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COMMERCIAL READINESS INDEX FOR LITTAR® ASPHALT CONCRETE

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Abstract: *The present study aims to introduce the use of Commercial Readiness Index (CRI) for developing new materials, i.e., the novel Littar® asphalt concrete for refurbishing roads infrastructure. The analyzed indicators outlined the factors within the technology development process, making up the CRI: Technology Performance (TRL); Market Opportunities (MRL); Regulatory Environment (RRL); Stakeholder Acceptance (ARL); and Organization's Maturity (ORL). The CRIs framework helped recognize the KPIs within the case study's manufacturing process. It also helps companies to understand and learn about the possibilities regarding commercialization of a complex product. The technology, market, regulatory, acceptance and organizational framework, with respect to the associated uncertainties, revealed in a simple and clear way how any innovative project risks are strongly influencing the manufacturing process and commercialization of any new product.*

Keywords: *Commercial Readiness Index, Aggregated Readiness Level, Littar® asphalt concrete.*

INTRODUCTION

The Commercial Readiness Index (CRI), created by the Australian Renewable Energy Agency (ARENA), evaluates the commercial readiness of renewable energy solutions [1]. Unlike the Technology Readiness Level (TRL) framework, the CRI assesses various innovative projects' commercialization stages. While TRL addresses technology risk, commercial readiness remains uncertain, especially in projects like road infrastructure refurbishment, where high capital costs hinder rapid deployment. The CRI includes eight Indicators: Regulatory Environment, Stakeholder Acceptance, Technical Performance, Costs, Revenue, Industry Supply Chain and Skills, Market Opportunities, and Company Maturity. By defining commercial readiness, CRI offers structured guidelines, surpassing TRL's limitations. It aids investor due diligence, providing a systematic approach to reduce uncertainty and accelerate innovative process deployment.

The authors of the paper "Multi-Index Analysis with Readiness Levels for Decision Support in Product Design" [2] proposed a method to assess a new product's viability by considering various design parameters affecting success. Unlike the widely used Technology Readiness Level (TRL) for technical readiness, the authors found it insufficient for evaluating a product's overall viability. They introduced a Multi-Index Analysis (MIA) that consolidates 10 existing metrics into a single comprehensive index. MIA serves as a proactive design methodology, emphasizing understanding unbalanced design processes to enhance products during development. This innovative approach evaluates designs

comprehensively, integrating technical and commercial aspects. In summary, MIA offers a holistic evaluation of a product's readiness and viability through a single index, introducing a proactive and comprehensive design methodology.

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The paper "Littar: Asphalt Concrete Made with Aggregates Derived from Waste Glass and Waste Plastics" [3] discusses an innovative method to repurpose plastic and glass waste for road construction. Traditional recycling methods are inefficient, leading to substantial "negative-value waste" in landfills or the environment. Littar® addresses this by using waste glass and plastic aggregates, bitumen, and filler to create a sustainable foundation material. It outperforms traditional road materials and aligns with existing asphalt production methods, enabling quick industry adoption. Tests, including the Marshall Stability test, prove its enhanced durability and load-bearing capacity. Littar® significantly reduces landfill waste by repurposing all types of plastic and glass waste, minimizing the need for raw materials. However, further studies are required to assess Littar®'s long-term performance in diverse conditions, ensuring its complete viability.

The paper "Methodology for an Aggregate Readiness Level Assessment of Innovative Technologies" [4] introduces a six-dimensional framework to assess the readiness of emerging materials and technologies, expanding on traditional Technology Readiness Levels (TRL). The methodology incorporates TRL, Market Readiness Level (MRL), Regulatory Readiness Level (RRL), Acceptance Readiness Level (ARL), Organizational Readiness Level (ORL), and Commercial Readiness Index (CRI), offering a comprehensive approach. The authors advocate for employing an Aggregated Readiness Level (AgRL) method, combining results from these dimensions into a holistic readiness estimator. This approach aids product development, technology selection, R&D prioritization, and other areas involving emerging technologies. The paper applies this methodology to assess Littar® asphalt concrete, providing detailed readiness assessments across these dimensions.

OBJECTIVES OF THE STUDY

The introduced concept of Commercial Readiness Index (CRI), as noted above, is often used also as a measure of commercial continuity. The present study aims to introduce the use of CRI for developing new materials, i.e., the novel Littar® asphalt concrete for refurbishing roads infrastructure. The following indicators will outline the factors within the technology development process, that make up the CRI: Technology Performance (associated to TRL); Market Opportunities (associated to MRL); Regulatory Environment (associated to RRL); Stakeholder Acceptance (associated to ARL); and Organization’s Maturity (associated to ORL). To identify risks and support “actors” in evaluating the novel technology, an average composite readiness index, i.e. CRI, will be evaluated. Motivation is clear, because CRI is often used to define the framework against which management-based approaches can be compared and measured, allowing stakeholders to assess the maturity of the technology in complex innovative processes, allowing the technology to be evaluated across its various stages of development.

The largest obstacle in the commercialization of new / innovative asphalt concretes is the lack of investment that is currently being injected into this area of applications. Furthermore, obtaining the funding necessary to cover the costs of the process is a difficult task, given the lack of established financial benchmarks and the lack of data that investors can use to assess these technologies' commercial viability. So, this study suggests that the assessment generated by the CRI framework will provide investors with an all-inclusive, easily accessible, and transparent report that will manage their expectations and allow for better-informed investment decision-making. The expectations of the authors is that, in the future, the use of a CRI framework will be an essential instrument for new materials process's development, and will improve the manufacturing and physical fit of products, supporting the road infrastructure maintenance industry's focus on enhancing customization, irrespective of geographical, economic and social context.

To evaluate the CRI framework, our case study will be focused on the innovative process of manufacturing and commercialization of the novel Littar® asphalt concrete, specifically used in refurbishing road infrastructures, providing a professional assessment for the levels of maturity for each independent commercial indicator, in order to determine the “global” commercial product maturity through a single commercial readiness index. The determined CRI framework will further identify the specific Key Performance Indicators (KPIs), within the case study's manufacturing process. Two stages of development are taken into consideration: first, the initial status of the Commercial Scale-up

(Hypothetical Commercial Proposition) placed at CRI 1st level (minimal / basic level - Almost "ready" at technology level, but commercially just preliminary tested and unproven real market value; still needed subsidizing, by public funding, for product development), and secondly, the next / future stage (Commercial Trial), placed at CRI 2nd level ("Ready" at technology level, with preliminary commercially market validation; still needed some public funding subsidizing, but recommendable to attract also private investment resources).

Once more, the present study will emphasize the inability of the Technology Readiness Levels (TRL) solely to evaluate the commercial readiness of development of any novel materials. In the past, researchers used a step-by-step risk assessment for the manufacturing of such new materials. However, despite the fact that different associated risks are lative high, the manufacturing process still needs to be verified, and this study adds to the body of knowledge, in order to enable investors to assess the commercial viability of the novel Littar® asphalt concrete development, providing a framework to facilitate improved decision-making process for investors.

In the present case study, starting from the exercise made in [4], when the authors developed a questionnaire comprising responses to adapted questions to the specific of the applications of the novel Littar® asphalt concrete, two types of responses were centralized in the schematics presented in Fig. 1, where italic style responses correspond to actual / initial status of technology and bold style responses reflects the next stage / future / desired status of development.

Questionnaire for evaluating the maturity of a product on five representative dimensions

Question no.	TRL	MRL	RRL	ARL	ORL	If YES the level is
1	Is the product fully mature and ready for market use?	**Is the product fully available on the market with a mature business model?**	**Has the use and manufacture of the product fulfil all regulatory issues?**	Is the use of the product perfectly acceptable, from a political and socio-economic point of view?	**Can the product be used seamlessly with other existing products?**	9
2	**Is the product widely tested and validated?**	Is the market demand for the product stable or increasing?	*Does the use and manufacture of the product meet general regulatory requirements?*	**Is the use of the product considered questionable, in the context of unfair competition at national and international level?**	*Is the use of the product adapted to current work processes and/or other specific technologies required?*	8
3	Is the product tested and validated in the natural environment?	Is the market requirement for the product fully confirmed?	Are the necessary approvals/permissions close to being granted?	*Is the use of the product seen as lacking "political support" at the local/regional/national level?*	Are only minor organizational changes required to use the product?	7
4	Is the prototype of the product tested and validated in the relevant environment?	*Was the product sold in small quantities to test the market?*	Are the necessary approvals/permissions likely?	Is the use of the product seen as "bothering" certain socio-economic interest groups?	Are significant organizational changes necessary for the product to be manufactured?	6
5	*Are the main features of the product tested and validated in a laboratory /simulated environment?*	Has a business model been developed?	Will using the product require easily accessible permissions/approvals?	Is the use of the product seen as economically unsustainable among certain interest groups?	Is there a plan to integrate the product with current business processes?	5
6	Are the main features of of the product planned to be tested and validated with specific procedures?	Market requirement and product specification are confirmed by potential customers?	Will using the product require difficult permissions/approvals?	Is the use of the product seen as polluting / environment unfriendly among certain socio-economic groups?	Has potential integration and adaptation of the product to current business processes been described?	4
7	Is the product concept fully demonstrated and described?	Are the market requirement and product specification clearly defined?	Will use of the product require hard regulatory changes?	Is the use of the product seen as very expensive among certain socio-economic groups?	Has an idea been formulated regarding the integration and adaptation of the product to the current functional processes?	3
8	Is the idea of the product fully described?	Were the market requirement and possible technical solutions been identified?	Will using the product require fully new legal regulatory changes?	Is the use of the product controversial, due to ignorance, among some socio-economic categories?	Is product integration with current business processes unclear or problematic?	2
9	Is the product idea formulated?	Was the market requirement analyzed?	Are the legal and regulatory aspects of the product unpredictable /unknown?	Will the use of the product be considered unacceptable in terms of socio-economic impact?	Will the use of the product represent a fundamental change in the current operational processes?	1

Figure 1: Responses to questionnaire comprising dimensions of analyzing the maturity

Starting from the data presented in Table 2 from [4], and adapting the values for the specific or our present approach, the equivalences between CRIs and different levels of the dimensions (TRL, MRL, RRL, ARL and ORL) taken into analyze are presented in Fig. 2, where in italic style are four of dimensions, with CRIs similar distribution, while bold style is specific only for MRL, with other configuration of equivalences.

For TRL, RRL, ARL and ORL …	*in between 1 ÷ 7 …*	*and 8, 9*
Equiv. of CRI is …	*1 …*	*and 2 ÷ 6*
For MRL …	**in between 1 ÷ 8 …**	**and 9**
Equiv. of CRI is …	**1 …**	**and 2 ÷ 6**

Figure 2: Equivalences between CRIs and different levels of the dimensions (TRL, MRL, RRL, ARL and ORL)

Synthetic correlations of data between values of the five dimensions of analyze (TRL, MRL, RRL, ARL and ORL) and the equivalent values of CRIs, comprised in Fig. 1 and Fig. 2, are presented in Fig. 3.

TRL	CRI / TRL	MRL	CRI / MRL	ARL	CRI / ARL	RRL and ORL	CRI / RRL and CRI / ORL
5	*1*	*6*	*1*	*7*	*1*	*8*	*2*
8	**2**	**9**	**2**	**8**	**2**	**9**	**2**

Figure 3: Synthetic correlations of data between values of the five dimensions of analyze (TRL, MRL, RRL, ARL and ORL) and the equivalent values of CRIs

Analyzing the tables, it comes clear that, in the actual situation (in red color - for TRL, MRL, and ARL), CRI is at minimal level, i.e. 1, the fact that, for RRL and ORL, the same indicator is 2 doesn't modify the average appreciation, because, in a simple approach: 3 of 5 criteria being 1, the arithmetic average is closer to 1 (i.e. 1.4), which is not relevant (trivial mathematic approach) for our analysis; if taking into account a professional appreciation, the regulatory and organizational criteria are harder "in control" of the manufacturer, implying more money / efforts to be invested for significant improvement, thus authors are "happy" with their already attained level of 2.

STUDY ACHIEVEMENTS

The KPIs, corresponding to the manufacturing process of the new product Littar®, are in close correlation with the dimensions of the analyze of its maturity (TRL, MRL, RRL, ARL, and ORL), also associated to corresponding CRIs, and offering a "structured portrait" of commercialization potential for the developed innovative asphalt, intended to be introduced in roads refurbishment modern technologies, at the level of national and international specialized market.
Expanding the interpretation of the numbers mentioned in the previous paragraph, in the specific context of our case study, the detailed explanations are given below.

CRI = 1 / Hypothetical Commercial Proposition / Almost "ready" at technology level, but commercially just preliminary tested and unproven real market value; still needed subsidizing, by public funding, for product development

TRL 5 - The Littar® [5] product components are established by a proprietary recipe and tested together. The recipe obtained meets all the requirements according to the "REGULATION AND 605-2016 REGARDING ASPHALT MIXTURES" [6], imposed for technical class 3, 4 and 5 roads. The process for obtaining the new asphalt mixture type material is the subject of a pending filed patent (WO2023113631 (A1) [7]) and has been technically validated under laboratory conditions and under the conditions of a simulated environment. An experimental road section was manufactured, which consists of a driveway and parking lot, but this road sector does not fall into technical class 3, 4 or 5. Also, in October 2022, a Littar® pilot project was successfully implemented in Cluj-Napoca, Romania. For this 35 square meters driveway foundation project, Littar® up-cycled plastic and glass waste equivalent to 70,000 single-use plastic bottles and 6,000 glass wine bottles while preventing 4 tons of CO2 emission. This project has successfully shown the turn-key production and application aspect of Littar®, as well as its circular-economy benefits, which connects local waste processors with local asphalt stations, for refurbishing roads, by reducing CO2 emissions up to 83%.
MRL 6 - The testing was carried out both for the product and for the process of obtaining it. The paving station was classic, automated, and not different from a conventional process. A business model/plan has been developed, which shows that for a quantity of 1000 tons, a 200 m long road can be produced, in the case of a road category with 2 traffic lanes. Each kilometer of road built with Littar® reduces 1046 tons of CO2 emission. Fewer resources are required to

produce, transport, and apply Littar® foundations, compared to conventional foundation materials or waste recovery solutions. The result is the obtaining a shorter road construction time, lower costs, and emissions throughout the entire process.

RRL 8 - Necessary approvals/permissions have been granted. In 2022, the product obtained a Technical Approval for use, this document being issued by CTPC - the Permanent Technical Council for Constructions, a body under the authority of the Ministry of Development, Public Works, and Administration (MDLPA). The use and manufacture of the product does not raise regulatory issues, but approvals from Environment Agencies and Local Public Authorities are still required to allow this product and technology to be included in the specifications for road refurbishment projects.

ARL 7 - Being a new product (Littar®), there is some normal reluctance to use it, a multi-step approach being recommended, i.e., a use of the product for local roads, then county roads and only at the last stage moving to the implementation of the new technology for 2-lanes national roads of circulation. The use of the product is extremely environmental favorable, because it uses large amounts of glass and plastic waste, which otherwise end up in landfills in large quantities. This technology may disturb certain socio-economic interest groups, as vouchers are given for recycling this waste.

ORL 8 - The product Littar® falls into the category of asphalt concrete (it uses bitumen) and is perfectly adapted to the current work process for the construction of road structures (for the base and connecting layers). A great advantage of this product is the fact that it does not use scarce materials, but on the contrary, it protects natural resources (stone aggregates) because the recycled glass granulated material and recycled plastic shredded material replace a large part of the classic natural aggregates. Placing and compaction of Littar® is done with the same machines and under the same conditions used for conventional asphalt mixtures. The product cannot be used seamlessly with other existing products, as there must be a specific recipe corresponding to the built road layer and road category, depending on the level of road traffic.

CRI = 2 / Commercial Trial / "Ready" at technology level, with preliminary commercially market validation; still needed some public funding subsidizing, but recommendable to attract also private investment resources

TRL 8 - Going beyond the pilot project from October 2022, the product needs to meet wider testing and validation, getting just one step before being fully mature and ready for market use, from technological point of view, still needing some public funding subsidizing, and attracting private investment resources, not only envisaging wider practical testing and validation, but also bringing some improvements for the manufacturing process. Once specific risk management team identifies the causes of the technology risks, the team must develop possible solutions to manage or prevent technology risks. In this respect, as the team develops a response for each technology risk, that response should be broken into specific action steps, which become part of the risk management plan.

MRL 9 - Littar® asphalt will no longer be in the experimental or testing phase but should be officially introduced to the market, available for purchase, use, or integration into construction projects by customers, contractors, or relevant industries. The developed / matured "business model" will outline how the company intends to generate revenue and sustain its operations, refining its approach for earning stable / constant revenue and likely experiencing stability and success in its operations. Marketing risk management works to neutralize the potential for marketing risk. Thus, the manufacturer marketing departments should focus on the planning and execution phases for marketing activities, but they would be remiss to stop there, being needed to go a step further and engage in marketing risk management to ensure that the marketing activities aren't impacted by events or circumstances that could have been planned for in advance.

RRL 9 - Most of the necessary approvals/permissions have already been granted, the only necessary progress at maturity level being that the product should fulfill all needed regulatory issues, at all levels and in all aspects, at national and international level, justified by the fact that the envisaged market is also the international one, confirmed by the level of granted Trademarks (EUTM018272020 [8], and UK00918272020 [9], 19 (Nice Classification)). Regulatory / legal risk management is needed to identify, prevent, and respond to the threat of legal risks. By developing a comprehensive risk management framework, company will perform routine risk audits and adapt their policies and operations as appropriate, closely related to enterprise risk management, which is the practice of identifying and responding to risks that could threaten an organization's ability to achieve its goals.

ARL 8 - Certain efforts, supported by means of all policy instruments (e.g., environmental ones, connected with vouchers that are offered for recycling all type of waste) and lobby actions addressing several political levels, should diminish the reluctance of certain socio-economic interest groups in applying this innovative technology for refurbishing national roads. Acceptance is closely related to a good communication policy, but there is always a certain risk involved in delivering a message. For each project that kicks off under developing new technologies / products, is mandatory assess what is the project communication risk and understand how to minimize it, i.e., to diminish the reluctance of certain socio-economic interest groups in applying this innovative technology for refurbishing national roads.

ORL 9 - The product Littar® falls into the category of asphalt concrete (it uses bitumen), and is perfectly adapted to the current work process for the construction of road structures (for the base and connecting layers), no maturity progress being mandatory, in this respect. The new Littar® product could be used seamlessly with other existing products, without any specific recipe corresponding to the built road layer and road category, depending on the level of road traffic, as stated today. The arguments presented above, viewing each dimension of analyze (TRL, MRL, RRL, ARL and ORL), describe well what is needed to undertake, to attain in the future an average CRI of 2, covering all dimensions. Thus, companies concern themselves with organizational risk because it has a direct impact on the financial

stability of their business. So, launching the new product requires a great deal of time and money and introduces risk in business, because manufacturer isn't sure if the product will be successful, while commonly tracking customer engagement metrics to ensure they're interacting with their audience at an appropriate frequency, mitigating the risk of brand fatigue, and – very important – the failure meeting government regulations could mean fines, lawsuits or damage to the business's reputation.

CONCLUSIONS

The case study helped authors in understanding the difficulties of our methodological approach used to determine the CRI for the new product Littar®. The indicator levels are assessed according to an "actual status" (in red color, at this moment), and a "next step" (in yellow color, in the future) degrees of maturity.
Average "actual status" of the product Littar® is at CRI 1, while the "next step" is intended to be at CRI 2, being necessary to identify mechanism / measures to be taken by the manufacturer to improve the maturity of the indicators, respectively to assess the commercial maturity of the enterprise, focusing on its ability to unlock the potential of proposed emerging new technology.
The CRIs framework helped recognize the KPIs within the case study's manufacturing process. It also helped the company to understand and learn about the possibilities regarding commercialization of a complex product. The CRIs framework helped us also to identify the main barriers, that need to be addressed, to move from the "actual status" (in red color) to the "next step" (in yellow color) degree of maturity. The technology, market, regulatory, acceptance and organizational framework, with respect to the associated uncertainties of the product, revealed in a simple and clear way how any innovative project risks are strongly influencing the manufacturing process and commercialization of the new Littar® product.
The Commercial Readiness Index (CRI) is valuable for evaluating Littar®'s market potential, but has limitations:

- ✓ Subjectivity: Evaluation can be subjective, influenced by different perspectives on commercial maturity.
- ✓ Data Quality: Incomplete or inaccurate data can lead to errors in CRI assessment.
- ✓ Context Dependency: CRI varies across industries and contexts, making comparisons challenging.
- ✓ Environmental Changes: Legislative or market shifts can impact CRI, rendering a product irrelevant.
- ✓ KPI Relevance: Omitted or irrelevant Key Performance Indicators distort CRI assessment.
- ✓ Temporal Variations: Commercial maturity indicators fluctuate, requiring periodic evaluations.

Critical assessments and regular updates of the CRI are vital to ensure accurate evaluations of Littar® or similar products.

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