INTEGRATED FRAMEWORK FOR ASSESSING INNOVATION READINESS

TECHNOLOGICAL SECURITY CONTEXT

The development of innovation, which is an integral part of ensuring technological security, should take into account engineering aspects on an equal footing with social, political, organisational, legal, economic and ethical aspects. In the face of the growing scale of hybrid threats, digital attacks on critical infrastructure and disruptions to global supply chains, technological sovereignty is becoming a pillar of the defence and development strategies of the EU and world powers. Without a clearly defined, multidimensional readiness assessment framework – including Societal Readiness Levels (SRL), Policy Readiness Levels (PRL), Organisational Readiness Levels (ORL), Legal Readiness Levels (LRL), Economic Readiness Levels (ERL) and traditional Technology Readiness Levels (TRL) – we risk introducing solutions that, although technically sound, may be susceptible to social, administrative, legal or economic rejection, and thus ineffective and costly to implement.

The implementation of SRL in the Polish research and innovation ecosystem will enable the systematic identification and resolution of social barriers at the early stages of technology development, while the extension of the assessment to include PRL and ORL will allow for the consideration of political aspects and the readiness of organisations to implement innovations. At the same time, the integration of LRL and ERL will ensure that the solutions developed comply with applicable regulations and demonstrate real economic potential. As a result, the design process will become participatory and multidimensional, and stakeholders, from local communities and organisations to public institutions and regulators, will co-create solutions tailored to real needs, social values, legal requirements and market conditions. This, in turn, will contribute to increased public confidence, greater acceptance of implementations, streamlined legislative processes and reduced financial and organisational risk, minimising the costs associated with the need for subsequent amendments, renegotiations or withdrawal of innovations – at least in theory.

Currently, for the effective development of innovation and the strengthening of technological sovereignty in Poland, comprehensive institutional and financial support is necessary, aimed at:

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- building interdisciplinary teams combining engineers, sociologists, political scientists, lawyers, economists, ethicists and representatives of the administration, who will jointly develop standards and tools for a comprehensive assessment of readiness levels – social, political, organisational, legal, economic and technological.
- educating and disseminating knowledge about multidimensional readiness models among scientists, entrepreneurs and decision-makers so that they become an integral part of everyday research and development practice and innovation policy.
- implementation of pilot projects implementing these models in various sectors of the economy, enabling the collection of empirical data, evaluation of the effectiveness of procedures and their improvement prior to widespread implementation.

Such an integrated model of innovation assessment and development is one way to build a solid foundation for technological sovereignty and competitive advantages based not only on advanced, autonomous and secure technical solutions, but also on social acceptance, ethical responsibility, regulatory stability, organisational readiness and sustainable economic profitability.

INTEGRATED FRAMEWORK FOR ASSESSING INNOVATION READINESS – PROPOSAL

Contemporary innovation processes increasingly require an integrated, multidimensional approach that combines technological development with social, political, organisational, legal and economic analysis. Traditional innovation assessment frameworks, such as Technology Readiness Levels (TRL), focus mainly on measuring technological maturity, while ignoring a number of other factors that determine effective implementation. Meanwhile, insufficient consideration of social (SRL), political (PRL), organisational (ORL), legal (LRL) and economic (ERL) aspects often leads to a fragmented understanding of implementation dynamics, resulting in socio-cultural resistance, lack of adaptation to institutional structures, regulatory barriers and economic inefficiency of innovation.

In response to these challenges, both in scientific literature and design practice, there are increasing calls to extend classic technology readiness models with additional dimensions of analysis. Supplementing TRL with SRL and PRL allows for a better understanding of the impact of the social and political context on innovation processes. The parallel consideration of ORL, LRL and ERL, in turn, allows for the assessment of organisational capacity to implement a solution, compliance with legal regulations and the economic potential of a project.

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This combination of six readiness scales is an attempt to integrate them into a coherent analytical framework. It not only shows their mutual complementarity, but also points to the need for a systematic approach to innovation assessment, in which the technological dimension is analysed in parallel with social, political, organisational, legal and market aspects.

The purpose of this comparative framework is to juxtapose different readiness levels across the domains of technology, society, policy, organization, law, and economy, enabling a multidimensional assessment of innovation development. The table facilitates the identification of development stages and barriers to the full deployment and functioning of new solutions, based on existing conceptual proposals.

The table was developed through a synthetic analysis of the literature and existing readiness models, including TRL, SRL, PRL, ORL, LRL, and ERL, which were collected and compared in terms of their shared features and areas of application. Each level was standardized to allow parallel interpretation and application in interdisciplinary research and implementation practices.

The result is a reference tool that integrates various readiness perspectives into a coherent model, enhancing the transparency of assessing technological development and deployment phases. The table supports holistic and comparative analysis, facilitating decision-making at the intersection of science, business, and policy. At the same time, it should serve as a starting point for further reflection and methods of integrating the above dimensions to maximize the effectiveness of innovation management.

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Table 1. Proposal for an integrated model for assessing innovation readiness

Level	TRL – Technology	SRL – Societal	PRL – Policy	ORL – Organizational	LRL – Legal	ERL – Economic
1	Observation of basic principles and scientific phenomena	Identification of a societal problem and its significance	Recognition of a political or policy need	Identification of organizational needs (infrastructure, skills, processes)	General consideration of legal and ethical aspects	Initial recognition of market-related ideas, no cost analysis
2	Formulation of a technology concept and potential application	Initial stakeholder engagement and problem diagnosis	Preliminary policy concepts and analysis	Conceptualization of solution, identification of roles, structures, processes	Articulation of need to enhance legal frameworks and regulatory awareness	Defined economic concept, description of customer segments
3	Experimental proof of concept and basic lab research	Design of socially-informed prototypes and concepts	Draft policies and initial stakeholder consultations	Comprehensive description of organizational impacts: roles, competences, infrastructure	Abstract description of legal and ethical compliance of the solution	Preliminary market validation (desk research, interviews), feasibility check
4	Validation of technology in the lab	Testing in social settings and impact analysis	Pilot testing of policies, impact assessment	Validation through simulations; beginning to build organizational capabilities	Validation of legal prospects and alignment with regulation	Market sizing, customer segmentation, early business model
5	Validation in a relevant operational environment	Implementation of prototypes in real communities, monitoring	Policy adaptation based on data and stakeholder input	Validation in real organizational settings; achievement of necessary capabilities	Legal compliance status after pilot testing	Value proposition and profitability analysis; cost and revenue structure; funding sources

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6	Demonstration of model or subsystem in operational environment	Scaling and dissemination of social solutions; outcome analysis	Policy scaling and wider implementation	Demonstration in real-world environments with stakeholder feedback	Detailed proposals for legal or regulatory changes	Market entry strategy, positioning, customer testing, operational planning
7	System demonstration in real-life environment	Long-term integration into social practices	Standardization and institutionalization of policies; performance monitoring	Refinement of roles, processes, and infrastructure; retesting	Refinement within the legal system and proposals for regulatory improvement	Market pilot readiness, MVP tested with users, contracts with partners
8	Technology complete and qualified for commercial production	Broad social acceptance and everyday use	Maintenance and policy responsiveness to societal change	Complete and qualified solution with full organizational embedment	Legal audit completed, solution ready for launch	Market entry achieved, operational business model, early revenues and investments
9	Fully operational and utilized technology	Systemic social and cultural change	Evaluation, modification or phase-out of policies	Solution fully adopted in relevant organizational settings	Legally and ethically proven solution post-market launch	Market share achieved, customer retention, profitability and sustainable growth

Source: own study

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MODEL IMPLEMENTABILITY

The above summary can be treated as an integrated innovation management model. As such, it has several characteristics:

- multidimensionality and comprehensiveness, from technology to legal and economic aspects, which allows for a holistic approach to innovation assessment. This makes it easier to identify gaps between technological readiness and, for example, legal or organisational readiness, which are often underestimated;
- consistency of development stages and analysis of the pace of development in various dimensions;
- identification of systemic and implementation barriers through multidimensional mapping of barriers in the innovation implementation process: both internal (e.g. lack of organisational competence – ORL) and external (e.g. low level of social acceptance – SRL);
- It can be applied to the design and evaluation of development strategies, public policies and research and development projects, technological investments, and as a tool for assessing the maturity of solutions in grants or public policies;
- enables the analysis of the compliance of the development path with the needs of the innovation ecosystem and thus increases the compliance of the implemented solutions with real market and institutional conditions;

However, the above proposal has a number of disadvantages resulting mainly from the complexity of the proposed solutions, which significantly affect its applicability. The main disadvantages and limitations include:

- the multiplicity and complexity of the model, which limits its operationalisation;
- the need to engage additional analytical resources;
- the lack of universal indicators and criteria for assigning readiness levels, leaving room for interpretation;
- deficits in the interaction between levels, as feedback loops are not taken into account here – e.g. the impact of changes in law (LRL) on the pace of social (SRL) or organisational (ORL) acceptance, which requires further analysis and conceptual work;
- full application of the model is disproportionate to the scale of the project (it does not apply to small projects);
- the risk of formalisation and excessive focus on meeting levels at the expense of the actual impact and usefulness of innovation.

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The proposal for an integrated innovation readiness assessment model is a step towards increasing the effectiveness of implementing new solutions and innovations by identifying barriers between technological maturity and social, political, organisational, legal and economic conditions. This model enables a systematic, comparative approach to innovation management, enhancing the transparency of decision-making processes in R&D projects, public policies and strategic investments.

However, the exceptional complexity of the structure, the lack of standardised indicators and high analytical requirements limit its practical implementation, especially in the case of smaller projects. The proposal needs to be supplemented with operational tools, primarily adaptive matrices and sets of indicators for selected technology sectors, which will enable scalability and flexibility of application.

In the long term, this model can serve as the foundation for a systemic, multidimensional approach to technology security management, integrating risk assessment, organisational capabilities, regulatory compliance, and compliance with the public interest and social values.

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