



Derived from Ryan, M. J.; Wheatcraft, L.S., "On the Use of the Terms Verification and Validation", February 2017

Needs and Requirements are the common threads that tie all lifecycle activities and artifacts together. When formulating the needs and requirements it is important to understand the role of needs and requirements within the context of verification and validation. Once the needs are verified and validated, all subsequent artifacts are validated against the needs and once the resulting design input requirements are verified and validated, all subsequent artifacts are verified against those design input requirements.

When defining needs and requirements, it is important that they have the characteristics of well-formed needs and requirements. These characteristics are a result of following the rules defined in the Guide to Writing Requirements (GtWR) as well as performing the activities associated with the definition of the needs and requirements as discussed in the Needs and Requirements Manual (NRM) and Guide to Needs and Requirements (GtNR). The underlying analysis from which a need or requirement was derived is as important as how well the need or requirement statement is formed.

Definitions

An **entity** is a single item to which a concept, need, or requirement applies: an organization, business unit, project, supplier, service, procedure, SOI (system, subsystem, system element), product, process, or stakeholder class (user, operator, tester, maintainer, etc.).

A **concept** is a textual or graphic representation that concisely expresses how an entity can fulfill the problem, threat, or opportunity it was defined to address within specified constraints with acceptable risk that provides a business capability in terms of people, process, and products.

A **set of lifecycle** concepts includes multiple concepts across the lifecycle of how the organization (and stakeholders within an organization) expect to manage, acquire, define, develop, build/code, integrate, verify, validate, transition, install, operate, support, maintain, and retire an entity.

A **need statement** is the result of a formal transformation of one or more lifecycle concepts into an agreed-to expectation for an entity to perform some function or possess some quality within specified constraints with acceptable risk.

A **requirement statement** is the result of a formal transformation of one or more needs or parent requirements into an agreed-to obligation for an entity to perform some function or possess some quality within specified constraints with acceptable risk.

<p>Formal Transformation. Given the need and requirement is a result of a formal transformation, the following characteristics of a well-formed need or requirement have been derived:</p> <ul style="list-style-type: none"> • C1 - Necessary: The need or requirement statement defines an essential capability, characteristic, constraint, or quality factor needed to satisfy a lifecycle concept, need, source, or parent requirement. • C2 - Appropriate: The specific intent and amount of detail of the need or requirement statement is appropriate to the level (the level of abstraction, organization, or system architecture) of the entity to which it refers. • C5 - Singular: The stakeholder need or requirement statement should state a single capability, characteristic, constraint, or quality factor. • C8 - Correct: The need statement must be an accurate representation of the lifecycle concept or source from which it was transformed. The requirement statement must be an accurate representation of the need, source, or parent requirement from which it was transformed. • C9 - Conforming: Individual needs and requirements should conform to an approved standard pattern and style guide or standard for writing and managing needs and requirements. 	<p>Agreed-to Obligation. Since the need and requirement is to be a part of a fair agreement to meet an obligation, the following characteristics of a need or requirement have been derived.</p> <ul style="list-style-type: none"> • C3 - Unambiguous: Need statements must be written such that the stakeholder intent is clear. Requirement statements must be stated such that the requirement can be interpreted in only one way by all the intended stakeholders. • C4 - Complete: The requirement statement sufficiently describes the necessary capability, characteristic, constraint, or quality factor to meet the need, source, or parent requirement from which it was transformed without needing other information to understand the requirement. • C6 - Feasible: The need or requirement can be realized within entity constraints (for example: cost, schedule, technical, legal, ethical, safety) with acceptable risk. • C7 - Verifiable: The requirement statement is structured and worded such that its realization can be verified to the approving authority's satisfaction..
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Characteristics of well-formed needs and requirements.



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A **need set** is a structured set of agreed-to need expressions for the entity (enterprise/business unit/system/subsystem/system element/process) and its external interfaces.

A **requirement set** is a structured set of agreed-to requirement expressions for the entity (enterprise/business unit/system/subsystem/system element/process) and its external interfaces.

<p>Formal Transformation. Given the set of needs and requirements is the result of a formal transformation, the following characteristics of the need and requirement set have been derived:</p> <ul style="list-style-type: none"> • C10 - Complete: The need or requirement set for a given SOI should stand alone such that it sufficiently describes the necessary capabilities, characteristics, functionality, performance, drivers, constraints, interactions, standards, regulations, and/or quality factors without requiring other sets of needs or requirements at the appropriate level of abstraction. • C11 - Consistent: The sets of needs and requirements contains individual needs or requirements that are unique, do not conflict with or overlap with others in the set, and the units and measurement systems they use are homogeneous. The language used within the sets is consistent (i.e., the same words are used throughout the set to mean the same thing). All terms used within the needs and requirements statements are consistent with the architectural model, project glossary, and project data dictionary. 	<p>Agreed-to Obligation. Since the set of need and requirements is to be a result of a fair agreement to meet an obligation, the following characteristics of the set have been derived:</p> <ul style="list-style-type: none"> • C12 - Feasible: Sets of needs and requirements can be realized within entity constraints (for example, cost, schedule, technical) with acceptable risk. • C13 - Comprehensible: The set of needs and set of resulting requirements must be written such that it is clear as to what is expected of the entity and its relation to the macro system of which it is a part. • C14 - Able to be validated: It must be able to be validated that the integrated set of needs will lead to the achievement of the product goals and objectives, stakeholder expectations, risks, and lifecycle concepts within the constraints (such as cost, schedule, technical, legal and regulatory compliance) with acceptable risk. It must be able to be validated that the set of requirements will lead to the achievement of the integrated set of needs and higher-level requirements within the constraints (such as cost, schedule, technical, and regulatory compliance) with acceptable risk.
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Characteristics of well-formed sets of needs requirements.

Attributes of Need and Requirement Statements (defined in the NRM)

An **attribute** is additional information associated with an entity which is used to aid in its definition and management.

A **need expression** includes a need statement and a set of associated attributes.

A **requirement expression** includes a requirement statement and a set of associated attributes.

A minimum set of attributes that should be defined for each requirement are annotated with an asterisk (“**”)

<p>Attributes to Help Define Needs & Requirement and Their Intent</p> <ul style="list-style-type: none"> A1 - Rationale* A2 - Trace to Parent* A3 - Trace to Source* A4 - States and Modes A5 - Allocation/Budgeting* <p>Attributes Associated with System Verification & System Validation</p> <ul style="list-style-type: none"> A6 - System Verification or System Validation Success Criteria* A7 - System Verification or System Validation Strategy* A8 - System Verification or System Validation Method* A9 - System Verification or System Validation Responsible Organization* A10 - System Verification or System Validation Level A11 - System Verification or System Validation Phase A12 - Condition of Use A13 - System Verification or System Validation Results A14 - System Verification or System Validation Status <p>Attributes to Help Maintain the Requirements</p> <ul style="list-style-type: none"> A15 - Unique Identifier* A16 - Unique Name A17 - Originator/Author* A18 - Date Requirement Entered A19 - Owner* A20 - Stakeholders A21 - Change Board A22 - Change Proposed A23 - Version Number 	<ul style="list-style-type: none"> A24 - Approval Date A25 - Date of Last Change A26 - Stability/Volatility A27 - Responsible Person A28 - Need or Requirement Verification Status* A29 - Need or Requirement Validation Status* A30 - Status of the Need or Requirement A31 - Status (of Implementation) A32 - Trace to Interface Definition A33 - Trace to Dependent Peer Requirements A34 - Priority* A35 - Criticality or Essentiality* A36 - Risk (of Implementation) * A37 - Risk (Mitigation) A38 - Key Driving Need or Requirement (KDN/KDR) A39 - Additional Comments A40 - Type/Category <p>Attributes to Show Applicability and Allow Reuse</p> <ul style="list-style-type: none"> A41 - Applicability A42 - Region A43 - Country A44 - State/Province A45 - Market Segment A46 - Business Unit <p>Attributes to Aid in Product Line Management</p> <ul style="list-style-type: none"> A47 - Product Line A48 - Product Line Common Needs and Requirements A49 - Product Line Variant Needs and Requirements
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Rules for Need and Requirement Statements and Sets of Needs and Requirements

<p>Accuracy</p> <p>R1 - Use a structured, complete sentence: subject, verb, object.</p> <p>R2 - Use the active voice in the main sentence structure of the need or requirement statement with the responsible entity clearly identified as the subject of the sentence.</p> <p>R3 - Ensure the subject and verb of the need or requirement statement are appropriate to the entity to which the need or requirement refers.</p> <p>R4 - Define terms in a glossary, data dictionary, etc.</p> <p>R5 - Use definite article “the” rather than the indefinite article “a.”</p> <p>R6 - Use appropriate units when stating quantities. All numbers should have units of measure explicitly stated.</p> <p>R7 - Avoid the use of vague terms such as “some”, “any”, “allowable”, “several”, “many”, “a lot of”, “a few”, “almost always”, “very nearly”, “nearly”, “about”, “close to”, “almost”, and “approximate”.</p> <p>R8 - Avoid escape clauses such as such as “so far as is possible”, “as little as possible”, “where possible”, “as much as possible”, “if it should prove necessary”, “if necessary”, “to the extent necessary”, “as appropriate”, “as required”, “to the extent practical”, and “if practicable..</p> <p>R9- Avoid open-ended clauses such as “including but not limited to”, “etc.” and “and so on.”.</p> <p>Concision</p> <p>R10 - Avoid superfluous infinitives such as “.. be designed to ...”, “...be able to”, “...be capable of...”.</p> <p>R11 - Use a separate clause for each condition or qualification.</p> <p>Non-ambiguity</p> <p>R12, 13, 14 - Use correct grammar, spelling, punctuation.</p> <p>R15 - Use a defined convention to express logical expressions such as “[X AND Y]”, “[X OR Y]”, “[X XOR Y]”, “NOT[X OR Y]”.</p> <p>R16 - Avoid the use of “not.”</p> <p>R17 - Avoid the use of the oblique (“/”) symbol except in units, i.e. Km/hr</p> <p>Singularity</p> <p>R18 - Write a single sentence that contains a single thought conditioned and qualified by relevant sub-clauses.</p> <p>R19 - Avoid combinators that join clauses, such as “and”, “or”, “then”, “unless”, “but”, “as well as”, “but also”, “however”, “whether”, “meanwhile”, “whereas”, “on the other hand”, or “otherwise.”</p> <p>R20 - Avoid phrases that indicate the purpose of the need or requirement.</p> <p>R21 - Avoid parentheses and brackets containing subordinate text.</p> <p>R22 - Enumerate sets explicitly instead of using a group noun to name the set.</p> <p>R23 - When a need or requirement is related to complex behavior, refer to the supporting diagram or model.</p>	<p>Completeness</p> <p>R24 - Avoid the use of pronouns and indefinite pronouns.</p> <p>R25 - Avoid relying on headings to support explanation or understanding of the requirement.</p> <p>Realism</p> <p>R26 - Avoid using unachievable absolutes such as 100% reliability, 100% availability, all, every, always, never, etc.</p> <p>Conditions</p> <p>R27 - State applicability conditions explicitly.</p> <p>R28 - Express the propositional nature of a condition explicitly for a single action instead of giving lists of actions for a specific condition.</p> <p>Uniqueness</p> <p>R29 - Classify the needs and requirements according to the aspects of the problem or system it addresses.</p> <p>R30 - Express each need and requirement once and only once.</p> <p>Abstraction</p> <p>R31 – When defining design inputs avoid stating a solution unless there is rationale for constraining the design. Focus on the problem “what” rather than the solution “how.”</p> <p>Quantifiers</p> <p>R32 - Use “each” instead of “all”, “any” or “both” when universal quantification is intended</p> <p>Tolerance</p> <p>R33 - Define quantities with a range of values appropriate to the entity to which the apply and to which the entity will be verified or validated against.</p> <p>Quantification</p> <p>R34 - Provide specific measurable performance targets appropriate to the entity to which the need or requirement is stated and against which the entity will be verified to meet.</p> <p>R35 - Define temporal dependencies explicitly instead of using indefinite temporal keywords such as “eventually”, “until”, “before”, “after”, “as”, “once”, “earliest”, “latest”, “instantaneous”, “simultaneous”, “at last”.</p> <p>Uniformity of Language</p> <p>R36 - Use each term consistently throughout need and requirement sets.</p> <p>R37 - Use a consistent set of acronyms.</p> <p>R38 - Avoid the use of abbreviations.</p> <p>R39 - Use a project-wide style guide for individual needs and requirements and for sets of needs and requirements statements.</p> <p>Modularity</p> <p>R40 - Group related requirements together.</p> <p>R41 – Conform to a defined structure or template for sets of needs and requirements</p>
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Rules to Characteristics Cross Reference Matrix

Quality Focus	Rule	Subject	Characteristics for Individual needs and requirements									Characteristics for Sets of needs requirements				
			Necessary	Appropriate	Unambiguous	Complete	Singular	Feasible	Verifiable	Correct	Conforming	Complete	Consistent	Feasible	Comprehensible	Able to be validated
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
Accuracy	R1	Structured, complete sentence			X	X			X	X	X					
	R2	Use active voice		X	X	X			X							
	R3	Use appropriate subject verb		X	X				X			X				X
	R4	Define terms			X				X				X		X	X
	R5	Use definite article "the" vs "a"			X				X							
	R6	Use appropriate units			X	X			X	X						
	R7	Avoid vague terms			X	X			X							
	R8	Avoid escape clauses			X				X							
	R9	Avoid open-ended clauses			X	X	X		X							
Concision	R10	Avoid superfluous infinitives			X				X							
	R11	Use a separate clause			X	X			X	X						
Non-ambiguity	R12	Use correct grammar			X				X	X	X					
	R13	Use correct spelling			X				X							
	R14	Use correct punctuation			X					X						
	R15	Logical expressions			X				X							
	R16	Avoid the use of "not."			X				X	X						
	R17	Avoid the oblique ("/") symbol			X				X							
Singularity	R18	Use single thought sentence			X		X		X		X				X	
	R19	Avoid combinators			X		X									
	R20	Avoid phrases of purpose or reason	X				X									
	R21	Avoid parentheses & brackets					X									
	R22	Enumerate sets explicitly			X		X									
	R23	Supporting diagram or model			X	X	X									
Completeness	R24	Avoid pronouns & indefinite pronouns			X	X			X							
	R25	Avoid relying on headings				X										
Realism	R26	Avoid using unachievable absolutes						X	X	X				X		
Conditions	R27	State applicability conditions explicitly				X			X	X						
	R28	Single condition for a specific action			X				X							
Uniqueness	R29	Classify by type or category										X	X			
	R30	Express once and only once	X								X		X			
Abstraction	R31	Avoid stating a solution		X												
Quantifiers	R32	Use "each" for universal quantification			X				X	X						
Tolerance	R33	Define quantities with a range of values			X	X		X	X	X				X		
Quantification	R34	Specific measurable performance targets			X	X			X					X		
	R35	Define temporal dependencies explicitly			X	X			X							
Uniformity of Language	R36	Use terms & units of measure consistently			X					X	X		X		X	X
	R37	Use a consistent set of acronyms			X						X		X		X	X
	R38	Avoid the use of abbreviations								X		X		X	X	X
	R39	Use a project-wide style guide				X	X			X		X		X	X	X
Modularity	R40	Group related needs & requirements				X					X	X	X		X	X
	R41	Conform to a defined structure or template										X	X		X	X



NRM Concepts and Activities to Characteristics Cross Reference Matrix Part 1

NRM Concepts and Activities		Characteristics for Individual needs and requirements									Characteristics for Sets of needs requirements				
		Necessary	Appropriate	Unambiguous	Complete	Singular	Feasible	Verifiable	Correct	Conforming	Complete	Consistent	Feasible	Comprehensible	Able to be validated
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
SECTION 3: INFORMATION-BASED NEEDS AND															
3.2.1.1	Communication			X				X							X
3.2.1.2	Power of Expression			X	X			X						X	X
3.2.1.3	Managing Sets of Needs And Requirements				X									X	
3.2.1.5	Attributes	X												X	
3.2.1.6	Formal, Binding Agreement	X		X	X		X	X						X	X
3.2.1.7	System Verification and System Validation							X							X
3.2.2.1	Analysis from Which Needs and Requirements are Derived	X					X		X		X	X	X	X	X
3.2.2.2	Completeness										X			X	X
3.2.2.3	Consistency											X		X	X
3.2.2.4	Identity and Manage Interdependencies								X			X		X	X
3.2.2.5	Support Simulations							X						X	X
3.2.2.6	Key to Understanding													X	X
SECTION 4: LIFECYCLE CONCEPTS AND NEEDS DEFINITION															
4.3.3	Identify External and Internal Stakeholders										X				
4.3.6.2	Technology Maturity						X						X		
4.3.7.1	Classes of Risk - Development Risk						X						X		
4.4.3	Get Stakeholder Agreement	X		X	X			X	X		X	X		X	X
4.4.4	Completeness										X				
4.5	Lifecycle Concepts Analysis and Maturation	X			X		X	X	X			X			
4.5.1	Feasibility						X						X		
4.5.3	User of Diagrams and Models for Analysis	X							X		X	X			
4.5.4	Levels of Detail and Abstraction		X												
4.5.7.1	Model Development, Analysis, and Maturation	X							X		X	X			
4.5.7.4	Zeroing in on a Feasible Architecture and Design						X						X		
4.6.2.3	Organizing the Integrated Set of Needs									X	X				
4.6.3.1	Managing Unknowns			X	X		X	X	X						
4.6.3.2	Appropriate to Level		X												
4.6.3.3	Completeness of the Integrated Set of Needs										X				
4.6.3.4	Needs Feasibility and Risk	X	X				X						X		
4.7	Plan for System Validation														X
4.8	Baseline & Manage Lifecycle Concepts & Needs Definition Outputs	X		X	X		X		X		X	X	X	X	X
SECTION 5: NEEDS VERIFICATION AND NEEDS VALIDATION															
5.1.2	Perform Needs Verification	X		X	X					X	X	X			X
5.2	Needs Validation														X
5.2.2	Perform Needs Validation			X			X		X		X		X	X	X



NRM Concepts and Activities to Characteristics Cross Reference Matrix Part 2

NRM Concepts and Activities		Characteristics for Individual needs and requirements									Characteristics for Sets of needs requirements				
		Necessary	Appropriate	Unambiguous	Complete	Singular	Feasible	Verifiable	Correct	Conforming	Complete	Consistent	Feasible	Comprehensible	Able to be validated
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
SECTION 6: DESIGN INPUT REQUIREMENTS DEFINITION															
6.2	Perform Design Input Requirements Definition	X	X					X	X		X	X	X	X	X
6.2.1	Transforming Needs into Design Input Requirements	X			X						X				
6.2.1.1	Organizing Sets of Design Input Requirements		X							X	X				
6.2.1.2	Considerations For Each Type Of Requirement				X			X	X		X				
6.2.1.4	Appropriate to Level		X												
6.2.1.5	Managing Unknowns			X	X		X	X	X						
6.2.2	Establish Traceability	X									X	X			
6.2.2.1	Establishing Traceability Between Dependent Peer Requirements											X			
6.2.3.6	Interface Requirements Audit	X			X			X	X		X	X			X
6.2.5	Plan for System Verification							X							
6.2.6.2	Completeness, Correctness, and Consistency								X		X	X			
6.2.6.3	Requirements Feasibility and Risk	X	X				X						X		
6.3	Baseline and Manage Design Input Requirements	X		X	X		X		X		X	X	X	X	X
6.4.3	Allocation – Flow Down of Requirements		X								X	X			
6.4.4	Defining Child Requirements that Meet the Intent of the Allocated Parents										X				
6.4.5	Budgeting of Performance, Resource, and Quality Requirements										X	X			
6.4.7	Use of Traceability and Allocation to Manage Requirements	X							X		X	X			X
SECTION 7: DESIGN INPUT REQUIREMENTS VERIFICATION & VALIDATION															
7.1.2	Perform Design Input Requirements Verification	X		X	X			X		X	X	X			X
7.2	Design Input Requirements Validation														X
7.2.2	Perform Design Input Requirements Validation	X		X	X		X		X		X	X	X	X	X
SECTION 8: DESIGN VERIFICATION AND DESIGN VALIDATION															
8.1	Design Definition Process Overview			X	X		X	X	X		X	X	X	X	X
8.2	Early System Verification and System Validation			X	X		X	X	X		X	X	X	X	X
8.4	Design Verification			X	X		X	X	X		X				
8.5	Design Validation										X	X	X	X	X
SECTION 14: NEEDS, REQUIREMENTS, VERIFICATION, & VALIDATION MANAGEMENT															
14.2.1	Baseline Needs, Requirements, and Specifications	X		X	X		X		X		X	X	X	X	X
14.2.4	Managing Unknowns			X	X		X	X	X		X				
14.2.7	Combine Allocation and Traceability to Manage Requirements	X							X		X				X
14.2.8	Managing Interfaces										X	X			X
14.2.9	Managing System Verification and System Validation							X							X



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