Assessing Responsible Innovation in Tunisia: An Empirical Analysis through the Lens of the AIRR Dimensions

Yosra Ben Abbès[1], Bouthaina Maazoun [2], Raoudha Kammoun [3]

[1,3]Department of Management, Faculty of Economics and Management of Sfax, University of Sfax, Tunisia

[2]Higher Institute of Industrial Management of Sfax, University of Sfax, Tunisia

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ABSTRACT

Context: In the face of global environmental crises and increasingly stringent international regulations, innovation is moving beyond an exclusively financial approach to incorporate ethical and social requirements through the paradigm of Responsible Innovation (RI). Based on the AIRR framework (Anticipation, Inclusivity, Reflexivity, Responsiveness), this model promotes the participatory governance of technologies.

Research Question: How do organizations in emerging economies prioritize the dimensions of the AIRR model (Anticipation, Inclusion, Reflexivity, Responsiveness)?

Objective & Methodology: This article assesses the extent to which the AIRR framework is embedded within the Tunisian industrial sector. The study is based on a quantitative approach using an online questionnaire administered to certified companies engaged in modernizing their processes.

Results & Contributions: The empirical results map the maturity of RI practices in Tunisia, shedding light on the gap between theoretical stance and operational implementation. The article discusses the theoretical and managerial implications of these findings and offers recommendations to support responsible innovation trajectories in emerging countries.

Keywords: Responsible Innovation, AIRR Framework, Industry, Emerging Economy, Tunisia.

INTRODUCTION

In a global economic landscape marked by recurring ecological crises, major technological disruptions, and increasingly stringent international regulatory frameworks, the ability to innovate is no longer merely a prerequisite for market survival: It now embodies an imperative of equity and societal legitimacy. Long viewed exclusively through a technological or financial lens, innovation is now undergoing a strategic paradigm shift. This shift places ethical, environmental, and social issues at the very heart of Research and Development (R&D) decision-making. It is precisely at the intersection of this dual demand for operational performance and global responsibility that the concept of Responsible Innovation (RI) has emerged. Formalized and theorized around the four pillars of the AIRR framework : Anticipation, Inclusion, Reflexivity, and Responsiveness (Owen et al., 2013), this model proposes a renewed and participatory approach to governing technological trajectories.

However, while this conceptual framework has seen significant advances in terms of operationalization and psychometric validation (Zhang et al., 2023), its implementation within organizations facing significant resource and infrastructure constraints continues to fuel intense strategic debates (Brand & Blok, 2019; Fraaije & Flipse, 2020).

In this regard, Tunisia's industrial sector offers a particularly revealing field for academic investigation. Deeply engaged in modernization programs and directly exposed to the sustainability requirements of partner markets (particularly European ones), Tunisian manufacturing companies now find themselves at a crossroads.

This research specifically fills this gap by offering a first-of-its-kind quantitative assessment of the implementation of the AIRR framework among certified companies in Tunisia.

Accordingly, this study revolves around the following central question: How are the four pillars of responsible innovation (anticipation, inclusion, reflexivity, and responsiveness) operationalized within certified industrial companies in Tunisia?

To address this issue, this study employs a quantitative empirical approach based on data collection via a structured online questionnaire.

The article is organized as follows. The second section presents a review of the literature on the theoretical origins of IR and the structure of the AIRR framework. The third section details the methodological design, the construction of the questionnaire, and the sampling procedure. The fourth section presents the empirical results and a discussion of them. Finally, the conclusion summarizes the main theoretical and managerial contributions while outlining avenues for future research.

LITERATURE REVIEW

Definitions and Conceptual Framework of Responsible Innovation

The concept of responsible innovation has gradually emerged over the past two decades, as issues related to the social, environmental, and ethical impacts of new technologies have come to the forefront of public and academic debate. Long viewed solely through the lens of economic performance, innovation now incorporates requirements for sustainability and responsibility that are redefining its goals and processes. This evolution has given rise to a variety of theoretical approaches, put forward by different authors and institutions, which do not always converge on a single, consensus-based definition. To grasp the richness and diversity of these perspectives, it is useful to compare the main definitions proposed in the literature. The following table presents the various definitions of responsible innovation. **(Table 1).**

Table 1. Definitions and Theoretical Approaches to Responsible Innovation

Authors	Theoretical Approach	Definitions
Fraaije & Flipse (2020)	Systemic and Operational	A conceptual framework defining IR as a systematic and ongoing process of incorporating ethical, social, and environmental considerations throughout the technology development cycle.
Long, Blok, Dorrestijn & Macnaghten (2020)	Management and Entrepreneurship	A business-oriented approach that translates IR into a set of decision-making tools enabling companies and startups to anticipate societal impacts while maintaining their commercial viability.
Christofi, Khan & Iaia (2024)	Contextual	An approach based on institutional specificities, defining IR as adaptive governance that requires taking into account the socioeconomic and regulatory disparities specific to each market.
Zahoor, Khan, Khan & Akhtar (2024)	Strategic	A definition focused on the absorptive capacity of SMEs, in which innovation relies on interorganizational learning and strategic alliances to transform sustainable pressures into product and process innovations.

Source: Authors

A cross-analysis of recent research reveals a significant epistemological shift in the literature: the debate has gradually moved from a normative conceptualization toward an operational and measurable analysis within organizations. Initially, researchers laid the groundwork for managerial integration and developed rigorous quantitative measurement scales. Currently, the most recent studies show that the practical effectiveness of responsible innovation depends on the learning capabilities and network dynamics specific to each industrial sector, especially in transition economies.

Beyond these conceptual foundations, recent literature has gradually converged toward an operational analytical framework to guide and measure these requirements: the AIRR four-pillar model (Anticipation, Inclusion, Reflexivity, Responsiveness). It is around this governance framework that the measurement of responsible innovation within organizations is now structured.

The AIRR Framework (Anticipation, Inclusion, Reflexivity, Responsiveness)

The AIRR framework, as defined by Stilgoe et al. (2015) and Owen et al. (2013), structures responsible innovation around four pillars: anticipation, inclusion, reflexivity, and responsiveness. Research has recently moved beyond normative debates to develop implementation tools (Fraaije & Flipse, 2020; Long et al., 2020) and validated measurement scales (Zhang et al., 2023). Finally, recent studies on emerging markets highlight that the adoption of the AIRR pillars depends closely on the local institutional context, strategic alliances, and firms' absorptive capacity (Christofi et al., 2024; Zahoor et al., 2024).

Anticipation: Far from being reduced to a simple statistical forecast or a financial risk assessment, anticipation involves critically exploring the environmental, ethical, and societal repercussions of a technology from the very beginnings of the R&D process. On a conceptual level, Stilgoe et al (2019). emphasize that it constitutes a normative approach aimed at the co-construction of desirable futures. Although it represents the dimension most frequently integrated into impact assessment procedures and institutional roadmaps, it remains exposed to the constant risk of "bureaucratization," sometimes transforming into a mere formality with no real influence on strategic orientations.

Reflexivity : Reflexivity requires an organization to question its own assumptions, cognitive routines, ethical frameworks, and the relevance of its knowledge. It encourage R&D teams to examine the blind spots in their projects.

As Fraaije and Flipse (2020) point out, reflexivity is often the weakest link in the AIRR framework. Due to anchoring biases and time-to-market pressures, companies struggle to transform their internal review mechanisms into genuine spaces for critical introspection. Without a corporate culture open to constructive skepticism, reflexivity tends to evaporate in favor of superficial procedural compliance.

Inclusion : Inclusion ensures that decision-making processes are open to a diverse range of stakeholders in the ecosystem: users, local residents, researchers, NGOs, and regulatory authorities. Contemporary literature generally distinguishes between two types of inclusivity:

- Inclusion as a means (process-oriented): the implementation of participatory co-design mechanisms.
- Inclusion as an end (distributive): ensuring an equitable distribution of the value created, thereby preventing the exclusion of vulnerable populations.

The analyses by Christofi et al. (2024) demonstrate the importance of contextualizing inclusivity according to specific regional socio-institutional characteristics. In emerging and middle-income economies, such as Tunisia's industrial sector, the implementation of inclusivity requires explicit consideration of regional disparities and barriers to access to information.

Responsiveness : Finally, responsiveness reflects a company's operational ability to reorient, modify, or halt the course of an R&D project in response to new signals, ethical concerns, or early-stage feedback.

This dimension acts as the logical connector for the entire AIRR system. Through their study of manufacturing companies, Cha and Park (2024) demonstrate that organizational agility is the prerequisite for

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converting foresight (anticipation) into effective strategic realignments. Anticipation without responsiveness condemns the organization to helpless lucidity; responsiveness without anticipation condemns it to reactive crisis management.

In short, the literature agrees that responsible innovation is not limited to impact neutrality but is based on the dynamic synergy of these four dimensions: anticipating emerging risks, reflecting on underlying values and assumptions, systematically including stakeholders, and the ability to respond to uncertainties. Together, they transform the innovation process from a purely technical endeavor into a strategic and ethical lever, ensuring continuous alignment between technological advances and societal and environmental challenges.

METHODOLOGY

Research Context

This study focused on the industrial sector in Tunisia as the target audience. Tunisia is a country in the Maghreb with a fairly significant economic diversity. The country's economy is largely service-oriented, with the tertiary sector generating approximately 62% of GDP through consumer services such as lodging, transportation, and telecommunications, according to data from Tunisia's National Institute of Statistics (INS) for the year 2025. This pattern demonstrates Tunisia's economic shift toward a diversified model that blends established service industries with newly developed manufacturing capacities. The Tunisian sector thus provides an intriguing and pertinent research backdrop for our investigation.

Data Collection and Sample

This research is descriptive and quantitative; therefore, the survey-based approach has been used. The design was deductive in nature to evaluate the four dimensions of responsible innovation.

Data was collected via a structured online questionnaire that was designed using Google Forms. The Google Forms platform offers a mechanism for the distribution and extraction of data for statistical analysis. The target population was composed of Tunisian firms in different industrial sectors and regions.

Regarding the sampling and recruitment process, a total of 150 questionnaires were distributed via email between July and September 2026. Out of these, 63 fully completed and usable responses were retrieved, yielding an effective response rate of 42%.

Unit of analysis and respondent profile

In this study, the unit of analysis is the firm (organizational level), while the respondents act as key informants (individual level) capable of providing reliable strategic information on behalf of their organization. Unit of analysis and respondent profile.

The criteria for selecting the eligible companies were (a) they are legally established in Tunisia, (b) they are active in industrial and service sectors, and (c) they have sufficient operational experience to report on innovation practices. The key informants that answered the survey were mainly senior managers, directors, or innovation/R&D managers, which ensured high reliability of the data.

Sample Characteristics

The companies included in the study were selected from various industrial sectors to form the sample. This diversification was intended to ensure sufficient representativeness and relevant variation within the sample. The following figures present the specific characteristics of the participating companies:

The results show that more than half of the companies in the sample (55%) are located in the Center region, followed by 30% in the North and only 15% in the South. The geographic distribution is therefore clearly unbalanced, with a marked concentration in the central region.

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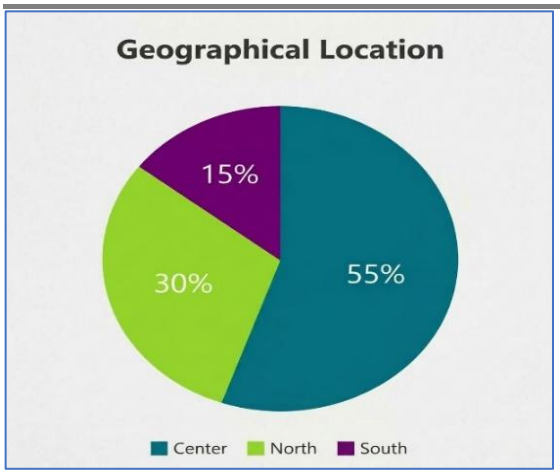


Figure 1. Geographic distribution of company in the sample

The distribution of the sample by size, measured by the number of employees, shows that medium-sized companies predominate (46.0%), followed by large companies (28.6%) and small companies (20.6%). Micro-enterprises account for only 4.8% of the sample. Thus, nearly three-quarters of the enterprises studied (74.6%) employ at least 50 employees, reflecting a predominance of medium-sized and large enterprises, which are generally more organised and formalised.

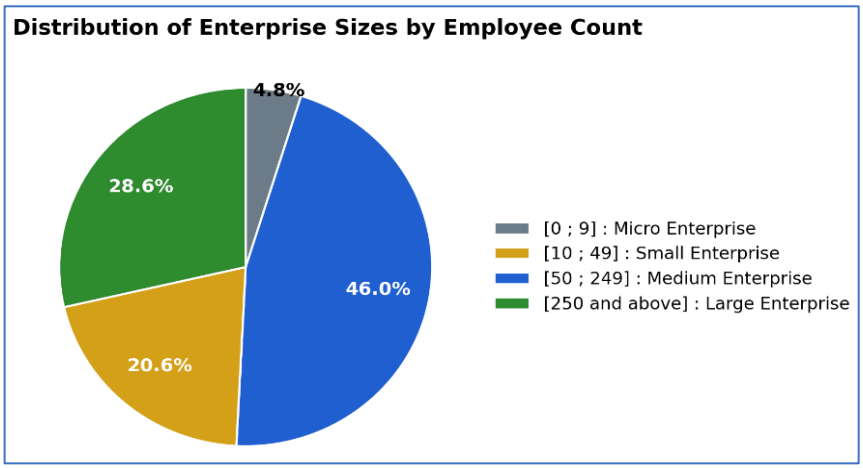


Figure 2.Distribution of enterprise sizes by employee count

With regard to revenue generated in 2025, the results indicate a marked predominance of companies with high revenue. In fact, 77.8% of respondents reported revenue exceeding 50 TND, while 20.6% fell into the intermediate range of 10 to 50 TND. Companies with revenue of less than 10 TND, meanwhile, account for only 1.6% of the sample. This distribution reflects a sample composed primarily of medium-sized and large companies.

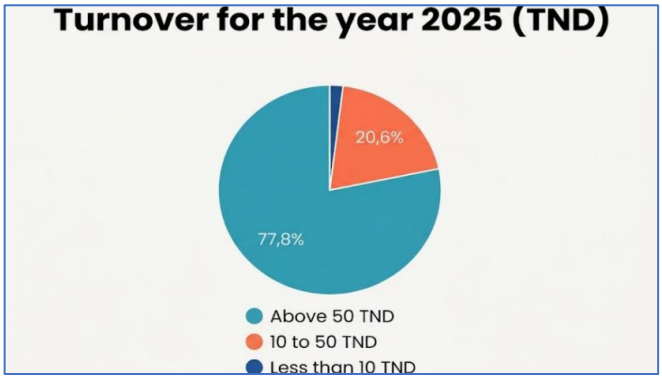


Figure 3. Sample distribution by 2025 revenue

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In terms of the sample's composition, it is dominated by the agri-food industry (49.2%), followed by construction materials, ceramics, and glass (23.8%), and then by the mechanical engineering and metallurgical industries (14.3%). These three sectors alone account for approximately 87% of the companies surveyed, while the other sectors (chemicals, textiles, wood, leather, the electrical industry, and miscellaneous industries) remain underrepresented. Distribution of the sample by industry

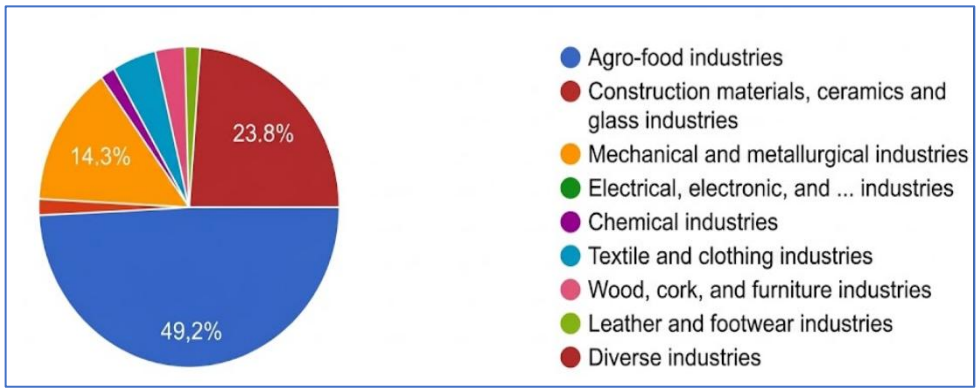


Figure 4.Distribution of the sample by industry

Questionnaire Structure

The main questionnaire consists of twenty questions divided into three sections: the first section covers general questions regarding the company's profile (number of employees, revenue, location, size, industry); the second section is devoted to assessing the four dimensions of responsible innovation

Measurement of Variables

The measurement items for the four dimensions of the AIRR framework were adapted from established literature and are detailed in Table 1 below.

Tableau 2. Measurement Scale of the AIRR Framework for Responsible Innovation

Dimensions	Items	Description / Statement (Adapted for the Study)	Sources & References
Anticipation	ANT1	Our organization defines long-term innovation objectives.	(Hoffmann et al., 2026)
	ANT2	We conduct future-oriented actions to mitigate potential risks.	(Memon et al., 2024)
	ANT3	We implement anticipatory practices to ensure the sustainability of our innovations.	(Applebee & Zejnilovic, 2025)
	ANT4	Our innovations contribute to a better future.	(Adomako & Tran, 2022)
Inclusion	INC1	Our organization considers the diversity of social groups when defining innovation objectives.	(Ooi & Memon, 2025)
	INC2	We actively involve stakeholders in the innovation process.	(Ooi & Memon, 2025)
	INC3	We integrate the viewpoints of different stakeholder groups into our decisions.	(Adomako & Tran, 2022)
	INC4	Innovation responsibility is shared with the concerned stakeholders.	(Ooi & Memon, 2025)
Reflexivity	REF1	Our organization regularly analyzes its role in the innovation process.	(Hoffmann et al., 2026)
	REF2	We critically examine knowledge gaps within our R&D department.	(Memon et al., 2024)
	REF3	We regularly evaluate whether our innovations are economically, environmentally, and socially	(Applebee & Zejnilovic, 2025)

		sustainable.	
	REF4	We develop a comprehensive understanding of our innovation impacts through continuous reflection.	(Adomako & Tran, 2022)
Responsiveness	RES1	Our innovation objectives are flexible and adaptable to emerging changes.	(Ooi & Memon, 2025)
	RES2	We adapt our objectives based on new scientific discoveries.	(Memon et al., 2024)
	RES3	We recognize that rapid adaptability is crucial for innovation progress.	(Applebee & Zejnilovic, 2025)
	RES4	We ensure the relevance of our innovations by adapting to market evolutions.	(Hoffmann et al., 2026)

Source: Authors

Data analysis metho, north

Data Analysis Method: The quantitative data (N = 63) were processed using SPSS through a three-step procedure: first, psychometric reliability was validated via Cronbach's alpha coefficients; second, validated items were aggregated to generate continuous composite scores on a 1-to-5 scale; and third, univariate descriptive statistics (means and standard deviations) were computed to assess the anchoring of each dimension.

RESULTS AND DISCUSSION

In order to evaluate the anchoring of responsible innovation within organizations in Tunisia, a rigorous quantitative approach in three successive steps was conducted using the SPSS software based on a sample of N = 63 respondents, ensuring both methodological rigour and clarity in the evaluation:

- **Step 1: Verifying the reliability of measurements (alpha de Cronbach)**

Before moving on, an internal coherence test was conducted for each of the AIRR framework's dimensions. obtained Alpha de Cronbach coefficients above the necessary reliability thresholds (generally > 0.70), confirming the high reliability and homogeneity of the items measuring anticipation, inclusion, flexibility, and activity.

- **Step 2: The calculation of composite scores by dimension**

The raw ordinal Likert scales were converted into continuous quantitative variables by computing the arithmetic mean of the validated items per dimension using SPSS. This yielded normalized composite scores ranging from 1 to 5, which were subsequently used to establish the univariate descriptive statistics.

Table 3. Reliability and descriptive statistics of items

Dimensions and Items	Average (Item)	Standard deviation (Item)	Global Cronbach's alpha
1. Anticipation			0,948
ANT 1	4,03	1,077	
ANT 2	3,94	0,998	
ANT 3	3,89	1,064	
ANT 4	3,94	0,982	
Overall score of the scale	Average = 15,79	Variance = 14,715 / Standard deviation = 3,836	
2. Inclusion			0,927
INC 1	3,76	0,856	
INC 2	3,73	0,865	
INC 3	3,75	0,761	

INC 4	3,83	0,752	
Overall score of the scale	Average = 15,06	Variance = 8,609 / Standard deviation = 2,934	
3. Reflexivity			0,954
REF 1	3,9	0,946	
REF2	3,86	0,84	
REF 3	3,89	0,952	
REF 4	3,86	0,913	
Overall score of the scale	Average = 15,51	Variance = 11,738 / Standard deviation = 3,426	
4. Responsiveness			0,94
REA 1	3,98	0,924	
REA 2	4	0,984	
REA 3	4	0,967	
REA 4	4,16	0,865	
Overall score of the scale	Average = 16,14	Variance = 11,899 / Standard deviation = 3,449	

The table above summarizes the results of the reliability test (Alpha de Cronbach) as well as the descriptive univariate statistics (moyennes, types, and variances) for each item that makes up the four dimensions of the responsible innovation. The internal consistency of the measurement scales was assessed using Cronbach's alpha coefficient. As presented in Table 2, the coefficients range from 0.927 to 0.954 across the four dimensions. While values exceeding 0.90 generally call for caution regarding potential item redundancy, the close examination of inter-item correlations confirms that these high scores reflect strong and robust internal consistency without redundant overlapping, thus validating the reliability of the constructs for subsequent analyses.

Reactivity at the forefront of organizational practices: With an average overall score of 16.14 (or an average of 4.04 per item), reactivity stands out as the most strongly emphasized dimension. This result highlights a pronounced operational agility: the surveyed companies demonstrate an excellent ability to adjust their trajectories, absorb uncertainties, and react efficiently to feedback and the inherent uncertainties of innovation processes. These observations echo recent writings highlighting that the ability to adapt quickly is a key lever of resilience in emerging contexts (Von Schomberg, 2019).

Anticipation and reflexivity as pillars of management: Anticipation (average overall score of 15.79) and reflexivity (average overall score of 15.51) also receive high and consistent scores. This reflects, on the one hand, a genuine ability of the structures to project themselves upstream to assess the potential impacts of their innovations and, on the other hand, the maintenance of a critical space for analyzing their motivations and underlying practices (Kuhlmann and Rip, 2014).

Inclusion: a proven potential for improvement: Although it remains at a satisfactory level with an average overall score of 15.06, inclusion records the lowest score in the study. This result suggests that systematic openness to external stakeholders and the involvement of civil society in decision-making processes remain more delicate approaches to formalize within the Tunisian organizational fabric, thus constituting a priority area for managerial optimization (Owen et al., 2012).

The analysis of the descriptive scores reveals that all dimensions of responsible innovation are clearly above the neutral theoretical average (set at 3.00), indicating a generally favorable anchoring of these practices within the Tunisian organizational context. However, a clear hierarchy emerges among the components of the AIRR model, aligning with the foundational works on the governance of responsible innovation (Owen et al., 2013).

- **Step 3: The descriptive evaluation of responsible innovation in Tunisia**

The analysis of the univariate descriptive statistics of the composite scores (presented in the table above) allows for a fine evaluation of the operational anchoring of each constitutive dimension of the AIRR model within the studied organizations. The overall averages obtained are consistently and significantly above the neutral theoretical threshold (set at 3.00), which attests to a global and favorable appropriation of the principles of responsible innovation in the Tunisian context.

However, the comparative examination of the average scores highlights a distinct hierarchy in organizational priorities and maturities:

Tableau 4. Descriptive statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Score_Anticipation	63	1,00	5,00	3,9484	,95900
Score_Inclusion	63	1,00	5,00	3,7659	,73352
Score_Reflexivity	63	1,00	5,00	3,8770	,85651
Score_Reactivity	63	1,00	5,00	4,0357	,86236
Valid N (listwise)	63				

A priority is given to agility and operational responsiveness (mean of 4.0357 / standard deviation of 0.86236): Reactivity ranks first among the evaluated dimensions. This high score highlights a strong organizational flexibility: the companies surveyed demonstrate a pronounced ability to absorb uncertainties, respond promptly to feedback, and adjust their trajectories in the face of the unpredictabilities inherent in innovation processes.

A well-established prospective and critical approach (Anticipation and Reflexivity): Anticipation (mean of 3.9484 / standard deviation of 0.95900) and reflexivity (mean of 3.8770 / standard deviation of 0.85651) occupy solid intermediate positions. These results reflect, on the one hand, a deliberate intention to project oneself upstream to assess the potential impacts of projects and, on the other hand, the existence of a critical stance in evaluating motivations and internal practices.

Inclusion as the main lever for optimization (mean of 3.7659 / standard deviation of 0.73352): Although it falls above the neutral average, inclusion records the most moderate score of the study. This index, combined with the narrowest standard deviation in the sample, reveals a convergent consensus among respondents: systematic openness to external stakeholders and the involvement of civil society remain practices that are more difficult to formalize on a daily basis, thus constituting a priority area for managerial improvement to complete the transition toward fully responsible innovation.

In summary, the empirical analysis conducted on the Tunisian sample (N = 63) allows for a generally positive but nuanced diagnosis of the integration of responsible innovation.

The main lessons from this evaluation can be summarized as follows: A solid operational foundation: The overall scores, which are significantly above the theoretical neutral average, confirm that organizations are actively integrating the dimensions of responsible innovation into their practices.

A maturity marked by action and anticipation: The predominance of reactivity and anticipation demonstrates that the structures favor an agile approach, focused on adapting to uncertainties and prospective projection in the face of field challenges.

A major managerial challenge: The decline in the inclusion score highlights the main point of concern for Tunisian companies. This result highlights the imperative need to formalize collaborative openness and the integration of external stakeholders, in order to transcend a purely reactive posture toward a truly inclusive co-creation model.

CONCLUSION

The main objective of this research was to evaluate the empirical anchoring of responsible innovation within organizations in Tunisia, through the analysis of the four constitutive dimensions of the AIRR framework (Anticipation, Inclusion, Reflexivity, Responsiveness) (Owen et al., 2013).Employing a rigorous methodological approach based on an administration to a sample of N = 63 respondents and statistical processing using SPSS (reliability validation through Cronbach's Alpha and calculation of composite scores), the study provided a precise diagnosis of field practices.

The results of the univariate descriptive analysis revealed an overall favorable positioning, with all scores clearly above the theoretical neutral average. More specifically, the evaluation highlighted a clear hierarchy in organizational priorities: on one hand, reactivity (mean of 4.0357) and anticipation (mean of 3.9484) stand out as the most strongly anchored and mastered pillars, reflecting a pronounced operational agility in the face of uncertainties. On the other hand, reflexivity (average of 3.8770) and inclusion (average of 3.7659) are positioned in the background. In particular, the inclusion score highlights the main managerial challenge to be addressed: the need to further formalize collaborative openness and the integration of external stakeholders to transcend a purely reactive stance toward a truly inclusive co-creation model.

On a theoretical level, this contribution enriches the literature on the governance of responsible innovation by applying it to an emerging context, while validating the empirical robustness of the AIRR model scales. On the managerial level, it invites decision-makers to structure more systematic openness approaches with their ecosystem.

Nevertheless, this work has certain limitations, particularly the geographic and sectoral concentration of the sample, as well as its modest size (N = 63). These specificities call for caution in generalizing the conclusions to the broader national economic fabric. Future research would benefit from conducting expanded multi-sectoral and nationwide surveys, or integrating longitudinal causal analyses to measure the direct impact of these dimensions on the overall performance of companies.

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