Technology readiness revisited: a proposal for extending the scope of impact assessment of European public services

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ABSTRACT

The Technology Readiness Level (TRL) scale has been widely adopted at EU, national and regional levels in the current (2014-2020) programming period as a tool for decision making when financing Research, Development and Innovation investments with public grants. We propose the extension and generalisation of this scale in three further directions, namely the Legal, Organisational and Societal Readiness Levels. With the only, partial, exception of the Legal, the three proposed scales closely track the expected progress of Technology Readiness and, in a normative perspective, should be enhanced and supported in any technology take-up pilot aiming to be successful. The resulting, 4-axis framework has been used to assess the potential of new and existing digital technologies to promote innovation in European public services while ensuring cross-border and cross-domain interoperability. We propose the adoption of this framework as a public sector innovation policy tool to evaluate the performance of EU funded Research, Development and Innovation projects in the next programming period 2021-2027.

CCS CONCEPTS

• **Social and professional topics** → **Computing / Technology Policy** → Government Technology Policy → *Governmental regulations*

KEYWORDS

Digital public services, technology readiness level, assessment of innovation potential, interoperability

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1. INTRODUCTION

Since 2014, the Technology Readiness Level (TRL) scale has become part of the EU Horizon 2020 Work Programmes and in many countries and regions of Europe has been widely adopted in the context of ERDF (European Regional Development Fund) supported Research, Development and Innovation investments.

The scale is arranged in 9 evolutionary stages, showing how far a technology is from being ready for use in its intended operational environment [1]. Although the definitions used in the General Annexes to Horizon 2020 Work Programmes are rather synthetic (see Table 1), the linear progress is well outlined from

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an initial stage of curiosity-driven research to a final stage of fully developed and tested innovation, launched as a new product and/or service in the respective market.

Table 1: TRL scale used in Horizon 2020 and ERDF

MATURITY LEVEL	DESCRIPTION
TRL1	Basic principles observed
TRL2	Technology concept formulated
TRL3	Experimental proof of concept
TRL4	Technology validated in lab
TRL5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL7	System prototype demonstration in operational environment
TRL8	System complete and qualified
TRL9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Source: [2]

Intuitively, the level of abstraction of this categorization is so high that it can be profitably used to:

- Compare different – even very diverse – technologies, just on the basis of their respective positioning on the above scale. This may lead the analyst to conclude, for example, that Blockchain and Distributed Ledger Technologies have gained a lower level of maturity than Digital Signature or e-Identity in the European public sector so far;
- Monitor the progress of a single technology (usually across time) along the pathway from the initial to the final stages. This may be – and often is – associated with an evaluation of the appropriateness and/or effectiveness of the allocation of a public grant in support of Research, Development and Innovation investments. It may also, no less frequently, be supportive of a case study analysis of "technology implementation pilots", whereby the prototype at hand is experimentally tested and verified across a number of small scale, simulated or real, situations of use, to be improved along the process and reach a complete and robust configuration and technical specifications.

From the experience of the 2014-2020 programming period, both at EU and national/regional levels, a wider usage has been made of the TRL scale in the latter than the former direction. For instance, it has been (and still is) a requirement of the Horizon 2020 funding application form, to specify the initial and final TRL of the project – thus helping the evaluator assess the specific, and differential, contribution of the EU grant to enabling the transition from stage X to stage Y. Incidentally, this way of using the TRL also facilitates the understanding of a granted project's positioning along the linear development scale: TRLs 2-4 meaning that the initial idea has not yet left the laboratory where it was elaborated, while in TRLs 5-7 the usage context comes into play and TRLs 8-9 describe a fully implemented and tested innovation. The closer is a project to TRL 9 in its initial stage, the less likely will be that it receives any public funding, due to the application of State-Aid rules, which prevent from supporting commercialization.

Despite its broad success, the TRL based approach to Research, Development and Innovation funding has not been exempt from criticism. One of the strongest objections – yet only partly appropriate, as we will argue below – is related to the non-linear, i.e. cyclical and iterative, shape of most technology development processes. For instance, it is well known from experience that making sound progress in experimentation, by reaching and maintaining TRLs between 5 and 7, often demands to come back to the laboratory and revise the founding principles of that innovative solution. Likewise, if we see a technology product as a composition of different sub-products, it may well be that (some of) those individual components at a certain point in time hold different TRLs – although maybe not too far from each other – and proceed at different speeds along the proposed scale.

However, these and other arguments are weakened by the fact that the TRL is mostly used as a Research and Innovation Policy tool – i.e. to support decision making when financing Research, Development and Innovation investments with public grants – rather than as ontological description of how technologies are developed and rolled out in the respective usage contexts. In this sense, it brings an invaluable help to clarify and specify the differential impact of the public grant on some, though maybe not all, the subprocesses leading to a certain progress along the TRL scale. Ultimately, such progress (from a basic idea to a tested and validated product) can be acknowledged to be somehow linear, at least if temporally defined, although determined at least in part by the intertwining of several concurrent, and sometimes cyclical or iterative, reflective and experimental activities.

In this paper, we adopt the same train of logic as presented above to argue that in several respects, the informative value of using TRL alone within a grant impact evaluation exercise might be profitably extended by the consideration of three more related dimensions – and maturity models – namely:

- The integration of societal aspects in technology modelling and experimentation, with an eye on the readiness to adopt the resulting innovation, measured by a 9-stage SRL (Societal Readiness Level) scale;
- The consideration of possible organisational impacts of testing and/or adopting that innovation, leading to e.g. infrastructure, process and/or human skills related requirements, measured by a 9-stage ORL (Organisational Readiness Level) scale; and

- The complex interaction with the AS-IS legal and ethical (values) system, including any pressure to modify it because of the new innovative solution, which is approached – if not properly measured – by a 9-stage LRL (Legal Readiness Level) scale.

With the only partial exception of the latter scale, we will show that by construction, and probably not by chance, the newly proposed maturity models resonate along with the TRL and that the nine individual stages of each scale are largely juxtaposed. This is not only a matter of coherence, but also points at the multiple facets (societal, organizational, legal) of a single development and testing process that – particularly when supported financially by the State – must lead to a successful introduction of the proposed innovation in its market of reference.

These Readiness Levels, however, are also particularly relevant in the context of the European public sector. Ideally, public services must be built on bullet proof technologies (hence with high TRLs). Based on experience, though, it is also particularly important that the new services are actually used by the targeted audience, hence the need of a high SRL, and are not create any short circuit in the functioning of Public Administration, hence the concern for a high ORL. Finally, although it may be conceivable for a private business to challenge the existing laws (if not operate at the margin of them), this cannot be case for the deployment of a governmental service, hence the importance of a high LRL.

In the context of the Study under which this paper is written –referenced in the Acknowledgments – all of the above aspects are equally relevant. First, as far as the TRL is concerned, a particular technology to be used in the shaping of a new public service must be mature enough, to avoid that the supported service failed or be disrupted. The SRL is relevant to consider in relation to the use of e.g. personal data governments have access to and ultimately to the "never ask twice" principle with regard to that information. In turn, the ORL is particularly important as public services do not operate anymore in isolation and new, appropriate organisational structures are to be put in place to ensure interoperability and alignment of business processes. Last but not least, concerning the LRL, while private sector innovators can indeed operate in grey areas, this does not apply to governmental institutions, which are obliged to comply with extant laws and regulations in full.

Indeed, the above considerations are inspired largely by the European Interoperability Framework (EIF) that is part of the Communication from the European Commission adopted on 23 March 2017 [COM(2017)134]. In fact, the EIF is structured in four interoperability layers (see [3]):

- Organisational, referring to distinct public sector bodies being able to align their business processes, responsibilities and expectations to achieve commonly agreed and mutually beneficial goals;
- Legal, which occurs when organisations that operate under different legal frameworks, policies and strategies are capable of working together;
- Semantic, ensuring that the format and meaning of exchanged data and information are preserved and understood throughout exchanges between parties; and finally
- Technical, covering applications and infrastructures linking systems and services. Aspects of technical interoperability include user interface specifications, interconnection services, data integration, display and exchange services, secure communication protocols etc.

In addition to the above, we can safely state that considering the relevance of societal aspects (thus the SRL) is tightly related with the 8 user centricity principles outlined in the Annex to the latest Declaration on eGovernment, signed by 32 Ministers in charge of policy and coordination of digital public services in the countries of the European Union (EU) and the European Free Trade Area (EFTA), during the Estonian Presidency of the EU Council on 6 October 2017 (henceforth: the Tallinn Declaration [4]).

In this paper, the superior explanatory value of a framework based on four Readiness Levels rather than just one will be highlighted, with examples from the aforementioned Study. Then we will conclude our analysis by formulating the proposal to EU, national and regional policy makers, to consider the option of integrating the SRL, ORL and LRL alongside TRL within the set of decision making support tools to be made available in the next programming period 2021-2027.

The remaining part of the paper is organised as follows: Section 2 is a brief overview of maturity models in general and a history of the TRL scale in particular. Section 3 serves to frame the proposed research within the purposes of a Study carried forward on behalf of the European Commission during the year 2019. Sections 4 through 6 introduce the three additional Readiness scales constituting the main outputs of this ongoing research while Section 7 discusses their integration and use potential, with particular regard to the Study within which they have been introduced for the first time. Section 8 presents some exemplary implementations of the framework and analyses three pilot projects and the results achieved by each of them, also in terms of interoperability and user centricity. In Section 9 we will draw some conclusions and formulate recommendations for future work.

2. BACKGROUND

Maturity models have been in use for several decades in support of Information Systems-related, as well as Organisational, research and consultancy. Thus, the (white and grey) literature that concerns them is endless. A recent, rather systematic though probably still incomplete, overview of state of the art [5] found

409 relevant papers and a plethora of methods for classification, many of which still needing a real validation.

In essence, a maturity model is a collection of development stages of a certain phenomenon, usually 5 of them, arranged along a (supposedly) linear pathway of progress in terms of performance, effectiveness or value creation. Examples exist aplenty, such as the Carnegie-Mellon University's CMMI-Capability Maturity Model Integration, serving to clarify whether an organisation is capable to perform a contracted project; or TMMi Foundation's Test Maturity Model integration evaluating a software testing business; or P3M3 also known as Portfolio, Programme and Project Management Maturity Model from the UK Office of Government Commerce and the Project Management Institute, focusing on the management of processes that involve portfolios, programs and projects.

Maturity models have been used to assess the status and the progress of Information Systems [6], eGovernment applications [7] and Smart Cities [8]. The basic idea, though often criticised for being overly simplistic and supported by a deterministic vision of things, is to communicate and share with the relevant stakeholders, in a synthetic and easy-to-grasp manner, all available information on a certain issue, to stimulate reflection and possibly ignite a reaction. Due to this twin aim of the generic maturity model, the interest of the business consultancy community in designing and exploiting it as an operational tool for the profession has usually prevailed over the concern of the scientific community to remove contradictions and conceptual overlaps from the various examples in circulation.

Though a bit different for the unusual number of stages that are part of it, also the TRL scale can be considered as an example of maturity model. Historically, it was born in the aerospace industry with a lower number of stages [9] and its current shape is attributed to work done inside NASA, followed by the thematic extension to other technological assessment contexts, still in the US [10]. As far as Europe is concerned, the concept was imported in the context of the ongoing reflections on the KETs – Key Enabling Technologies – which have later become the backbone of the current EU funding system for Research, Development and Innovation [11]. Another big push was given by the findings of the High Level Expert Group on Key Enabling Technologies (HLG-KET), established in 2011 by the European Commission, and whose recommendations were included in the 2012 Communication entitled "A European strategy for Key Enabling Technologies – A bridge to growth and jobs". [COM(2012)341].

As already stated in the Introduction, the TRL can be considered as a sort of rule of thumb approach to assess the maturity of a certain technology. Being based on readiness (i.e. closeness to the market), it has the big advantage of being technology neutral, and in fact has become widespread in all technology sectors. In terms of Table 1 above, TRLs 1-3 pertain to the initial stages of any Research and Development project, where a proof-of-concept is formulated and gradually refined, while TRLs 4-6 belong to the validation and demonstration phases, which can and should be realised first in a closed laboratory environment, then in real or near-real world conditions. TRL 7 is the final stage of prototyping, while TRLs 8-9 constitute the usual pre-market and market launch conditions of any new innovation.

Quite interestingly, the key competitor of TRL in the domain of technology assessment was (and is) the TRI, Technology Readiness Index, a multi-item scale developed since 2000 by A. Parasuraman from the University of Miami and C. Colby, the founder of the US Rockbridge Associates consultancy company. In essence, the TRI focuses on the concept of customer propensity to adopt a certain technology, in dependence of four key factors, two acting as drivers or enablers and two as barriers or inhibitors. Motivating factors include Optimism – a general belief that technology and innovation has positive benefits – and Innovativeness – an inherent tendency to want to experiment with, learn about and talk about technology. Contrasting mechanisms are associated to Discomfort – a perceived lack of control over technology - and Insecurity – a belief that technology can result in adverse impacts on the user and society.

As the authors put it [in 12], "TR is a mindset, not a measure of competence or knowledge". The TR concept has been validated across several research and empirical studies, using first a 36-dimension and then a 16-dimension scale, proving to be "a stable characteristic that does not change easily for an individual". Thus, it can be considered of a similar level of abstraction – or if one prefers so, technology neutrality – than the 'rival' maturity model, despite the fact that each of the two has a radically different focus: the industrial actors delivering that technology in the former case, the people ultimately using it in the latter.

Both assessment methods have been widely adopted since their invention, proving good potential to deliver the expected results to the industrial or policy stakeholders they have been used for. On the other hand, it must be acknowledged that the two approaches belong to very distinct and separate 'schools of thought', with little chance for reciprocal contamination or cross-fertilisation. This is a pity, if one considers that the chances of any new and innovative technology to be successful in its target market strongly depend on a combination of supply and demand related aspects.

Indeed, the standard or predominant way of implementation of these two approaches (each in its own right) has raised very little criticism in both literature and practice. Their prevalent usage has been similar to a 'plug-and-play' solution, embedding at the same time the capacity of tackling the problem at hand and the limitations deriving from the partial or incomplete formulation of the problem itself.

3. RESEARCH FRAMEWORK

The purpose of this section is to contextualise our proposal, as we put it already in the title of this paper, for enlarging the scope of impact assessment of European public services through a revision and extension of the TRL scale presented in Table 1.

The original idea was born in the context of a Study, the ultimate goal of which is to support governments from all over the EU in adopting and making extensive use of digitalized public services to deliver value to citizens and businesses. Although the digitalisation trends of public service have considerably fastened over the past decade, the take up of the potentially most impactful

technological innovations (such as Blockchain and Distributed Ledgers, Artificial Intelligence, Virtual and Augmented Reality, Big Data Analytics, etc.) is still low and the associated business models are currently under-embraced in EU national and regional public administration. This also has implications in terms of persistence of gaps between expectations and achievements of government transformation, which in turn are likely to be associated with the poor levels of digital service usage and public engagement in the digital economy, still noteworthy in a number of European countries.

Therefore, the Study proposes to define and assess the impact that novel technologies already established in the state of the art, if properly adopted, could bring to public administration, in terms of value created, user experience and interaction, effectiveness of policy making, improvement of service delivery and so on. Based on the results of this impact assessment, more focused activities could be planned and executed to promote a diffused take-up of those technologies at government level in the future.

Moreover, a precise requirement of the Study was to carry out this impact assessment not in abstract terms, but in relation to very concrete, real or realistic, implementations of each identified technology – possibly, though not inevitably, in a public sector environment. Therefore, one of the analytical goals was to retrieve each new technology within the borders of a specific "pilot" – a term used in literature and practice to designate a small-scale, short-time experiment that nevertheless holds all the key traits of a large-scale, permanent adoption and thus helps the organization involved in the trial to learn what implications such adoption might have, for whom and why.

Inevitably, Technology Readiness (however defined) was only part of this picture. More broadly, the assessment perimeter should include the societal, organisational and legal aspects, alongside the purely technological ones, to the extent they could materialize in a specific pilot context and contribute to shaping – for good or bad – its operations and outputs. In fact, a distinct, but no less important objective of our analysis consisted in measuring the 'transitioning pathways' that each pilot project may undertake during its lifetime, in dependence of all of the above dimensions.

Finally, the whole exercise was conceived of in such a way to make sure that the resulting framework could be easily reused, thus helping to disseminate the lessons learnt from the trials on how to transfer, replicate or further develop the pilots in other public sector organisations.

The resulting, 4-axis framework was based on the extension and generalisation of the TRL scale in three further directions, namely the Legal, Organisational and Societal Readiness Levels, as will be clarified in the following sections.

4. SOCIETAL READINESS LEVEL (SRL)

The SRL is an approach originally proposed by Innovation Fund Denmark [13] to assess the level of societal acceptance of a certain technology, product, process, or intervention. The intuition behind it is that any innovation – be it technical or social – requires being integrated in the societal environment. Thus, the higher the SRL, the higher is such integration or the lower will be the need to set up ad-hoc measures to promote "a realistic transition towards societal adaptation".

The SRL is analysed through the readiness of the society to adopt the solution. Again, the approach is technology neutral and very importantly, there is no overlap with the TRL, making the two maturity models both valid and rigorous interpretative lenses.

According to its proposers, also the SRL has 9 possible stages, which are reported in Table 2 below (with slight modifications from the original list):

Table 2: SRL scale (adapted from Innovation Fund Denmark)

MATURITY LEVEL	DESCRIPTION
SRL1	Identification of the generic societal need and associated readiness aspects
SRL2	Formulation of proposed solution concept and potential impacts; appraisal of societal readiness issues; identification of relevant stakeholders for the development of the solution
SRL3	Initial sharing of the proposed solution with relevant stakeholders (e.g. through visual mock-ups): a limited group of the society knows the solution or similar initiatives
SRL4	Solution validated through pilot testing in controlled environments to substantiate proposed impacts and societal readiness: a limited group of the society tests the solution or similar initiatives
SRL5	Solution validated through pilot testing in real or realistic environments and by relevant stakeholders: the society knows the solution or similar initiatives but is not aware of their benefits
SRL6	Solution demonstrated in real world environments and in co-operation with relevant stakeholders to gain feedback on potential impacts: the society knows the solution or similar initiatives and awareness of their benefits increases
SRL7	Refinement of the solution and, if needed, retesting in real world environments with relevant stakeholders: the society is completely aware of the solution's benefits, a part of the society starts to adopt similar solutions
SRL8	Targeted solution, as well as a plan for societal adaptation, complete and qualified; society is ready to adopt the solution and have used similar solutions on the market
SRL9	Actual solution proven in relevant societal environments after launch on the market; the society is using the solution available on the market

Source: adapted from [13]

As shown in the Table, the connection between TRL and SRL is very close and direct even if we think of the target solution as a technological one. However, the proposed approach is broader than that, as it encompasses new solutions that may not be technical – wholly or at least in part. We will keep this statement in mind while presenting (in sections 7 and 8) some results of the EU funded Study dealing with digital public services, whereby the SRL is analysed in terms of both societal readiness to adopt the supporting digital technology and of readiness of the technology itself to be adopted in the public service domain. Indeed, for their peculiar combination of technical as well as non-technical aspects (such as user centred design, social acceptance, etc.), digital public

services can be considered as optimal examples of the target solution mentioned in the Table.

In the above respect, our reading of SRLs 1-2 is that they reflect the growing awareness of a Research and Development team about the existence of a societal readiness issue. In turn, SRLs 3-6 are concerned with the more and more extended inclusion of societal stakeholders (such as prospective users or other similar groups) in the testing, validation and demonstration phases of the Research and Development outputs. Then SRL 7 well matches TRL 7 in its being referred to the final stage of prototyping, while SRLs 8-9 belong to the pre-market and market launch phase of the target solution – a phase that may also be related to a non-commercial situation, as can evidently be the case for a newly developed digital public service, which will be delivered free on any charge.

5. ORGANISATIONAL READINESS LEVEL (ORL)

While the TRL and SRL scales (particularly the former) are already established in both literature and practice, the ORL is an original approach – though conceptually akin – that is presented here for the first time. By analogy to (esp.) SRL, ORL has to be seen as an ad hoc maturity model related to the organisational impact of a certain technology, product, process, or intervention.

Following Eleanor D. Glor [14], the term "impact" is defined to include both the results of an innovative effort (outputs of e.g. Research and Development activities) and their broader effects within the perimeter of the specific organisation implementing that innovation (outcomes). Key impact areas span from professional roles, competencies and skills to organisational functions, processes and physical infrastructures. Being Public Sector Innovation policy the domain of election for our analysis, we should probably add "governance systems" as a further analytical dimension to people, functions and structures. This relates directly to one of the four layers of the EIF – not by chance, organisational interoperability – as the capacity of a public body to survive to the introduction of an innovation is one of the key prerequisites for the same innovation to last over time. However, this "inward looking" aspect of Organisational Readiness is partly compensated for by the "outward looking" orientation of the SRL presented in the previous section, and that we propose to consider here jointly with the ORL.

For a matter of symmetry, we propose nine possible instances for the ORL, which are presented in the Table below:

MATURITY LEVEL	DESCRIPTION
ORL1	Identification of the organizational need (infrastructures, capabilities, skills) and associated organisational readiness aspects
ORL2	Formulation of proposed solution concept and potential impacts; appraisal of organisational readiness issues; identification of relevant roles, processes, functions and structures for the solution
ORL3	Comprehensive description of proposed solution's impacts within the organisation in terms of roles, competences and skills, physical infrastructures required
ORL4	Solution validated through simulation of major induced changes to substantiate proposed impacts and organisational readiness: the organisation which is developing the solution starts to acquire roles, competences and skills, physical infrastructures required
ORL5	Proposed solution validated through pilot testing in real or realistic organisational environments: the organisation which is developing the solution achieves roles, competences and skills, physical infrastructures required
ORL6	Solution demonstrated in real world environments and in co-operation with relevant stakeholders to gain feedback in order to improve roles, processes, functions and infrastructures required
ORL7	Refinement of the roles, processes, functions and infrastructures required and retesting of the solution in relevant organisational environments
ORL8	Targeted solution, as well as a plan for organisational embedment, complete and qualified: roles, processes, functions and infrastructures are available
ORL9	Actual solution proven in relevant organisational environments: roles, processes, functions and infrastructures are correctly used for the solution on the market

Source: the authors, inspired by [14]

Table 3: ORL scale (our elaboration)

ORLs 1-2 match SRLs 1-2 in reflecting the growing awareness of a research team about the existence of an organisational readiness issue. In turn, ORLs 3-6 are concerned with the more and more extended consideration of roles, processes, functions and structures (and governance systems) in the phases of testing, validation and demonstration of the targeted outputs. ORL 7 matches both SRL 7 and TRL 7 in its being referred to the final stage of prototyping of the complete solution, while ORLs 8-9 belong to the pre-market and market launch phase, meeting the prerequisite of organisational readiness in full.

An important aspect to stress is that the ORL based approach presented in this paper is reversed from that predominant in the organisational literature: knowing what the major impact areas of an innovative solution can be, we are more interested in defining the preparedness level of an organisation receiving it, instead of analysing the consequences of introducing that innovation in terms of improved organisational performance or other factors.

The assumption here is that any innovation – be it technical or social – requires being embedded in the organisational environment to become permanently adopted. Thus, the higher the ORL score, the higher such embedment or the lower will be the need to set up some ad hoc measures to promote "a realistic transition towards organisational adaptation" – to paraphrase the SRL description by Innovation Fund Denmark [13].

Once more, this approach is technology neutral and crucially, there is no overlap with either the TRL or the SRL, making the three maturity models jointly usable for the purposes of experimentation and assessment.

6. LEGAL READINESS LEVEL (LRL)

Like ORL, also LRL is an original approach invented for the purposes of our research. Conceptually, it is even less rooted than ORL in academic literature or practice. However, the analogy with (esp.) SRL and ORL can be developed far enough to allow the formulation of a maturity model that looks at the legal and regulatory implications of innovations in terms of compliance, but also transformative power. In fact, it is obviously true that no new technology, product, process, or intervention can survive if proven to go against the existing set of binding rules that govern the selected domain. Yet, the opposite is also (to a large extent) true: namely that any legal system evolves over time, as a result of breakthrough innovations, bringing to the surface the need of limiting the range of possibilities and configuring new spaces of legitimate action.

Take as an example the field of Artificial Intelligence, recently explored in a joint JRC-EIT workshop [15]. While it can be safely stated that all related Research and Development projects and start-up companies stably operate within the borders of the existing legal system, it's also meaningful to ask whether any legal and regulatory obstacles or gaps can be identified, the tackling of which would favour the deployment of those technologies in a more innovation prone and also individual rights protective environment.

The implicit assumption here is that innovation – especially if disruptive – requires a sort of legal compliance check to become permanently adopted. Thus, the higher the LRL score, the higher is such compliance level or the lower will be the need to set up some ad hoc measures to promote "a realistic transition towards legal compliance" – to paraphrase the statements issued in the previous sections.

Once more, this approach is technology neutral and again, there is no perceived overlap with the TRL, SRL and ORL maturity models, making the four assessment criteria jointly usable.

As a final note, we stress the fact that the definition of legal compliance, especially in the context of corporate legal departments, has recently been expanded to include understanding and adhering to ethical codes by involved professionals [16]. Thus, we consider acceptable to include ethical considerations into the scope of legal compliance as being particularly relevant to promote the evolution of the legal system towards a redefinition of available spaces for the innovators' actions.

Again for a matter of symmetry, we propose nine possible instances for the LRL, which are presented in the Table below:

Table 4: LRL scale (our elaboration)

MATURITY LEVEL	DESCRIPTION
LRL1	Generic consideration of legal and ethical compliance aspects are observed but nothing has yet been done for the development of the solution
LRL2	Formulation of the need to enhance the legal normative, laws, rules and guidelines and solution concept; appraisal of legal and ethical compliance issues
LRL3	Abstract description of the proposed solution's legal and ethical compliance
LRL4	Solution's legal and ethical compliance prospects validated against any required or recommended changes in the legal and/or regulatory system
LRL5	Definition of the proposed solution's legal and ethical compliance status after pilot testing in real or realistic organisational environments
LRL6	Detailed description of the required or recommended changes in relevant laws, regulations or organisational rules to ensure full compliance with the proposed solution
LRL7	Refinement of the solution within the existing legal and ethical system and, if needed, proposals for required or recommended changes to some aspects of it
LRL8	Targeted solution, as well as a legal and ethical compliance audit, complete, qualified and ready to be launched on the market
LRL9	Actual solution proven legally and ethically compliant after launch on the market

Source: the authors

Therefore, LRLs 1-2 match ORLs and SRLs 1-2 in reflecting the growing awareness of a research team about the existence of a legal and ethical compliance issue. In turn, LRLs 3-6 are concerned with the more and more extended consideration of laws, regulations, ethical principles and organisational rules in the testing, validation and demonstration of the targeted solution. LRL 7 matches the same score of ORL, SRL and TRL in its being referred to the final stage of prototyping, while LRLs 8-9 belong to the pre-market and market launch phase.

7. DISCUSSION

Taken together, the four Readiness Level scales form the building blocks of a unifying framework that we have used to assess the potential of new and existing digital technologies to promote innovation in European public services in a sustainable fashion.

In fact, with the only, partial, exception of the Legal, the three newly proposed maturity models reproduce the expected progress of Technology Readiness and therefore, in a normative perspective, should be enhanced and supported in any technology take-up pilot aiming to be successful.

Another relevant aspect, already mentioned in the previous section and confirmed by Figure 1 below, is that there is a very good match between TRLs, SRLs, ORLs and LRLs holding the same score. This is largely artificial, i.e. obtained by construction, but also very logical, considering that our main aim is to reach a more complete understanding of the enablers and barriers of a successful take-up of technologies in the social, organisational and legal contexts they act within.

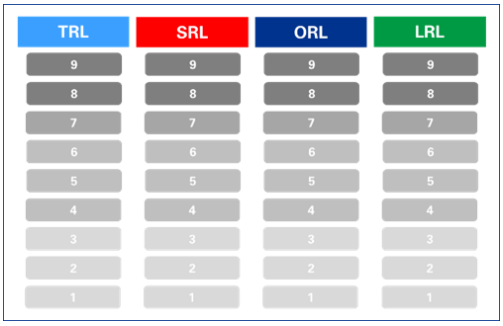

Figure 1: Overview of the proposed 4-axis framework

To facilitate understanding of how this framework can be used as a Research and Development Policy support tool, we start by the description of a simplified scenario, where the TRL of a given technology is known and fixed in advance. Conceptually, such scenario can be represented as a point in a 3d space having (l, s, o) coordinates – where obviously l stands for legal readiness, s for societal, and o for organisational – like in the following Figure :

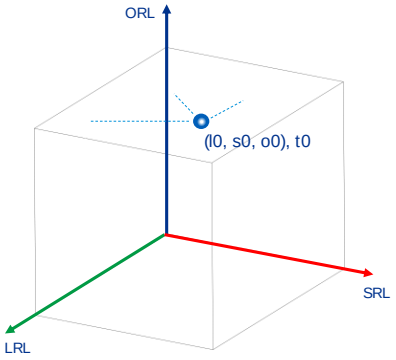

Figure 2 - The non-technological dimensions of the framework

Adding the TRL as fourth explanatory variable, would imply to think in terms of a "4d cube" based on (t, l, s, o) quadruplets, that only machines can handle and would become impossible for human eyes to visualize. In our Study, we measure the fourth variable "t" by the size of the small ball inside the cube, which becomes bigger and bigger across time, along with the progress of technological readiness of the underlying pilot.

The following figure makes the example of a technology pilot run between t_0 and t_1 in a certain location, where both Technology and Organisational Readiness progressed considerably during the trial, while Legal and Societal Readiness observed a slower increase.

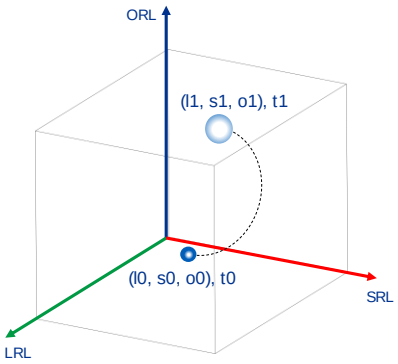

Figure 3 - Proposed framework in action (transition pathway)

What is a possible narrative associated to this description? We may think of a state of the art, possibly off-the-shelf technology item (having already a TRL 9 or close to that) that has been introduced in a pilot context for the first time. Initially the SR and OR levels are quite low, meaning that neither the external environment (for instance, the constituency of a government body) nor the staff and other resources of the involved organisation (for instance, a public service provider) were actually ready to receive and adopt that innovation. However, after the end of the trial, both the Societal and the Organisational conditions for take up appear to have improved, which sheds a positive light on the future outcomes (in terms of sustainability) of that experimentation.

While this narrative may be too similar to a non-technological project, it becomes more intriguing if we bring the TRL back into the picture, though at the cost of leaving the realm of visualisation and staying within that of verbal argumentation only. The real or realistic story we can talk about is obviously similar to the "typical" EU or national/regional funded project of Research, Development and Innovation, where the starting TRL of the solution is low and expected to improve considerably by the end of the trial.

In this context, a closer inspection of the pilot can be done by following (at least) two distinct approaches:

- Explanatory, looking into "what went wrong" in the pilot, making the improvement of TRL lower than expected;
- Predictive, controlling for all the variables that can possibly be relevant for the success of a future take-up trial.

Following the first line of reasoning, and based on the information that could be retrieved, ex post, by a summative evaluation effort, a number of "hidden correlations" between the different Readiness Levels may come to the surface. By way of exemplification, we list some of them in the following Table:

Table 5: Ex post analysis of a technology pilot (examples)

WHAT HAPPENED IN THE PILOT	WHAT MAY THIS HAVE IMPLIED
The LRL was and remained low (indicatively below 4)	The trial did not take enough consideration of legal and ethical compliance aspects or only in a rather abstract fashion
The LRL indeed grew up but stayed below 5	Despite a certain and growing degree of awareness of the importance of such aspects, the trial did not include any validation of the solution adopted after a desk analysis
The LRL actually moved up but stayed below 6	There can be risks of non-compliance with the existing legal and ethical system due to the novelty of the solution and the lack of a complete audit in that respect
The ORL was and remained low (indicatively below 4)	The owner of the trial was aware of some or all of the issues related to the organisational impacts of innovation but only in a rather abstract fashion
The ORL indeed grew up but stayed below 5	The organisational solution adopted after a desk analysis was not properly dealt with during the pilot
The ORL actually moved up but stayed below 6	The outcomes of the validation have not been transposed into a concrete organisational embedment plan
The SRL was and remained low (indicatively below 4)	The owner of the trial made only a preliminary and high level analysis of the sharing needs and processes for the envisaged solution
The SRL indeed grew up but stayed below 5	Pilot testing was never done in real or realistic conditions and this has lowered the impact on societal readiness
The SRL actually moved up but stayed below 6	There is a need to go beyond the pilot results and formulate a clear proposal for stable user engagement

Source: the authors

Even more considerations could be associated to looking at the joint or concurrent transition of the three dimensions, but the substance is clear. How many times has the failure of a technology pilot been related to its being "ahead of its time", or to users "not being ready to receive it", or to "lack of sufficient capacity" in the people who are expected to adopt it? One of the key benefits of the first proposed approach is to enable the viewer to take a global look at the pilot from all relevant perspectives at the same time. Generally speaking, however, to classify a project as "unsuccessful" it is sufficient to observe that one of the four Readiness Levels did not grow over time to the same extent as the other three.

The second proposed line of reasoning totally reverses the angle, and formulates all the above questions with a predictive inspiration, i.e. trying to assess the starting conditions of a pilot and even more attentively, to define the possible pathways through which a concurrent and significant improvement of all the four relevant dimensions of the pilot can be achieved.

Indeed, this situation is pretty similar to the one characterizing the way the TRL concept is currently being used in Horizon 2020 or national/regional ERDF funded programme projects. Much in the same way as a prediction of the future level of TRL can be made, a similar task should be dedicated, in our opinion, to the SRL, ORL and LRL, with the additional advantage – as highlighted before – that to a very great extent these dimensions seem to go hand in hand or reinforce each other during pilot execution.

To adopt and concurrently track the four Readiness Levels as assessment criteria for technology take up pilots, a structured representation based on "transition pathways" from the initial to the final status of each type of Readiness must be generated, increasing the level of awareness of trial owners on the conditions under which adopted technologies could be brought to maturity, achieve impacts and realise their transformative potential.

While this paper was being written and reviewed, the proposed 4-axis framework was extensively used for the collection of case studies in the area of digital public service innovation at EU and Member State level. In so doing, the heuristic and informative value of the model will be implicitly validated. Another important output of this exercise will be a searchable database gathering all information concerning the cases analysed. This – if adequately shared and advertised – will remain available for further use and implementation by both academics and practitioners in the field.

8. APPLICATIONS

This section presents – by way of exemplification, and preserving the anonymity of observed cases – the results achieved by applying our framework to three real pilots developed in the European public sector.

The first successful implementation is an open data initiative that concerned public utilities and related domains (such as water supply, public transport, environmental services, planning etc.) in a European city region. The pilot aimed to make service related data available to a wide audience, enabling cross-sectoral collaborations and promoting new data-driven businesses and innovations. This was achieved through an open data platform combined with an innovation network exploiting data visualisations through a mobile app, also enabling data downloads and requests for ad hoc data by the users themselves. The pilot is considered a success story and in fact shows concurrent and proportional increases in all Readiness Levels, starting from low initial scores that grew high after the completion of the testing phase. Moreover, the pilot satisfied most of the user-centricity principles identified in the Tallinn Declaration and the interoperability layers were in a pretty good shape.

In particular, the Technology Readiness Level was 3 in 2011 and in six years reached 9, the highest score of the scale. The same can be said for the Societal and Organisational Readiness Levels. This means that back in 2011 the maturity of the underlying technology was at the level of an experimental proof of concept, that there was only an initial and preliminary sharing of the proposed solution with relevant stakeholders and that only a limited number of individuals and social groups were aware of the solution or similar initiatives in the field. Moreover, a comprehensive description was still required of the proposed solution's impacts within the public sector organisations (public utilities) in terms of roles, competencies and skills, physical infrastructures and also governance systems.

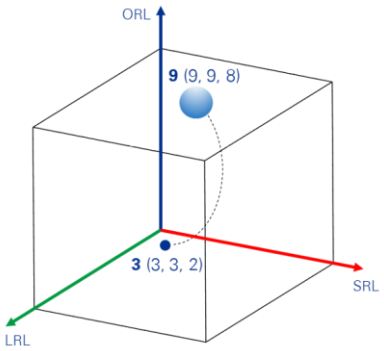

Figure 4 – Observed transition of case 1

The development of this innovation in six years' time has led to a solution that is proven in operational, societal and organisational environments. Contrary to the other three dimensions, the LRL only increased up to 8 from an initial 2 rather than 3 score. This was due to the existence of a full legal and ethical compliance audit, while a complete and qualified solution, ready to be launched on the market in 2017 was still missing.

Considering user centricity, the pilot project fulfilled 6 of the 8 principles outlined in the Tallinn Declaration, notably digital interaction, accessibility/security/availability & usability, reduced administrative burden, digital delivery of public services, citizen engagement and incentives for digital service use. Actually, a central feature was the deep user involvement since the outcome of experimentation also relied on data streams and live feeds. The only 2 unfulfilled user centricity principles were protection of personal data and activation of redress and complaint mechanisms, but only because they were not relevant to the case at hand.

The pilot also demonstrated good interoperability in all layers (legal, organisational, semantic and technical), since the processes were aligned and data and information were considered as a public asset that was appropriately generated, collected, managed, shared, protected and preserved. As far as technical interoperability, the dataset was conforming to the pilot's metadata standards, so this aspect could be considered good as well.

A second, also successful pilot implementation was in the field of the Blockchain technology for the provision of automated and tamper-proof online identity verification services by the use of multifactor biometric authentication. Therefore, the pilot combined different technologies, such as biometric identification and screening, which, as it is evident for the Blockchain, have already reached a pretty good overall level of technical readiness.

During implementation, the pilot focused on all four Readiness Levels, which resulted into a homogeneous growth of all of them. In particular, the TRL moved from level 8 to 9, since the Blockchain was already a complete and qualified system before the pilot successfully proved it in an operational environment. As far as both SRL and ORL are concerned, the piloted solution required only small adjustments and refinements of processes, roles and functions. Thus, both SRL and ORL scored near the top of the scale, also thanks to the involvement of relevant stakeholders in the pilot activities. As for the LRL, it also passed from level 8 to 9. It started from a high level because of the juridical literature that has been produced since the introduction of the blockchain and was only to be tailored to the pilot's authentication solution.

Interoperability was also quite high for all the four analysed layers. This was due to the easiness of the solution to be replicated both technologically and legally, thanks to its high level of data protection. However, semantic and organisational interoperability still presented some issues to be tackled, such as communication protocols. Finally, the pilot fulfilled 7 of the 8 user centricity principles, mainly thanks to the possibility for the solution to be fully operated by the end users.

As in the previous case, the pilot registered homogenous growth of all the four Readiness Levels, reaching, each of them, near the top score. In conclusion, we can consider the Blockchain based online identity verification service a successful pilot, as witnessed by the steady increase of all four Readiness Levels during its implementation.

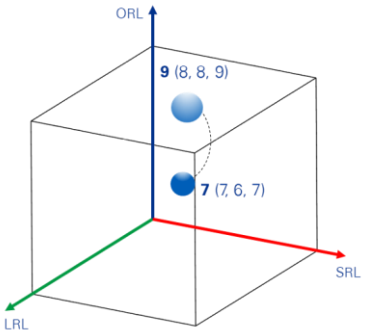

Figure 5 – Observed transition of case 2

However, as anticipated in the previous section, observing the evolution of the Readiness Levels may also suggest that the results of a certain pilot project fell beyond initial expectations. More specifically, it may happen that by the end of the testing phase, the Readiness Levels be quite far from each other, or may have grown at different speeds rather than harmoniously. This means that at the end of the experimentation, significant gaps affecting any of the technological, societal, organisational and legal dimensions of the framework are likely to be neglected.

In fact, the third case presented did not reach the goal of creating (as announced) some 'virtual hubs' to integrate heterogeneous data sources in the domain of general public utilities. The project was developed to combine several technologies, such as Software and Services and the Internet of Things, in order to fully exploit Open Geographic Information (OGI), and provide users with a single point of access to geospatial datasets through new or already existing platforms and infrastructures and ultimately stimulate innovation. However, at present, the OGI world is still extremely heterogeneous: user and system requirements are too varied to be satisfied by a single solution and therefore the pilot aims revealed overambitious. In

fact, from t0 to t1 only the TRL grew from 2 to 8, whereas the other three Readiness Levels (SRL, ORL, LRL) only moved from 2 to 3.

Regarding the TRL, the technology concept was formulated at the beginning of the pilot testing phase (t0) whereas the system was complete and qualified at its completion (t1). Conversely, the SRL, ORL and LRL did not grew in parallel with the TRL, but stayed almost still. The absence of a strict correlation between the four variables led to classify the pilot as a failure.

In fact, at t0 the SRL scored 2, meaning that the societal need and a proposed solution concept were formulated and the main stakeholders were identified. At t1 however, the SRL just moved up to 3: the proposed solution for the pilot was shared with relevant societal stakeholders but only a limited group was aware of it.

Regarding the ORL, the score was 2 at t0, implying that the organizational need and a proposed solution concept were both identified to adapt relevant roles, processes, functions and physical infrastructures and governance systems. However at t1 the ORL only became 3: the pilot did not produce much further than a description of proposed solution's impacts within the organisation.

Finally with respect to the LRL, the need to enhance the legal compliance of the innovation was formulated at the beginning of the pilot testing phase (t0) but at the end of it (t1) only an abstract description of the proposed solution's legal and ethical compliance was made available, thus the annotation of a slight change from 2 to 3 of this Readiness Level.

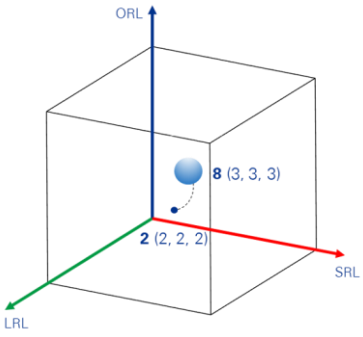

Figure 6 – Observed transition of case 3

Moreover, semantic and technical interoperability challenges were only met to a limited extent, due to the plethora of different and heterogeneous system requirements, creating a barrier to realizing the full exploitation potential of OGI. With respect to the user centricity principles identified in the Tallinn Declaration, the project only fulfilled 2 of them: reduction of the administrative burden and accessibility, security, availability and usability.

This analysis, reiterated on additional cases classified as 'failure stories', clearly shows that any initiative evolving across time with divergent Readiness Levels, also has good chances of not being capable of meeting key interoperability challenges and can struggle to put users really at the centre of public service provision.

We see this as a crucial lesson learnt from our framework's implementation: for those public sector organisations willing to design and deliver digital services that meet citizen and business expectations in full, our strong advice is to pay more attention to the concurrent growth of Technological, Societal, Organisational and Legal Readiness Levels, instead of carrying forward activities that have a prevalent technical (or even non-technical) nature.

9. FINAL REMARKS

To conclude the paper, we would like to highlight some of the benefits of experimentally adopting this framework as a support for EU grant distribution in the next programming period. The benefits of this framework stem from its being, at the same time:

- Respectful of the variety of innovation modes that characterise the EU socioeconomic scenario. For instance, some technological innovations may be disruptive if properly introduced, despite their not being based on new cutting-edge technologies. Or the same consolidated and well-functioning technology may not be easily transferred to another similar context, unless all relevant variables are controlled for;
- Attentive to the combination of contextual aspects (legal, organisational, societal and sometimes cultural or capacity related) that make a technology be adopted and produce changes. Think of the role of "first buyer" attributed by the law and praxis of innovative procurement to the public sector, introducing solutions that are not yet in the market through the identification of appropriate and replicable use cases. Think also of the "impossible mission" of scaling up new and emerging technologies already piloted at micro level with good success, but totally unexplored at meso or macro levels;
- Compatible with a wide variety of technological and even non technological domains, some with definitions that may look sometimes loose or actually an 'ensemble' gathered under umbrella terms, and thus requiring further adaptation and specification to become meaningful at pilot project (and community) levels;
- Verifiable: like TRL, also SRL, ORL and LRL include high level descriptions that are adaptable to different pilot contexts and nevertheless make the results of the analysis (in terms of lessons learnt) comparable and replicable;
- Parsimonious: collection of evidence can be discontinued at any time, without procuring harm to the proposed model or hampering its heuristic and informative value for the cases already analysed;
- Scalable: not only for the trivial reason that the framework works the same if/when the number of collected items goes up, but also because with a little more attention paid to the details, each surveyed pilot may

genuinely and uniquely be associated with a longer string of cardinal numbers, the first four of them being the attributed/observed values for the (t, s, o, l) quadruplet, while others may reflect the contextual conditions, domain characteristics and impact areas of the pilot at hand.

For instance, in the context of the aforementioned EU Study, we successfully applied this 4-axis framework to the assessment of public service digitalisation pilots using a previously identified set of technologies and have outlined recommendations with specific regard to the identification of interoperability issues/risks and to the possible ways to improve user centricity according to the Tallinn Declaration principles.

The expected outcome of this exercise has been to highlight the crucial importance of all the Readiness Levels progressing at the unison in the direction of improvement (or as required, redefinition and/or restructuring) of public service delivery.

Likewise, in the new setup of the projects funded by Horizon Europe (the 9th EU Framework Programme for Research, Development and Innovation) as well as in the national/regional initiatives supported by ERDF in the new programming period 2021-2027, the progress of TRL could still be used to assess the closeness to the market of a certain innovative solution before and after the funded intervention, but the concurrent growth of the other three Readiness Levels could easily become the backbone of a more structured, holistic, and impact aware, evaluation approach.

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