A Product Innovation Readiness Level Framework

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Abstract

The term readiness became popular following emergence of NASA's now widely recognised technology readiness level (TRL), leading to studies examining the readiness levels of a particular field or context. Whilst TRL is widely accepted and various types of readiness level frameworks have emerged, there is a weakness in the literature specifically examining the concept of innovation readiness. This is evident in the lack of comprehensive frameworks designed to assess the readiness of a product innovation. Accordingly, the aim of this study is to establish the first multi-dimensional framework to assess the level of readiness of product innovations. In order to construct this framework, we conducted a systematic literature review and examined a total of 55 articles from the product innovation and readiness levels literature. Our findings provide several contributions to the literature. Firstly, by merging two streams of literature we link the main themes of product innovation success factors to potential readiness level scales. As a result, we establish the first product-innovation readiness level (P-IRL) framework: consisting of four readiness levels that include project, market, product and technology capability readiness levels. **The P-IRL framework** is introduced to support the **product innovation investment decisions.** The results of our study provide important implications for innovation managers, fund providers, and product innovation managers.

Keywords: Innovation Readiness Level, Technology Readiness Level, Product Innovation Readiness Level

Managerial relevance statement:

P-IRL framework has several benefits to relevant stakeholders including innovation managers and funding providers. Our framework can be used for the assessment of **product innovation projects** to maximise commercial success and to minimise investment risks. Product innovation projects can be assessed with a multiple dimension approach based on different readiness levels and product success factors. Our P-IRL framework would also bring in **coordination between multiple departments and teams for the proposed product innovations**. This framework can also be used by fund providers to **evaluate projects as a decision support system**. We suggest our model should be used at the beginning of any product development process as part of project development efforts and funding mechanisms.

1. Introduction

The Technology Readiness Level (TRL) has become a widely recognized measurement system to track the progress of a new technology, or the technological dimensions of a new product [1], [2]. Despite its widespread acceptance and use, both academia [3] and policymakers, such as the EU Commissioners [4], have highlighted the need for relevant frameworks to improve the management of innovation projects. Policy-makers in particular, report the need to develop comprehensive frameworks to better understand and evaluate the progress of a product innovation project [4]. This reveals the limitations of TRL, which focuses on the technology alone, and as a result it lacks the ability to holistically capture other factors that influence the success of a product innovation, thus limiting its applicability in **internal or external project submission assessments**. This identifies the need for a more comprehensive model; Innovation Readiness Level (IRL).

Existing IRL models have proposed frameworks to assess different types of innovations which our study builds upon [5], [3], [7]. Firstly, Evans and Johnson [5] illustrate a framework implemented at Lockheed Martin to assess the organisation's capabilities with regard to a business model innovation opportunity. More importantly for our analysis, this framework is described as a tool to assess early stage ideas relative to the verifications required in key functions of the firm (e.g. marketing, manufacturing). Secondly, Tao et al. [3] propose an IRL model to evaluate incremental innovations, considering different dimensions (e.g. market, technology). Lastly, Hasenauer et al. [7] propose a two-dimensional IRL model used in start-up funding process, and [8] refers to investment readiness levels following different project development phases for investment management.

Despite these attempts to design IRL frameworks, existing attempts are limited in two main respects. Firstly, the frameworks they present fail to comprehensively address the multidimensional aspects specific for product innovations and their success. Secondly, these frameworks have not specifically addressed product innovations and hence are unable to detail the factors specifically relevant to their success (e.g. as project, product design). Hence the aim of our study is to design a new **Product Innovation Readiness Level (P-IRL) framework** enabling a **multidimensional product innovation project assessment.** In doing so, we contribute to the literature by providing a novel and comprehensive approach to establishing the readiness of an innovation, as well as providing innovation managers and other decision-makers for investment decision making. In addressing this aim, our study adopts the definition of innovation presented in Crossan and Apaydin [91], where the process of innovation in a firm precedes the final outcome as the *type* of innovation where we focus specifically on product innovation. To achieve this, we design a new framework that embeds the critical "product innovation" success factors [44]. For this study we consider product innovation as related to the development of *manufactured goods*, hence we do not cover other types of innovation such as *service, process or business model innovations.* Also, in contrast to other innovation related RLs, we do not believe that one model can be applicable to every innovation scenario considering different characteristics, processes and success factors.

We argue that the product innovation literature regarding success factors combined with the existing readiness level literature provides the foundation for a more comprehensive understanding of innovation's market and commercialisation potential. Thus, our tool would be highly relevant for the assessment of projects, either incremental [3], related to new ventures [7], [8] and specifically for overall innovation project assessment. Also, **P-IRL framework could be used to assess both internal and external investment decisions specific to the product innovations.**

This paper contributes to the literature by providing a new measurement system tool, **"P-IRL framework", to assess product innovation projects for both internal and external investment decisions** [4, 8]. Our first contribution is to extend existing business model related [5] and incremental innovation specific [3] IRL approaches. By contrast, we provide a new readiness level model specific to products. Our new product innovation readiness model provides a more comprehensive approach founded upon an extensive systematic literature review (SLR) that combines two sets of literature. Specifically, we integrate the findings of 30 studies related to product innovation, and 25 related to different aspects of "readiness levels". Based on our analysis, we contribute by offering a product innovation specific, multi-dimensional model which captures a broader number of dimensions that require assessment in order to establish the readiness of an innovation project. In doing so, we create nine new levels of readiness for four novel dimensions of overall product innovation readiness, namely: 1) Project Planning Readiness Levels, 2) Market Analysis Readiness Levels, 3) Product Planning Readiness Levels, and 4) Technology Capability Readiness Levels. Our second contribution is to studies examining how to improve decision-making along innovation projects [6]. The P-IRL framework provides a novel approach to conceptualising the dimensions that innovation managers need to address within decision-making on new product developments, by providing a comprehensive set of readiness dimensions that help to understand the readiness of a product innovation and supports investment decisions. We also introduce a P-IRL matrix model that illustrates how different RLs can be used in an integrated fashion.

The following paper is structured as follows: Section 2 will review the literature on readiness levels and specific to the IRL separately, to subsequently perform the systematic review for our study. Section 3 will describe our SLR method. Section 4 will present the new P-IRL framework. Section 5 discusses further the contributions of our model by relating it to the previous literature and finally limitations and future recommended studies are discussed.

2. Literature review: Relevant Readiness Levels For Product Innovations

In this section, we separated the literature review for TRL and other "readiness level" (RL) models. Firstly, we reviewed the TRL models and how TRL is implemented in different contexts. This allowed us to understand how the TRL model has been transferred and expanded in other areas. In the next section, to position our study, we examined other readiness level models to examine the innovation readiness related gap and weaknesses in the literature.

2.1 Technology Readiness Levels and its Applications

The Technology Readiness Level framework originates from the aerospace industry at NASA [1]. The 9-level TRL model is a measurement scale to monitor the technological aspect of projects, from basic technological knowledge to prototyping and launch [1]. Since its inception, this model has supported the development of different technology applications within industries and government organisations, which have each tailored it to their own contexts [9]. For example, the American Department of Defence applied the manufacturing readiness level to better track the development of a manufacturing process along TRL levels [10]. Another example is the personalised "relevant environment", in which technology needs to be tested to reach TRL 5 (analytical laboratory work). This would be different in IT projects, where the environment differs from an aircraft lab; forming a system of "cooperative software development" [11]. As another example, the drilling of oil reservoirs would entail the initial assessment of finance to geotechnical data, health policy monitoring and the life cycle [12]. Whilst such studies capture differences in the environment and requirements that may differ by context, they fail to address other dimensions affecting the success of an innovation, and thus provide an indication of its overall readiness.

Since the earlier applications of TRL, other variations of RL models have been developed overtime under the logic of TRL. Rolls Royce, for example, applied a Manufacturing Capability Readiness level to generate a higher degree of engineering and supply chain knowledge, from which other studies shaped a manufacturing technology readiness level [13].

A more recent interpretation of TRL is provided by studies on sustainable development innovations (aviation turbo propellers or waste management technologies), by linking the levels of the TRL framework to the conceptual layers of the Multi-Level Perspective (MLP) model[1]. Thus, using both TRL and MLP to track the progress of different innovation projects [14]. Further studies have tailored the TRL framework to specific contexts either grouping its levels by relevant activities or adding other readiness levels, such as societal or consumer readiness (Munir et al., [14], [15]. In synthesis, Mankins [2] provided a retrospective description of over 30-years of TRL use, suggesting that the scope of TRL has been bounded to solving the three key challenges of projects, as a basic guideline tool: performance, schedule, and budget. Thus, as a general 'guideline tool' the TRL fails to address other project factors which results in a gap in the literature. This limitation is detailed in the work of Olechowski et al. [9] who explored the context of different industrial firms (NASA, Google, John Deere, BP, and Bombardier). These firms encountered challenges in implementing TRL to track the level of advancement of complex technological systems.

[1]"MLP has been developed as a model to grasp technical change by synthesizing the factors affecting innovation process. MLP explores the innovation process of three levels (and interactions among them): niche innovations, the socio-technical regime, the socio-technical landscape" (Nakamura et al. [14]).

The seminal study from Sauser et al. [16] on System Readiness Level forms another example of the hierarchical relationships between TRL and other readiness levels. Their work proposes a need to connect TRL with integration readiness, which relates to the compatibility of different technologies into the final product [17]. Thus, a system maturity assessment (i.e. the iterative verification) is introduced and system readiness (i.e. the validation of maturity) of the technologies used for the product.

The potential value of a tool to evaluate innovation readiness is particularly evident in the context of entrepreneurial environments. Venture Capital Funds or Accelerators require more complete evaluation tools in order to address the gaps in investment practice requirements, namely, from Minimum viable products (MVPs), to Time-to-Market, and commercialisation. In this respect, Blank's [8] investment readiness level assesses the level of progress of start-up companies to manage the different rounds of funding.

In conclusion, TRL is widely used in project applications for both internal and external funding mechanisms by many firms and funding organisations. Yet, existing readiness levels tools and conceptualisations fail to provide a comprehensive assessment within the process of product innovation due to their sole emphasis on the technology, which forms only one of a number of dimensions of a product innovation project. Hence there is a need for a more comprehensive measurement tool for product innovation and development activities. The following section examines "RL" models in order to report the different contexts in which these have been applied, as well as product development dimensions included or neglected.

2.2 Readiness Level Models

A review of the literature on existing relevant readiness levels reveals that they can be divided into six RL areas, based on their purpose and applications areas, which are as follows; (i) TRL variations, (ii) Manufacturing, (iii) System, (iv) Market impact, (v) Innovation and (vi) Project Management Readiness Levels. Table 1 below summarises all the relevant RLs and IRLs present in the existing literature. The remainder of this section is organized according to this table.

Table 1. Summary of Readiness Levels related to Product Innovation

Type of RLs	RLs Type	Context/Reference	Missing Dimensions
Technology	*TRL Contextual variation*	*Multi-level perspective* (Nakamura et al. [14]).	*Use of TRL to other important aspects of Innovation. Main variations do not address a multidimensional use of TRL with other RLs.*
		Recycle/Waste Management (Rybicka et al. [15])	
	TRL Quantitative measurements	*Project Advancements* (Shishko [71])	
		Project time slippage [69].	
		Hardware and software contexts (Smith, [72]; Conrow [79]).	
Manufacturing	*Manufacturing Readiness Level*	*Manufacturing acquisition system* Department of Defence [10].	*Quantitative measurements only rely on the technological performance of the product design. No interconnection with market aspects product commercialisation*
	Manufacturing Capability Readiness Level	*Extension of Manufacturing Readiness level* (Peters [13])	
	Innovative Manufacturing	*Nanotechnology analysis* (Islam, [18])	
System	*System readiness Level (and integration readiness level)*	*Integration of different technological systems* (Sauser [16], Ramirez-Marquez et al. [19])	
Market Impact	*Market Readiness Level*	*Market and demand Readiness levels for sustainability* (Hjorth and Brem [20]);	*All models intersect TRL or other existing RLs. The missing aspect is the multidimensional concept.*
	Market Attractiveness (& Consumer readiness level)	*Technological diffusion* (Kwon & Son, [23])	
	Technology, Regulatory, Market	*Market readiness, Regulatory Readiness Levels* (Kobos et al. [22])	
	Demand Readiness Level	*Technology Transfer* (Paun, [24])	
Innovation	*IRL 6 dimensions*	*Multiple contexts* [3]	*Methodological assignment of value to each RL, and set of relevant product innovation dimensions*
	IRL Use of existing IRL	*Food processing* (Setiawan et al.[70]	
	IRL 2 dimensions	*Start-ups* (Hasenauer et al., [7])	
	Innovation readiness concept	*Multi-dimensional analysis* (Zerfass, [82])	
Project	*IRL Project Management*	*Project Management context* Galvez et al. [59].	

Firstly, the Manufacturing Readiness Level (MRL) [10] introduced variations of RLs to track the development of manufacturing process innovation related to new products. For example, the MRL tool of Islam [18] aimed to assess the maturity and uncertainties within micro- and nanotechnology manufacturing. Further, Peters [13] proposed the manufacturing technology readiness level for a comprehensive assessment of pre-mature manufacturing technologies, such as additive manufacturing, also for production system performance.

Secondly, System Readiness Level (SRL) models have been introduced by scholars to assess the integration of different technologies within a technology system [16], [17], [19]. SRL is an important model to assess readiness of other relevant technological developments. This becomes even more important for complementary technologies where a newly proposed technology needs to be integrated into existing systems and architectures.

Thirdly, different types of Market Readiness Levels (MktRLs) exist in the literature, and as with the previously mentioned SRL levels, integration forms a key aspect of these approaches. Hjorth and Brem [20] assess Market Readiness intersecting three different RLs: integration and demand, leading to an aggregate MktRL. Hicks et al. [21] proposed another model as an extension of the TRL with regards to the product's lifecycle. Their model follows eleven levels and related sub-readiness levels. For example, in the sub-levels of TRL10, the framework includes the potential need to develop new product features or the commencement of new product R&D. Kobos et al. [22] propose a technology-regulatory-market exploring the timing of renewable energy technologies development, meeting the readiness of the market, policies and regulations.

Fourth, aligned with product innovation factors, the market attractiveness readiness level proposed by Kwon and Son [23] encompasses: Global market size, growth rate, policy suitability. This model integrates TRL and a customer readiness level relatively to product diffusion levels. Similarly, we also identified the demand readiness level [24]; mostly applied to technology transfer contexts.

Having described different readiness levels models that are related to product innovations, it is apparent that few academic studies present IRL frameworks with scale level measurement [3], [5], [7]. Hasenauer et al.'s [7] Innovation Readiness Level (IRL) model is based on analysing the degree of impact of the social environment, the environmental impact, and the economic driver trade-offs. These main levels include many other sublevels but only related to Market (e.g. supply, demand, customer, product) and Technology (e.g. intellectual property, integration, manufacturing). Each of the sub-levels presented are linked to a nine-level scale, following TRL logic. Further, the IRL framework from Tao et al. [3] is tailored to support incremental innovations. Moreover, their work aims at providing a generic innovation framework considering the internal organisation as one of the dimensions and including the lifecycle of the product until its potential changeover. Further, Evans and Johnson [5] present a more focused framework on business model innovation, including the organisational changes required when a new business model is required for a new product. Hence, also highlighting the importance of developing capabilities.

Overall, our review of prior IRL studies reveals that the majority fail to provide a comprehensive coverage of factors relevant to the overall readiness of innovations and specifically for product innovation investment decisions. This weakness results from either their scope in the type of dimensions (Hasenauer, et al., [7]) or a focus on specific technological contexts [25]. More importantly, even though Tao et al. (2010) present a model with different dimensions, their framework is not founded upon an analysis of the product innovation literature to determine these dimensions and specific activities to consider for investment decisions. This results in a failure to systematically and comprehensively address the factors required to provide a complete assessment of the readiness of a product innovation

None of the existing IRL frameworks in fact, are designed upon a comprehensive set of product innovation success factors and existing readiness level literature. We argue that this is a critical aspect underlying the need to design a model based on a specific innovation type (Crossan and Apaydin [91]), as opposed to a generic innovation readiness framework (Tao et al., 2010).

As innovations have various dimensions to their success, current models fail to provide a comprehensive model for product innovation managers and other decision-makers to follow. These limitations reduce the overall utility of a model, which should resolve a number of questions for innovation managers and scholars. In particular, it would help identifying other critical RLs and factors other than TRL that needs to be considered for product innovations. These limitations, alongside other aspects of a product innovation that existing models fail to recognise, highlight a need for further conceptual development of IRL. We summarise the limitations of existing models in Table 2. This informs the rationale for the present study, which aims to address these limitations by presenting a multidimensional model.

Table 2. Limitations of IRL models

Readiness Levels Limitations	**Product Innovation Rationale**
Comprehensiveness	*Existing models are not specifically designed for product innovations (either incremental or radical)*
Product Innovation Levels	*Levels need to have a focus on the pillars of product innovation and product success specific considerations*
Assessment Methodology	*Assessment methodologies need more precise methods at both qualitative and quantitative scale levels analysed*

The conceptual framework for our study is shown in Figure 1, which captures the two sets of literature we synthesise through a systematic literature review approach. This underpins the subsequent development of a new product innovation readiness level model, namely the 'P-IRL framework'. To achieve this, we: (i) review studies related to the factors influencing the success of product innovations, and (ii) integrate our RL-related findings with other product innovation related RL models. This results in the new RLs specific to P-IRL framework. Specifically, previous innovation-relevant RL models are assessed and modified considering product innovations. Hence the relevant aspects of product innovation and RL models are integrated into a final P-IRL framework.

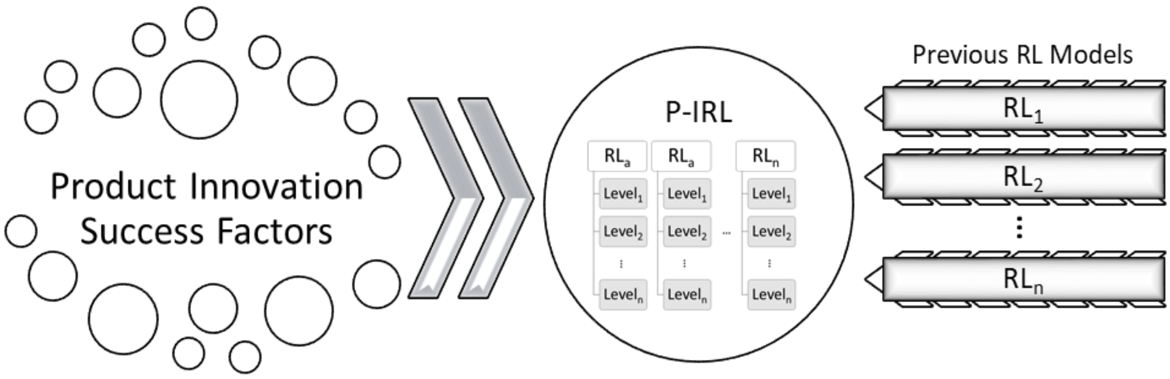

Figure 1. Conceptual framework for P-IRL

3. Methodology

The literature on readiness levels and IRL have delineated the main problems of creating an assessment method to manage projects. The methodology adopted for our study is a systematic literature review (SLR) [26], which is developed in a sequential approach towards a systematic mapping [27]. This consisted of a separate search for: (i) product innovation success factors, and (ii) readiness levels.

The literature analysis follows the principles of a SLR [28], and to minimize bias in our procedure, we adopted the widely recognised PRISMA checklist protocol [29] (see the PRISMA steps as depicted in Figure 2 below). The logical development of this study is also aligned with the guidelines of Tranfield, Denyer and Smart [30]. Firstly, a pre-understanding of the topic allowed the authors to outline the nature of the subject, as well as the evaluation of different methodological approaches [26]. Secondly, within the adopted systematic mapping rationale [27] two separate database interrogations were conducted for: (i) successful product innovation and (ii) readiness levels. These searches were performed on the

Web of Science and Scopus databases (searches completed 05.02.2021). In doing so, we aimed to integrate and capture the linkages between two separate literature streams and subsequently lay the foundations of our comprehensive P-IRL framework (see Figure 2). Prior systematic reviews have adopted a similar approach, attempting to merge two distinct research streams when seeking definitions of specific underexplored topics ([31], [32]). In order to provide a comprehensive picture of both product innovation success factors and readiness levels we included both theoretical and empirical studies [33], whilst not restricting the data collection to a specific period [31].

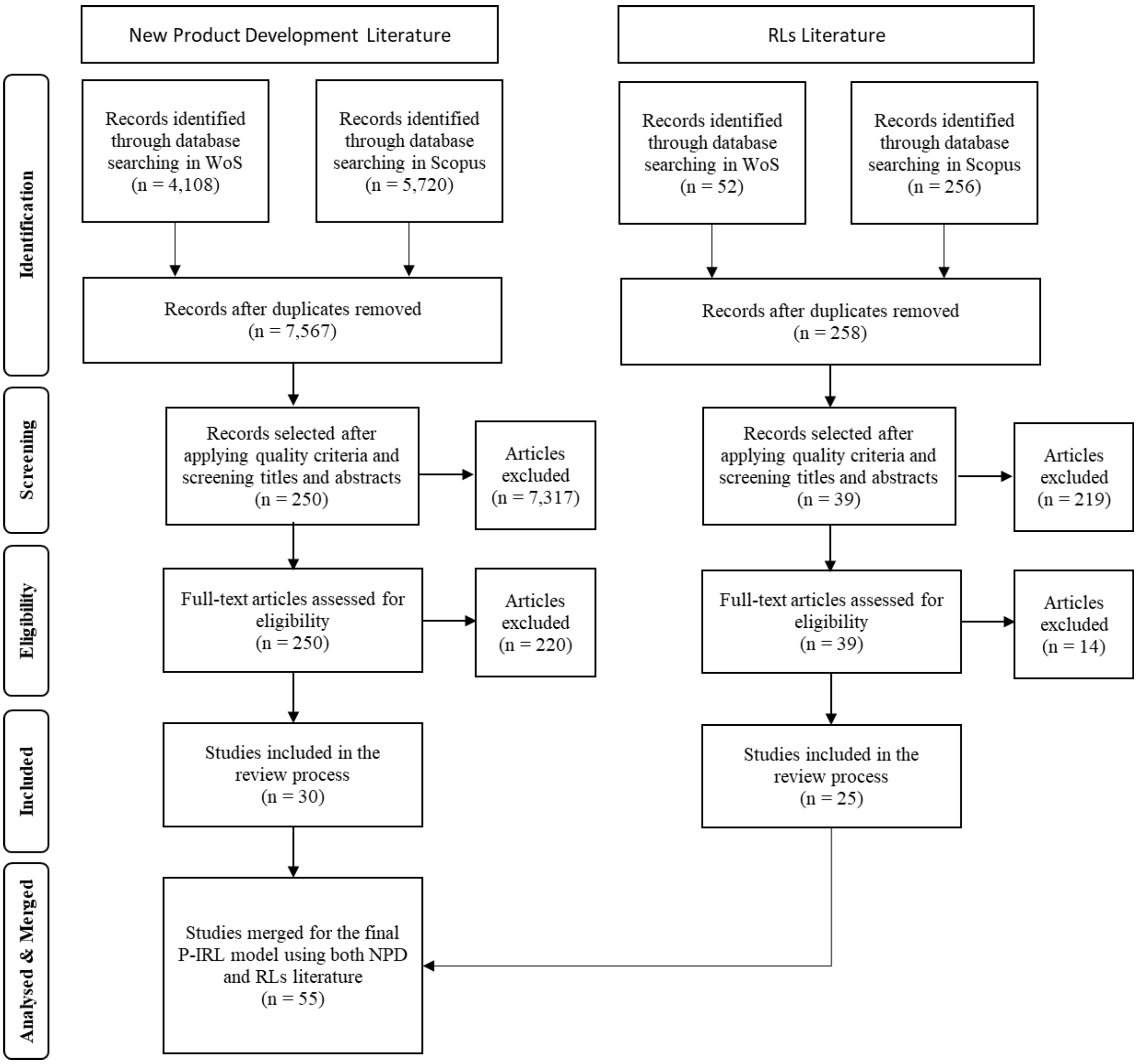

Figure 2. PRISMA flowchart

Firstly, for new product development and product innovation success factors, articles that are focusing on success or failure related determinants were aimed to be retrieved. Thus, our query to retrieve product innovation studies was (“product innovation” OR “product development”) AND (success), performed into title abstract and keywords of the articles. This returned a total of 7,317 articles after the elimination of duplicates using Endnote citation software [34]. This study followed both quantitative and qualitative inclusion and exclusion criteria. The quantitative inclusion criteria focused on papers identifying success factors; from CABS ranked journals[2] and studies that had minimum 10 citations. The spread of citations across our sample featured 68% of the sample exhibiting 100+ citations, following from Scopus citation metrics (see Appendix A for greater detail on the quality of the sample). Following the qualitative inclusion and exclusion step, the studies are assessed for their eligibility to make sure each article covers why certain product innovations are successful or unsuccessful focusing on different factors and contexts (e.g. Holland, [54]; Hart [55]). As the focus of the study was to identify the success factors and embed these into the newly proposed P-IRL model, any studies that focused on other aspects such as efficiency of the NPD process were excluded. This resulted in a final sample for the product innovation success literature of thirty articles.

Secondly, the approach to readiness levels and innovation readiness level adopted broader criteria, due to the emerging nature of the field of readiness level analysis and papers closely analysing the concept of innovation readiness. Therefore, we also included conference proceedings and evaluated as a team those additional sources relevant to the scope of the analysis. This resulted in considering those papers relevant to TRL variations, alternative types of readiness level scales originating from TRL logic and Innovation Readiness Level

[2] We consulted the Academic Journal guide (AJG) 2018 from the Chartered Association of Business Schools (CABS). The AJG is based upon peer review, editorial and expert judgements following from the evaluation of publications, and is informed by statistical information relating to citation (CABS, 2018; p.4). The guide is based on a quality scale ranging from 1 to 4 and 4* rated journals.

academic work. To this concern, a broader query for Readiness Levels included the terms considered key in a sequential approach to product innovation analysis as shown below: *(technol* OR innovation OR product OR market OR system OR project OR planning OR maturity OR consumer OR demand OR risk) AND ("readiness level" OR "levels of readiness").*

Our search query retrieved 734 studies after the removal of duplicates from WoS and Scopus databases, which was limited to business and management and engineering categories. Following the remaining steps, as shown in the PRISMA flowchart (see Figure 2), twenty-five readiness level studies were included in the final examination step (we included one model that was implemented by EU funded entity, as there are limited number of relevant studies available for IRL model) [25]. After selecting the relevant studies, thematic coding was conducted in NVivo 12 software for both sets of literature [28]. Here, open coding and focused coding were conducted, and a subsequent inter-rater coding reliability index, following recent sources based on calculating the level of agreement on the coded themes (Cinar et al., 2019). The three authors coded a sample of the ten papers from a defined coding scheme. These papers were selected based on the most cited within the overall sample. Subsequently, through NVivo 12 an inter-rater reliability comparison query was performed (Nivo, n.d [94]) with no evident inconsistencies revealed [35] and with an agreement ratio of 90%. The final phase was to report the results in a narrative synthesis using the concepts of the coding [36]. Throughout this analysis, the identified themes acted as connectives between the different studies (e.g. McPhearson and Holt, [90]) mainly represented by the joint analysis of product innovation success factors and readiness levels. Further detail on the different themes is presented in section 4 through a summary of tables for each readiness level proposed.

To illustrate the model, we integrated the systematic literature review analysis, explained in Figure 2, with a secondary data analysis (e.g. See Ebolor, 2023). In doing so, we first conducted a systematic review of the product innovation and readiness levels literature that have shaped the description of each readiness level (Section 4.1). Secondly, we conducted a separate search in both Sage Business Cases database and Scopus to select sources which enabled a retrospective analysis of product innovation success or failure factors. In doing so, we searched for product innovation cases that would discuss in detail the different dimensions related to either success or failure of the case.

Following the development of the P-IRL framework, a thematic analysis was conducted to code the information related to the selected cases according to the different readiness levels (Project, Market, Product, Technology). In analysing the case studies, we coded the most relevant illustrative quotes using the main dimensions of the P-IRL as a reference coding scheme. The evidence of the cases does not aim to validate the P-IRL framework, instead the specific cases are introduced to illustrate how the identified dimensions could apply to innovation cases analysed. This approach enabled us to link the issues to a number of levels (e.g. Market analysis aspects from MRL 2-7), or where RL activities had been addressed (e.g. Project Level activities for General Electric cases). These are summarised in section 4.4 with relevant quote examples.

In order to further illustrate the relevance of the P-IRL by analysing the cases, we also presented a diagram (Figure 5) illustrating the assumed overall level for each dimension related to the Google Glass case based on the analysis done.

4. Overview of Findings

The following sections present the synthesis of findings, which set the foundations of our P-IRL framework. Based on the preceding discussion, we first identified critical themes and success factors in the product innovation literature. Subsequently, we proposed readiness levels for each of the identified themes. This analysis is summarised in Table 3 through the proposed four Readiness Levels. The comparison between product innovation success factors and readiness levels highlights that the readiness levels literature has to date neglected important aspects, which are identified as critical in the product innovation literature. In this respect, Table 3 reports our proposed readiness levels based on both product innovation success factors and relevant RLs. This latter detail is clarified in section 4.1, where we explain the rationale for the P-IRL framework with the newly proposed RLs.

Table 3 is also designed to report the references that are used in this study in groups of RL and product innovation literature. In order to provide a descriptive account of the two literature streams, sections 4.2.1 to 4.2.4 provides a detailed analysis and descriptions for all the developed RLs. In addition, the section 4.3 is provided to explain and illustrate how different RLs and teams can work together through the P-IRL framework's requirements. Finally, the section 4.4 is provided with carefully selected three case studies to illustrate how the P-IRL framework could be implemented to minimise the chance of product innovation failures or maximise the potential success. This section demonstrates how the lack of attention to specific readiness levels may effectively lead to the product being unsuccessful in the marketplace. Also, the section 4.4 provides an illustrative case to show how the P-IRL could be implemented for funding or investment decisions.

Table 3. Product Success and Readiness Levels Literature Comparison

Product Innovation Literature	*Summary of Supporting References*		*Summary of Literature Review Evidence*	*Proposed Readiness Levels in P-IRL*
Themes in the literature	***Studies from Product Innovation Literature supporting proposed level***	***Studies from Readiness Level Literature supporting proposed level***	***Success factors from Product Innovation Literature***	
Planning	Cooper [38]-[41], De Medeiros et al. [57]; Cormican and O'Sullivan [42]; Sun and Chung [43]; Maidique and Zirger [44]; Verworn et al., [45];		*High importance of Project planning* *Clear Strategic Posture of Project* *Detailed level of "pre-work" activities* *Firm consideration of Reduced risks*	**Project Planning Readiness Levels**

Team	Cooper [38]; Johne and Snelson [52]; Holland et al. [54]; Moenaert et al. [46]; Verworn, [47]; Kandemir et al. [48].	Galvez et al. [59]; Blank, [8]	*Configuration of relevant teams* *Management appointed Project Champion* *Professional team project managers* *Evaluation of Product Innovation Quality of teams*	
Complexity	Balachandra and J. H. Friar [58]; Calantone et al. [60]; Cooper [38], [40]; Cormican and O'Sullivan [42]; Evanschitzky et al. [77]; Griffin and Page [56],[51]; John and Snelson, 1988; Maidique and Zirger [44]; Paladino [53]; Tatikonda and Rosenthal [50]; Verworn, [47]; Verworn et al.,[45]; Liu and Su [65].		*Identification of Project Complexity* *Market oriented allocation of resources* *Resource oriented allocation of resources* *Evaluation of product portfolio resources* *Evaluation of Project requirement and difficulties*	
Consumer	Cooper [38]-[40]; Cormican and O' Sullivan [42]; Calantone et al. [60]; griffin and Page [51]; Hise et al. [61]; Evanschitsky et al., [77]; Liu, and Su [65]; Maidique and Zirger [44]; Calantone et al. [60]; Paladino [53]; Sun and Chung [43]; Kandemir et al. [48].	Hjorth and Brem [20]; Kobos et al. [22]; Hasenauer et al., [7]; Kwon and Son [23]; Paun [24]; Tao et al. [3];	*Opening to existing or non-existing markets* *Inter-functional cooperation* *Identification of target Markets* *Identification of attractive markets* *Identification of Product growth Potential* *Identification of consumer segments* *Alpha testing analysis* *Voice of the customer analysis (VoC)* *Ethnography analysis* *Trade-off analysis* *Positioning and re-positioning of products.*	**Market Analysis Readiness Levels**
Commerciali-isation and Advertising	Boso et al. [64]; Ernst et al. [62]; Evanschitzky et al. [77]; Hise et al. [61]; Ragatz et al. [73]; Sun and Chung [43]; Paladino [53]; Christofi et al. [63]; Holland et al. [54]; Moenaert et al. [46]; Kandemir et al. [48].		*Sales Forecasting procedures* *Integration of Sales and R&D* *Synergy between advertising, marketing, engineering* *Monitoring of Post-Launch activities* *Quality of advertising and promotion*	
Originality	Cooper [38], [40], [41]; Griffin and Page [51]; Paladino [53].	*No RL article reporting aspects of Product Originality*	*Analysis of USP (Unique superior product)* *Identification of superior product features* *Product Performance evaluation* *Product performance in relative Portfolio*	**Product Planning Readiness Levels**
Design	Cormican and O'Sullivan [42]; Hart [55]; Sun and Chung [43]; Maidique and Zirger [44]; Griffin and Page [51]; Christofi et al. [63]; De Medeiros et al. [57]; Wong [67]; Tatikonda and Rosenthal [50].		*Profiles of Product design and modules* *Use of QFD* *Use of Six Sigma* *Concurrent Engineering practices* *Use of FMEA* *Value Analysis* *Outline of Minimum Viable Product*	
System	Tatikonda and Rosenthal [50] ;	Sauser et al. [16], [17]; Ramirez-Marquez et al. [19]; Hasenauer et al., [7]; Magnaye et al. [78]; Jesus et al.[86], Tompkins et al. [87]	*Estimate of technical performance of Product Modules*	**Technology Capability Readiness levels[3]**
Manufacturing	Tatikonda and Rosenthal [50] ;	Department of Defence [10]; Islam [18]; Peters [13]; Hasenauer et al., [7];	*Evaluation of Manufacturing processes* *Adaptation to Manufacturing flows and stages* *Evaluation of new manufacturing equipment* *Awareness of manufacturing technology development*	
Product Technology	[58]; Tatikonda and Rosenthal [50];	Mankins [1]-[37]; Hicks et al. [21];	*Product Technology related to other contextual factors*	

			Relationship to the nature of the Product Innovation *Relationship to the nature of the Marketing strategy*	
Intellectual Property	Cooper [38]; [58]; Maidique and Zirger [44].	Hasenauer et al., [7];	*Intellectual Property as a Product Innovation success factor* *Preliminary assessment of IP protection* *Technology licensing procedures* *Verification of product technology patentability*	

4.1 P-IRL FRAMEWORK

This section describes the logic of the readiness level scales relative to our P-IRL framework. We propose a scale concept composed of four Readiness Levels that are: (i) Project Planning Readiness Levels, (ii) Market Analysis Readiness Levels, (iii) Product Planning Readiness Levels, and (iv) Technology Capability Readiness Levels. As detailed, the proposed levels derive from the success factors identified in the product innovation literature and their linkage to the relevant RLs. In order to clarify this relationship, Table 3 illustrates the development of each of the proposed four RLs by identifying the product innovation literature themes (e.g. team, complexity). Our analysis led us to propose new RLs through our critical examination of the factors identified in both product innovation and RL literature. The outline of each of the readiness levels is proposed to align with each other following the structure of TRL model (e.g. nine levels) which also builds upon prior IRL studies [3], [7]. The rest of the paper and the relevant subsections are organised based on the four RLs that are illustrated in Figure 3.

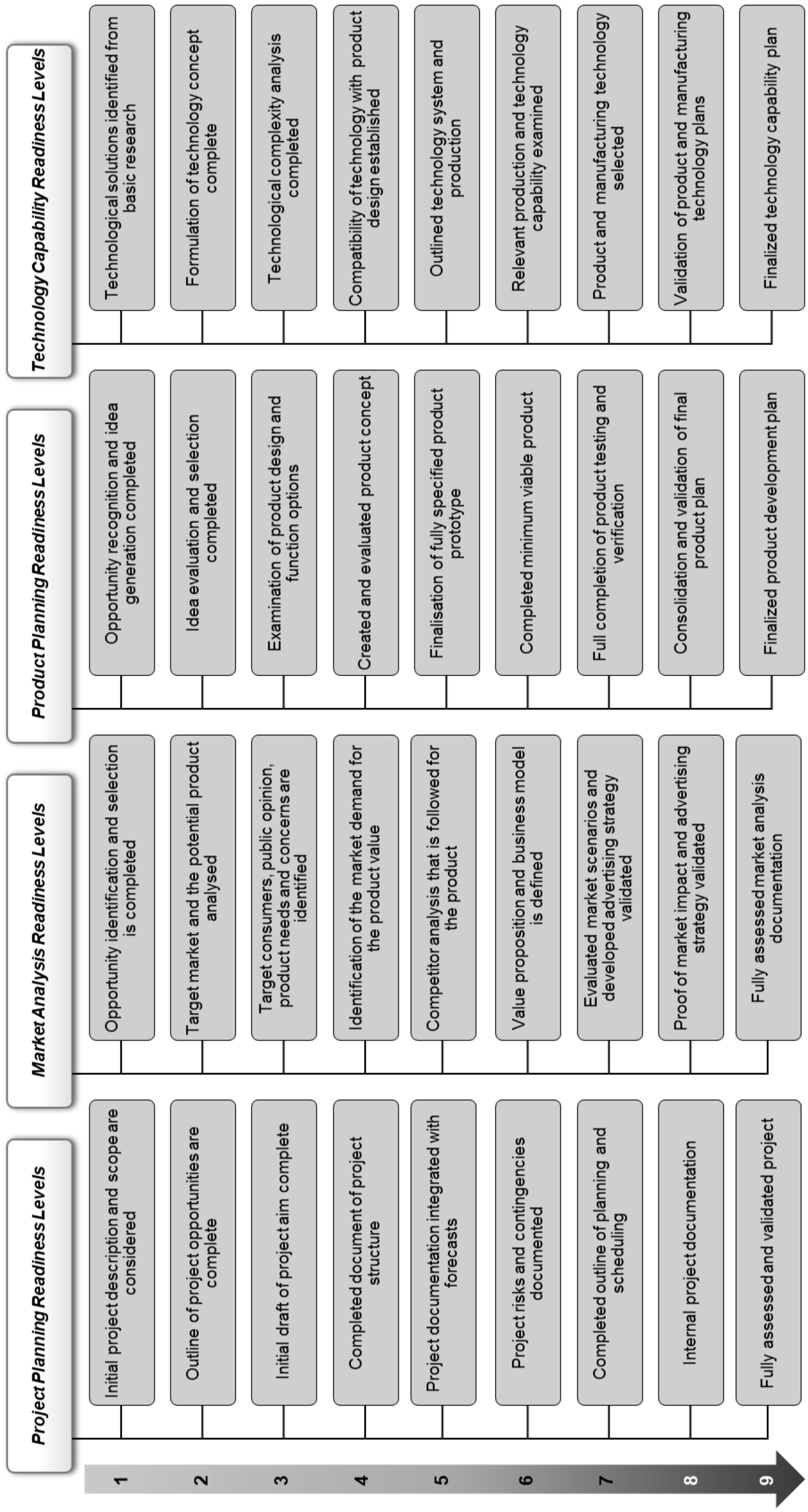

Figure 3. P-IRL Framework

4.2 *Readiness Levels Scheme and findings*

In the following sections we explain our P-IRL framework with relation to each readiness level. As also explained in previous sections, the basic logic and structure underlying our framework is the TRL model. Specifically, we benefited from the TRL model of Mankins [37] in terms of the basic logic of main levels in relation the newly proposed P-IRL. According to these approaches, we contextualised product innovation success factors and relevant RLs for each of the proposed levels.

4.2.1 *Project Planning Readiness Levels (Proj-RL)*

As previously mentioned, P-IRL framework is designed to support the project selection and investment decisions. The ability to select a relevant innovation project among a portfolio of projects is widely acknowledged as a critical success factor in the product innovation literature [38]-[41]. The unit of analysis for this readiness level is the project, considering its strategic and resource dimensions [42]. The purpose of the described Project Planning Readiness Levels (Proj-RL) is to track progress from an initial stage of project analysis to thoroughly planned and finalized project documentation. The Proj-RL encompasses nine levels, reflecting themes identified in the literature, particularly the significance of planning, teams for product development decisions, and the complexity of projects in relation to necessary resources [42]-[48]. Table 4 provided below to describe each Proj-RL levels.

Table 4: Description for Project Planning Readiness Levels

Levels	Descriptions for Proj-RL
1	**Initial project description and scope are considered:** To reach Proj-RL 1, a firm must establish the initial project description and scope, such as preliminary ideas of a new product opportunity, which could be radical or incremental [3], [8]. This level is generally associated with low costs [37], and there may be basic consideration given to the potential for strategic product applications, relevant to the firm's portfolio management [49]. In our model, this reflects the initial rationale for an innovation project as a whole, primarily representing the business strategy underlying the project [38].
2	**Outline of project opportunities are complete:** Proj-RL 2 necessitates a completed outline of project opportunities, which should be regarded as potential options for development. The literature emphasizes that several initial ideas may emerge from the results of informal meetings on the need for specific R&D or leveraging existing technologies [50]. Additionally, this level should also present broader assumptions about the project's strategic fit and commercial potential [38], [44], [51].

3	**Initial draft of project aim is complete:** At Proj-RL3 level, a preliminary analysis of the project team is required. To achieve this level, a firm should consolidate the initial project formalization, which should include more detailed information on how the project would be positioned against other firm projects and its strategic fit [38]-[41], [52], [77]. Furthermore, initial data on the project's growth opportunities and challenges should be identified [53]. Additionally, to achieve this level, the firm should provide an initial analysis of the project team appropriate for the project [38], [54].
4	**Completed document of project structure:** To achieve Proj-RL4, the firm should present: a) The outline of suitable NPD teams and required resources identified, b) a more detailed description of the business strategy and project plan is established [38], [39], [51]. Cooper [38] associates this with existing resources, such as R&D and technology, as well as required management capabilities, manufacturing capabilities, or technical support to customers [38].
5	**Project documentation integrated with forecasts:** In order to achieve Proj-RL5, firms must outline key investment and success parameters for evaluation [55]. For example, key growth forecasts can be assessed [51], [55]. Griffin and Page [56] suggest various financial measures concerning product success. Here, we specifically refer to the project's financial dimension, including initial completed estimates of break-even, IRR/ROI, and profitability goals [56].
6	**Project risks and contingencies documented:** Proj-RL 6 requires further examination of the project's complexity degree [47], [50]. This ultimately entails further verification of the risks associated with the project and the specific allocation of resources [57], [38], [42].
7	**Completed Outline of planning and scheduling:** Proj-RL7 involves an outlined final project complexity description concerning product and process innovation interrelationships [50]. At this level, we assume firms reach what Cooper and Kleinschmidt [40] call "the determinateness of the project" (p.216) [38]. This involves planning and scheduling the introduction of a new product based on resource availability, time limitations, and financial restrictions [58].
8	**Internal project documentation:** Proj-RL 8 is achieved with an internal approval decision on the project validation and schedule of product introduction [38], [59]. This level indicates that the firm is ready to commit to the project, as its feasibility has been determined and it is supported by the organization. The project documentation should be completed and verified with the relevant teams including marketing, product, R&D and project management teams [38], [40], [42].
9	**Fully assessed and validated project:** At Proj-RL9, the project's readiness can now be assessed on the basis of several measures, such as the financial dimension [56], the strategic fit [38], and the allocation of resources [57]. To achieve this level, the firm to confirm that the project has gone through a rigorous evaluation process and is considered to have the highest level of readiness to be executed.

4.2.2 MARKET ANALYSIS READINESS LEVELS (MRL)

The units of analysis of this readiness level reflects the themes identified in the literature highlighting market related success factors. The aim of the following readiness levels is to ensure that managers consider *target consumers, competitors, the business model and advertising strategy of the project*. Consequently, Table 5 summarises the literature findings into each identified readiness levels and describing the aspects to be completed in order to move from one level to another.

Table 5: Description for Market Analysis Readiness Levels

Levels	Description for Market Analysis Readiness Levels
1	**Opportunity identification and selection is completed:** To fulfil this level, managers need to present initial assumptions of market demand for the product. Thus, also evaluating the radical or incremental nature of the product idea the product innovation, linked to the degree of novelty for both the focal firm and market [40]. For example, in the case of radical product innovations, markets may not exist at all, thus requiring initial assumptions [65]. This, however, also applies to incremental innovation in existing IRL models [7] Hence, at this first level we propose that managers need to document the underlying rationale behind a selected market opportunity which, will be further analysed throughout this market dimension.
2	**Target market and potential product analysed:** This level requires managers to provide a higher level of detail with regards to the targeted market and the type of product analysis. Following the previous example of considering either radical or incremental product innovations [40], [44], some studies explored the importance of expected growth rate of the product where successful products are ideally positioned or re-positioned in growing markets [44], [51], [58]. Hence, this level requires managers to be more specific about the market for the product and its overall value for potential consumers [65], providing a significantly higher level of detail compared to MRL1.
3	**Target consumers, public opinion, product needs and concerns are identified:** For this level, managers are required to critically evaluate the type of consumer types or personas gathering empirical evidence to justify assumptions made. This can be done through the use of different approaches, such as voice of the customer or initial interaction with consumers to refine and gather product ideas and feedback on the type of segments accepting the "product concept" offering [38], [42]. At this level, the consumer RL becomes highly important [7]. In conducting such analysis, managers should also retrieve information on the broader view of the product for society. Hasenhauer et al. [7] propose to consider both societal and technology acceptance
4	**Identified market demand for the product value:** This expands the prior analysis in MRL3 evaluated against the assumptions of potential different advantages and disadvantages. Overall, this level requires managers to complete an initial proof of concept of the relevant market analysis. Thus, we propose that at this level, the analysis focuses on of the market focuses on scenario analysis as this has been relevant in the product innovation literature [44], [23], [20]. In doing such analysis, managers should attempt to simulate the potential long-term value of the product. This has been highlighted as critical in the model of Evans and Johnson [5] where the product can be evaluated against their short-term or long-term benefits based on the market scenarios considered.
5	**Competitor analysis that is followed for the product:** At this level, managers are required to conduct a specific competitor analysis. This is an evident success factor in several sources from the product innovation literature [53], [57], [64]. This should reflect the type of product value that competitors are offering as well as their capabilities. De Medeiros et al. [53] highlight the need for competitor monitoring also to perform intelligence in the context of sustainable product innovation. The aspects pertinent to competitor analysis highlight the importance of considering competitors also as a form of organisational competitiveness [57]. Similarly, Paladino [57] emphasised that overlooking the importance of competitive forces may hinder opportunities to better serve customers
6	**Value proposition and business model defined:** At this point managers need to provide evidence of the value of the product, following up from competitor analysis and how the firm is able to deliver that value. In this respect, we identified several references that highlight the importance of establishing a clear value proposition and business model. Cooper [38] emphasises that a "compelling value proposition" is a driver of success in product innovation. Thus, at this stage we propose that managers use several tools to highlight this. For example, in order to assess the investment readiness level, Blank [8] builds on the Business model canvas (BMC) to highlight the progress of the project. Similarly, we propose that managers should have utilised relevant tools such as the BMC to define the business model in its structure of value creation, capture, and delivery. In addition, following Evans and Johnson [5] analysis on business model innovation, managers should also consider the types of marketing and sales resources needed for the business model anticipating the need for particular communication/promotion strategies.
7	**Evaluated market scenarios and developed advertising strategy validated:**

	This level requires managers to have validated the potential target segments, market scenarios identified and related this information with potential advertising strategies. This process requires the need to integrate sales, R&D and marketing. This collaborative relationship in fact has been found to reduce product failure rates through the knowledge that salespeople have on consumers [61], [62] impacting product innovation success [43], [46], [54], [61]-[63]. Supporting the synergy of the firm's resources in terms of advertising, marketing, engineering is "attacking from a position of strength" [40]. To achieve this level, there needs to be a proposed consumer segment for the product offering, as well as the type of advertising methods required for the selected segments [63]. Cooper and Kleischimdt [40], [41] also use the term synergy between production and advertising as correlated to higher financial performance. The literature highlights that more radical projects require new distribution channels and advertising [45]. At this level in fact, our model proposes to outline the specific sales channels and the relevant advertising required which is a success factor found in many sources. This is fundamentally related to the reduction of risk and comprehensive communication related to the type of product proposed [40], [43], [45], [52], [63].
8	**Proof of market impact and advertising strategy validated:** This requires marketing managers to have considered different types of dimensions of the project in order to provide the feasibility of market analysis conducted [56], [51]. The concept of market impact is found in Cooper and Kleinschmidt [40] as a performance indicator. In this work, it refers to the impact of the product in both domestic and foreign markets and more specifically to the overall value of the product (e.g. customer benefits, use of advanced technologies). This reinforces the multidimensional nature of product innovation success. To achieve this level firms should provide assumptions on the feasibility of this impact based on the analysis done in previous levels. For this reason, at this level, managers should present the final documentation on commercial and advertising planning. The literature emphasises the importance of the quality of advertising and pertinence to the project as a way to reduce the risk of product failure [48].
9	**Fully assessed market analysis documentation.** This requires managers to present a finalised document with details on each of the readiness levels described.

4.2.3 Product Planning Readiness Levels (Prod-RL)

The Product Planning Readiness Levels (Prod-RLs) emphasize two relevant themes in the literature: product originality and product design. These levels focus on the technical and design aspects of the product [50], [51], including initial design options, the originality of the product in its aesthetic and functional aspects, and relevant product testing and development. Prod-RLs differ from product innovations or the P-IRL framework since not all products result in successful innovations, and other proposed readiness levels are needed, as presented in the P-IRL framework. Please see Table 6 for Prod-RLs descriptions.

Table 6: Descriptions for Product Planning Readiness Levels (Prod-RLs)

Levels	Descriptions for Product Planning Readiness Levels
1	**Opportunity recognition and idea generation completed:** Prod-RL 1 represents the completion of opportunity recognition and idea generation, stemming from cross-functional team cooperation or preliminary consumer knowledge [65]. This level is linked to the results of product idea generation activities, which may also involve collaboration with external networks to generate product ideas, especially for complex product systems (CoPs) [65].

2	**Idea evaluation and selection completed:** Prod-RL 2 focuses on the completion of idea evaluation and selection, with a higher level of analysis into identified product architecture options. Managers should have outlined various product architecture opportunities [50], [58] and considered the degree of originality and "product uniqueness" they aim to achieve [38], [40], [44], [47], [52], related to the opening of new categories to the firm, solving a problem to the customer, and balancing value through performance-to-cost ratios and contribution margins [38], [50].
3	**Examination of product design and function options:** Prod-RL 3 involves examining product design and function options, considering the initial product structure, degree of originality, and performance dimensions. The literature highlights the importance of functional and aesthetic benefits [44], and the specific competitive advantages achieved will likely be unique to each product, such as in sustainability contexts, where e-products complying with standards deliver efficiency and customer satisfaction [57], [63], [67].
4	**Created and evaluated product concept:** Prod-RL 4 deals with creating and evaluating the product concept, with a higher level of detail than Prod-RL 3. Managers must provide a more detailed quantification of the product's technical performance measures [55], [56], considering various dimensions of product success, such as surpassing the competition technically or in market share [55]. They should have also considered anticipated scenarios within the NPD team, including development cost, launch timing, product performance levels, product quality, cost measures, and speed to market [56]. The use of tools like Quality function deployment may also require completion at this level [45], [56], [57].
5	**Finalisation of fully specified product prototype:** Prod-RL 5 entails the finalization of a fully specified product prototype, reflecting a flexible and agile approach to product development [38]. This stage involves creating a working model of the product that incorporates the most critical features and characteristics, thereby demonstrating its value proposition to potential customers. The prototype should be feature-limited and capable of generating revenue, which serves as an initial market entry strategy and helps gather real-world user feedback. A successful prototype can be a strong indicator of potential product success, as it often attracts attention from investors and stakeholders [84]. Iterative prototyping helps refine the product and reduce the risk of failure, as developers can address design issues and customer needs before full-scale production.
6	**Completed minimum viable product:** Prod-RL 6 requires completing a minimum viable product (MVP) that can be used in subsequent levels of the framework (e.g., Prod-RL 7) [38, 45]. The MVP is a product version with enough features to satisfy early adopters and validate the product concept while minimizing development costs and time. Research suggests that effective MVPs are key to successful product innovations, as they help identify potential issues and opportunities for improvement before further investments are made. Additionally, MVPs facilitate the testing of hypotheses regarding customer needs and preferences, leading to more targeted and successful product iterations [89].
7	**Full completion of product testing and verification:** Prod-RL 7 represents the full completion of product testing and verification in a relevant environment [38], [39], [42], as an iterative process with key stakeholders. This level precedes consumer testing and verifies the properties of the completed minimum viable product. Product testing is crucial to successful innovations, as it helps ensure the product meets industry standards, regulatory requirements, and customer expectations. This process may involve various types of tests, including functional, usability, and reliability tests, which can lead to enhanced product performance and increased customer satisfaction. Engaging key stakeholders, such as customers, suppliers, or partners, in the testing process helps uncover unforeseen issues and gathers valuable feedback, increasing the likelihood of product success.
8	**Consolidation and validation of final product plan:** Prod-RL 8 is the consolidation and validation of the final product plan, with the relevant documentation. Managers should structure the documentation of the results achieved in the preceding levels and consolidate the final assumptions for the final product version [38], [40], [42]. The final product plans should be validated with the relevant teams including marketing, product, R&D and project management teams [38], [40], [42]
9	**Finalized product development plan:** Finally, Prod-RL 9 represents the finalized product development plan. This plan can be used to initiate the product development process or manufacturing depending on the previously completed levels. Depending on how ready the Prod-RL is, the company can move on to the manufacturing process where the product is actually produced. If certain steps are missing, such as Prod-RL 6 or 7, then the company can start their project from a particular stage and then move on to the final production.

4.2.4 *Technology Capability Readiness Levels (TCRL)*

The TCRLs range from basic research on technological solutions to the full impact on the manufacturing process development. Our proposed readiness levels, in fact, differ from TRL as they include different dimensions of technological development such as; **system** [16]; **manufacturing** [13], and **intellectual property** (Hasenauer et al., [7]) readiness levels. TCRL also benefits from the product innovation literature as well [58]. These are summarised in Table 7 below:

Table 7: Description of Technology Capability Readiness Levels

Levels	Description of Technology Capability Readiness Levels
1	**Technological solutions are identified from basic research**: As with other levels, this is the start of the research, in this case focused on the understanding of the technological solutions for the product (e.g. material use, analysis of potential technological combination, existing/non-existing technologies), and differs from the aforementioned Prod-RL evaluation. In this case the analysis should focus on the detailed technology characteristics of the product [50]. Since this is explicitly a technology readiness level type we refer to the level of research needed in the TRL model [37]. As Mankins [2] emphasises, initial levels are speculative and relatively low in terms of investment costs. However, this also depends on the type of product innovation the project is aimed at. At this level, assumptions should be formulated over the technological components needed [16], the potential manufacturing process and intellectual property opportunities [7], [50], [58].
2	**Formulation of technology concept complete:** This level is still speculative in nature however it builds on the need to demonstrate the following aspects: a) based on the model from Peters [13], concepts could relate to the applicability of types of manufacturing processes (e.g. manufacturing to make the product), b) initial outline of the technology system integration into a full system to reduce the risks of different technologies that may fail when integrated (Technology system analysis) [16], and c) proposed options on patentable product aspects (intellectual property) [7].
3	**Technological complexity analysis completed:** This level follows the first two readiness levels through the TRL3 scheme where a proof of concept is designed. At this level, managers should also provide a proof of concept of the manufacturing feasibility of the product through laboratory testing [13]; conduct an initial testing of technological components integration to verify any potential incompatibilities [16], and detailed documentation of existing patentable inventions [50]. Overall, managers should be able to demonstrate that the technological concept has some degree of feasibility [2]. Recent IRL models have included an intellectual property readiness level as either aggregate of technology readiness levels [7], or as levels required within sustainable product development contexts [25]. It is worth highlighting that in the initial levels of our proposed scale we consider the first 3 levels as linked to a limited knowledge on both technology application and maturity. Some companies in fact, may decide to use existing technologies for the innovation project. However, in some cases rushing into the market without further analysing technological maturity aspects may jeopardise the success of the product itself [68].
4	**Compatibility of technology with product design established:** This level follows the TRL scheme to a higher level of fidelity in analysing the feasibility of the product technology [38]-[41]. For example, if a physical product requires an additional software design, then the integration levels will need to be assessed simulating the operational efficiency of the product [16]. The level also requires the assessment of the manufacturing process and in its “production capability” assumptions. Lastly, intellectual property aspects should be analysed against appropriate novelty and defined intellectual property strategy (e.g. trade secret or patent type).
5	**Outlined technology system and production:** Following our assessment scheme, in order to achieve this level, firms need to provide a further demonstration of the technological capability. First, by testing the integration of technologies and that there is sufficient control between the different component integration. For example, further reducing any technology integration problem.

	In terms of manufacturability, at this level Peters [13] proposes the concept of a plant and production line concept designed. Thus, based on the project we propose the evaluation of key suppliers for potential contract manufacturing or in-house options [65], [73]. For intellectual property instead, depending on whether firms are using existing technologies, we propose that there may be a need to proceed to either filing of patents or exploring specific licensing agreements [7].
6	**Relevant production and technology capability examined:** This requires the firm to test the product technology in a production simulation [13]. Measures such as overall equipment effectiveness and the efficiency of manufacturing processes and logistics should be considered tested as well. Moreover, from a technological integration point of view, firms should perform the testing of different integration scenarios (e.g. different ways in which the technologies can be integrated for its applications). As for the IP aspect, it is expected that a positive response from patent application is reached and potential national phases achieved. Alternatively, ensuring that any licensing agreement is also established with relevant partners [63].
7	**Product and manufacturing technology selected:** Following the TRL scheme at this level a more detailed system prototype is needs to be delivered based on the examination done at TCRL6. Hence, ensuring the product technology architecture and design conforms to manufacturing requirements and is ready to ensure that the product can be produced. The outcome of this step is also the last step to confirm the *technology selection* considering its overall project requirements. This step is achieved with rigorous tests and for the software-oriented products, it can be called as the Alpha Testing.
8	**Validation of product and manufacturing technology plans:** At this level further validation is performed together with the product team to finalise the technology selection and integration plans to the product design. With the marketing team, it is investigated that it fulfils its requirements considering the expectations of relevant users and stakeholders. This can be achieved with product tests, analyses, inspections and/or demonstrations. For software-oriented products, it can be called as the Beta Testing [13], [92].
9	**Finalised technology capability plan:** This level can be achieved after validation of the technology plans working together with other relevant teams. Following the previous assessments, a detailed and finalised plan is established for the technologies that are selected for both the product itself and its manufacturing process. The final plan after the validation includes specifications of the technology, IP assessments, and also the details of the manufacturing process and technologies [50], [58].

4.3 Integration of RLs of the P-IRL Framework

In section 4.2, RLs are explained in detail separately for each level. In this section, Table 8 and Figure 4a, 4b and 4c present the P-IRL Matrix to illustrate how different RLs can be integrated and used collaboratively with various teams. This further supports our explanation of how the proposed RLs are relevant to the overall maturity of product project plans and readiness to execute the product development process in an integrated fashion.

P-IRL can be adjusted according to the requirements of the funding mechanism. It would be wrong to assume that every organisation or fund provider would accept the same RL levels and the risk appetite. For instance, a fund provider or a mechanism may accept lower RLs and a higher risk for a funding mechanism specific to the start-ups compared to those more established organisations. Each project can also differ where a company may have a previously developed technology or a product, and they may have a different starting point. As shown in Figure 4a, 4b and 4c represents different scenarios specific to the product innovations where it could be initiated from the following: firstly, the product innovation can be based on a product centric approach (see Figure 4a) where the innovation processes follow the approaches such as NPD process [38]-[41] where the product design and its functions is the main concern. As shown in Figure 4b, it can also be based on a market-centric approach where the innovations are developed based on a model such as “market pull” [24], [64, [65], [93]. Finally, the P-IRL model can be adjusted according to the technology-centric approach (see Figure 4c) where the innovations are generated from a model such as “technology push” [24], [93]. Each of the proposed scenarios would result in variation in the order of the RLs being initiated, as well as the actual level at which each commences.

To illustrate the above discussion, in the example of the product-centric scenario the idea can be generated within a product development team (Prod-RL1) but this idea can be evaluated with the marketing team considering the market analysis (MRL2) and this information can be fed into the product development team for Prod-RL2 where product design and features are evaluated. The R&D team can commence from TCRL4 when they have detailed information about the product and technology to evaluate the relevant technology, capability and its suitability for the product. Finally, when there is more clarity about the product’s features and requirements, the project management team can start with the first step – Proj-RL1 to initiate the project development and documentation. The application of P-IRL specific to the integration of different levels and their specific linkages can be also seen in Figure 4b and 4c. The key point in each integrated process is that where the innovation is generated from or which team has the dominant role (the main team who is in charge of the innovation project) over a specific innovation project. Certainly, these dynamics between different teams may not be that apparent in projects where innovations are developed by smaller companies or multidisciplinary project-based teams. Table 8, P-IRL Matrix provides a more detailed explanation with examples of how different teams may work on the product innovation projects in an integrated fashion.

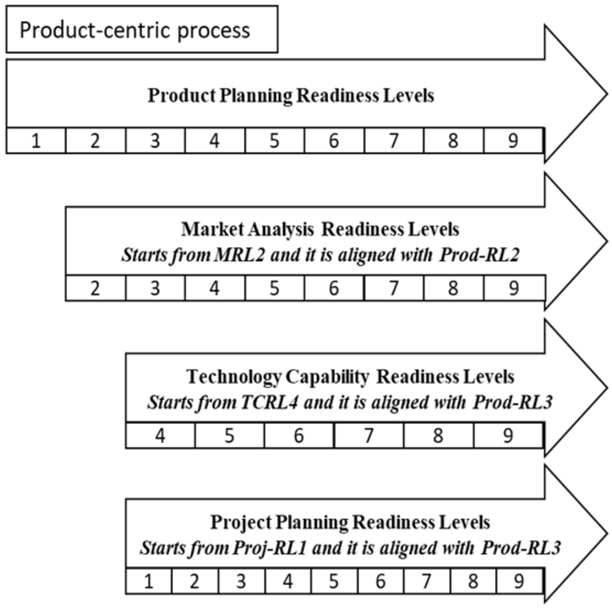

Figure 4a. Scenario for Product-centric Integrated Processes for P-IRL Framework

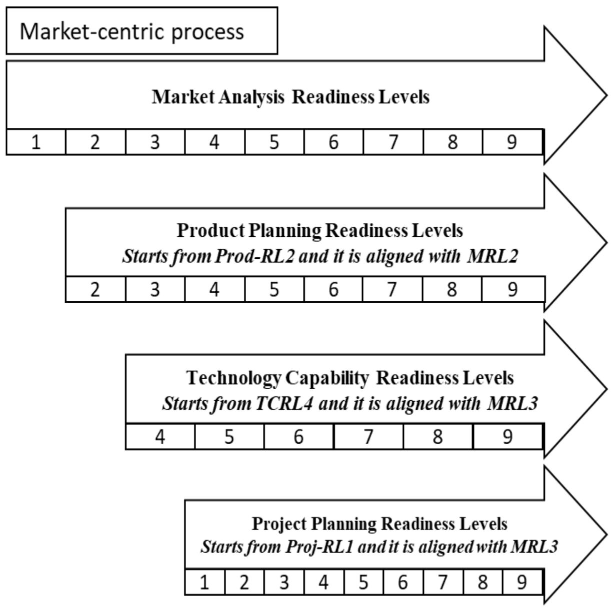

Figure 4b. Scenario for Market-centric Integrated Processes for P-IRL Framework

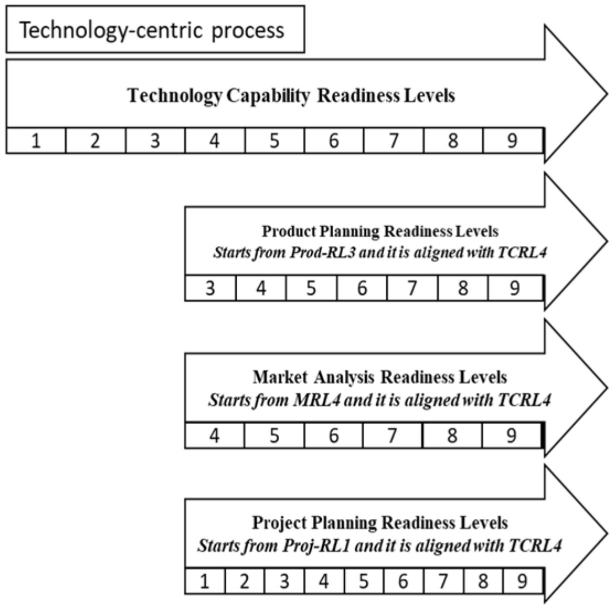

Figure 4c. Scenario for Technology-centric Integrated Processes for P-IRL Framework

Table 8: P-IRL Matrix

P-IRL Matrix	Integration between Levels	Description	Examples
Proj-RL	Proj-RL 1 with MRL 1, Prod-RL 1 and TCRL 1.	The teams responsible for assessing Level 1 for MRL, Prod-RL, and TCRL have provided the project team with information regarding the product opportunity. This information will be used by the project management team to formulate the initial project documents.	The marketing team has identified a product innovation opportunity based on market needs. They have shared this information with the project management team to initiate the project documentation process.
	The project team manages Proj-RL 2-7 in collaboration with other teams at all levels.	The project management team has requested required information from the marketing, product, and R&D teams at different levels. This information will include details such as deliverables, work packages, and risks, and will be necessary for successful project planning and execution.	The marketing team provides information about the market demand, while the product team provides details about the product features. The R&D team provides information about the technology capabilities, taking into consideration the viability of the product innovation.
	Proj-RL 8 and 9 with level 8 and 9 of MRL, Prod-RL and TCRL.	A complete draft of the internal project documentation has been shared with all the teams for review. The purpose of this action is to ensure that the project requirements and information are accurate and up-to-date at Level 8 of the project, with any necessary corrections and finalization to be completed at Level 9. The teams will carefully examine the project documentation and validate the accuracy of the information presented. Complete draft of internal project documentation is shared across with all the teams to check the project requirements and accuracy of the information at level 8 and the	Product team checks the documents and identifies that associated risks are not well assessed in the project documentation. They suggest corrections on the project documents. The project documents are revised and finalised for level 9.

		information to be corrected and finalised at level 9.	
MRL	MRL 1-4 with Prod-RL 2 and 3, TCRL 1 and 2 and Proj-RL 1 and 2	Marketing team informs about the opportunities that they identified to the product and R&D teams (market pull) or the marketing team is informed by the product or R&D for a potential product innovation (technology push). There is a continues engagement between the teams to make sure the most appropriate opportunities are filtered through and selected. Project documents are initiated based on the provided information from the marketing team.	Marketing team receives feedback from customers about product features and required improvements. The information is passed onto the product and R&D teams to establish priority areas and seek for potential solutions.
	MRL 5 with Prod-RL 4-6, TCRL 5-7 and Proj-RL 3-7	The marketing team informs the product and R&D teams of the opportunities they have identified (market pull). Alternatively, the marketing team may be informed by the product or R&D teams of potential product innovations (technology push). There is continuous engagement between the teams to ensure that the most appropriate opportunities are filtered through and selected. This ongoing communication and collaboration also helps to ensure that the selected opportunities are aligned with the market needs and company's overall goals and objectives.	The marketing team identifies the key product features of competitors and their value proposition. Additionally, they investigate the strengths and weaknesses of the competitors, considering opportunities in the market. The product and R&D teams then design the product, taking into account the competitiveness in the market and the key features of previous solutions. They also seek to understand if their solution is unique compared to offerings provided by their customers.
	MRL 8 and 9 with level 8 and 9 of Proj-RL, Prod-RL and TCRL	A complete draft of the internal marketing analysis, business model, and advertisement strategy documentations has been shared with all the teams. The purpose of this action is to ensure that the product-related information is consistent with the information held by other teams. The teams will review the draft and validate the accuracy of the information presented. Any inconsistencies or gaps in information will be identified and addressed promptly to avoid potential issues in the later stages of product launch.	The marketing team prepares a business model and marketing strategy, taking into consideration the product design and features. Reviewing the provided documents, the product team identifies any misrepresentation of the product capabilities and key offerings. If they find any inaccuracies, they inform the marketing team and request revisions to the relevant documents. This ensures that all marketing materials are accurate and represent the product's capabilities and features in the best possible way.
Prod-RL	Prod-RL 1-4 with MRL 2-4, TCRL 1-4 and Proj-RL 1-2	The product team informs the marketing and R&D teams of the opportunities they have identified, which is known as technology push. Alternatively, the marketing team may inform the product team of potential product innovations, known as marketing pull. There is continuous engagement between the teams to ensure that the most appropriate opportunities are filtered through and selected. This ongoing communication and collaboration helps to ensure that the selected opportunities are aligned with the market needs, company's overall goals and objectives.	The product team identifies a potential design or product solution, and then passes this information on to the marketing team to seek market and customer information. Additionally, the product team checks with the R&D team to consider the technological options. This approach helps to ensure that the potential solution is viable and feasible from both a market and technological perspective. By leveraging insights from both teams, the product team can make informed decisions about the solution's viability and potential success in the market.
	Prod-RL 5-7 with MRL 5-7, TCRL 1-4 and Proj-RL 3-7	The product team develops the first prototype of the product and shares it with the marketing and R&D teams. The teams provide feedback, and the product team redesigns or iterates on the design until they	The MVP is completed after several iterations. These iterations involve a series of tests conducted by the R&D team to identify any technical problems with the product or underlying technology that need to be fixed or

		reach the minimum viable product (MVP). Once the MVP is developed, it is also shared and feedback is received. To conduct product tests, the R&D team performs in-house tests, while the marketing team conducts concept, user, and market tests. This iterative process helps to refine and improve the product based on user feedback and ensures that the final product meets both the market and technological requirements. Project documents are initiated based on the provided information from the product team.	improved. The marketing team provides feedback on the design and usability of the product, considering their engagement with potential customers. They share their opinion on whether the product meets the customer's demands. Based on their feedback, the product is either redesigned or moved to the final stages.
	Prod-RL 8 and 9 with level 8 and 9 of Proj-RL, MRL and TCRL	A complete draft of the product development plan, final product design, and product specifications have been shared with all the teams. The purpose of this action is to ensure that the product-related information is consistent with the information held by other teams. The teams will review the draft and validate the accuracy of the information presented. Any inconsistencies or gaps in information will be identified and addressed promptly to avoid potential issues in the later stages of product development.	The product team has shared the product specifications with all the teams. However, the project management team has identified that some of the associated risks have not been taken into consideration. As a result, they have requested the product team to explore alternative options and provide further information on the risk management items. The marketing team has noticed an inconsistency between the information they have regarding the product offerings and the information that has been provided by the product team. In order to address this issue, the marketing team requests additional clarification.
TCRL	TCRL 1-2 with Prod-RL 1-4, and MRL 1-4	The R&D team provides information about a newly identified technological solution to the product and marketing teams. They seek potential application areas of the technology. The product and marketing teams examine the technology and identify potential application areas, then check with the R&D team if the given technology can be implemented in the provided solutions. All teams identify the most applicable ones and prioritize areas considering the potential demand in the market and the originality of the product solution.	The R&D team has developed a new material that has the potential to increase the durability and performance of the product. They inform the product and marketing teams about this new material and its properties. The product and marketing teams examine the material and identify potential application areas, such as using it to improve the product's strength or reliability. They check with the R&D team to ensure that the material can be implemented in the provided solutions. All teams then prioritize the most applicable application areas based on potential demand in the market and the originality of the product solution.
	TCRL 3-7 with MRL 5-7, Prod-RL 5-7 and Proj-RL 1-7	The R&D team continues to work on the application areas of a newly developed technology based on the feedback received from the marketing and product teams. They examine the technology in more detail and illustrate its compatibility with a chosen option. The marketing and product teams provide suggestions on how the technological application can be improved considering the product design or more suited to meet the market needs. Project documents are initiated and fully developed based on the provided information from the R&D team.	The R&D team continues to work on the application areas of the newly developed material, taking into account feedback from the marketing and product teams. They examine the material in more detail and illustrate its compatibility with a chosen option, such as a specific feature of the product. Meanwhile, the R&D team also investigates the relevant production capabilities of the material to ensure that it can be manufactured in a cost-effective manner. The marketing and product teams after the test of the solution provide further suggestions on how the material can be improved, considering its impact on the overall product design and its suitability for the target market. Based on this feedback, the R&D team makes further improvements to the material solution and makes a final decision on the application area of the material.
	TCRL 8 and 9 with level 8 and 9 of	A complete draft of the selected technology has been shared with all the teams. The purpose of this action is to ensure that the	The R&D team has selected a new composite material for to increase the durability of a product. They provide a complete draft of the

	Proj-RL, MRL and Prod-RL	application area of the technology specific to the market needs and product features is consistent with the information held by other teams. The teams will review the draft and validate the accuracy of the information presented. Any inconsistencies or gaps in information will be identified and addressed promptly to avoid potential issues in the later stages of R&D activities.	material specifications to the product and marketing teams. However, after reviewing the draft, the teams realize that some of the technical details provided by the R&D team are not accurate or complete. There are technical limitations that were not considered or not fully documented. The teams asks further documentation and clarification in the technical details of the new solution.

4.4 Application of P-IRL to Case studies

Based on the prior discussion on how the RLs relate to each other, Table 9 summarises different case studies based on illustrative examples of the relevance of P-IRL when analysing cases [88], [89]. Hence, as explained in section 3, we aim to explain how the different levels in the P-IRL would pertain to the evidence presented in each of the cases by retrospectively analysing *unsuccessful innovations* (e.g. Google Glass), *successful innovations* (GE products for bottom of the pyramid markets) *EU commission funded research programmes* (e.g. Clean sky project for sustainable aviation products). Lastly, following the logic of Table 4 explained in the previous section (RL matrix), we explained how the analysis of the cases also provides evidence of the inter-relationship between RLs. Respectively, Table 9 describes how the literature sources provide information for each assumption made, supported with examples of quotes. Overall, it highlights the relevance of the P-IRL framework alongside critical aspects to consider for product innovation success. Hence, through the secondary data we explain where the firm may have failed to adhere to the specific activities and the related sequence of the RL dimensions proposed in the P-IRL. By presenting such analysis we consider an ideal scenario where the firm would successfully achieve each RL. More specifically, reporting quotes which in some cases illustrated how there may have been a lack of considerations for a range of levels. For example, the market related aspects in Google Glass were mainly related to potentially unsuitable customer segments, enabling the researchers to link this aspect to activities relevant to different MRLs. Another illustrative example, is the *clean sky* research programme (EU funded project) where the P-IRL dimensions would support the analysis of the value proposition of sustainable products within its overall project complexity. This latter point also builds on EU reports claiming the need to include a more comprehensive readiness level model to assess funded research programmes (Doussineau et al., 2017).

Lastly, through Figure 5 we provide an illustration of the levels achieved for the Google Glass case study. We selected this case in particular because it provides a clear example of a radical technological innovation which was instead unsuccessful due to factors linked to all P-IRL dimensions.

Table 9: Case analysis using related P-IRL dimensions

Case study description and references	Case analysis using related P-IRL dimensions (with quote examples from cases)
***Unsuccessful product innovation case**: Google Glass* wearable device with digital functionalities such as photo camera. *(Gozuacik et al., 2021)*	**Proj-RL:** Although the case study does not provide specific information at a project management level, it is possible to find evidence that relevant RLs such as Proj-RL6 (project risks and contingencies) have not been fully achieved. This is evident when observing the limitations of this product from market, product and technological standpoints and which also characterised the type of risks linked to the product as a radically new product in the market. **MRL:** For the market dimension, it is possible to assume that MRL2 to MRL8 specific to the target market and public concerns may have been neglected according to the P-IRL logic. As mentioned in Gozuacik et al., 2021: *"Google Glass was not a failure, it was marketed incorrectly. Target market was too generic".* Overall, excluding MRL5 because there were no competitors at the time when the product was developed and launched, the product has assumingly failed to address MRLs from 1-8. **Prod-RL:** From the case study, the main aspect that is possible to see for Google Glass is the lack of suitable design features. This may relate to critical RLs not fully considered such as Prod-RL3 to 7 (e.g. from prototyping to testing related levels): *"UX least requires better interaction design and perhaps a different form factor. Google glass failed because it forgot about human design."* **TCRL:** Arguably, this RL appears to have greater compliance to P-IRL compared to other RLs. This is justified by the fact that Google had the relevant technological capabilities and they were pioneer in this field. However, there were significant technological limitations such as related to the battery life and limited technological functionalities. Thus, looking at the logic of P-IRL the selected technologies were not well linked to the product design considering a gap in addressing the required information of the levels going from TRL2-7 before the product technology selection.

	RL Matrix: Considering RL results as shown above, it appears that the marketing, product and R&D teams should have collaborated better considering different RLs to minimise the failure before the investment decision was made. For example, if the marketing team identified the public concern and pointed out the potential problems then the product and R&D teams could have designed the product accordingly.
***Successful product innovation cases**:* *GE MAC 400 and Phototherapy Product Innovation Success factors for the development of products for Bottom of the Pyramid (BoP) markets* *(Malodia and Jaswal, 2015)*	**Proj-RL:** The case study offers evidence on how GE was able to analyse several factors ranging from ProjRL 1-7. For example, before outlining a strategy and planning the firm several types of assessment before the project could be validated: "*A major challenge in targeting the BoP market was that it was either underserved or completely unserved. Therefore, the major challenge before GE product team was to formulate a strategy for market creation for a new product. However, prior to that, a team had to make a business case forecasting demand, financials projection to calculate net present value (NPV) and internal rate of return (IRR) for getting project approvals"* **MRL:** It is possible to observe that GE moved from the evaluation of a general market opportunity to a specific market context (BoP) and then to analyse different customers (addressing levels MRL 1-7). Ultimately reaching a final value proposition: "*After a comprehensive analysis of healthcare market in India and other emerging markets, the senior management team of GE in India realized that in order to meet the ambitious goals, the company should focus on BoP market."* **Prod-RL:** In both cases of products, the article illustrates how the initial understanding and concept creation was a key to shape the rationale of the product design. Through this information, it is possible to assume that GE achieved levels going from Prod-RL 1-4. The following quote illustrates this: *GE's initial idea was of "Scaling down existing products by removing undesired features bv "de-featuring".* **TCRL:** For this RL, the case study offers a unique example of how the technology used was tailored from existing technologies. It also illustrates that the technological capability in NPD process may provide opportunity for Intellectual property protection as in the P-IRL. Through an illustrative quote, it is possible to assume that in this case there was thorough evaluation and patenting of the technology. Hence, fulfilling levels from TCRL 1-7. This was particularly evident for the Phototherapy product: *This product essentially used exclusive LED technology and had 10 LED bulbs in a particular pattern designed to distribute light uniformly on the surface of the body and was patented by GE (LED Phototherapy)* **RL Matrix:** The case study provides evidence of how the inter-functional collaboration has contributed to the innovation outcomes of the analysed cases. From the technological side it illustrates how the *design* of the products then reflected the selection of technologies. Similarly, this was linked to a defined market segment and related project considerations. Throughout the case, the importance of this cross-functional information sharing contributed to the success of the products.
	Project RL: This research programme enables collaboration among different participating firms. From this detail it is possible to assume that the project

***Research Programme for Product Innovation**:* *Clean Sky is a large-scale European Union (EU)- wide research programme involving a total of 86 organizations from 16 countries aimed at developing sustainable products for the aviation industry* *There is currently a Clean Sky 2 chapter.*	management aspects are highly relevant to the success of the programme. By analysing the case study, it is possible to assume that Proj-RL have been critical to the success of the funded product proposals. **“***To date, the partners in this particular SAGE programme include Italy’s Avio Aero, Britain’s GKN, Aerospace and France’s Aircelle (part of Safran) along with Snecma (Eshel, 2014), the firm leading the project. Each of these partners is a specialist in its field. For example, Avio Aero specializes in gearboxes, while GKN Aerospace, which is providing the majority of the engine’s rotating module (Reals, 2016) that includes the rotors themselves, specializes in composite aerostructures including things like helicopter blades.”* **MRL**: The rationale of the research programme is based on the identification of a clear market opportunity reflecting the type of information required for MRL 1-4. This is linked to the evidence of evaluating product opportunities not only for predicted market changes but also sustainability concerns: *“Commercial market forecasts indicate that sustained growth in air transport of 5% per year will continue until 2030 (Airbus, 2007; Boeing,2008). At this rate, air transport can be expected to double every 15 years, leading to a six-fold increase by the middle of the century (Palmer, 2015). Given the projected sustained rapid growth of the air transport industry, aircraft emissions are expected to constitute a significant proportion of greenhouse gas emissions by 2050 (Daley, 2010), since emission reductions, assuming turbofan engines continue to be used, are unlikely to be sufficient to offset the continued growth in air travel.* **Prod-RL:** There is particular evidence in the importance of product prototyping through technology demonstrator program. This fact illustrates that the product evaluation went through the more basic evaluations to its testing and validation. The following quote illustrates this through the technology demonstrator test (e.g. Prod-RL 1-8): *The technology demonstrator programme began with Snecma testing a one-fifth scale model of a contrarotating open rotor (CROR) design. These tests were carried out at the French research agency ONERA’s SM1A wind tunnel at its research facility in Modane in the French Alps starting in 2010. They confirmed the open rotor’s efficiency (Warwick, 2014) and that a 2030 timeframe for the introduction of open rotor engines into airline service was technically feasible.* **TCRL:** Based on the product testing example, the technological demonstrator programme also highlights that it was critical to identify a to demonstrate technology viability, but also the manufacturing feasibility. Hence, this also fulfils TCRL 5-6. Another quote, illustrates this: *The production stage will be particularly challenging due to the complexity of the engine’s rear assembly comprising as it does a gearbox and a variable pitch system for the rotor blades.* **RL Matrix:** The above case shows that also within the context of research programmes the four dimensions proposed in the P-IRL are critical for funding programmes. Thus, firms participating within this type of project as well as fund providers may benefit from the RL to make investment decisions and analyse the gaps or strengths for different project proposals.

Based on the evidence in Table 9, Figure 5 illustrates the scenario for each readiness level and dimension for the Google Glass case study. For example, Figure 5 shows a level of Prod-RL 2 which is related to the secondary data evidence of the lack of attention in “human design”. As previously mentioned, we consider a scenario where the firm would have successfully achieved each level. Thus, for example, we do not assume that Google may have missed to create a minimum viable product (Prod-RL 6). However, according to the logic and sequence of our P-IRL, we consider that activities already relevant to Prod-RL 3 (examination of product design functions and options) may have been neglected. Specifically, regarding the originality and relevance of product design for defined customer segments [44]. The case description in Gozuacik et al., 2021 also provides evidence on the lack of market related aspects. For example, considerations on public concerns related to wireless radiations. Thus, figure 5 shows potential issues ranging from MRL 3. Moreover, the case of Google Glass shows a potential lack of integration between available technologies (e.g. photo camera) and the relevance of this to the device itself and the way users perceive it (e.g. lack of consideration for human design). For this reason, Figure 5 also portrays a scenario where levels from TCRL 2-7 may have not been adequately addressed before the product technology selection. Lastly, the project dimension as explained in Table 9 is presented as Proj-RL 6 (Risks and contingencies). This is justified by the risks related to such a radical product innovation and its performance within the market.

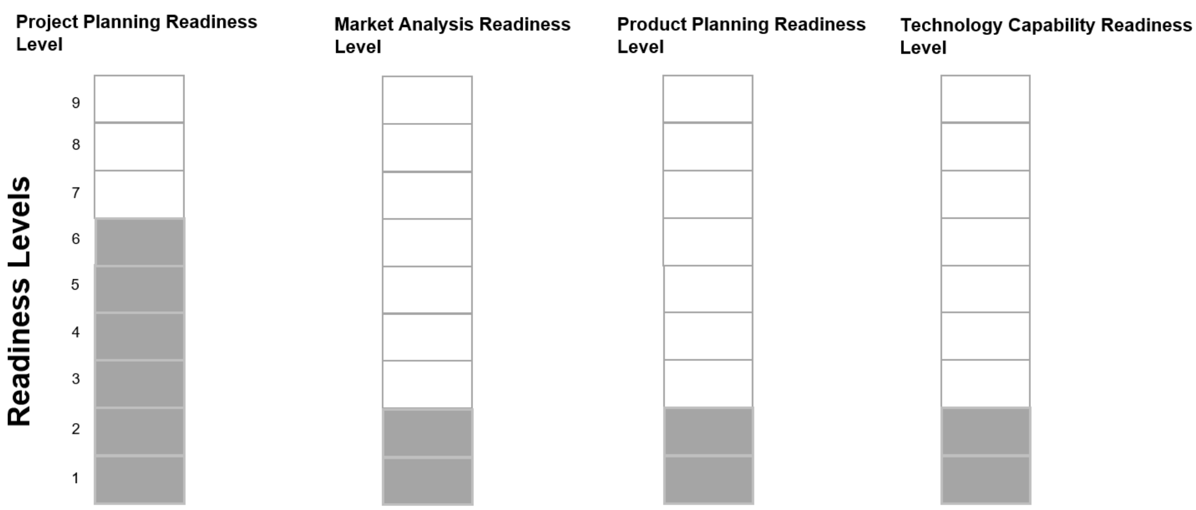

Figure 5. Google Glass case analysis using P-IRL framework

5. Discussion and Conclusions

Our proposed P-IRL framework, underpinned by an SLR, provides several contributions to the body of the literature of both product innovation and readiness levels. Our initial contribution is to propose the first RL specific to product innovations consisting of multiple dimensions. The dimensions proposed in this model provides a new comprehensive approach, as a result of being founded upon recognised product innovation success factors and relevant RLs, through an integrated approach. In doing so, we also proposed new RLs using the product success factors that were not previously evident in the literature. Our model can be implemented by practitioners in multiple departments and teams towards product development plans and investment decision making which could include project, marketing, product and R&D teams or departments. The activities of these teams should be overseen by an innovation manager and can be coordinated by a project manager.

Our new readiness level model contributes to prior RL's, which to date have been specific to incremental product developments (Tao et al. [3]) and business model innovations (Evans and Johnson [5]). Hence they have failed to provide a comprehensive approach to assessing readiness, and furthermore this has resulted in the lack of a readiness level framework specific to product innovations. In doing so, we contribute to enabling improvements in innovation management in practice (Tao et al. [3]). Uniquely our readiness level approach highlights four specific dimensions of readiness that have not been addressed in prior studies, namely: 1) Project Planning Readiness Levels, 2) Product Planning Readiness Levels, 3) Market Analysis Readiness Levels and 4) Technology Capability Readiness Levels. The approach adopted, combining prior RL studies with the success factor literature provides a more comprehensive approach and framework than was previously evident. This is evident not only in the four dimensions proposed but also in the content of each of those relative readiness levels. Hence, in addition to proposing unique dimensions not present in other frameworks in fact (e.g. *project planning readiness level)*, our P-IRL also presents unique nine level structures, distinct from existing readiness levels, such as market readiness levels (Hasenhauer et al; Hjorth and Brem [20]). For example, Hjorth and Brem [20] have proposed a *Market Readiness Level* considering existing scales related to demand and integration RLs. In contrast, building on two literature streams, our framework presents a more comprehensive set of factors ranging from market opportunity identification to business model understanding and competitor analysis. This enables a more comprehensive assessment of readiness. Our second contribution is to studies examining how to improve decision-making along innovation projects [6]. Our framework would be a great addition to the TRL based fund or investment decisions that are followed by funders or organisations. The IRL framework offers a new approach to comprehending the key dimensions that innovation managers need to address within decision-making on new product developments. It provides a comprehensive set of readiness dimensions that help with understanding the readiness of a product innovation and supporting investment decisions for relevant project stakeholders, including managers and external fund providers (Doussineau, 2017). Hence, we offer a first step towards creating a comprehensive and integrated framework that can provide a commonly understood approach for internal and external stakeholders to comprehend the relative readiness of a product innovation project. The introduced P-IRL framework should be used by the fund providers in addition to the TRL to have a more comprehensive evaluation of the submitted projects.

Thirdly, our integrated P-IRL framework extends NPD related preparations with the RL logic for a more comprehensive coordination of all product innovation project decisions related to the investments and approvals. This is related to our choice of using the TRL model as a basic structure [3] and connecting this to the logic of other NPD studies [38]. Following the aim of our analysis to structure a P-IRL framework to assess *product innovation projects*, we were able to propose this interrelated logic through the evidence of product innovation articles, where several innovation dimensions are explicitly interrelated in our analysis [50], [58]. As explained in the P-IRL matrix (see Table 8), the development of product innovation projects requires an interaction between different teams. This matrix illustrates how different teams can collaborate and engage considering different levels of four RLs. It is evident that the successful plans require information and engagement between teams.

Our new proposed product innovation readiness model has several benefits from an innovation management perspective. Our study implies that the assessment of NPD projects requires moving beyond the temporality of project management documents or TRL models that are being conducted, extending this view through a different product innovation dimensions [80] that offers a way of assessing in a comprehensive way. Our P-IRL framework, enables us to assume that a low RL scores may reflect the poor planning of a particular team or lack of coordination between teams.

The rationale for this research was also based on policy-makers researching on such assessment tools needed for product innovation projects [4]. We suggest that our model should be used for any funding decisions. The P-IRL framework can be provided to project reviewers to assess how ready the project is. The funders can allocate minimum thresholds to accept the project applications. The projects can be reviewed with interdisciplinary teams to make sure the considerations for different RLs are met before the investments are made. Also, the project funders may ask the applicants to review their projects according to different levels and resubmit their applications after addressing the low RLs. At this stage, we do not propose a minimal acceptance level for projects but as each project funding conditions differ such as for those seed funds to the funds for collaborative large projects, each funder should set their minimal thresholds for RLs.

This paper also illustrates with multiple cases why P-IRL is important for product innovation investment decisions and to increase the successful output of the product developments. In doing so, we analysed several cases from the literature in retrospect [88], [89], demonstrating that the logic of assessing a product innovation project through the P-IRL dimensions can provide a useful framework to increase the chances of product success. This was particularly evident for both Google Glass and the GE products for bottom of the pyramid markets.

We build on recent studies assessing strengths and weaknesses in innovation projects [6] and to the reviewed literature on product innovation success factors. As this study was based on an SLR approach and illustrations of case studies from the secondary data, an empirical study should follow to test the model in its proposed dimensions with a data from either fund providers or companies' data regarding the internal product investment decisions. Secondly, as our model developed based on an SLR approach, the proposed P-IRL framework may be limited to the factors and RLs that are evident only in the literature but there may be new factors or RLs that can be identified with empirical data.

We propose future studies leverage the gaps on the theme of Innovation Readiness Level in order to emphasise the importance of different dimensions. This will enable the path to understand the framework here proposed in its structural limitation and to determine the levels and scales of each RLs. Also, our framework does not propose weights for each RLs towards the overall P-IRL score. This is, to our knowledge, the main weakness of current readiness levels and in other innovation assessment models [81]. Thus, further research should extend the contributions of our framework by introducing a weighted system and by also enriching each readiness level. Also, a minimal threshold can be introduced for each RL for successful product innovation investment decisions.

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Appendix A - Product Innovation ABS Journal quality table

ABS Journals	CABS 2018 ranking	N	% sample	Sum of papers Average Citation	Lowest Citation from Journal
Journal of Product Innovation Management	4	10	28.50%	372	175
Research Policy	4*	1	2.80%	95	95
Journal of Marketing	4*	1	2.80%	187	187
Journal of Marketing Research	4*	1	2.80%	865	865
Technovation	3	3	8.50%	132	79
IEEE Transactions on Engineering Management	3	3	8.50%	455	370
Long Range Planning	3	2	5.70%	53	49
R&D Management	3	2	5.70%	135	107
Industrial Marketing Management	3	2	5.70%	194	68
Journal of business research	3	2	5.70%	159	49
International Small Business Journal	3	1	2.80%	236	82

International Journal of Management Reviews	3	1	2.80%	122	122
International Journal of Innovation Management	2	1	2.80%	11	11
Journal of business and industrial marketing	2	1	2.80%	38	38
Research Technology Management	2	1	2.80%	196	196
Journal of Cleaner Production	2	1	2.80%	262	262
Marketing Intelligence and Planning	1	1	2.80%	25	25
European Journal of Innovation Management	1	1	2.80%	85	85
Total		**35**	**100%**		
Average	***2.43***			***201***	***159***