties in Eliciting and Elaborating Requirements

✓ Eliciting and elaborating requirements can be challenging due to various factors. Here are some common difficulties encountered in these processes:

- Incomplete or Inconsistent Stakeholder Input
- Ambiguity and Lack of Clarity
- Changing Requirements
- Conflicting Requirements
- Domain Complexity and Technical Expertise
- Communication and Collaboration Issues
- Unrealistic or Infeasible Expectations

Requirements Validation

- ✓ Requirements validation is the process of evaluating and verifying the captured requirements to ensure that they are complete, consistent, correct, and aligned with stakeholder expectations.
- ✓ It is an essential part of the requirements engineering process and helps in identifying and addressing any issues or problems with the requirements before proceeding with system development. Some key aspects and techniques involved in requirements validation:
 - ✓ Review and Inspection
 - ✓ Prototyping and Simulation
 - ✓ Requirements Traceability
 - ✓ Stakeholder and User Feedback and Confirmation

Requirements Documentation

- ✓ Writing well-formed requirements can be achieved by using the following guidelines
- Ensure each requirement is a necessary, short, definitive statement.
- Define the appropriate conditions (qualitative or quantitative measures) for each requirement.
- Ensure that each requirement is verifiable associated with writing a verification requirement statement.
- Avoid over-specification, unnecessary constraints and unbounded statements.
- Ensure readability by defining standard templates for describing requirements; using natural language simply, consistently and concisely; using short sentences

Requirements Documentation ...

10	Requirement	Interface	Priority	Risk	Criticality	Feasibility	Originato	Type
12.1.1	Requirement							
12.1.1	Performance statement							
12.1.1	Verification statement							
12.1.1	Rationale statement							
12.1.2	Requirement							
12.1.2	Performance statement							
12.1.2	Verification statement							
12.1.2	Rationale statement							
R								
12.1.3	Requirement Statement							

✓ Figure: Suggested format for a paper-based specification.

Requirements Management

- ❖ Requirements management is the process of effectively managing and controlling the requirements throughout the entire lifecycle of a system, software, or product.
- ❖ It involves activities aimed at capturing, organizing, prioritizing, tracing, and maintaining requirements to ensure their completeness, consistency, and alignment with stakeholder needs and project objectives.
- ❖ It is crucial for successful project execution and delivering a solution that meets customer expectations. Here are the key aspects of requirements management:

1. Requirements Change Management

Requirements Management ...

3. **Requirements Management Tools** are software applications designed to assist in the effective management, documentation, analysis, and traceability of requirements throughout the project lifecycle.

- ❖ These tools provide a centralized platform for capturing, organizing, and maintaining requirements, facilitating collaboration among stakeholders, and supporting efficient requirements management processes.
- ❖ Some commonly used requirements management tools:
- ❖ **IBM Rational DOORS**: is a popular requirements management tool that allows for the capture, analysis, and traceability of requirements. It provides features for organizing requirements hierarchically, creating relationships between requirements, and generating traceability matrices. It also supports version control, change management, and collaboration features.
- ❖ **Jama Connect**: is a web-based requirements management platform that offers capabilities for requirements capture, analysis, and traceability. It provides customizable templates, collaborative

Requirements Management Tools ...

- ❖ **Microsoft Azure DevOps:** formerly known as Visual Studio Team Services (VSTS), is a comprehensive platform that includes requirements management as part of its Application Lifecycle Management (ALM) suite. It offers features for requirements capture, tracking, and traceability, along with integration with other development and project management tools.
- ❖ **Atlassian Jira:** is a widely used project management tool that includes features for requirements management through its plugin called Jira Software. Jira allows for the creation and tracking of requirements as user stories or issues, and it supports traceability through linking requirements with development tasks and test cases.
- ❖ **Gatherspace:** is a cloud-based requirements management tool that provides features for capturing, organizing, and tracking requirements. It offers traceability capabilities, collaboration features, and customizable templates for requirements documentation.

Requirements Management Tools ...

- ❖ Some of the most important **features** of a requirements management tool:
 - Supports requirements elicitation
 - Allows readers to browse
 - Allows specific requirements to be retrieved
 - Supports forward and backward traceability
 - Supports the generation of good requirements
 - Generates reports
 - Allows import and export of requirements in various formats
 - Supports change control and change impact assessment.
 - Supports allocation and logical-to-physical translation
 - Does not enforce a particular requirements engineering process

Requirements Engineering Tools

- ❖ There are a large number of tools that may assist in requirements engineering, including the context diagram, functional flow block diagrams (FFBD), requirements breakdown structure (RBS), and N2 diagrams.
- ❖ Other tools include structured analysis, data flow diagrams (DFD), control flow diagrams (CFD), IDEF diagrams, behavior diagrams, action diagrams, state/mode diagrams, process flow diagrams, function hierarchy diagrams, state transition diagrams (STD), entity relationship diagrams (ERD), structured analysis and design, object-oriented analysis (OOA), unified modelling language (UML) structured systems analysis and design