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## Reframing Technology Readiness Level (TRLs) for Non-Profit Technology Transfer Offices (TTOs) for Grounded Innovations



**Abstract:** - The utilization of Technology Readiness Level (TRL) assessments, initially crafted for the aerospace and defense industries, has proliferated into diverse sectors. This study is dedicated to tackling the hurdles encountered by non-profit Technology Transfer Offices (TTOs) when integrating TRLs into their operations. By exploring the theoretical disparities and pinpointing pivotal issues, it aims to provide a holistic understanding of this complex landscape. This paper addresses the issue from theoretical and practical gap, by scrutinizing the misalignment between the original intent of the TRL framework and the multifaceted nature of research projects managed by non-profit TTOs. These projects often entail iterative and non-linear pathways, contrasting with TRLs' sequential framework, leading to implementation challenges. The critical problems faced by non-profit TTOs in TRL adoption encompass resource constraints, diverse stakeholder expectations, and a shortage of expertise for effective TRL assessments. The study proposes qualitative case studies and data triangulation using Cohen's Kappa analysis in order to gain comprehensive insights into these challenges. By shedding light on these issues, it is hoped to enhance the adoption of TRLs in non-profit TTOs and contribute to their successful technology transfer endeavours.

**Keywords**— “Technology readiness levels (TRLs)”, “technology transfer offices (TTOs)”, “non-profit”, “innovations”, “technology assessment”.

### I. INTRODUCTION

Technology Readiness Levels (TRLs) have gained prominence as a standard tool for assessing the maturity of new technologies [1]. Initially developed for use in the aerospace and defence industries, TRLs have gained widespread recognition and utilization across various sectors. TRLs serve as a graded system that provides a structured framework for assessing the readiness of a technology, guiding it from its conceptual stages to full-scale deployment. Non-profit Technology Transfer Offices (TTOs), which act as intermediaries in the transfer of research outcomes to the market [2], have found the adoption of TRLs challenging, warranting a deeper investigation into the matter.

In their original context, within the aerospace and defence sectors, TRLs were designed to address the specific challenges and complexities inherent to these industries. The primary aim was to gauge the preparedness of technology for integration into highly regulated and critical systems. The TRL framework divides technology development into discrete stages, typically ranging from TRL 1 (conceptual or basic research) to TRL 9 (fully mature technology ready for widespread use) [3].

In the case of non-profit TTOs, the objectives are similar yet operationally differs. TTOs play a distinct and crucial role within the research and innovation ecosystem. Summarizing from [2] TTOs is more than intermediaries between research institutions, such as universities and research laboratories, and the commercial sector. Their primary mission is to facilitate the transfer of research outcomes, which may include novel technologies, inventions, or innovations, from the academic or research sphere to the marketplace. This transfer is essential for harnessing the economic and societal benefits of scientific discoveries and innovations [4].

Given the growing importance of TRLs in assessing technology maturity, non-profit TTOs have been encouraged to incorporate this framework into their operations. The Malaysian Ministry of Science, Technology, and Innovation (MOSTI) for instance, pursue its objective along with its funding agencies and partners, has made available a diverse array of financial resources, spanning from pre-seed funding to support for commercialization

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efforts. While MOSTI may not directly adhere to the TRL framework, it is well-acquainted with the concept and may integrate analogous principles into its policies and initiatives. For any type of the grants offered by MOSTI, a broad definition perspective as per Figure 1 must be incorporated [5], yet, requiring further clarification and elaboration.

For example, Malaysia Commercialisation Year (MCY) represents one of the strategic initiatives under MOSTI, aimed at the assessment of projects derived from grants within the Ministry of Higher Education. Within the framework of MCY, a rigorous due diligence workshop is conducted to assess and identify products, technologies, or services that align with their objectives. As a reward, projects attaining a TRL of 5 or higher become eligible candidates for the prestigious MCY Awards.

In the first quarter of 2023, the Innovation and Commercialization Centre (ICC) was assigned to validate TRL for 88 projects at Universiti Teknologi Malaysia (UTM), funded by the Ministry of Higher Education through various research grants such as PPRN, MYLAB, PRGS, and UTMPR grants. Specifically, projects financed under PPRN, MYLAB, and UTMPR grants are mandated to undergo TRL validation when it comes to the MCY initiative. Despite the requirement, the application instructions for these grants lack detailed TRL guidance, providing only a broad definition that is readily accessible online, summarized in the general guidelines shown as Table 1.

Taking these cases among others, the application of TRLs in non-profit TTOs has exposed its own challenges. Several factors contribute to the difficulties they face when adopting TRLs. The challenges can be prompted from two points of views, theoretical and practical gaps [6]. Therefore, the rationale behind this encouragement is to provide a standardized method for evaluating and communicating the readiness of technologies, thus enhancing their marketability, and facilitating smoother transitions towards commercialization.

## II. LITERATURE REVIEW

Currently, TRL is widely accepted for each level of technology maturity evaluation method across various industries, engineering, and research and development (R&D). [6] emphasized the growing relevance of TRLs across sectors, but also cautioned about its blind adoption without considering sectoral differences. The careful assessment of TRL is essential, as it guides the development of a technology from its conceptual stage through research, development, and eventual deployment. Universities and government funding sources tend to focus on TRLs 1-4, while the private sectors improve in on TRLs 7-9 [3]. However, the critical phase lies between TRL 4 and 7, where the development process takes centre stage [6]. During this phase, a technology reaches a crucial juncture where it either advances or is abandoned, often referred to as the 'Valley of Death.' This term signifies the frequently overlooked TRLs 4 through 7, with neither academia nor the private sector prioritizing investment in this range.

The European Union (EU) adopted the NASA TRL definitions in 2010, facilitating their application across various industries beyond space exploration. This adaptation was particularly influential in the context of funding research and innovation projects. As TRL's scope widened from its space program origins, its application became less rigid and more ubiquitous, leading to a gradual simplification and broadening of its use. Nowadays, TRL is acknowledged as a key method for gauging technology maturity in a range of sectors, including engineering and R&D. Research highlighted by [8] examined the challenges faced by TTOs in academic settings, underscoring the hurdles of turning academic research into market-ready products. TRL is one of the tools used in this process, though it sometimes proves insufficient.

In 2013, the TRL scale was further endorsed when the International Organization for Standardization (ISO) issued the ISO 16290:2013 standard, thus providing a more formalized approach. The following year, TRLs were incorporated into the EU's Horizon 2020 program, which was established to encourage research and innovation. This formal adoption of the TRL framework has seen its application in a variety of fields, such as recycling of composite materials [9], technology for biomass fuels and chemicals [10], carbon capture [11], and formalin production processes [12].

There has been an in-depth exploration or study conducted to understand the challenges and complexities that non-profit organizations face when it comes to assessing and adopting new technologies. [13] delved into how non-profit organizations grapple with technological assessments. Their findings suggested a need for more flexible and adaptive tools tailored to the specific needs of non-profits. The non-profit TTOs aware of the involves assessing how these technologies can be effectively integrated to improve operations, achieve goals, and enhance services. TRL applications can be categorized into three distinct areas: evaluating system complexity, planning and review processes, and ensuring the accuracy of assessments [14].

### III. METHODOLOGY

The research design for this study involves adopting a qualitative case study approach. Qualitative research is particularly well-suited for investigating complex phenomena in-depth and exploring the experiences, perceptions, and challenges of individuals or organisations. In this case, the objective is to gain a comprehensive understanding of the challenges faced by non-profit TTOs in implementing TRLs.

For this research design, a multiple non-profit TTOs will be selected as cases for the study. Case studies provide a rich and context-specific perspective, allowing researchers to delve deeply into the experiences of individual organisations. By studying several TTOs, the research aims to capture a holistic view of the challenges faced, which can help identify common themes and variations across different TTOs.

#### 3.1 Data Collection

In obtaining specific data for this study, two primary data collection methods were used which are semi structured interviews and focus group discussion. In semi-structured interviews the session was conducted with key personnel within the selected non-profit TTOs. These interviews provided an opportunity to engage with individuals who have first-hand experience and expertise in TRL implementation. The semi-structured nature of the interviews allows for flexibility in exploring participants' experiences and perspectives while ensuring that specific research questions are addressed.

The next data collection was conducted through research focus group discussions which, aims to obtain a collaborative and interactive research approach to exploring the problems of implementing TRL assessments in non-profit TTOs. The discussion which gathers non-profit TTOs based on their specific functions in Malaysian national innovation ecosystem allow for the exploration of group dynamics, consensus building, and the collective perspective of participants, providing valuable insights for addressing the unique challenges faced by these organisations.

#### 3.2 Data Analysis

In the current study, thematic analysis is utilized to in order examine and interpret the data obtained from interviews and documents. This qualitative research approach is instrumental in meticulously identifying, examining, and conveying recurring patterns or themes that emerge within the dataset [15]. The process will begin with a detailed coding of the data, which serves as the foundation for the subsequent extraction and refinement of themes. Following this, we will embark on a comprehensive interpretation of the data, aiming to draw meaningful insights.

The adoption of this methodical thematic analysis is pivotal, as it is intended to bolster the reliability and validity of the findings. This rigorous analysis, is committed to ensure that the study faithfully reflects the specific challenges encountered by non-profit TTOs as they strive to implement TRLs, providing an accurate and in-depth understanding of their experiences.

### IV. FINDINGS AND DISCUSSIONS

The initial design and intent behind TRLs were for sectors with massive R&D budgets, long product life cycles, and a clear distinction between each development stage [6]. Non-profit TTOs function in a different realm, where the lines between research and marketable products are often blurred. Based on the thematic analysis conducted, the challenges are categorized into two (2) main themes, theoretical and practical gaps. Based on the initial data

#### 4.1 Purposes Mismatch

Non-profit TTOs often oversee research projects that exhibit iterative and non-linear trajectories, which contrast with the sequential innovation process for which TRLs were originally designed. This mismatch in purposes arises from the fundamental differences between the objectives and nature of research projects managed by non-profit TTOs and the structured TRL framework, as well as the KPIs mandated for fulfilment within the incubation program, similar to findings of [9, 10 & 11]. In the traditional aerospace and defence industries where TRLs were first developed, the innovation process is typically linear and sequential. It progresses through stages from basic research (TRL 1) to the development of a fully mature technology (TRL 9) [16]. The primary purpose of TRLs in this context is to assess and communicate the readiness of technologies for integration into highly regulated and mission-critical systems.

In contrast, concluding from [17], during transfer of knowledge, non-profit TTOs operate in a more dynamic yet asymmetric environment. They oversee research projects originating from various domains, including academia, healthcare, environmental science, and more. These projects often involve collaborative and

interdisciplinary efforts, frequently leading to iterative and non-linear research trajectories. As a result, the traditional TRL framework may not effectively align with the evolving and complex nature of the research projects managed by non-profit TTOs. This mismatch can lead to misalignment, as TRLs may not adequately capture or represent the multifaceted aspects of research projects that diverge from the linear progression assumed by the TRL framework. Consequently, non-profit TTOs may face difficulties in accurately assessing and communicating the readiness of their technologies when utilizing TRLs.

#### 4.2 Contextual Variabilities

Non-profit TTOs are tasked with managing a wide array of research projects, each stemming from various domains and characterized by unique characteristics and requirements. These contextual variabilities reflect the inherent diversity of research activities undertaken within the non-profit sector [17]. The TRL framework, by design, offers a standardized approach to assessing technology readiness. It provides a uniform set of criteria and stages for evaluating the maturity of technologies [16]. However, this uniformity can be a limitation when non-profit TTOs are dealing with research projects across different fields.

The application of TRLs to individual research projects must consider the unique set of variables that each project entails. These factors include distinct timelines, diverse funding sources, various regulatory frameworks, and different industry benchmarks. Furthermore, the aims of technology transfer and the envisioned market applications can vary widely between projects, making the adoption of a universal TRL assessment model impractical for addressing the specific needs inherent in each project. Consequently, non-profit TTOs encounter significant hurdles when attempting to uniformly apply a standard TRL assessment across a broad spectrum of research endeavours. This underscores the essential need for adaptability and flexibility within technology assessment methodologies to cater effectively to each project's distinctive characteristics and objectives.

In summary, the purpose mismatch and contextual variabilities highlight the challenges faced by non-profit TTOs in implementing TRLs. These challenges stem from the mismatch between the TRL framework's original purpose and the nature of research projects managed by non-profit TTOs, as well as the diversity of contexts and requirements inherent in their diverse project portfolio.

On the other hand, the reality of adopting and adapting TRL is also a non-linear trajectory. The additional challenges encountered are themed as the practical gap in incorporating TRLs into the technology development process. The practical gaps are due to limited resources, varying stakeholders' expectations, and lack of expertise.

#### 4.3 Limited Resources

Non-profit TTOs are frequently tasked with achieving their objectives within the bounds of limited resources, especially when compared to their for-profit counterparts in the high-tech industry. The integration of a detailed TRL system presents an array of challenges stemming from such resource constraints. Typically, these organizations are working with tight budgets that may not allow for significant investments in the specialized infrastructure or sophisticated tools that are required for a thorough TRL evaluation. This fiscal restraint can impede their capacity to effectively collect and analyse critical data, which is essential for an accurate assessment of technology readiness.

Furthermore, non-profit TTOs often operate with a leaner workforce than larger high-tech entities, which can present additional hurdles. Conducting meticulous TRL assessments necessitates professionals who are not only skilled but also possess specific knowledge in gauging the maturity of technologies. Given their financial limitations, non-profit TTOs may find it difficult to attract and maintain a workforce that has this niche expertise. Consequently, these organizations may struggle to carry out comprehensive TRL evaluations within their operational constraints.

Additionally, the constant pressure of time adds another layer of complexity for non-profit TTOs. With a limited number of staff members and financial aid, these offices are often pressed for time, balancing multiple roles and responsibilities. The extra effort required to perform TRL assessments can further stretch their limited human resources, possibly leading to delays in other critical activities that facilitate technology transfer. Such time-sensitive environments demand not only effective time management but also strategic prioritization, which can be a strenuous undertaking when attempting to conduct thorough TRL assessments without compromising other vital functions of the technology transfer process.

#### 4.4 Varying Stakeholder's Expectation

Non-profit TTOs often operate in the public sector and cater to a wide array of people and organizations that have an interest in how technologies develop. This includes academics who are working on new technologies, the

organizations that provide the money to fund this work, as well as the companies and individuals who eventually use these technologies. Each group looks at TRL assessments with different expectations in mind.

For example, researchers typically want TRL assessments to help them further their technological developments in line with their scientific goals. They look to TRLs to back up their applications for grants and other funding sources. On the other hand, those who provide funding are interested in understanding how close a technology is to being ready for the market. They rely on TRL assessments to guide them in deciding which technologies are worth the investment.

Lastly, the end-users, such as businesses that will use the technology, care about how practical and scalable the technology is for real-world use. They want TRL assessments to give them confidence that the technology can be applied effectively in their operations.

For non-profit TTOs, the challenge lies in balancing all these different needs and viewpoints. They must ensure that the TRL assessments they provide are fair and accurate, while also making sure that the various stakeholders understand and are satisfied with the process and results. This balancing act requires clear communication and a keen understanding of everyone's needs.

#### 4.5 Lack of Expertise

The process of applying TRLs is quite complex and requires a certain level of expertise in assessing how ready a technology is for the marketplace. Non-profit TTOs often face hurdles because they don't always have staff members who are specialists in TRL. The TRL framework demands a detailed and methodical process to evaluate technology effectively. For TTO staff to use TRLs correctly, they need to be well-versed in its evaluation methods.

However, a common issue for many non-profit TTOs is the absence of these specialized skills among their personnel, primarily due to their limited budget. Training existing staff or recruiting new talent with the required expertise can be expensive, and these costs are often beyond the budgetary constraints of non-profit organizations. This leads to a gap in expertise that is difficult to fill.

Additionally, even if a non-profit TTO manages to train its staff in TRL assessment, there's the ongoing challenge of keeping up with the latest methods and best practices. The field of technology assessment is not static; it evolves with new insights and innovations. Thus, TTOs need to continually invest in professional development to ensure their team remains knowledgeable about the most current and effective assessment techniques. This need for continuous learning can strain already tight resources, affecting the quality and accuracy of the TRL assessments they provide. Consequently, without up-to-date assessments, the TTOs might struggle to give a true picture of a technology's readiness, which is crucial for making decisions on further development or investment.

In summary, limited resources, varying stakeholder expectations, and a lack of training pose significant challenges to non-profit TTOs when implementing TRL assessments. Addressing these challenges may require creative solutions, such as seeking external expertise, streamlining assessment processes, and finding ways to better communicate and align with the diverse needs of their stakeholders.

## V. CONCLUSIONS

The integration of TRL assessments within non-profit TTOs presents unique challenges stemming from the distinct nature of these organisations and their diverse array of research projects. As highlighted earlier, non-profit TTOs often oversee research endeavours characterized by iterative and non-linear trajectories, and they manage a wide range of projects across various domains. These characteristics diverge significantly from the original context for which TRLs were developed, which was the aerospace and defence sectors with their sequential innovation processes. Therefore, it is significant to recognize the challenges in application of TRLs. Non-profit TTOs play a pivotal role in facilitating the transfer of research outcomes from academic or research institutions to the commercial sector. This transfer is crucial for harnessing the economic and societal benefits of scientific discoveries and innovations. To achieve this, TTOs need reliable methods for assessing the readiness of technologies. Recognizing the unique challenges is fundamental in ensuring that technology transfer is efficient and successful.

The effective transfer of technology from research to the market is not only vital for individual organizations but also for fostering innovation ecosystems at large. Addressing the challenges faced by non-profit TTOs can lead to the development of more adaptable and context-specific assessment tools, which can, in turn, stimulate innovation, economic growth, and job creation. Collaboration among all parties in the ecosystem are vital to improve the function of an impactful innovation ecosystems.

Furthermore, to be more efficient, enhancing collaboration between respective non-profit TTOs with a broad spectrum of stakeholders, including researchers, donors, industry partners, and regulatory bodies will allow better understanding of the challenges associated with TRLs. Output from such collaboration may open an avenue towards better communication and engagement with stakeholders effectively. This can lead to more successful partnerships and increased support for their technology transfer efforts.

The research conducted successfully addressed these challenges and made a meaningful contribution to the field of technology transfer. By conducting an in-depth investigation into the specific difficulties faced by non-profit TTOs, the study aims to shed light on these challenges and their underlying causes. However, a straightforward thematic analysis is unable to explain the strengths and weaknesses of the findings. A better qualitative analysis using software like Atlas.ti and adopting more sophisticated analysis such as Cohen's Kappa may improve the research findings by discriminating unique characteristics of their research projects, considering the iterative and non-linear trajectories and diverse contexts in which TTOs operate.

By providing insights and recommendations based on more solid empirical evidence, future study should contribute venture into the ongoing effort to enhance the effectiveness of technology transfer in non-profit TTOs. It is important to bridge the gap between the standardized TRL framework and the dynamic, multidisciplinary environment in which these TTOs operate, ultimately fostering more successful and efficient technology transfer processes. By recognizing these challenges and understanding the contextual nuances is crucial for effective technology transfer hence hoping to pave the way for better technological assessment tools tailored for non-profit TTOs.

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