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A Multidimensional Approach for Assessing Technological Development Projects – The Example of Electric Road Systems

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Summary

Technology Readiness Levels (TRL) has become a standard approach to assessment of technological development projects. The origin of TRL is the US moon rocket programs. However, to develop and put into practice advanced technology projects, also other aspects are important to evaluate in a systematic way.

This paper provides a tentative analytical model of four main perspectives to analyze readiness levels of technology projects; Technology Readiness Level (TRL), Political Readiness Level (PRL), Social and Societal Readiness Level (SRL), and Commercial Readiness Level (CRL).
To be successful we need to explore and understand the process, interconnectivities between and the impact based on all those four aspects in an integrated way.

1 Background and Research Questions

Technology Readiness Level (TRL) has become a standard method to assess the maturity of a particular technology. In essence, TRL captures whether technologies are ready to be adopted by potential users. Additionally, TRL is also a method used in decision and risk analysis in order to steer away from *"sources of significant cost and schedule overruns, scope reductions, and cancellations of … military and commercial projects"* [Kujawski, 2013]. TRL is an approach to create a rational analysis, evaluation and decision making in choosing suitable technology solution.

Technological project proposals are commonly evaluated based on the TRL scale, and many governmental agencies and funding bodies use it as their primary method to assess the feasibility of a proposal. Despite the apparent success of the TRL scale, it has been criticized from different perspectives. For instance, a noted weakness is that the TRL only provides an ordinal scale that does not give opportunities for mathematical operations [Conrow, 2011]. Moreover, TRLs have been criticized because they *"are not a measure of design validity . . . They do not indicate the difficulty in achieving the next TRL level."* [Kujawski, 2013].

One important line of criticism points at the limited scope of TRL to only evaluate the technological aspects. Although it can be argued that the technological readiness is a consequence of many aspects apart from purely technological ones, they are not explicitly addressed in the TRL scale, such as commercial aspects of a specific technology. Furthermore, it can be argued that many complex development projects are deeply embedded in social, societal and political contexts that complicates the evaluation of the technological feasibility of a project, aside of the commercial. Different attempts have been made to add dimensions to the

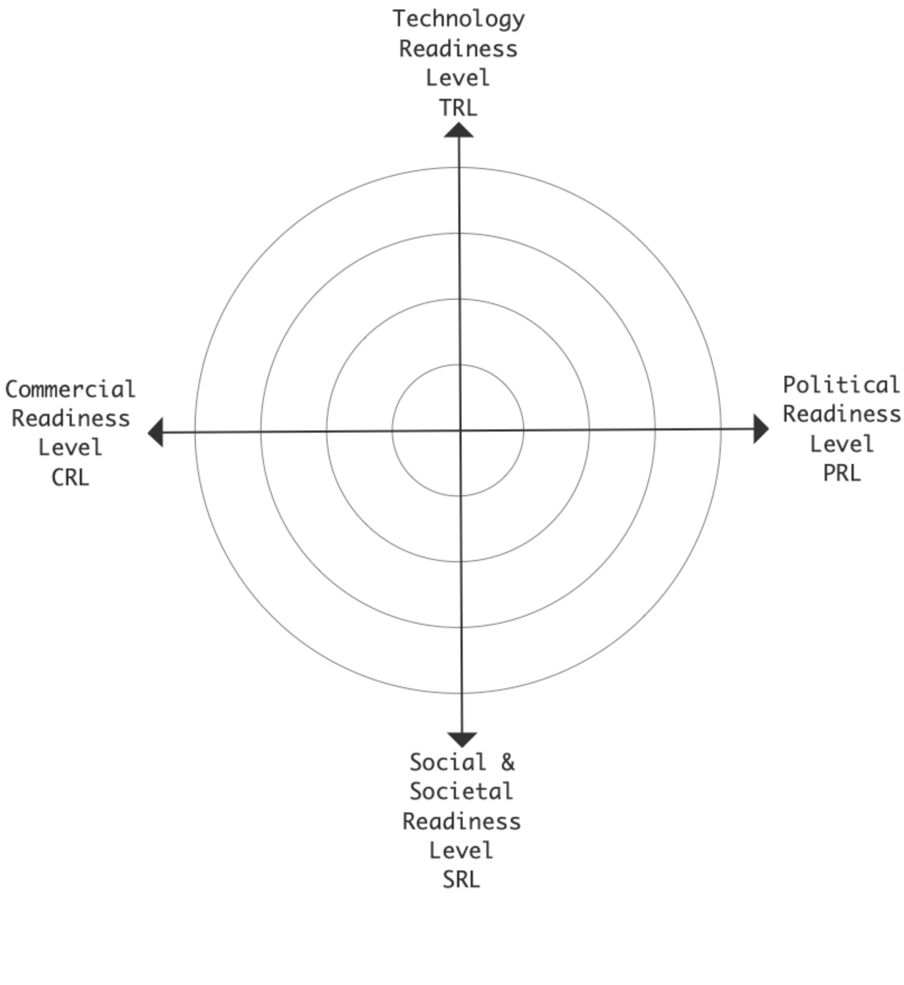
TRL scale, such as the Commercial Readiness Index [Animah & Shafiee, 2018], and the Technological Readiness Index that shift the focus over to the end user/consumer and the process towards acceptance of an emerging technology [Parasuraman, 2000]. In this abstract, we propose a more elaborate conceptual approach to evaluating emerging technologies, focusing on the context of the development, covering other important perspectives than just technology. The model is applied to the emerging technology of ERS, and more specifically the choice between conductive and inductive technology.

2 Methodology

Our approach in this research is based on literature reviews and our empirical research on contemporary ERS technology development in Sweden and in China. We have noticed that different approaches have been chosen in different countries. These empirical observations led us to a more analytical approach, further literature reviews, and a synthesis of our observations and literature-based reviews into a tentative conceptual model presented in this paper.

3 Results

TRL has its historical roots in the large-scale technology development projects initiated by NASA with the purpose to bring man to the moon. TRL became a method for NASA to monitor the development of systems being readied for space. The underlying idea of the TRL-scale is that different technologies can be depicted and rational comparison between alternatives can be done. The assumption is that the higher TRL level the technology is being developed to, the closer to implementation and commercialization it is. The final decision on choosing between projects is expected to be based on evaluation of technology aspects only. However, there are other critical aspects that need to be evaluated and contextualized before a technology can be chosen. In the NASA case the announcement to go to the moon was based on extensive political, social, societal and economic evolution of the intended moon project. When the decision was made in public by President Kennedy the remaining uncertainty was technology related, as all the other were decided upon behind the public scenery of going to the moon.



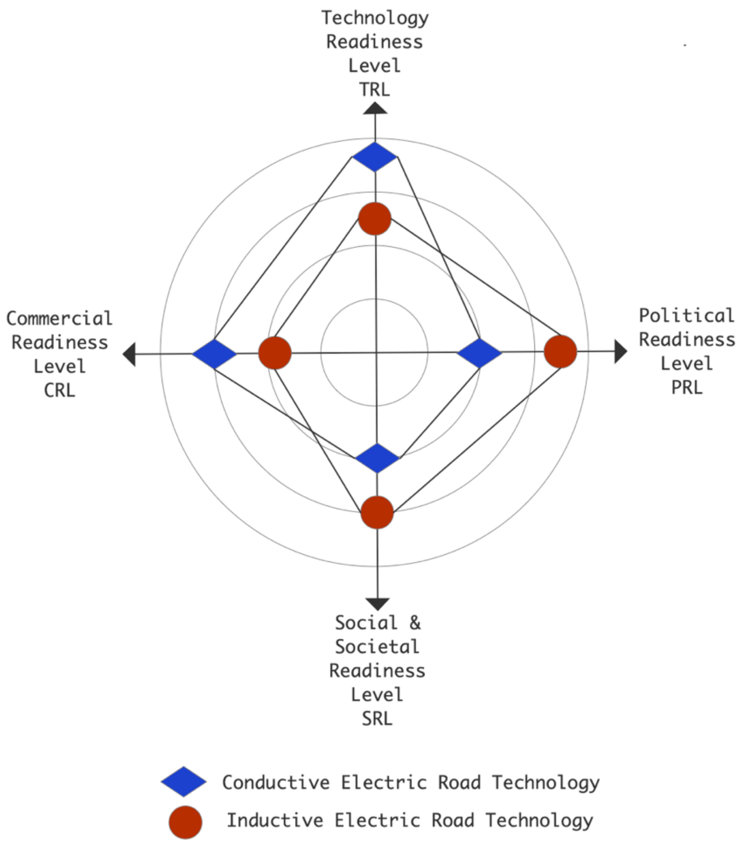
We are adopting an innovation perspective in our approach to explore the TRL and to identify other main aspects that need to be understood and put into a system approach. Innovation is not only about technology itself, it is the capacity of a company to make business success with a suitable business model. From a business model perspective, the technology aspect is only one of the key aspects. To make business success, technology has to be integrated and embedded in the appropriate and relevant context. From potential technology solution to successful innovation accepted by majority of the market, ecosystem consists of value chain and infrastructure to create and deliver the innovation need to be in place; the core values embedded in the innovation need to be compatible to public and social groups' value system; the economic, environmental, societal, and national security etc. influence the innovation brings must pass political actors' examination and get their endorsement. Looking at successful innovations in our society, airplanes, fast train systems, the Internet, social media, smartphones, electric cars, or hydrogen cars and many others, they are all embedded in the political, economic, social and societal context of their own times. Without social acceptance in the society, the technology implementation and diffusion will encounter endless public resistance. If the political, institutional and regulatory actors are not supportive, the technology being developed and commercialized will have difficult to attract investment and partners into the field and reach positive commercial result. Therefore, a technology needs to be seen, analyzed and evaluated in the web of relations consist of technical, political, societal and commercial dimensions as afore shown model.

In this multidimensional model that we are proposing all four identified main perspectives can be depicted, compared between different projects, and analyzed based on positioning on the web of relations between the four perspectives. The final decision has to be based on exploration and understanding of the forces and the relations in the complex web of perspectives of the specific context. In the following, we will use ERS as a case to further discuss the multidimensional model. The decision to use only four main perspectives is a trade-off between taking all possible aspects into consideration at the same time and the manageability of an overall assessment view of a technology. As a result of the proposed model, each of the four perspectives consist of a number of "sub"-aspects in each perspective. The figure below shows how this conceptual framework can support analysis and comparison between inductive and conductive ERS technologies. The data used is based on our exploration of Swedish and Chinese ERS technologies and context.

A review of stationary charging and other alternatives to fossil fuel propulsion technologies was undertaken by the PIARC group in 2018 [PIARC, 2018]. A total of 17 viable ERS systems were identified. The majority of contemporary western inductive ERS have an estimated technology readiness level (TRL) between TRL 3-4; with few systems advancing beyond TRL 6. Conductive counterparts are more mature, typically between TRL 4-5, with some systems between TRL 6-8. All three types of ERS are undergoing road trials of some form, with rapid advancements in the last five years. Similar analysis of Chinese status of inductive technology was conducted in 2018 [Danilovic and Yan, 2018] showing that Chinese inductive technology was on TRV levels 3 to 7.

The global PIARC study of ERS solutions shed light on developed solutions mainly from a technology perspective. However, in the report the authors also indicated the importance of stakeholders, business perspectives and also social and environmental perspectives, while not taking those aspects into consideration in their analysis. From an innovation perspective, other perspective than technology might be more important to explore and to understand the success of, in this case, implementation of a certain electric road technology. This is elaborated in the Chinese context by Danilovic and Yan (2018) showing the importance of political decisiveness in developing and implementing inductive technology.

First, we draw attention to the diffusion of electric road technologies. Based in the PIARC report and Danilovic and Yan report we see that Northern Europe is developing conductive technologies while Southern Europe, the US, Israel and China are focusing on inductive technologies. From an innovation perspective we know that standardization is crucial for the diffusion of technologies, products and services. Looking at the transportation industry and electric roads it would be complicated if European countries chose different conductive technologies, one for Sweden and one for Germany while the UK and south Europeans go for inductive technologies. The lack of standardization might lead to failure of large scale implementation of electric roads and technology diffusion. Considering the development in the Europe-Asia corridors linking those two continents, the necessity to engage in global solutions becomes even more crucial. Based on our research we see that China has made a decision to focus on inductive technology. Europe has many



approaches and lack political decisiveness so far to standardize technology and solutions. There is a risk that Europe will have several not mutually exclusive solutions. We need the global standardization of technology to achieve global technology diffusion and standardization of ERS. Otherwise, competing solutions will be established. To achieve this, it is important that political, institutional and regulatory actors act to support the development, and harmonization between aspects and standardization of solutions to enable large scale diffusion.

A more detailed description of the proposed multidimensional model, how perspectives can be composed of key aspects and measurable scales, and how to use in practice it will be further developed in future research.

Our analysis suggest that a formal TRL analysis is not a significant predictor of system quality, program performance or commercial success. When it comes to today's society the context is different, the complexity is greater and decision making is distributed among many countries, politicians, institutions, regulatory frameworks and business actors with a variety of agendas and waste interests. Thus, the decision-making today is probably more complex than it was in the 60s during the go to the moon era. At the same time, the TRL scale is still the predominant method for evaluation and assessment of such huge projects as electric roads being developed in the 2010-2020s. As our results shows a multidimensional analysis can deepen the understanding of the context and create conditions for technology development.

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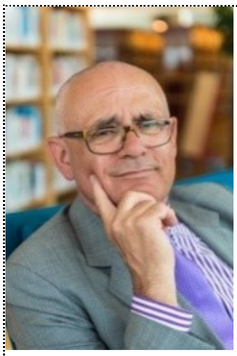

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