INTERNATIONAL DESIGN CONFERENCE – DESIGN 2024
https://doi.org/10.1017/pds.2024.126

Developing readiness levels for risk assessment in green transition engineering projects

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Abstract

This paper aims to develop a risk assessment framework that addresses both the complexities of the risk landscape that green transition portfolios face, but is recognizable and easily understandable by stakeholders. For this purpose, we build upon the framework of NASA Technology Readiness Levels (TRLs). This study analyzes six existing readiness levels framework that are held towards uncertainty factors from the Green Transition. The TRL scale are coupled with Risk, Uncertainty, and Ignorance to score the individual level of uncertainty. The paper ends with suggestion for further studies.

Keywords: green transition, portfolio management, uncertainty, technology readiness level (TRL), xRL

1. Introduction and motivation

The need to reduce and mitigate the effects of increased environmental impact due to increasing emissions from human activities and human consumption of finite resources has been recognized by numerous international organizations, such as the European Union (EU) (European Commission, 2019) and the United Nations (Messerly et al., 2019) as the primary challenge of our times. For engineering organizations, this creates the challenge to both adopt and scale new technologies in their product portfolio in a concise timeframe (Olechowski et al., 2015). This increases not only the risk of single engineering design projects but requires the development of novel approaches to manage and mitigate various risks at the portfolio level. This paper develops the foundations for an engineering project portfolio risk assessment framework for green transition projects as a first step towards improved portfolio risk management. This aim of this paper is to develop a risk assessment framework that addresses both the complexities of the risk landscape that green transition portfolios face but is recognizable and easily understandable by a wide range of stakeholders. For this purpose, we build upon the widely adopted framework of NASA Technology Readiness Levels (TRLs) (Mankins, 1995, 2009), which among other organizations has been adopted by the EU other funding bodies supporting ambitious green transition portfolios (Innovationsfonden, 2019; De Rose et al., 2017). The core hypothesis is to explore the applicability of using a "simple" understandable framework as a foundation to communicate the specific complex risk profile of engineering portfolios. This risk assessment forms the basis for deciding both portfolio composition and specific portfolio and project governance frameworks. This study analyzes six existing readiness levels framework (xRL), including Technology Readiness Levels, Policy readiness level (PRL), Business Readiness Level, Innovation Readiness Level. Based on previous work on identifying critical categories of risks for green transition projects (Business model, Finance and Insurance, Regulation and Law, Technology, and Behavior, we propose a framework to assess and express the specific levels of risk in each category on a specific xRL scale. The xRL profile for each project within a green transition portfolio will indicate the most significant barriers to successful project

https://doi.org/10.1017/pds.2024.126 Published online by Cambridge University Press

execution, and enable targeted portfolio and project governance actions. This is a critical challenge in the context of engineering design. Olechowski et al. (2020) addresses as challenges in TRL and system development gates is the lack of guidance to establish alignment between an organization's major development milestones and the TRLs (Olechowski et al., 2020). To address this gap, this paper proposes an approach to support the governance of green transition project portfolios, building on the Technology Readiness Levels (Mankins, 1995) as a framework for risk assessment. Such framework must be balanced between multiple factors to grasp the complexity of the green transition.

2. Method

This paper presents findings from two major research phases: a literature research on building a Readiness-Level based risk assessment framework for engineering project portfolios, including developing a preliminary assessment framework. Second, the framework is further developed through empirical findings from case study interviews in how organizations currently managing green transition engineering project portfolios.

2.1. Literature search

To do a comprehensive literature review in the area of the different types of readiness levels with portfolio, two databases were used in the search for articles that can be related to the topics, namely "Web of Science" and Scopus databases (Schryen et al., 2020; Webster and Watson, 2002). To open the search of the variety of "X-varieties of readiness level frameworks" related to portfolios in the academic literature, it was decided to use the search term "Readiness level*" in conjunction with portfolio. The reason for the "*" in level + *, is to ensure that level and levels is included in the search. Search string for the initial search. "Readiness level*" AND portfolio. The total Web of Science search revealed 37 pieces of work shared across the following scientific contributions. The contribution consists of 21 articles, of which 2 are review articles and 1 of the review articles is early access. In addition to the articles, the search revealed 16 proceeding papers. The Scopus search had 62 results shared across 38 conference papers, 20 articles, and 4 reviews. From the searches, there were two duplicates; both duplicates were the type proceedings/conference papers. The selected papers were collected and further analyzed through an abstract selection before entering the full paper reading. Deselection was due to missing focus on readiness levels or connection to portfolios. Another criterion for deselection was if it appeared from the abstract that the readiness level, such as the Technology Readiness Level, were used in the paper to describe the level of development of the technology under investigation. One example is a paper focusing on analyzing technologies that are at TRL 7 or above. For such a case, the TRL are not used, developed, or described but only used to set the limitation for accessing technologies used in the study, and therefore, such papers are out of scope for the study presented in this paper.

2.2. Case study interviews

To support the development of the readiness level framework evidence from 15 Semi-structured interviews were analyzed. The interviews were conducted in product development and manufacturing organizations, were the interviewees selected among central employees at the organization. The selection criteria for the interviewees is to be knowledgeable of the organizations' product and project portfolios, besides being knowledgeable about sustainability and how the green transition might influence the organization. The interviewee positions in the organizations consisted of vice presidents, concept developer, senior operation and supply chain managers, heads of sustainability, and climate officers from the different organizations. Each interview lasted between 54 minutes and 84 minutes, with the majority reaching the 60 set for the interview meeting. Each interview was supported by a printout of the semi-structured interview guide and was documented in handwritten notes supported by an audio recording. Interview sessions were initiated by clarifying the central purpose, and the semi-structured interview guide was introduced. All interviews were conducted in the same order: a general introduction of the Interviewer followed by a recap of the purpose. Each interviewee was instructed to introduce themselves, their positions and responsibilities within the organization, and an introduction to what the organization produces. This first step was followed by supporting questions to initiate the

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company‘s view of the Green Transition and its role in it. The interviews were conducted in Norwegian, Danish, Swedish, and English. Each interview ended with the interviewer giving a summary of the key points and takeaways from the interview for the interviewee to verify and adjust misunderstandings, as well as being able to provide final thoughts and reflections that the interviewee thinks would be valuable to the research study. Following each interview an interviewer summary was made on an audio recording to capture ideas and concepts to support the interview notes later. The interview notes were then revisited, restructured, and supported by additional notes and context with support from the audio recording. In addition to the interviews, internal documentation and reports were studied to support the understanding of the organizational complexity and challenges. Each interview summary was compiled and sent back to the interviewees for additional comments, corrections, and confirmation of the results.

3. Readiness Levels in engineering project portfolio management

Introduction to Readiness Levels – an expanding field

Readiness Levels is an expanding field since its origin in the mid 60ies, to illustrate a few of the most relevant Readiness Levels for this study is mentioned here: Technology Readiness Level (TRL), Business readiness level (BRL), Policy readiness level (PRL) (Rowan and Casey, 2021), Innovation Readiness Level (IRL), Implementation Readiness Level (IRL), Systems Readiness Level (SRL), Organizational Readiness Level (ORL), and Regulative readiness level (RRL)(Kobos et al., 2018)

3.1. Characteristics for Readiness Levels

Technical – TRL

The original TRL was introduced by Nasa model – the most generic and widely used model where the remaining elements are built during the 1960ties and consisted of 7 levels for technological assessment. (Mankins, 2009; Sadin et al., 1989). The additional levels 8+9 were added later in the Whitepaper by Mankins from 1995 but the edited version from 2004. The TRL scale was updated and expanded during improvements after the Challenger space shuttle accident. Fast forward to today, and the TRL scale is widely used for various readiness levels. Table 1., presents the difference between Mankins definitions and the European Unions TRL definitions.

Table 1. TRL definitions Mankins (NASA) and EU

TRL level	Mankins definition (Mankins, 2009)	EU definition (De Rose et al., 2017)
TRL 1	Basic principles observed and reported	Basic principles observed
TRL 2	Technology concept and/or application formulated	Technology concept formulated
TRL 3	Analytical and experimental critical function and/or characteristic proof-of-concept	Experimental proof of concept
TRL 4	Component and/or breadboard validation in a laboratory environment	Technology validated in lab
TRL 5	Component and/or breadboard validation in relevant environment	Technology validated in relevant environment
TRL 6	System/sub-system model or prototype demonstration in a relevant environment	Technology pilot demonstrated in relevant environment
TRL 7	System prototype demonstration in the expected operational environment	System prototype demonstration in operational environment
TRL 8	Actual system completed and “qualified” through test and demonstration	System complete and qualified
TRL 9	Actual system “flight proven” through successful mission operations	Actual system proven in operational environment

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One theoretical concept include sustainability and, thereby, green transition elements into the TRL framework can be seen in the paper by (Hallstedt and Pigosso, 2017). With this including sustainability consideration in from the early stages of product development. To empower ECO innovation from the United Nations Sustainable Development Goals, Rowan and Casey (2021), introduced a triple helix structure consisting of technology Readiness Leves, Policy Readiness Levels, and Society Readiness Levels (Ozcan et al., 2023; Rowan and Casey, 2021)1. Other authors and organizations also introduce and use overarching readiness scales, including several versions of earlier described readiness models. Such examples can be seen in the Innovation Readiness Scales, for example, the KTH Innovation readiness scale (KTH Innovation, 2023), Innovation Readiness level (Evans and Johnson, 2013), or Product readiness level concerning innovation (Ozcan et al., 2023). Such IRL is set to being useful in the early stages of innovation in alignment with business model innovation, where the IRL framework provides a tool to evaluate an idea's impact on the entire corporation, not just on the technical function (Evans and Johnson, 2013). Confusion can be found in the introduction of the different Readiness Levels; for example, IRL can mean both "innovation Readiness level" and "Implementation Readiness level" (Evans and Johnson, 2013; Tan et al., 2019). Suggestions for doing financial assessment of the portfolio allocation are introduced by (Tan et al., 2019) The financial assessment is based on calculating the System Readiness Level (SLR) from n numbers of technologies, based on Sauser's suggestion of the System Readiness Level of the Integration Readiness Level coupled with the Technology Readiness Level (Sauser et al., 2009). In contrast to traditional RL systems that hold nine levels, the Systems Readiness Level introduced by Sauser consists of only five levels (Sauser et al., 2009).

Other attempts have been made to combine multiple readiness levels. One such example is the balanced card by Vik et al. (2021), which also puts varieties of different readiness levels scores into a spider web diagram to investigate how agriculture is ready to adopt new technologies (Vik et al., 2021). However, this does not nearly cover the full scope of how an organization may investigate its portfolio. Ensure it is ready for the green transition or how it is positioned towards it. Other alternatives need to be put in place. For example, (Jesus and Junior, 2022) uses an architectural approach to analyzing the portfolio of projects which can be used for decision support in accelerating the development of the technologies and integration links that are behind and temporarily. To provide a brief overview of the varieties and disciplines in which the different Readiness Levels exist, Table 2, adopted from (Ozcan et al., 2023) provides an overview of product innovation readiness levels.

Table 2. Readiness Levels related to product innovation, adopted from (Ozcan et al., 2023)

Type of RLs	RLs Type
Technology	TRL Contextual variation
	TRL Quantitative measurements
Manufacturing	Manufacturing Readiness Level
	Manufacturing Capability Readiness Level
	Innovative Manufacturing
Systems	System Readiness Level (and Integrations Readiness Level)
Market Impact	Market Readiness Level
	Market Attractiveness (& Consumer Readiness Level)
	Technology, Regulatory, Market
	Demand Readiness Level
Innovation	IRL 6 dimensions
	IRL use of existing IRL
	IRL 2 dimensions
	Innovation readiness concepts
Project	IRL Project Management

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In relation to portfolio management, we have not been able to identify any direct studies pointing toward models that contain readiness levels related to portfolio management addressing the uncertainties of the green transition.

3.2. Limitations to the existing Readiness Levels

Other alternatives have been presented to showcase how companies or organizations are ready to transition into a circular structure. Concepts like ready-2-loop highlight how a structured framework is applicable for an organization to conduct a self-assessment of its level of readiness to transition into a circular business model. This approach measures the transitional readiness of a company's circular readiness assessment (Vik et al., 2021). The existing literature on readiness levels has certain limitations regarding the uncertainties introduced by the green transition. Filipovic (2023), introduces a framework for managing the uncertainties of the green transition in product development practices. This framework suggests six different factors that portfolio managers must investigate to recognize and balance the uncertainties across the activities in the portfolio. We combine the uncertainty levels with the readiness level methodology to construct a framework for the portfolio's development and governance phases. The uncertainties addressed in a study by Filipovic (2023) consist of Technology uncertainty, Finance and Insurance uncertainty, Regulation and Law uncertainty, Business Model uncertainty, Organizational uncertainty, and Market uncertainty (Filipovic *et al.*, 2023).
As a change to the concept, we have in this study decided to combine organizational uncertainty and market uncertainty and merge then into the topic of behavioral uncertainty to address the uncertainty of the organization and the market. As a result, the level of uncertainties that needs to be addressed in this readiness level for the green transition is five different factors. In (Filipovic *et al.*, 2023), such uncertainty level has already been addressed, stretching from "total ignorance," where little to no known knowledge is available. At the top of the certainty scale, we find "statistically," implying accurate data on the topic. No evident source connects the TRL scale to the risk evaluation of certainty through the concepts of risk, uncertainty, and ignorance, (Oehmen et al., 2020). However, we will borrow this concept to characterize the risk profile for each factor of the green transition. For each of the five factors, we will thoroughly explain how each readiness level will be examined and valued in the readiness scale. When combined, the final assessment of each factor will allow the portfolio manager to govern the portfolio activities to ensure a balanced portfolio readiness level toward a green transition.

4. Risk profiling in green transition projects using xRLs

Constructing the framework – starting with uncertainty levels

Based on the key limitations identified in the literature review, we iteratively developed a readiness-level based framework to capture the risk profile of green transition projects within a project portfolio.
Our framework addresses two major challenges: First, we introduce a generic hierarchy of uncertainty (Oehmen and Kwakkel, 2022) across all uncertainty dimensions: A low Readiness Level (1-3) corresponds to states of ignorance, levels 4-6 correspond to states of uncertainty, and levels 7-9 to states of quantified risk. Table 3, display one example of how an assessment of Law and Regulation will be evaluated in relation to the three readiness levels.

Table 3. Generic definition of Readiness Levels as levels of available knowledge

Readiness Level Range	xRL – Levels 1-3	xRL – Levels 4-6	xRL – Levels 7-9
Level of knowledge regarding critical factors that have significant impact on engineering project success	**Ignorance** Example: A project team is unaware of pending introduction of new legislation. No due-diligence regarding regulatory environment	**Uncertainty:** Example: A project team is aware of pending EU regulation affecting their product, but they do not know specifics. Basic due-diligence, but no specific or quantitative insights.	**Risk:** Example: A project team is aware that upcoming EU regulation will lead to a 15% price increase of their product. Data available to perform probabilistic risk and impact assessments.

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4.1. Introducing the Readiness Levels (RL)

Descriptions through interview studies has been established as a result of observation made from literature study coupled with observations made during the semi structured interviews. The factors are introduced randomly since the framework does not dictate any particular entry point to this assessment. The framework is multifaced, as its purpose is to be useful as object for discussion, during the project execution. Furthermore, the purpose is to inform decision-makers of how the portfolio conditions itself regarding the green transition.

Technical – TRL

Multiple considerations are addressed in the technical level. Lifetime considerations regarding material selection, processing, and storage methods. Around the processes and activities we are doing within the organizations, how do they comply with the upstream and downstream activities, its CO2 emission, the regulations, and other alternatives that we will have in the future. Innovation readiness level, and Product-innovation readiness level. (Ozcan et al., 2023). The product innovation readiness level covers four areas: Technology, Market, Technological capabilities, and product planning readiness levels.

Business Model – BMRL

Market Readiness Levels, have some aspects regarding uncertainties of the business model (Vik et al., 2021), yet the focus is on business model in the market place and lack the green transitional view.
Process activities such as in-house capabilities, material use, internal logistics, and operation methodology, such as we are in the process of producing and selling the assembly of specific solutions, are happening. Business model uncertainties related to the green transition consist of Upstream activities, including supply chain considerations and material input. Downstream activities include processes and activities related to the distribution of products and services. How the green transition impacts each of those consists of the complexity of the organization.

Finance and Insurance – FIRL

Readiness Levels concerning finance and insurance, focuses to ensure that valid resources are put aside for future development and that there are no misconceptions regarding future regulations. For example unforeseen tax that suddenly will influence the market or the market condition. Alternatives include new complex materials that could be used or different technologies that could influence it. It needs to be taken into consideration when analyzing the financial aspects. The concept is the same for insurance as parts of insurance is to ensure the stability of the supply chain, and guarantee the future production set-up. If not, to ensure financial security against potential losses due to abnormal market conditions e.g., blocking of Suez Canal, local road collapses, war etc.During the financial assessment of the portfolio (Tan et al., 2019), the majority of uncertainty related to the financial structure appears in relation to policy and regulation e.g., proposed taxations impact resources availability and the price difference of the financial uncertainty fundamental.

Law and Regulations – LRRL

Law and regulation compliments of how the existing RRL are, is no longer sufficient when talking about the green transition. During the assessment, the focus must be on the future, potential, or even restricted laws and regulations that will be implemented. Barriers can be found in regulations built on old assumptions or data from old technologies. On the law and regulation side there is a variety of uncertainties related to how well established are the knowledge of how the context will be impacted by the regulation set for the green transition. Most organizations indicates that they were fully aware of the importance of the regulative environment, felt secure that they could access the content when needed. However, other organizations were struggling with awareness of where these regulations came from and how often they showed up, they had no internal process to structure and organize the regulatory environment. Inspiration can be drawn from Readiness Levels are Policy readiness level and Regulative readiness level (Kobos et al., 2018; Rowan and Casey, 2021).

Behavior – BRL

The behavioral aspect of the green transition focuses on two sides. First, the consumer's behavior and the market's awareness of national and international trends. Examples of this can be seen in societal readiness levels like the one in 3 states from the Danish Innovation fund(Innovation Fund Denmark, 2019). Second, is the behavior of the organization which is part of multiple maturity models. Interviews pinpointed that the green transition has more to do with the mentality shift throughout the whole

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organization, from procurements to R&D, and sales. Constructing the right culture within the workforce to prioritize sustainable choices over profitable solutions was mainly addressed as a significant factor. Table 4., compile examples of risk perception expressed during the semi-structured interviews.

Table 4. Examples of uncertainty in the categories for the Readiness Level assessment

RL/ Factor	Risk	Uncertainty	Ignorance	Sub-categories
TRL	We are entering the final phases in testing (energy source) for our (critical technology).	To extend lifetime for our product, our whole system needs to change.	Leadership have set net-zero targets, and the only known processes are fossil fueled.	(Manufacturing, Materials, Lifetime, Knowledge, Energy, Products/Services)
BMRL	We are still in the process of picking the low hanging fruits, in reducing emissions in scope 1 and scope 2.	We have a few scenarios, so we monitor the (context) and are ready to move towards the winning technology.	We do not know how our supply chain will change when future regulations will be affective. Can we get the materials at a price where we can stay in competition?	(Supply chain, Circularity, Strategy and Vision, Partnerships, Portfolio management style, Capabilities (stretches across), Growth)
FIRL	We do engage in shared partnerships. We partner with universities, partners, and sometimes our competitors.	We do not profit from engaging in the green transition, so it can be a hard battel to do these investments.	We have not searched for external funding, which is not a tradition here, so I do not know what possibilities are out there.	(Internal funding, External funding, Governmental insurance, Supply chain insurance, Investment strategies (Global), Loss/Gain)
LRRL	We are at the forefront and already collect much of the data need. We will rater set the boundaries, then being a victim of them.	We can go in and find regulations for most areas within the timeframe for our development. But, in some regions of our business local policy is the law.	The regulation in our industry has been delayed many times, we do not know in which direction it will go.	(EU regulation, (Inter)-National and Local Regulation, ESG, CSRD, UN SDG, Standards)
BRL	We have the full commitment from leadership through to the individual worker in packaging. They know why we do it.	We see a willingness in the customer segment, and we therefore believe that we "win" by investing now.	We are aware regulations are coming, but it has not been prioritized. We are expecting a steep learning curve.	(Org. Traditions, Customer behavior, Perception, Culture, Design practices, Motivations, Social constructs)

TRL = Technology Readiness Level, BMRL = Business Model Readiness Level, FIRL = Finance and Insurance Readiness level, LRRL = Law and Regulation Readiness Level, BRL = Behavior Readiness Level

The examples shown in Table 4., are results generalized across the interviews. The last column ***"Sub-categories"*** refers to themes included and analyzed in relation to the each of the uncertainty factors (TRL, BMRL, FIRL, LLRL, BRL).

4.2. How to balance the readiness levels, and what can it tell the decision makers?

Learnings from interview studies indicate that interdependencies between each factor are essential. The answer is typically found by asking why. Uncertainties in the areas of technology have roots in the remaining four factors and within other areas of the factor technology. For example, a typical story from the interviews concerning technological properties of the product is as follows: Technological properties of the product creates uncertainties in the potential choices of materials to the product. Relations can be of how Law and regulations in EU carbon border tax will influence the materials used currently.

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Connected to Finance and Insurance, the identification concerns the cost of the material and the supply. The supply and cost are related to the particular product's business models. Through customer relations, the price, material, and supply are hugely affected by the customer and organizational behavior. Finally, the selection of material determine processes used in production etc., thereby influencing the other areas of technology. As illustrated, each factor is interdepended with other factors, the assessment must balance the inputs from each factor in its assessments. Balanced readiness level assessment (BRLa): A tool for exploring new and emerging technologies suggests the use of the spiderweb diagram for easy readability (Vik et al., 2021) criteria of various Readiness Levels could be an architectural approach to analyzing the portfolio of projects. For example, (Jesus and Junior, 2022) can be used for decision support in accelerating the development of the technologies and integration links that are behind and temporarily. Using an architectural approach, e.g., a DSM, to evaluate interdependencies and requirements seems to be beneficial to inform the decision-makers on the status of the portfolio. What our study contributes to in this context, besides the different views of looking at uncertainties for the project instead of the technology individually, is that we expand this to portfolio decisions.

4.3. Intended use of the framework

The framework will support portfolio risk governance by not 'just' prescribing classic quantitative risk management techniques to each risk profile. However, it will enable decision makers to draw from a broader range of risk management, robust decision making, and resilience approaches (Oehmen and Kwakkel, 2022). It is intended to allow portfolio managers to assess various risk profiles and common management and mitigation strategies across their portfolio, lowering overall portfolio (investment) risk and enabling a faster time-to-market. The aim is to develop an easy-to-implement and easy-to-use framework with five uncertainty factors. Each uncertainty category needs to be addressed through various questions connecting each uncertainty factor to the green transition. Such a framework must consist of evaluating the business model and the technology, as well as investigating the financial structure, the regulatory readiness level and finally, a behavioral map investigating how the organization and the consumer are ready to adopt new processes, services, and technologies.

5. How to balance and evaluate the Readiness Levels

While most readiness levels introduced in literature is used in assessment of ongoing projects or to assess products with a high technology readiness level into in the current context, our framework aims to assess future technologies and services into a future setting. This raises the consideration if the level of certainty is high to very high if the readiness level is high in the majority of the factors. If the certainty is very high, then we can expect that we are close to a market entering state, which means that it is within the realm of short-term planning. On the other hand, if the readiness level and many individual assessments are very uncertain, e.g., having a low readiness score, the suggested concepts will fit the long-term consideration. In that case, it will go into the portfolio decision process and be compared to other concepts with the same level of certainty to balance the portfolio level of activities in the lineman with the strategy and vision of the company. Therefore, we suggest that the portfolio should consist of projects with various green transition readiness levels, but we also suggest that there should be a different layer of consideration and that it is not a standalone tool that can be used in the portfolio process. Instead, we see the green transition portfolio readiness level as a tool to establish discussion and awareness of the different concepts introduced to the portfolio to evaluate where the organization is on this pathway to the transition that is desired and introduced in the organization's vision and strategy. One limiting factors of such a readiness level score related to uncertainties from the green transition can be found through the interdependencies of the questions. It is unclear how robust the readiness score is in addressing the critical marks in interfaces between elements such as internal policy and action and the actual business model. Another element to the readiness level method is how incorporate the results of the assessment in the existing portfolio and development practice. However, a broader assessment that relates to the impacts of the green transition and uncertainties to a framework that can both be used in the development phase and a thorough assessment of the portfolio is expected to have an immense impact on the usability and awareness of the different type of projects that portfolio consist of. It is expected that such a process, when in place, would increase the contribution of making a more robust

https://doi.org/10.1017/pds.2024.126 Published online by Cambridge University Press

and flexible portfolio to comply with the green transition. As the condition of the green transition involve a high level of complexity, individual assessments may be affected by the vast amount of data. To better organize such data, using a systems architectural approach might provide certain benefits. It might be possible to analyze across multiple readiness scales using the tools and methods provided by systems architecture, such as Design Structure Matrix, also known as DSMs (Jesus and Junior, 2022). The value in knowing how the interdependencies between uncertainties are related can lead to a significant increase in informed decision-making towards the green transition risks in the portfolios.

5.1. Contributions and further work

The main contribution of this paper is an additional view on the Readiness Level literature, providing a theoretical portfolio decision-making element to practices. The xRL approach presented in this paper is an expansion of current tools and understanding of the usage of readiness levels. The paper provides an addition perspective on risk and uncertainty in relation to portfolio decisions under the conditions of the green transition. Thereby, it adds a green transitional perceptive to the existing tools and methods previously developed to support the managerial process of product development and production. The managerial application of the xRL is a modified approach designed to evaluate where products and projects are in relation to the green transition. Another contributing factor of this paper is the practical application of the framework presented in (Filipovic *et al*., 2023), to address and work actively from the uncertainties identified through the development clarification process. For these contributions to be verified and adjusted for maximum impact in academia and the industrial context, further research needs to be done in the green transition portfolio readiness level area.

5.2. Further work

As the green transition imposes complex challenges to the independent factors, due to the complexity of the interdependencies the between each factor, portfolio managers must, to gain valuable insights, indorse more attentions to the different uncertainties then what the general and more familiar named readiness levels provides. As discussed, there is a lack in understanding the difference in short-term and long-term perspectives in of uncertainties. Therefore, additional studies must be conducted to determine the context the proposed framework is aimed to be used. This study must be two-folded to cover both the process of using the framework through the development phases and to document the status within each of the factors the framework consists of. Secondly, an investigation of how the framework Is used and provides input for valuable discussion throughout the portfolio governance process is essential to adjust the framework to be applicable for the portfolio managers as well. Both kinds of studies are suitable for test study research. A case study in multiple companies would preferably provide the desired insights into how the framework can be used in practice (Yin, 2014). Moreover, investigation of how such interaction with the framework happened throughout the development and assessment process. Additionally, how the portfolio managers will use the insights in a committee discussion to align with the company's transitional strategies. Finally the research will show how discussion points are used as input to adjusting the portfolio, and thereby for us to being able to adjust the framework to be more applicable for the industry and to expand the of portfolio management theory (Eisenhardt, 1989; Yin, 2014). Finally, structured frameworks like the DSM should be tested of its ability to deal with the interdependencies of the assessments, as a tool to organize the information, to help portfolio managers to take informed decisions.

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https://doi.org/10.1017/pds.2024.126 Published online by Cambridge University Press