TII Publications

Guidelines for the Implementation of Innovation

GE-GEN-01006
December 2020

Technical

About TII

Transport Infrastructure Ireland (TII) is responsible for managing and improving the country's national road and light rail networks.

About TII Publications

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Executive Summary

Transport Infrastructure Ireland (TII) supports innovation and the adoption of suitable technologies in order to deliver on their strategic objectives as outlined in their Statement of Strategy 2021-2025. TII is therefore committed to full engagement with an ongoing process of research, innovation and continuous improvement through the deployment of innovative technologies.

TII recognises the need to deliver a future for the organisation that is safe, sustainable, scalable and technologically aware. Vision and trust are the fundamentals of innovation and will form the basis of TII's innovation culture.

For an innovation process to succeed it must firstly:

   a)   Manage the potential conflict between implementation of the process into the core business;

   b)   Manage the risk and vulnerabilities, resultant from the innovation;

   c)   Continue to scan the marketplace for compatible developments from stakeholders, suppliers and influencers, that may affect future business.

These TII 'Guidelines for the Implementation of Innovation' have been developed to provide a consistent approach to the assessment of the readiness of potentially innovative products and processes. Dependent on their assessed maturity they may be adopted directly into unrestricted use or progressed to Technology Readiness Level (TRL) 9 through research and /or deployment as a pilot or trial. This document complements the Innovation Strategy and Implementation plan developed to address Innovation both external to and within TII and to ensure consistency of approach as well as cultural fit around Innovation. The Guidelines themselves encourage the creativity required to innovate, whilst identifying the "rules" that must govern new innovations, allowing TII to analyse the potential risks of the introduction of such innovations in a consistent manner as part of a TII Innovation Strategy. TII has exploited existing TLRs to create a new mechanism to achieve the following key aims:

   1.   Ensure **transparency** around innovation deployments;

   2.   Ensure **efficiency** by streamlining market engagement; and

   3.   **Manage risk** to TII by safeguarding its risk profile.

TII has created its own TRLs and assessment methodology for application in the specific environment of the TII road and light rail networks. It enables TII to assess the risks of deploying innovative technologies and allows the supplier and TII staff to assess the level of readiness for deployment when benchmarked against the criteria outlined in this document.

TII has identified a number of different risks that align with the requirements of the different TRLs and has developed associated actions/responsibilities for the supplier and TII. The approach put forward has been designed with the specific aim of ensuring consistency in the engagement between the supplier and TII in terms of assessment and fit for use.

Creating a bespoke approach to TRLs, developed on the basis of TII's particular needs and project profile, ensures that the benchmarking and evaluation will be appropriate for universal application across all of TII's future technological or innovation deployments. This allows TII to fully appreciate the risk of the proposal, from both a piloting stage to long term operations integration, whilst simultaneously allowing the supplier to understand their requirements.

TRLs were originally developed in the 1960s by NASA in order to provide a cohesive methodology for migrating from an 'idea' to a 'product' and managing the associated risk and confidence levels.

The TRLs outlined in this document are based on the NASA approach but have been modified in order for the same approach to be fit for purpose for products/process or technologies that have been developed already to some degree of TRL and will not start at TRL 1 but at a different TRL. The table overleaf identifies the base level requirements for each level and clarifies the level of documentation and testing etc. that is expected from a potential supplier to demonstrate the TRL level to which the product has been developed.

The table is a critical part of the document and it presents the supplier with an overview of expectations around progress across the TRLs and describes the principal distinguishing characteristics for each level.

In parallel, it is also recognised that technology maturity in itself is not the only indicator of the likelihood of a positive outcome from the implementation of innovation. TRLs are just one of many "readiness-level" indicators, and the commercial viability of an innovation, irrespective of its TRL, must also be assessed. TII therefore also considers business readiness levels (BRLs), which represent the stage of business development for process, service, technology or social innovations. BRLs are usually used to communicate the amount of risk and uncertainty associated with an innovation, and often represent a decision-making tool for the implementation of an innovative idea. A BRL assessment scale will be used in conjunction with the TRL scale in TII's final decision-making process regarding innovation. Further information can be found in Appendix A.

TRL	Solution Function Defined	KPIs for solution provisionally defined	Component Specification	Laboratory Testing	CRS and CBS	System Testing	Prototype Testing	Monitored Deployment	Risk Acceptable Deployment	Evidence required for moving between TRLs
1	■									N/A
2	■	■								Further contextual evidence and solution description are provided; KPIs are provisionally defined, and possible development trajectories are provided, including funding
3	■	■	■							Breakdown of system components is provided; functional specification is defined; laboratory testing is being designed; more detailed risk assessment
4	■	■	■	■						Laboratory testing is taking place; KPIs for the solution are verified and validated; conformance to relevant Standards is demonstrated; route to market is summarised, and preparations are being made for production
5	■	■	■	■	■					CRB and CRS are defined; technical specification is developed; system-level integration is being defined; performance is being tested; and production methods are validated
6	■	■	■	■	■	■				Testing is performed in operations-representative environment; financial risk management procedures are developed
7	■	■	■	■	■	■	■			Prototypes are developed; testing is taking place in a live environment to verify its functionality; deployment parameters are being developed; and solution performance is approved
8	■	■	■	■	■	■	■	■		The solution is being deployed under control to exclude anomalies and capture any situational performance issues; the system is ready and qualified for live deployment
9	■	■	■	■	■	■	■	■	■	The solution is proven and fit for purpose

1.   Introduction

In line with the TII Statement of Strategy 2021-2025, the TII Innovation Guidelines facilitate creative solutions to enhance the services it provides through the adoption of innovative technologies and practices. The Guidelines are designed to promote and encourage innovation in a way that incorporates sustainability.

1.1   Context

As stated in the Innovation Strategy and based on the OECD (Oslo Manual of the Organisation for Economic Co-operation and Development), Innovation is "the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations".

However, innovation is a broad area of consideration, both in terms of how it can be embedded into an organisation as well as how external innovation can be introduced. To ensure that internal TII drivers are aligned to external market forces it is important that an innovation development management process is created. This will be composed of three main elements with three key deliverables:

- An Innovation Strategy, documenting the vision for fostering a culture of innovation within TII;

- An Innovation Implementation Plan to complement the strategy, demonstrating the methods for embedding a culture of innovation within TII; and

- Innovation Guidelines for encouraging and monitoring innovation during collaboration with external suppliers.

The Innovation Guidelines focus on creating a clear and transparent guideline process for external collaborators to engage with TII. The other documents, such as the Innovation Implementation plan that is in development, form part of TII's own approach to ensuring a culture of Innovation.

1.2   Purpose of this Document

TII supports innovation and the adoption of suitable technologies in order to deliver on their strategic objectives. TII is therefore committed to full engagement with an ongoing process of research, innovation and continuous improvement through the deployment of innovative technologies. The purpose of the development of Innovation Guidelines includes the following:

- Ensure **transparency** around innovation deployments;

- Ensure **efficiency** by streamlining market engagement; and

- **Manage risk** to TII by safeguarding its risk profile.

This document outlines TII's policy on the development and management of innovation with a view to facilitating the introduction of new technology onto the national road and light rail networks in the most effective manner. It outlines the process and results of the methodology employed to develop TII's own framework for assessing the maturity, or technology readiness level, of any new product, system or technology that it intends to deploy.

It explains the technology maturity assessment tool developed specifically for TII – the nine-level TII Technology Readiness Level (TRL) scale – and provides suppliers with a guide for its use.

The TRL scale will be used alongside a second readiness-level indicator system known as Business Readiness Levels (BRLs), also known as innovation readiness levels (see Appendix A). Further information is provided on this below.

1.3 Application

These Guidelines are appropriate for use in the following:

- Evaluation of new solutions, technologies and processes as proposed by the supplier market in response to a request from TII itself;

- Proposals from the supplier market based on technical insight or other projects that in turn could provide benefit to TII that is not readily identified as yet; and

- Validation of fundamental changes to existing processes or technologies that sit outside current standards and specifications as used by TII.

1.4 Areas of Consideration

To ensure the Guidelines are fit for purpose and are aligned to TII activities, it is important that a number of elements are considered as part of an overall approach to Innovation and how the Guidelines align to these. Key elements include:

- Procurement

- Risk

- Pilots and Trials

- Research

- Governance

Procurement

Guidance exists already within TII ('Guide to Procurement Law') in terms of how procurement is undertaken and aligned to EU requirements as stated in the *2014 EU Procurement Directives*. The new Directives include a number of features to promote the procurement of innovative works, services and supplies. Most notably, the Directives introduce the "innovative partnership", a new procedure designed for use in circumstances where a contracting authority or entity has a requirement for products, works, and/or services which is not met by the market, and requires the development of a new, innovative product, work or service. The procedure allows contracting authorities and entities to establish long-term partnerships with tenderers, covering the development and the subsequent purchase of a new, innovative product, work or service, provided it can be delivered to the agreed levels of performance and costs. The roots of this procedure lie in the Europe 2020 Strategy and specifically, the strategic role assigned to procurement as a means of encouraging innovation. The procedure is designed to facilitate the procurement of innovative products, services and works. In this regard, the procedure allows contracting authorities and entities to establish a long-term relationship with one or more partners for the development as well as the subsequent purchase of a new, innovative product, service or works. Depending on the type of product or process it will require agreements on approaches to both intellectual property rights and mitigation for non-performance costs.

Risk

The management of Risk against the learnings and outcomes from innovative approaches and technologies must be at all times centred around ensuring no change to the safety and operational requirements of TII at a minimum.

Through the development of details outlined in the Guidelines themselves, there is a structured and clear approach that ensures a structured and informed approach to risk exposure. The risk management strategy complements the technical details in this document.

Pilots and Trials

TII has a defined process for assessing products in their latter development phases through its Pilots and Trials (P&T) procedure. The Innovation Guidelines are intended to support suppliers in their development of an innovative product or service from the research phase to the piloting phase, allowing a seamless transition from ideation to deployment, if the product has not attained previously sufficient maturity to be assigned a TRL 9 performance level. The Pilots and Trials procedure documents the management requirements from the TII side for testing of an innovation that has attained a TRL deemed sufficient to allow it to be trialled.

Research

Research and Innovation can go hand in hand depending on how and where the research is to be applied. It is important that there are transparent and consistent approaches to both areas and in turn how they work together.

As such, the objectives of strategic research undertaken must remain cognisant of the Guidelines themselves as well as an overall approach to Innovation. TII's Research and Development Strategy provides for the development of innovation products and services at the lower end of the TRL scale, and it will be important to ensure that the Innovation Guidelines incorporate the objectives of fundamental and applied research as outlined in the Research Strategy.

Governance

To ensure sustainable outcomes from innovation, three fundamentals must always be considered, namely:

- Technical requirements
- Financial requirements
- People requirements

As outlined in this Guideline document, these elements are considered across the various Technology Readiness Levels.

Governance requires the establishment of procedures and continuous monitoring of their implementation in an equitable and transparent system. The Guidelines provide a structure that is fully compatible with the principles of good governance.

A summary of these findings is included in the Table below:

Table 1.1   Alignment Summary

Identify Management Areas for Consideration	Potential issues / conflicts	Identify Resolution
Procurement	Ascertain any potential impact on existing public procurement processes; align with EU approaches; what possible changes would be required to accommodate innovation?	Resolution is that the Procurement team must be engaged as part of the process to ensure that competitive advantage is not created alongside testing and evaluation of Innovation.
Risk	Is any risk exposure brought about through openness to innovation being managed? Is there any impact on risk management procedures?	There is no obvious risk exposure at this point in time. The risk management strategy complements the technical details in this document.
Pilots and Trials	Do protocols for P&T and for Innovation implementation align? If not what should be done to ensure consistency?	The documentation relating to the Pilots and Trials will need to acknowledge the Guidelines as well as reference their use and applicability in relation to relevant TRL levels etc.
Research	How does Innovation management tie in with research strategy? If not what should be done to ensure consistency?	Outcomes to be achieved along with strategic research objectives must be aligned to the Guidelines document as well as ensuring the Research strategy itself references this work.
Governance	What would a lack of template for encouraging and facilitating innovation in TII deployments demonstrate about governance within the organisation?	Formal procedures within the assessment of TRL level are consistent the principles of good governance.

1.5   Process

The Guidelines also outline a clear process for the assessment and approval of new technologies. This includes the following steps:

1.   Solution review

2.   Risk analysis

3.   TRL assessment

4.   TII confidence level assessment

5.   Decision on action for TII and supplier based on Technology Readiness Level (TRL)

A process flow diagram is provided below.
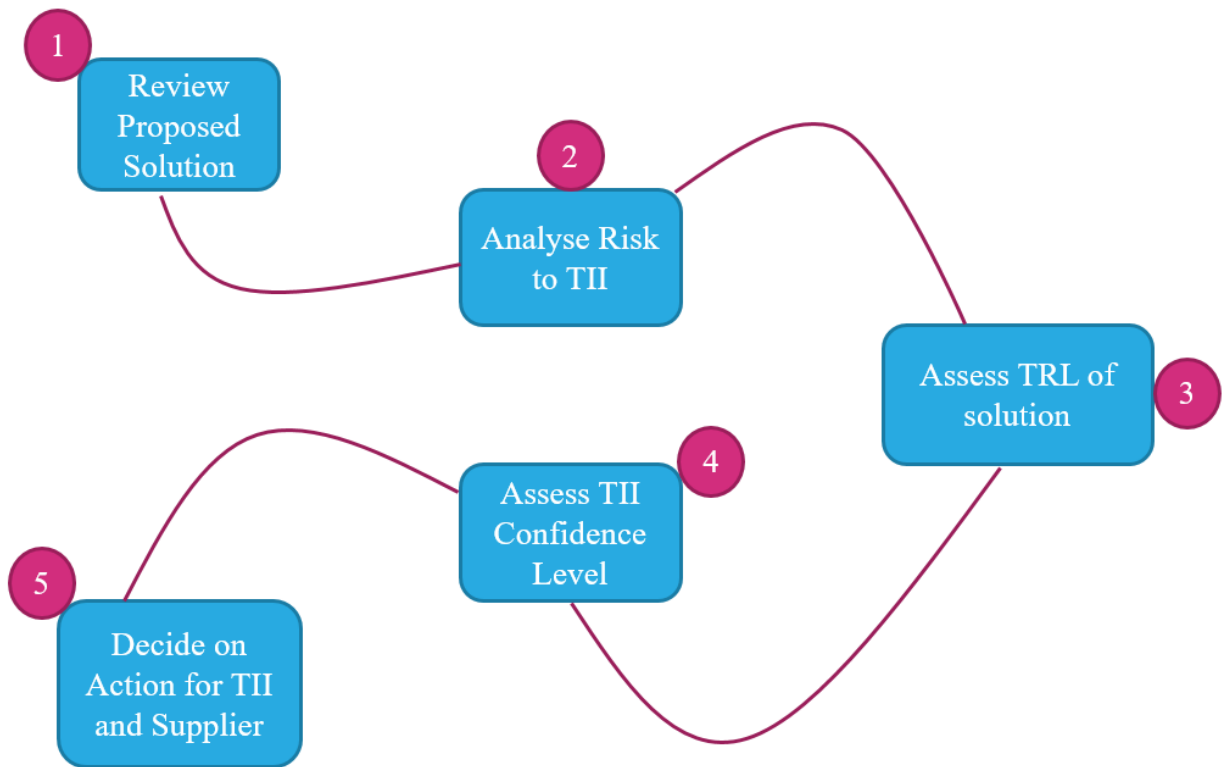
New Solution Assessment

Figure 1.1   New Solution Assessment

The process will determine the TII TRL that a proposed innovation solution has achieved. It is expected that, after stage 5, a decision will be made with respect to the progress of an innovative solution and a way for this to develop towards deployment.

1.6   Approach

The starting point for these Guidelines is the assumption of a competitive dynamic between suppliers and TII. This would consist of the supplier market forging 'association' with TII in order to drive market awareness, increase sales and position themselves as a respected innovation solution in a competitive market. The supplier market wants to achieve this either through piloting or full scale deployment. In response, TII must ensure that risk is managed and controlled at all times. The selected methodology was therefore designed to take a broad view of existing similar technology readiness scales in order to develop a scale tailored to the requirements of TII, and accounting for its specific risk profile.

This document contains detail that is relevant to a variety of interested parties. Readers concerned exclusively with the assessment of an innovation solution can proceed directly to **Chapter 4: TII Technology Readiness Levels** and **Chapter 5: TII TRLs - The Supplier Guide** and continue from there.

2.   Methodology

A global approach to understanding the level of maturity and risk associated with innovative deployments is to benchmark the capability of the supplier offering against an index of technology readiness levels. This is the approach that TII has adopted, incorporating an international assessment of related and relevant examples of technology readiness assessment methodologies. An overview of the key steps followed in the methodology for producing these Guidelines is provided below:

1. Purpose

2. Application

3. Methodology

4. Review of relevant industry TRLs

5. Adaptation of TRLs for TII

6. Scoping and defining Risk for TII

7. Defining TRL requirements for TII solutions

8. Defining actions for TII and for the supplier at each level

9. Assessment methodology for new solutions

10. Benefits to TII

At the forefront of the assessment tool is the Technology Readiness Level (TRL) scale, developed by NASA in the twentieth century as a system to assess the maturity level of aerospace technologies. Each technology project is evaluated against the parameters for each technology level and is then assigned a TRL rating based on the project's progress. There are nine technology readiness levels, as illustrated below.

TRL 9
•Actual system "flight proven" through successful mission operations

TRL 8
•Actual system completed and "flight qualified" through test and demonstration (ground or space)

TRL 7
•System prototype demonstration in a space environment

TRL 6
•System/subsystem model or prototype demonstration in a relevant environment (ground or space)

TRL 5
•Component and/or breadboard validation in relevant environment

TRL 4
•Component and/or breadboard validation in laboratory environment

TRL 3
•Analytical and experimental critical function and/or characteristic proof-of-concept

TRL 2
•Technology concept and/or application formulated

TRL 1
•Basic principles observed and reported

Figure 2.1   NASA TRL Scale https://www.nasa.gov/sites/default/files/trl.png
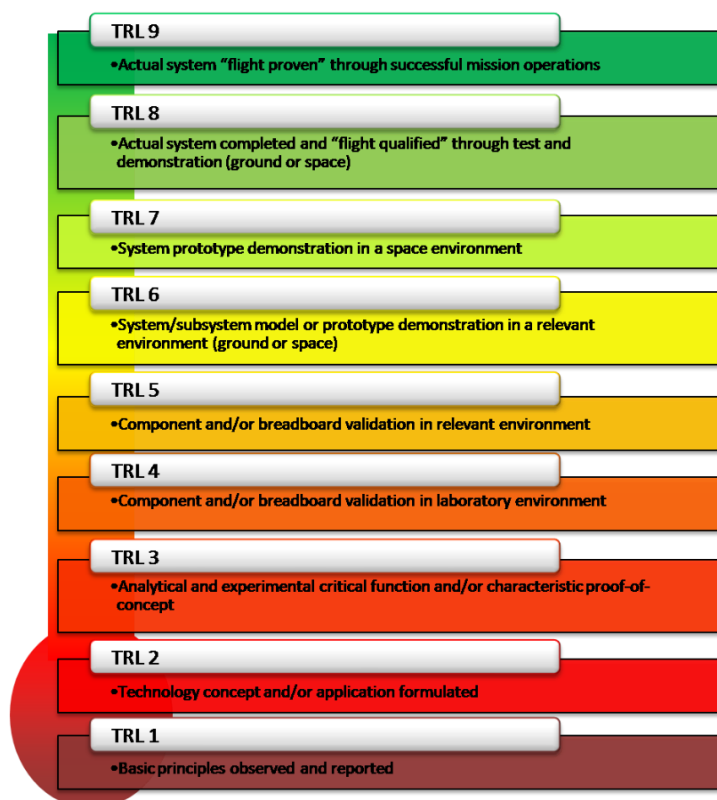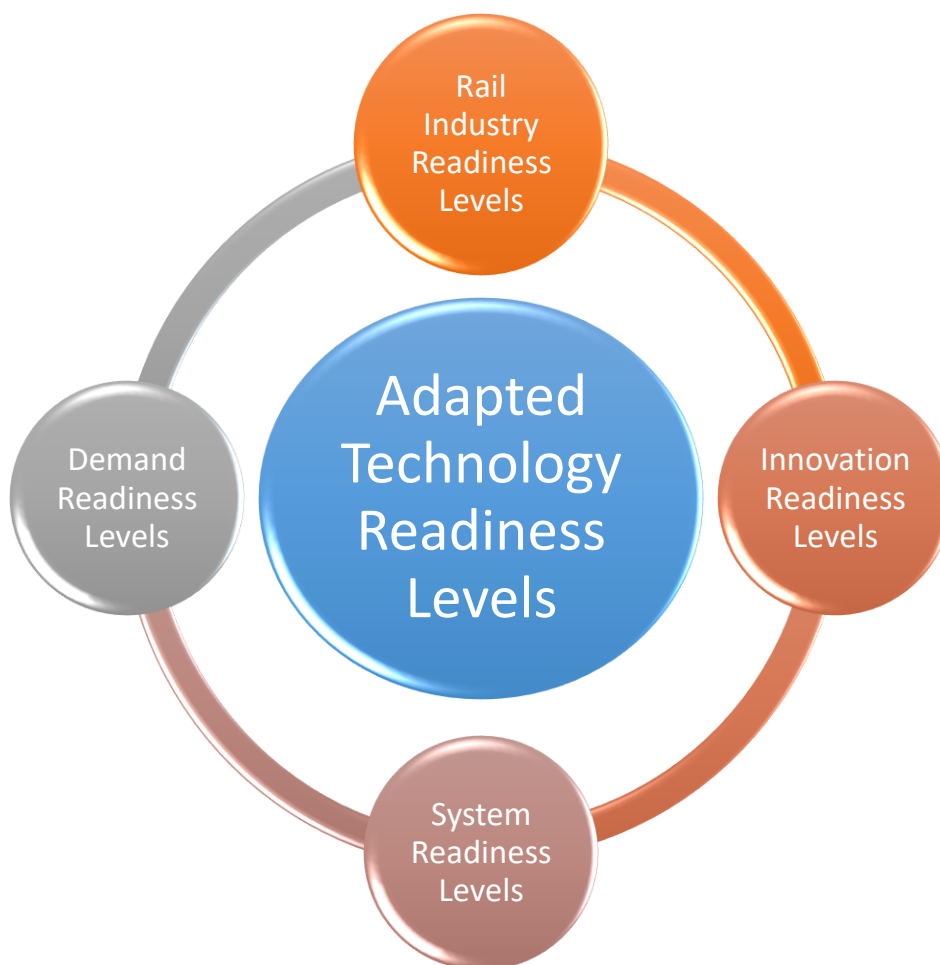
The NASA TRL scale has been adapted by many industries and serves as an appropriate point of departure. An international assessment by TII of various existing readiness assessment levels identified a range of approaches, linked to solutions that exist across a variety of industries as outlined below.

Figure 2.2   Range of Readiness Levels

The four adapted technology readiness levels consulted all share similarities but differ in their specific focus. The review of these levels allowed TII to extract the most relevant criteria to be assessed in the deployment of innovative technologies on the TII network. These criteria were subsequently incorporated into a relevant benchmark, or TRL, proper to TII. The TII TRLs are directly linked to realistic scenarios defined by TII to ensure the assessment tool is fit-for-purpose.

The Innovation Guidelines represent TII's own defined process and methodology for engagement and risk management, applicable to any innovation deployments on the TII network. Alongside the TRL system, TII will also assess the commercial readiness and risk/uncertainty associated with innovation projects, using a Business Readiness Level (BRL) scale. The BRL scale is from 1-9, mirroring the developing process of the TRL scale. BRLs focus on the commercial viability and "realism" of the innovation, rather than just its technical or technological development. However, both scales share a common approach to maturity and risk assessment of an innovation with parallel stages from ideation to full deployment. Whilst the TRL system is more appropriate for assessing the potential of new products or technologies that may be deployed particularly on TII's light rail and road networks, the BRL system will be more suitable for assessing ideas pertaining to innovation internally to TII. This may mean their systems, processes or procedures, for example communications policies, digital transformation, or ideas to assist in dealing with coming trends or changes. Further information can be found in TII's Innovation Implementation Plan**.**

3. Risk Management

3.1 Background

TII is committed to systematically identifying and managing risk across its activities in accordance with established principles of risk management. TII has produced a Risk Management Policy with which these Innovation Guidelines comply. A key element of this policy is the management of risks to the delivery of TII's strategic and business objectives, under which the deployment of new technologies falls.

3.2 TII TRL Risk Management

In the introduction of innovative technological deployments, the management of risk to TII is a crucial factor. Managing risk ensures the best possible outcomes for TII's innovative deployments. Using a bespoke and consistent methodology to engage with the supplier community, it allows TII to fully appreciate the risk of a proposal, from both a piloting stage to long term operations integration.

Significant exposure to risk can be generated from an inconsistent approach to technology readiness assessment. In providing a bespoke benchmarking tool, established on the basis of TII's singular needs and project profile, the TII TRLs will create a standardised approach to the management of operational risk. The TRL system is considered appropriate for universal application across all of TII's future technological or innovation deployments. They also reduce the risk of application of technologies that are not at an appropriate stage of readiness. This has the added benefit of ensuring transparency in engagement with suppliers, and streamlining TII's own procedures.

It is also important to understand the business requirements linked to the solution itself and if driven by TII, a handover mechanism to the market is required with clarity on long term funding also to be identified.

The guidelines are designed to be robust and fit for purpose in protecting the long term investment of TII. The assessment of the innovation proposals with respect to the BRL scale will help to ensure that the commercial risk associated with any uncertainty inherent in the innovation project is minimised.

Below is an outline of the risk exposure to TII in the context of technology readiness. The table comprises an amalgamation of the risk categories that must be managed within the process.

Risk Category	Definition
Operational	The functions being performed by the verified and validated solution, and the deployment of the solution itself i.e. the operation, outcomes it achieves, and maintenance requirements.
Political	The risk to the business through the introduction of the new solution, from the perspective of its national and international policy support for the solution, as well as legal implications of this new solution.
Financial	Cost-benefit analysis of the implementation of the solution, together with limiting he financial risk of exposure to elevated costs due to lifecycle issues.
Reputational	Reputational risk to TII using the solution, either through performance uncertainty, testing procedures, environmental, political values etc. Risk to TII reputation through inaction in the area that the solution addresses.
Digital	Consideration of the integration of the solution with current systems, practices, etc. and the levels of data produced as a result of the solution and its system.

Risk Category	Definition
Safety	Is the solution safe by design and will its introduction improve safety in any particular manner?

4.   TII Technology Readiness Levels

The TII TRLs are the amalgamation of the most relevant criteria against which the technological maturity of deployments on the TII network can be assessed. They have been defined taking account of the specific environment in which TII operates, and specifically developed in order to guarantee consistency of approach to all suppliers irrespective of the nature of their solution. In so doing, it also guarantees consistency across all TII's deployments. The TII TRLs are outlined below.

4.1   TRL Definitions

4.1.1   TRL 1 Concept Exploration/Fundamental Research

A novel solution to an existing challenge or process is conceived using new or existing tools and/or technologies and is reviewed based on research activities. This can be driven by the TII supply chain or by TII itself.

1. Desktop research to explore hypothesis and to identify mechanisms and steps needed to bring it to reality;

2. Review against global activity in this area and produce briefing note to ascertain possible development routes, identify potential opportunities and partners;

3. Overview of the proposed solution in a diagram defining the function, inputs and outputs generated from the solution itself;

4. A briefing note on possible funding sources for continuous development is produced; and

5. Outline risk assessment (based on the risks outlined in **Section 3.2**) of the solution.

4.1.2   TRL 2 Applied Research

In depth assessment of hypothesis and validation against global activities in the market place or identified business benefit is carried out.

1. Overview of the system in a diagram, linking the solution to other parts of a wider approach and defining the function, inputs and outputs generated from the solution itself;

2. Development of a proposal briefing pack based on further research consisting of an executive summary of challenges overcome and outcomes anticipated;

3. A statement on the route for funding to develop the proposal and identification of third parties required;

4. Provisional identification of the Key Performance Indicators (KPIs) of the solution itself;

5. Statement of perceived alignment with TII's Purpose, Vision and Values as stated in the 2021-2025 Statement of Strategy;

6. Updated briefing note on relevant funding model and investment requirements as well as collaboration required to move the product forward; and

7. Update Risk Assessment to validate decision to proceed to TRL 3.

Requirements to move from TRL 1: further contextual evidence and solution description are provided; KPIs are provisionally defined, and possible development trajectories are provided, including funding.

4.1.3   TRL 3 Research and Validation

Laboratory testing and/or modelling of the proposed solution is required in order to validate at a technical level the initial hypothesis and learnings from TRL 2. For products that have a long life cycle it is important that the reviews and/or testing/modelling of the product itself should reflect any known degradation over time. This step will provide further insight and guidance on the outcomes achievable and the conditions for its use.

1.   Development of initial proof-of-concept solution, based on research and concept development of TRL 1 and TRL 2;

2.   Create a functional specification and performance levels, identifying critical components, inputs/outputs and link to business improvement;

3.   Develop test report template identifying measurements and test parameters;

4.   Light level testing to explore the hypothesis and the outcomes proposed;

5.   Define models to be used for testing and verify their applicability; and

6.   Update Risk Assessment based on feedback from concept testing and validate decision to proceed to TRL 4.

Requirements to move from TRL 2: breakdown of system components is provided; functional specification is defined; laboratory testing is being designed; more detailed risk assessment.

4.1.4   TRL 4 Laboratory Testing

A controlled laboratory based environment is created to develop a suite of standardised, repeatable tests that validate the underlining principles of the hypothesis and the technical functionality. No user requirements are linked to testing at this stage.

1.   Development of test bed specification and environment with all fixed and variable parameters defined;

2.   Creation of test scenarios and functional assessment criteria;

3.   Updated technical specification based on feedback of testing;

4.   Validation of KPIs of the solution itself;

5.   Identification of the business improvement introduced by the solution;

6.   Verification of critical functionality across all ranges of performance;

7.   Delivery of robust test documentation to verify performance;

8.   Summary of ownership model and route to market;

9.   Identify details of all relevant Standards and Specifications relevant to the proposed solution and provide details of conformance to Standards and Specifications or equivalent conformity testing;

10. Create production-based requirements in order to standardise production methodology; and

11. Update Risk Assessment (based on the risks outlined in **Section 3.2**) with focus on migrating to an integrated solution with other products/processes, to validate decision to proceed to TRL 5.

Requirements to move from TRL 3: laboratory testing is taking place; KPIs for the solution are validated and confirmed; conformance to relevant Standards is demonstrated; route to market is summarised, and preparations are being made for production.

4.1.5　TRL 5 Isolated Representative Testing

The solution is tested in a non-operations representative environment and validated against stated functional performance levels and user requirements. This test site would be on a suitable area off the national road network; on a specially reserved piece of road acting independent of the rest of the road network; or a specially designated section of track.

The solution is verified in terms of individual functionality.

1. Produce detailed customer requirements brief (CRB);

2. Produce detailed customer requirements specification (CRS);

3. Produce detailed technical specification;

4. Identify required test environment and responsibilities for testing and validation across all stakeholders;

5. Verify functional performance meets CRS across all ranges and parameters;

6. Establish boundary conditions for integration into wider systems;

7. Capture the business operations requirements for deployment by TII;

8. Validate production methodologies and approaches; and

9. Update Risk Assessment (based on the risks outlined in **Section 3.2**) to validate decision to proceed to TRL 6.

Requirements to move from TRL 4: CRB and CRS are defined; technical specification is developed; system-level integration is being defined; performance is being tested; and production methods are validated.

4.1.6　TRL 6 System Based Representative Testing

The solution is validated as part of an overall system approach to future deployment. This is undertaken in a controlled but operations-representative environment, to be agreed between the supplier and TII, and validated against stated system performance criteria and outcomes. Financial risk in terms of cost exposure linked to ongoing performance and development activities is limited.

Requirements to move from TRL 5: testing is performed in operations-representative environment; financial risk management procedures are developed.

4.1.7　TRL 7 System Level Pre-Production Controlled Demonstration

A number of 'pre-production' prototypes, developed as part of a manufacturing run through, are assessed to validate its performance as part of a wider system. This is undertaken in a live but controlled operation environment. The solution is assessed against either agreed CRS or existing functional specifications that in turn will be adjusted to reflect CRS input.

1. A number of prototypes are created in line with defined manufacturing guidelines;

2. A controlled live environment is established to validate performance;

3. Agreed principles of operations and stakeholder governance for deployment is agreed and circulated;

4. Scenario and functional system test specifications are created and signed off by relevant parties;

5. Integration of solution with wider system is assessed against defined template;

6. Boundary case assessment is undertaken and validated against specifications;

a) A 'Boundary' case is where the various stress levels are at their greatest and as such have maximum possible impact for failure.

7. Certification of performance is issued in line with all relevant standards and specifications or equivalent conformity testing;

8. TII sign-off of test report validating performance capability; and

9. Update Risk Assessment (based on the risks outlined in **Section 3.2**) to validate decision to proceed to TRL 8.

Requirements to move from TRL 6: prototypes are developed; testing is taking place in a live environment to verify its functionality; deployment parameters are being developed; and solution performance is approved.

4.1.8   TRL 8 System Level Production Verification

Production level solution is deployed in a real-life but monitored environment. The monitoring regime is to be agreed between the supplier and TII on a case by case basis. This readiness level is to ensure the solution operates as expected, captures any anomalies introduced by the environment or changes in parameters such as time etc. and responds in an appropriate manner at all times.

Requirements to move from TRL 7: the solution is being deployed under control to exclude anomalies and capture any situational performance issues; the system is ready and qualified for live deployment.

4.1.9   TRL 9 Proven Solution Deployment

Once a solution is proven or successfully deployed in a real-life scenario, it can be considered to have achieved TRL 9. This level indicates that a solution has been tried and tested and is operationally safe, successful, and has been deployed. In the national road and light rail network context, deployment may have been in a live test environment for a period of 1 year or more, given that the desired life expectancy can be very long. TII will need to use its discretion to decide an appropriate length of live testing with respect to the lifecycle of the solution.

Requirements to move from TRL 8: the solution is proven and fit for purpose.

4.2   Testing Environment

Across TRLs 5-8 where testing takes place outside of laboratory conditions, it is important to distinguish the subtle differences in requirements relating to the testing and the environments.

For testing purposes:

TRL 4 states 'Functional testing in a controlled laboratory based environment'.

This is broken into three separate requirements, namely:

a) The 'solution' is tested from a functional performance perspective and is tested in isolation, as opposed to part of an integrated system.

b) The 'solution' being tested is a laboratory based product.

c) The testing is undertaken in a laboratory or equivalent environment where the testing itself is directly repeatable and all measurements can be directly compared to other readings.

TRL 5 states 'Individual functional testing in a non-operations representative environment'.

This is broken into four separate requirements, namely:

a)   The 'solution' is tested from a functional performance perspective and is tested in isolation, as opposed to part of an integrated system.

b)   The testing is undertaken in an environment that reflects the conditions that will be ultimately used in its production based deployment.

c)   The product/solution being tested has not been created from a manufacturing productised run but could be created specifically for the testing but closely aligned to the production requirements.

d)   This test environment is to be agreed between the supplier and TII itself and could be a number of various test areas such as a road on a test site or a non-active road on the road network, or an isolated piece of road that is not part of the operations requirements of TII and the operation requirements are not assessed as part of the testing.

TRL 6 states 'System level testing in a controlled but operations-representative environment'.

This is broken into three separate requirements, namely:

a)   The 'solution' is tested from a systems perspective. This means that the evaluation looks not just at the solution itself in isolation but in terms of how it behaves as part of its overall environment and system performance. It is intended that this brief will cover a range of possible deployments and can vary from a technology integrated within an overall systems architecture or from a road material deployed as part of an overall systems solution.

b)   The product/solution being tested has not been created from a manufacturing productised run.

c)   The testing is undertaken in an environment that is not live but would normally be used for operational purposes, such as the national road or light rail network, but the area of deployment is controlled for the purposes of the testing and evaluation. This test environment is to be agreed between the supplier and TII itself. The test area is not live so is not accessible to the general public as part of the testing. The test area could be, for example, a specified area on the road network that is operating under stricter control conditions and is accessible only to agreed test parties to allow for evaluation.

TRL 7 states 'System level testing of a prototype in a live but controlled operation environment'.

This is broken into three separate requirements, namely:

a)   The 'solution' is tested from a systems perspective. This means that the evaluation looks not just at the solution itself in isolation but in terms of how it behaves as part of its overall environment and system performance. It is intended that this brief will cover a range of possible deployments and can vary from a technology integrated within an overall systems architecture or from a road material deployed as part of an overall systems solution.

b)   The product/solution being tested is a final product, subject to changes brought about from testing and has been produced from an early manufacturing run in order to validate the production process for migration towards Business-as-Usual.

c)   The testing is undertaken in an environment that is live on the national road or light rail network, but the area of deployment is controlled for the purposes of the testing and evaluation. This test environment is to be agreed between the supplier and TII itself.

The test area is accessible to the general public and could be a number of different elements including but not limited to a specified area of road operating under specified conditions (reduced speed, reduced lane etc.) or a specified area on the road network that has reduced traffic flows etc.

TRL 8 states 'Production level solution in a real-life but monitored environment'.

This is broken into three separate requirements, namely:

a) The 'solution' is tested from a completely integrated perspective.

b) The product/solution being tested is a final product and is part of a Business-as-Usual manufacturing regime.

c) The testing is undertaken in an environment that is live on the national road or light rail network, but monitored as part of its migration to fully bedding in TRL 9.

5.   TII TRLs – The Supplier Guide

This section of the document is concerned with describing the TII approach to TRL assessment for suppliers. It describes what TII requires from the supplier and its innovation solution at each TRL, and in order to achieve the succeeding level. A detailed breakdown of the TRLs can be found in **Chapter 4: TII Technology Readiness Levels.**

TRLs were developed in order to provide a cohesive methodology not only for assessing the maturity of an innovation at a given time, but also for migrating from an 'idea' to a 'product' and managing the associated risk and confidence levels. As such, the TRLs outlined in this document are developed from that perspective. There are 9 TRLs, that TII has developed specifically for the national road and light rail environment, through a process of reviewing and adapting existing TRL scales that have been used in other industries. Further information on the methodology for developing the TII TRLs can be found in **Chapter 2: Methodology.** The 9 TRLs can be grouped into 4 broad categories, as below:

- **Concept:** At this level, TII is concerned with engaging and going to the market with/for ideas – this is Levels 1-3, nominally called the concept stage. These levels reflect new thinking and ideas by the suppliers and TII and allow for discussion and early testing to prove an idea. A supplier will use these levels when they are coming to TII at a very early stage of product development. The levels are to ensure the requirements of TII are fully understood as part of the engagement process and receive guidance as to the level of verification and idea validation etc. that is required against the risk levels identified. The supplier will need to conduct a self-assessment to identify what TRL is to be applied in this concept phase.

- **Stand Alone Validation and Verification**: Levels 4 and 5 represent technologies that are at a level of stand-alone testing and integration but have not been tested as part of an overall system. Relevant standards and specifications linked to core functionality are addressed. The levels help define the integration requirements from the overall system view as well as detailed technical specifications etc. Production based methodologies and requirements are developed during these Levels. The supplier will describe their product in reference to the relevant TRL based on the requirements of that TRL.

- **Arrangement of Systems**: Levels 6 and 7 are concerned with systems integration, evolving to laboratory prototype testing and assessment against agreed requirements. The evaluation is undertaken at levels of increasing complexity, from representative scenarios and environments to ultimately ensure stress testing and performance monitoring in a live but monitored environment.

- **Design Standards**: At levels 8 and 9, the TRL is concerned with ensuring real life testing and assessment is performed in order to reduce risk and impacts of failure as a pre-cursor to sign off to full scale business as usual deployment.

Although the TRLs begin at concept phase, TII understands that not all suppliers will be in contact with TII at this germinal phase. Therefore, this document is also fit for purpose for products/process or technologies that have already been developed to some degree and will not start the engagement process with TII at TRL 1, but at a higher TRL. As such, the table overleaf identifies the base level requirements for each level and clarifies to the supplier the level of documentation and testing etc. that is expected as part of the supplier stating what level of TRL their product aligns to. The table is a critical part of the document and it presents with a snapshot of expectations around progress across the TRLs, and describes the principal distinguishing characteristics for each level.

TRL	Solution Function Defined	KPIs for solution provisionally defined	Component Specification	Laboratory Testing	CRS and CBS	System Testing	Prototype Testing	Monitored Deployment	Risk Acceptable Deployment	Evidence required for moving between TRLs
1	✓									N/A
2	✓	✓								Further contextual evidence and solution description are provided; KPIs are provisionally defined, and possible development trajectories are provided, including funding
3	✓	✓	✓							Breakdown of system components is provided; functional specification is defined; laboratory testing is being designed; more detailed risk assessment
4	✓	✓	✓	✓						Laboratory testing is taking place; KPIs for the solution are verified and validated; conformance to relevant Standards is demonstrated; route to market is summarised, and preparations are being made for production
5	✓	✓	✓	✓	✓					CRB and CRS are defined; technical specification is developed; system-level integration is being defined; performance is being tested; and production methods are validated
6	✓	✓	✓	✓	✓	✓				Testing is performed in operations-representative environment; financial risk management procedures are developed
7	✓	✓	✓	✓	✓	✓	✓			Prototypes are developed; testing is taking place in a live environment to verify its functionality; deployment parameters are being developed; and solution performance is approved
8	✓	✓	✓	✓	✓	✓	✓	✓		The solution is being deployed under control to exclude anomalies and capture any situational performance issues; the system is ready and qualified for live deployment
9	✓	✓	✓	✓	✓	✓	✓	✓	✓	The solution is proven and fit for purpose.

TRL	Solution Function Defined	KPIs for solution provisionally defined	Component Specification	Laboratory Testing	CRS and CBS	System Testing	Prototype Testing	Monitored Deployment	Risk Acceptable Deployment	Evidence required for moving between TRLs
1	■									N/A
2	■	■								Further contextual evidence and solution description are provided; KPIs are provisionally defined, and possible development trajectories are provided, including funding
3	■	■	■							Breakdown of system components is provided; functional specification is defined; laboratory testing is being designed; more detailed risk assessment
4	■	■	■	■						Laboratory testing is taking place; KPIs for the solution are verified and validated; conformance to relevant Standards is demonstrated; route to market is summarised, and preparations are being made for production
5	■	■	■	■	■					CRB and CRS are defined; technical specification is developed; system-level integration is being defined; performance is being tested; and production methods are validated
6	■	■	■	■	■	■				Testing is performed in operations-representative environment; financial risk management procedures are developed
7	■	■	■	■	■	■	■			Prototypes are developed; testing is taking place in a live environment to verify its functionality; deployment parameters are being developed; and solution performance is approved
8	■	■	■	■	■	■	■	■		The solution is being deployed under control to exclude anomalies and capture any situational performance issues; the system is ready and qualified for live deployment
9	■	■	■	■	■	■	■	■	■	The solution is proven and fit for purpose

6.   Actions and Owners for TII TRLs

This section deals with the division of responsibility for the development of an innovation solution once its TRL has been established. Risk is a key factor for both supplier and TII at each of the TRLs, and as a result, risks must be identified and the associated owners must be assigned. This is an important step in order to identify both the distinction of ownership and associated actions/mitigations between the supplier and TII for the relevant TRLs and the risk element.

Shown below is a more detailed representation of the breakdown of risks as well as associated owners etc. This demonstrates the dynamic between supplier and TII, and the relationship between the "push" forces coming from the supplier market, and the "pull" by TII. It identifies the most likely driving forces at each TRL, as well as possible actions to be taken by both parties. Finally, it provides suggested actions and considerations specifically for TII across the entire innovation approval process.

TRL	Step	"Push" by Market	"Pull" by TII	Both	TII Action / Consideration
1	1			Desk top research to explore hypothesis and to identify mechanisms and steps needed to bring it to reality	Sponsorship
	2			Review against global activity in this area and produce briefing note to ascertain possible development routes, identify potential opportunities and partners	Sponsorship
	3			High level solution-based diagram defining the function, inputs and outputs generated from the solution itself	Sponsorship
	4			A high level risk-based assessment of the solution is undertaken against TII's guidelines	Sponsorship
	5		A briefing note on possible funding sources for continuous development		Business Process Advice
2	1			High level system-based diagram, linking the solution to other parts of a wider approach and defining the function, inputs and outputs generated from the solution itself	Sponsorship
	2			Development of a proposal briefing pack based on further research consisting of an executive summary of challenges overcome and outcomes anticipated	Technical Observation / Sponsorship

TRL	Step	"Push" by Market	"Pull" by TII	Both	TII Action / Consideration
	3		A statement on the route for funding to develop the proposal and identification of third parties required		Business Process Advice
	4			Identification of the provisional KPIs of the solution itself	Technical Review
	5			Statement of perceived alignment with TII's Vision and Statement of Strategy	Technical Review
	6		Updated briefing note on relevant funding model and investment requirements as well as collaboration required to move the product forward		Business Process Advice / Sponsorship
3	1	Development of initial proof of concept solution based on research and concept development of TRL1 and TRL2			Sponsorship
	2	Create a functional specification and performance levels, identifying critical components, inputs/outputs and link to business improvement			Technical Review / Sponsorship
	3			Construct test report template identifying measurements and test parameters	Technical Review
	4	Light level testing to explore the fundamental of the hypothesis and the outcomes proposed			Sponsorship

TRL	Step	"Push" by Market	"Pull" by TII	Both	TII Action / Consideration
	5	Define models to be used for testing and verify their applicability			Technical Review / Sponsorship
	6			Update risk assessment based on feedback from concept testing	Approval
4	1	Development of test bed specification and environment with all fixed and variable parameters defined and captured			Sponsorship
	2			Creation of test scenarios and functional assessment criteria	Technical Review
	3	Updated technical specification based on feedback of testing			Sponsorship
	4			Validation and verification of KPIs of the solution itself	Technical Review / Approval
	5		Validation of the business improvement introduced by the solution		Business Process Advice
	6	Verification of critical functionality across all ranges of performance			Sponsorship
	7	Delivery of robust test documentation to verify performance			Sponsorship
	8	Summary of ownership model and route to market			Business Process Advice

TRL	Step	"Push" by Market	"Pull" by TII	Both	TII Action / Consideration
	9	Identify details of all relevant Standards and Specifications relevant to the proposed solution and provide details of conformance to Standards and Specifications, or equivalent conformity testing			Technical Review
	10			Risk assessment update of migrating to an integrated solution with other products/processes	Technical Review
	11	Create production-based requirements in order to standardise production methodology for repeatable outcomes			Technical Review
5	1			Produce detailed customer requirements brief (CRB)	Sponsorship / Approval
	2			Produce detailed customer requirements specification (CRS)	Sponsorship / Approval
	3	Produce detailed technical specification			Technical Review / Sponsorship
	4			Identify required test environment and responsibilities for testing and validation across all stakeholders	Technical Review / Sponsorship / Approval
	5	Verify functional performance meet CRS across all ranges and parameters			Technical Review

TRL	Step	"Push" by Market	"Pull" by TII	Both	TII Action / Consideration
	6			Establish boundary conditions for integration into wider systems	Technical Review
	7			Limiting the financial risk in terms of cost exposure linked to ongoing performance and development activities	Business Process Advice
	8			Update Risk Assessment to validate decision to proceed to TRL level 6	Technical Review / Approval
	9	Validate production methodologies and approaches			Sponsorship
6	1	A number of prototypes are created in line with defined manufacturing guidelines, and boundary conditions are established to understand system interfacing			Sponsorship
	2			A controlled operation-like environment is defined and agreed	Technical Review / Approval
	3			Agree principles of operations and performance criteria of the system and its component parts	Technical Review / Approval
	4			Scenario and functional system test specifications are created and signed off by relevant parties	Technical Review / Approval
	5			Parameters are controlled and varied in order to represent an operating environment and responses and variances recorded	Sponsorship

TRL	Step	"Push" by Market	"Pull" by TII	Both	TII Action / Consideration
	6			System parameters are adjusted and agreed by all parties	Technical Review / Approval
	7			System-based assessment criteria established and solution approved	Technical Review / Approval
7	1	A number of prototypes are created in line with defined manufacturing guidelines			Technical Review / Sponsorship
	2			A controlled live environment is established to validate performance	Technical Review
	3			Agreed principles of operations and stakeholder governance for deployment are agreed and circulated	Approval
	4			Scenario and Functional system test specifications are created and signed off by relevant parties	Technical Review / Approval
	5			Integration of solution with wider system is assessed against defined template	Business Process Advice
	6			Boundary case assessment is undertaken and validated against specifications	Approval
	7			Certification of performance is issued in line with all relevant standards and specifications or equivalent conformity testing	Approval

TRL	Step	"Push" by Market	"Pull" by TII	Both	TII Action / Consideration
	8		TII sign-off of test report validating performance capability		Approval
	9			Limiting the financial risk in terms of cost exposure linked to ongoing performance and development activities	Business process Advice / Approval
	10			Risk assessment undertaken and reviewed in line with TRL6 requirements	Approval
8	1			Performance included as part of new KPIs being produced or improvements on existing ones	Technical Review / Sponsorship
	2			Limiting the financial risk in terms of cost exposure linked to ongoing performance and development activities	Business Process Advice
	3		Integration into asset management systems or equivalent is now understood and protocols in place and signed off		Business Process Advice
	4		PM close-out and handover to BAU team		Approval
	5		Risk reviews evaluated and completed for sign off to BAU		Approval
9	1		Final specification completed and included in TII Publications		Approval

Appendix A:

Business Readiness Levels

A1   Introduction

Innovation is a key driver of development within TII. TII's approach is the creation of an open innovation process that is purpose-driven, and encourages the formulation of plans to implement innovative ideas within TII's projects, products, and processes. In a culture of innovation, the process is receptive and flexible in the creative phase, where ideas are encouraged and supported, and more tightly controlled and rigid in the execution phase, where ideas become actionable solutions. This ensures a transparent and equitable system that can achieve a "win – win" for all stakeholders.

TII recognises that ideas must go through a development process and become fully mature before they can be implemented. Chief among the ways in which an idea can be assessed for feasibility and maturity are the Business Readiness Levels, or BRLs. In this document, the BRLs and how they relate to TII are addressed.

A2   Business Readiness Levels

Business Readiness Levels, or BRLs, are just one of a plethora of readiness-level indicators. BRLs represent the stage of business development for process, service, technology or social innovations, and are often known as innovation readiness levels. BRLs are usually used to measure the level of maturity of an innovative idea and consequently represent a decision-making tool for the implementation of an innovative idea.

As distinct from the now ubiquitous Technology Readiness Levels (TRLs), the BRLs are not a stage-gate process, but rather a "way to communicate the amount of uncertainty or risk in a business venture"[1]. They also focus on the commercial viability and "realism" of the innovation, rather than just its technical or technological development. However, both share a common approach to maturity and risk assessment of an innovation with parallel stages from ideation to full deployment.

Typically, business readiness is measured on a scale from 1-9, with the levels equating to the corresponding TRLs. BRLs are slightly more fluid than TRLs, and are typically grouped in triplets as below.

- BRL 1-3: identification of problems addressed and solved by the innovative idea, and its wider field of application. (TRL ideation)

- BRL 4-6: market segmentation and strategic market positioning decision. (TRL proof of concept)

- BRL 7-9: market launch (TRL prototyping).

Generally speaking, the higher the score on the BRL scale, will indicate the quantum of, support, and resourcing required to progress the innovation idea to deployment. The methodology of advancement through the process mirrors that of development along the TRL scale.

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[1] https://www.linkedin.com/pulse/using-business-readiness-level-brl-understand-new-richie-ramsden/

A3   Application of BRLs

BRLs are typically used in order to assess the level of maturity of an innovative idea relating to a policy, procedure, or process. The BRLs can be of use when the following indicators need to be identified:

1. Problem-solving: can we define the problem, and does our idea help to solve it?

2. Business concept: articulate the need for a resolution to this problem and the value that will bring.

3. Players: do we have the right team with the right skills blend to solve the identified problem and to implement the innovation?

4. Demonstration: is there a prototype/working model? Do we understand the long-term viability and sustainability of the solution?

5. BRLs can also be applied to assess the commercial viability of product innovations destined for deployment.

A4   Relevance to TII Innovation

Application of BRLs is highly relevant to TII's obligations as a public service body. Innovation is a key mechanism for TII to improve the way it operates by developing and implementing new policies, products, procedures and services, in support of a more efficient organisation. Ensuring that a robust framework for assessing the viability of innovations is a key element in TII's Innovation Strategy, which is where the value in readiness level assessment is most evident.

Alongside the TRL system, the BRLs can be applied to innovations that come to the attention of TII innovation management through the online innovation portal. Whilst the TRL system is more appropriate for assessing the potential of new products or technologies that may be deployed particularly on TII's light rail and road network, the BRL system will be more suitable for assessing ideas pertaining to innovation internally to TII. This may mean systems, processes or procedures, for example communications policies, digital transformation, or ideas to assist in dealing with coming trends or changes.

Where relevant, it is generally considered most effective to combine an assessment of an innovation's TRL and BRL concurrently. Demonstrating the maturity of the innovation and its practicality can be powerful in convincing TII's innovation champions that an idea not only has merit but is viable.

A5   Conclusions

BRLs are a useful tool in assisting TII with the implementation of innovative ideas intended to deliver tangible benefits to internal processes and procedures within the organisation. While BRLs are an indicative scale, they can be of assistance as a decision-making tool when prioritising ideas and in the allocation of funding and resources to further the innovative ideas with most merit. BRLs can also be used in conjunction with TRLs to assess the operational viability of technological or product innovation ideas that are of benefit to TII's national road and light rail network.