What is Technology Readiness Level (TRL)?

Technology Readiness Level (TRL) is a standardized scale used to assess the maturity of a particular technology, ranging from initial concept and basic research (TRL 1) to fully developed and operational systems (TRL 9). This framework provides a clear indication of a technology's development stage, serving as a valuable tool for informed decision-making in areas such as project funding, risk assessment, and technology transition.

Origin:

The Technology Readiness Level (TRL) framework was first introduced by NASA as a tool for managing technological risks in its space exploration programs.

Global Standardization:

The ISO 16290:2013 standard provided further standardization of the Technology Readiness Level (TRL) scale.

Technology Readiness Levels (TRL)

Actual system proven through successful mission operations.	9	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.
Actual system completed and qualified through test and demonstration.	8	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the en of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
System prototype demonstration in an operational environment.	7	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space.
System/subsystem model or prototype demonstration in a relevant environment.	6	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness.
Component and/or breadboard validation in relevant environment.	5	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
Component and/or breadboard validation in laboratory environment	4	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
Analytical and experimental critical function and/or characteristic proof of concept.	3	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
Technology concept and/or application formulated.	2	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
Basic principles observed and reported	1	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.

Image source: Defense Acquisition Guidebook, U.S. Department of Defense, 2010, https://api.army.mil/e2/c/downloads/404585.pdf.

Questionnaire for TRL Calculation

Please Answer (Yes/No/Not Applicable)

Basic Principles Observed	TRL-1
1: Have fundamental scientific principles been identified and examined?	
2: Has a literature review been conducted to explore relevant theories?	
3: Have observations or theoretical insights been systematically documented?	
Technology Concept Formulated	TRL-2
1: Have potential applications of the technology been identified?	
2: Has a conceptual model or hypothesis been developed?	
3: Have preliminary experimental designs been created?	
Experimental Proof of Concept	TRL-3
1: Were the initial laboratory experiments conducted?	
2: Were experimental results obtained to demonstrate feasibility?	
3: Were the key technical challenges identified?	
Technology Validated in a Lab	TRL-4
1: Have you created a working prototype in the laboratory?	
2: Have you carried out thorough laboratory testing?	
3: Have you recorded results verifying the expected performance?	
Technology Validated in a Relevant Environment	TRL-5
1: Has the technology been tested in a relevant environment?	
2: Have field tests or pilot studies been conducted?	
3: Has the effectiveness and reliability been demonstrated?	

Technology Demonstrated in a Relevant Environment TRL-6

- 1: Has an advanced prototype been developed that closely resembles the final product?
- 2: Has extensive testing been conducted in a relevant environment?
- 3: Have the documented results demonstrated compliance with performance criteria?

System Prototype Demonstration in an Operational Environment TRL-7

- 1: Was the system prototype developed to closely resemble the final product?
- 2: Were operational tests conducted in a real-world environment?
- **3:** Do the results confirm the technology's readiness for the final product?

System Complete and Qualified

TRL-8

- 1: Has the development been completed and successfully integrated into the final product?
- **2:** Has thorough testing and validation been conducted?
- **3:** Are there any certifications or qualifications confirming readiness?

Actual System Proven in an Operational Environment TRL-9

- 1: Has it been successfully implemented in a real-world operational setting?
- **2:** Are there documented case studies or proven operational outcomes?
- **3:** Has it been adopted and utilized by end-users or customers?

Application of TRL assessment:

1. Assessing Technology Maturity

- TRLs provide a standardized scale (from TRL 1 to TRL 9) to assess how developed a technology is—from basic research (TRL 1) to fully operational systems (TRL 9).
- Helps stakeholders understand the current stage and what is required to advance.

2. Guiding Funding Decisions

- Investors, governments, and R&D organizations use TRLs to decide where to allocate funding.
- Early-stage technologies (TRL 1-3) may need research grants, while mid-stage (TRL 4-6) might attract venture capital or pilot program funding.

3. Strategic Planning & Roadmapping

- TRLs are used in technology roadmaps to plot development paths and timelines.
- Helps identify technical risks and prioritize actions needed to advance a technology to the next level.

4. Proposal and Grant Requirements

- Many public and private funding bodies (like the EU's Horizon Europe, DOE, DARPA, etc.) require TRL levels in applications.
- Helps reviewers quickly gauge how close the technology is to deployment.

5. Risk Management

• Lower TRLs imply higher technical risk; organizations use TRLs to assess and mitigate such risks in R&D and product development.

6. Collaboration and Communication

- TRLs offer a common language between engineers, researchers, managers, and investors.
- Makes cross-functional and cross-organizational communication clearer and more effective.

7. Product Development and Innovation Management

- TRLs help track progress in innovation pipelines.
- Companies use TRLs to decide when to transition technologies from research to product development or commercialization.

8. Technology Transfer and Commercialization

- Institutions use TRLs to assess when a technology is ready to be licensed or spun out into a startup.
- Easier to match technology with appropriate partners, investors, or manufacturers.

To know more about TRL Calculation reach out at em_ipr@iiti.ac.in (Dr. Archana Chaudhary, Executive Manager, IP Management & Techno-commercialization)