Drivers and Barriers to the implementation of the RRI concept in small and medium-sized enterprises in the Chinese healthcare industry

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Management of Technology**

Faculty of Technology, Policy and Management

by

Ruijun Zheng Student

number: 5251818

To be defended in public on May 8th 2023

Graduation committee

Chairperson	: Dr. Ibo van de Poel, Ethics/Philosophy of Technology
First Supervisor	: Dr. Zenlin Roosenboom-Kwee, Economics of Technology and Innovation
Second Supervisor	: Dr. Ibo van de Poel, Ethics/Philosophy of Technology

TU Delft

Executive Summary

The concept of Responsible Research and Innovation (RRI) originated in the European Union, and in recent years research and innovation responses to globalization have gained widespread discussion and research. While RRI case studies have focused on large or multinational organizations in the U.S. and European markets, the RRI framework is still in the early stages of diffusion in emerging countries and economies. The lack of institutional support and enabling conditions make it difficult for SMEs in these countries to fulfill their mission of socially responsible innovation. Therefore, the implementation of effective innovation risk management, such as the RRI framework, in these countries is particularly important. China, as a typical emerging country, has social challenges in areas such as public health, environmental protection, gender equality, and energy, and Chinese SMEs play an important role in its economic development. Therefore, exploring the factors influencing the diffusion of the RRI framework among SMEs in emerging economies in the Chinese context can address their social governance challenges and provide lessons for other emerging countries to apply the RRI framework.

Based on the existing literature, this study summarized 24 influencing factors for implementing RRI in small and medium-sized healthcare companies in the Chinese context, which were classified into six categories: financial, policy, marketing, customer orientation, organizational structure, and external factors. Based on these influencing factors, the researchers developed questionnaires to understand the diffusion of the RRI concept and the ranking of the influencing factors among the Chinese SMEs. The questionnaire was then distributed at Gaush Teleon, a case study that fit perfectly into the research context. The questionnaire received a total of 179 valid responses. Thus, a statistical analysis of the questionnaire results was carried out. The results of the data analysis showed that policy factors were considered to be the most important influencing factor on the adoption of the RRI framework by Chinese SMEs, followed by organizational and financial factors. Unlike countries with high R&D intensity but low socio-technical linkages, the implementation of the RRI framework by Chinese SMEs in the healthcare sector is not primarily economically sensitive. The reasons for the different findings are attributed to differences in industry and firm size, which may lead to different types or models of innovation within firms.

The study acknowledges two limitations. First, the single case study approach makes it difficult to generalize the findings to other companies because the policy and innovation environment varies from region to region. Second, survey participants may not be representative of the stakeholders involved in implementing the RRI framework

because it is typically a decision made by management, whereas the study reflects the attitudes of the corporate community toward RRI. This study suggests that examining the alignment of Chinese society with RRI and exploring the feasibility of developing the RRI concept in China should be seen as an opportunity. The study reveals entry points for RRI in corporate innovation governance that can help developing countries like China assess how emerging technologies and society can evolve together.

Contents

1. Introduction

1.1 Background

Responsible research and innovation, RRI, has attracted the interest of policymakers and scholars worldwide as a science policy term first proposed by the European Commission (Martinuzzi et al., 2018) to align scientific innovation with broader societal values. René von Schomberg is widely credited with providing the most comprehensive explanation of the RRI concept (Owen, 2019). According to Schomberg, RRI involves an open and collaborative approach where innovators and societal actors engage in a transparent and interactive process. The ultimate goal is to ensure that the innovation process and resulting products are both ethical and sustainable, and meet the needs and desires of society as a whole. This process is critical for properly integrating scientific and technological advances into our society. The RRI is also recognized as having six key dimensions: "ethical dimensions, societal engagement, gender equality, open access/science and science education, and governance."

Rip (2016) argues that RRI is a "boundary object," meaning that as the concept of RRI begins to spread globally, especially from developed to developing countries, it will be defined differently by groups of scholars with different social backgrounds, values, and interests. Many scholars also believe that the factors to be considered when implementing the RRI framework in different countries should be based on local conditions rather than on the EU experience. However, compared to high-income economies, there are relatively few studies on RRI implementation in developing countries, especially on the RRI framework for SMEs (Hadj, 2020).

As an umbrella concept that originated in the EU, current case studies on RRI mainly focus on large or multinational organizations associated with the US and European markets (Macnaghten, 2014). The RRI concept and framework are still in the early dissemination stages for emerging countries and economies. Although there are some differences in research findings regarding the definition of RRI, the focus of RRI research is consistently recognized as addressing societal challenges (Taeyoung Park & Junyun Kim, 2020). Thus, the RRI framework remains relevant, especially in global is-sues.

Since most emerging economies are not well equipped to deal with societal challenges at the national level, various stakeholders (Hadj, 2020) at the societal level are expected to participate in a joint response to potential crises in the market and society. In

these emerging countries, the lack of institutional support and other enabling conditions makes it particularly difficult for SMEs to fulfill their mission of responsible innovation (Yoshino, 2018), even though they have become the mainstay of economic and innovation growth compared to governments and large firms. And most emerging economies are not aware of the RRI framework, and the innovation measures and strategies they adopt for economic development may have negative long-term socio-economic and environmental consequences. That is why it is essential to implement effective risk management of innovation, such as the RRI framework, in these countries.

As a typical emerging country, China has general global societal challenges in areas such as public health, environmental protection, gender equality, and energy. Moreover, China has a broad distribution of small and medium-sized enterprises in different industries (Liu & Fong, 2010), with a high share of SMEs in the GDP. According to 2022 data (www.chinabaogao.com, 2022), Chinese SMEs contribute more than 70% of patented technological innovations. Therefore, this paper argues that it is worthwhile to explore how the RRI framework can be promoted among SMEs in emerging economies in the Chinese context to address their social governance challenges and to provide lessons for other emerging countries to apply the RRI framework.

1.2 Research Objectives and Research questionnaires

The main research objective of this thesis is to identify the enablers and impediments to the diffusion of the RRI framework among SMEs in this industry. To achieve this goal, the current state of RRI diffusion among SMEs in the Chinese healthcare industry needs to be studied first. This step requires extensive literature research and questionnaire surveys to determine the level of awareness of the RRI framework among managers and practitioners. These surveys should also be able to identify the application of vague concepts similar to Responsible Innovation that already exist within the organization. Due to the conceptual similarities, the drivers, and barriers to RRI implementation should be summarized and verified in case studies.

As previously stated, this thesis will be organized around one main question. And a series of sub-questions will be bifurcated from the main question to discuss better, study, and arrive at a comprehensive answer. The sub questions will contain the information needed to answer the main research question, meet the research objectives, and logically derive the conclusion.

Main Research Question:

What are the drivers and barriers to implementing Responsible Innovation and Research (RRI) systems in Chinese small and medium-sized healthcare companies?

As a concept proposed by the European Union and developed here, RRI or RI does not seem to have a high level of adoption in emerging economies (Wong, 2016). However, many countries, especially China, offer similar perspectives to "responsible innovation" in terms of societal governance challenges such as sustainability and environmental protection. Therefore, to be able to conduct this study in a structured way, the following sub-questions are considered necessary:

Sub question 1:

What is the current situation of RRI and similar innovation management concepts in Chinese healthcare SMEs?

The researchers would like to understand the current diffusion of the RRI concept within this research target to determine whether the implementation of the RRI framework has a theoretical basis. Based on the discussion in the previous section, the RRI concept may be translated and disseminated in China as a concept with the same kernel (Doezema et al., 2019). Therefore, in this sub-question, researcher also needs to identify whether there are theories similar to the RRI concept and their prevalence status.

Sub question 2:

What are the factors that influence the presence of such innovation management concepts in Chinese healthcare SMEs?

Due to the existing knowledge gap, this sub-question aims to screen the influencing factors for promoting the RRI framework for healthcare SMEs in the Chinese context in a similar context. The screening will be conducted by means of literature research. The influencing factors summarized in the literature study will be verified in the next sub-question.

Sub question 3:

Which of these factors are identified as drivers and which are considered as barriers?

This sub-question will attempt to empirically validate the impact factors proposed in the previous sub-question and rank these factors in order of the severity of the positive and negative impacts.

1.3 Research Methodology

The research methodology and process of this study will be divided into four main phases, as shown in the figure below.

First, the literature study will be used to identify the influencing factors for the implementation of the RRI concept in SMEs that are applicable in the Chinese context. After that, the influencing factors obtained from the literature study will be classified to obtain the hypothesized driving and hindering factors. The third stage is the design and distribution of questionnaires for the obtained influencing factors and the target group of the study, and the questionnaire responses will be processed for subsequent analysis. Finally, the questionnaire responses will be statistically analyzed, and the results will be discussed to answer the main research questions and sub-questions.

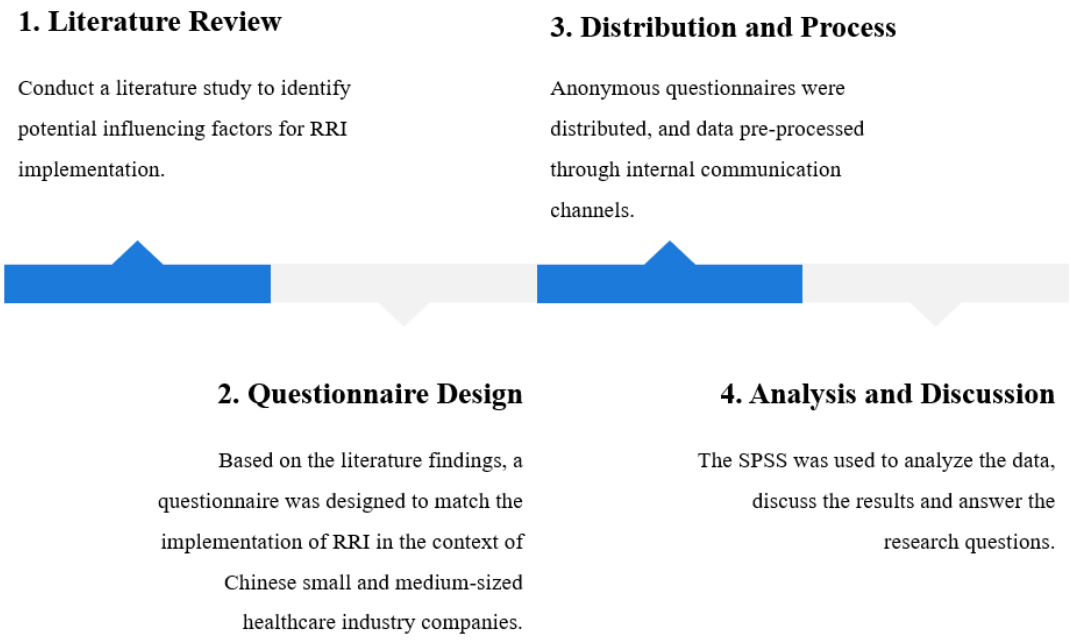

Figure 1. Research method phases

1.4 Thesis Structure

The thesis is structured as follows: this chapter identifies the background, objectives and questions of the study and identifies the phased research approach; Chapter 2 will review the relevant literature and obtain the main framework of the study; Chapter 3 will present the research methodology in more detail, including case presentation, data collection process, sampling and data analysis methods; Chapter 4 will present the results of the survey and data analysis; Chapter 5 will discuss the results of the data analysis and the causes of discrepancies in the study; Chapter 6 will summarize the study and provide valuable recommendations for the study case and similar replication of the RRI framework within Chinese SMEs, as well as point out the limitations of this study and directions for further research..

2. Literature Review

In this section, research on responsible research and innovation (RRI) will be reviewed, with a focus on the status and factors influencing the implementation of RRI in emerging economies.

2.1 Search Description and Selection Criteria

The criteria for literature selection will be developed based on the research objectives. In order to obtain relevant information by means of keyword search, it is first necessary to list and classify keywords according to the topic. Table 1 lists the keywords used to select references related to the topic.

Keyword	Synonyms
RRI	Responsible Innovation and Research, RI, Responsible Innovation
Developing Countries	Underdeveloped nations, developing nations, economically developing countries, Emerging economies, Emergent nations
Implementation	Application, usage, implementation framework, performance
SMEs	SME, Small and medium-sized enterprises, small-sized enterprises, small and medium-sized firms, small and medium-sized companies
Drivers	Push factors, advantage, stimulative, encouragement
Barriers	Obstacles, disadvantage, difficulties, hindrances

Table 1. Keywords identified

The first set of keywords searched were "RRI" and "developing countries" and their related terms. In the initial search, searching for these keywords in the "title" alone yielded very limited results (Table 2). This is because many of the relevant case studies only indicated the country in which the study was conducted in the title, but not whether it was a developing country or an emerging economy. The authors then attempted to search for case studies containing the terms "responsible innovation", "responsible innovation and research", and "developing countries and emerging economies" in the "title and abstract" and "abstract and body". Research" and "Developing Countries and Emerging Economies", and then more relevant literature was obtained. Since the concept of RRI in emerging economies started to emerge in 2013 (Harsanto et al., 2020), relevant literature from 2013 onwards was highlighted.

Search key words used	Article found
TS=(RRI AND Developing Countries) OR (RRI AND Emerging Economies)	5
T&AS= (RRI AND Developing Countries) OR (RRI AND Emerging Economies) OR (Responsible innovation AND Developing Countries)	67
T&AS= (RRI AND Developing Countries) OR (RRI AND Emerging Economies) OR (Responsible innovation AND Developing Countries) Literature after 2013	23
T&AS= (RRI AND SMEs) Literature after 2013	23
T&AS= (RRI AND SMEs AND Developing Countries) OR T&AS= (RRI AND SMEs AND Emerging Economies) Literature after 2013	7

Table 2. Article identified to RRI and developing countries

There are many duplicate articles in the bibliography because the author has conducted multiple searches using the same set of keywords or synonyms in various different databases. The author of this thesis began using Mendeley to manage articles that had been searched and literature that had been downloaded. In combination with the initial reading of the content and research topics of the existing literature, the keywords in the literature management were divided into four categories (Table 3), article type, geographical location, country type and industry type. Each category has its corresponding keywords, which will be combined with the reading aspects of the article in Notion in the form of tags. Using Notion's filtering feature, it is possible to find articles that correspond to each keyword, as well as articles that have several keywords at the same time. First, the titles and abstracts of the downloaded documents will be initially read, then pages will be created for them in Notion and tags will be selected. Then I identified a list of documents that I wanted to skim and read carefully. The author created a mind map and a gallery in Notion to track my reading progress.

Article type	**Geographical location**	**Country type**	**Industry type**
Case study	Asia	Developed countries	Healthcare
Implementation plan	Middle East	High-income developing countries	Manufacturing

Framework	South America	Low-income developing countries	Agriculture
Research report	Africa	Alliance of countries	ICT
	Others		SMEs

Table 3. Keyword clarification

When deciding on the final choice of reference range, for works related to common concepts, the authors decided to filter out literature with a high number of citations as a reference, since the number of citations or the reputation of the author can indicate the quality of the article. However, for more specific keywords, especially for country- and industry-specific RRI studies, the number of citations did not become a focus of selection. Therefore, the ultimate way to assess whether to use a reference is to read the abstract and check how well it fits the topic.

2.2 Development Status of RRI Concept

2.2.1 RRI Status in China

RRI is an integrated approach that better aligns research and innovation with societal needs; that is, RRI can guide the innovation process towards socially beneficial goals (Von Schomberg, 2013). How to benefit from innovation while reducing potential risks and costs is a major concern of current Chinese innovation policy. The RRI framework may help address some of the challenges and risks faced in China's research and innovation process. Current research on RRI has focused on high-income economies. Less attention has been paid to emerging economies, such as China. The currently published Chinese literature related to RRI mainly introduces RRI concepts and frameworks rather than practical applications of RRI. the extension of RRI concepts to a global issues governance perspective may run the risk of imposing explicit European interpretations of responsibility into global research and innovation discourse (Wang, 2016), and there are concerns from institutional concerns about democratic decision-making. But the practice of RRI in Chinese society is not without entry points and application scenarios; on the contrary, there are already many concepts or policy slogans similar to RRI in the Chinese context (Gao, 2019).

In the case of the Dalian port construction in northern China, Yan (2022) found that even though technicians were initially unfamiliar with concepts such as RI or RRI, examples of RI concepts could be found in practice. For example, the construction of

the port of Dalian promised "green port construction" and the development of a series of ecological projects. Although not explicitly following the European RRI or RI process, innovative projects were evaluated involving a very large number of stakeholders and based on diverse ethical values and social needs. The management framework and approach of the Port of Dalian (PDA) responds to the current leadership philosophy of the Chinese government and ruling party. 2012 saw the Communist Party of China (CPC) enshrine the concepts of "building an ecological civilization" and "sustainable development" in the party constitution, and as part of the government's Yan et al. also found that as PDAs and RI terminology continue to interact, more and more decision makers identify with and actively learn about RI concepts and promote RI practices. This provides some evidence that the current innovation management context and mainstream concepts in China have a high degree of fit with RI or RRI concepts.

China has experienced unprecedented economic growth in the past decades, and that growth was largely due to massive capital investment and resource-based expansion. However, this resource-oriented growth strategy is unsustainable as it incurs high social and environmental costs (Zhang, 2019). Therefore, the Chinese central government issued a policy on mass entrepreneurship in 2015, which is considered as a decisive moment to change the economic model. The policy (Ma, 2021) aims to encourage everyone to become an entrepreneur and to implement a new sustainable development strategy that focuses on mass entrepreneurship with the goal of improving economic performance, protecting the environment, promoting social equity, and building a harmonious society (Fu, 2021). This new development strategy has attracted academic attention because of its integration of mass entrepreneurship as a new economic driver and sustainability as a long-term economic goal. In the concept of "mass entrepreneurship and innovation," people are encouraged to be the subjects of innovation and entrepreneurship and to actively participate in creating value. RRI, on the other hand, emphasizes that the public should be included in the innovation process and that their views and opinions should be respected to ensure that innovation meets the expectations and needs of the public.

In general, variants of the RRI concept are prevalent in China's current social governance context, and some of the concepts that have received widespread social attention and recognition include "sustainable development," "building an ecological civilization," "green development The concepts that have received widespread social attention and recognition include "sustainable development," "building an ecological civilization," "green development," "mass entrepreneurship and innovation initiative," and

so on. According to the above description, "sustainable development", "building ecological civilization" and "green development" can be considered as the RRI framework for assessing science and technology development and formulating policies based on social needs and ethical values. The RRI framework focuses on the development of science and technology and environmental protection. Concepts such as "universal entrepreneurship and innovation", like the RRI concept, emphasize the role of diverse stakeholders in technological innovation and regulation.

2.2.2 RRI implementation in emerging countries

The concept of Responsible Research and Innovation (RRI) has gained considerable attention in recent years as a framework to promote research and innovation that is ethically, socially, and environmentally responsible. However, the development status of RRI in emerging countries is still in its early stages. Due to the lack of support from relevant studies, we extend the scope of our literature study from China to emerging economies, which has provided experiences of RRI implementation that can be referred to. In this chapter, we will explore the current state of RRI in emerging countries.

Some researchers (Harsanto et al., 2020). provided a macro-level overview of the development of the RRI concept in countries with emerging economies since 2013. The paper mentions that among the six dimensions of RRI, "inclusion" is the most discussed in RRI research in these countries, while "anticipation" is not much discussed in the initial stages of research and innovation. The author searched the literature through a literature review. The authors retrieved relevant literature containing "emerging economies" and "RRI" by means of a literature review and conducted a qualitative analysis of the textual data using the content cloud. According to Haesanto's study, most of the RRI-related studies that took place in developing countries were linked by the researcher to the European Commission's concept of RRI and showed strong geographical characteristics. When considering RRI research and implementation in developing countries, the most discussed aspect is "inclusion", i.e., opening up research and innovation to the public and increasing interdisciplinary collaboration. Harsanto's point is a valuable one, but its limitation is that the article only focused on published papers in English during the initial review process. This is why the number of references is relatively limited and the number of references that address the current state of RRI research in each country is severely underrepresented.

As a concept that has emerged in Europe, responsible innovation and research has been applied in more case studies in Western Europe and North America, developed

countries, than in other developing countries. Some scholars have compared the difference between the implementation status of RRI in developed and developing countries. Lukovics argues that different innovation contexts affect the success and effectiveness of RRI in implementation (Lukovics et al., 2017). In their study, the relative level of research funding and cultural background were found to strongly influence the motivation of participants, which would ultimately affect the implementation results of the STIR (Socio-Technical Integration Research) study. Early studies conducted in developed countries (including the Netherlands) suggest that researchers are motivated by the understanding that these aspects are crucial for the future. In contrast, in Hungary (as a Developing/Emerging High-income economy), actors seem to consider only the immediate costs and benefits due to daily survival strategies and the influence of the previous socialist regime. Lukovics therefore argue that if the goals of RRI are integrated into the costs and benefits that participants can visualize, i.e., if the feasibility of RRI is enhanced through economic benefits, it can help less developed countries to increase their "RRI readiness" at the grassroots level (Lukovics et al., 2019).

In addition to economic factors, in Chile, researchers (Barton et al., 2019) have highlighted the role of natural resources, the influence of social sciences on policy makers and implementers in RRI development. As a country that, like Hungary, has undergone a dramatic change in social ideology in recent decades, Chile has redefined the nature of research and innovation at the national cognitive and policy-making levels in the last two decades. The purpose of its state-funded programs has shifted from "solving employment" to "reducing poverty, inequality and guaranteeing a minimum standard of living for its citizens". The programs that have made this shift are certainly "responsible" and the RRI concept is expected to play a major role in this regard. But the problem in Chile is that the current RRI concept, popular in Europe, does not balance the contradiction between "active and sustainable regional development" and "the level of public participation in product innovation and research" in Chile. Barton believes that the scarcity of natural resources and the difficulties of national project approval make RRI an urgent necessity to address the current challenges in Chile's development process. However, it is due to this contradiction that the current state of development of RRI in Chile is considered inadequate at the level of preparation.

As a country also in economic and social transition, the current state of RRI in China (Yang, 2017), like Chile, has been heavily influenced by policy makers and the economic consequences of RRI have been focused on. In contrast to Chile, the Chinese government's STI focus has gradually shifted from an exclusive focus on economic

development to an equal focus on economic and social development since the 1970s. Moreover, the Chinese government has incorporated industrial structure optimization and strategic support for new and innovative industries into its long-term planning. However, the practice of RRI innovation in China shows an uneven regional development. Moreover, the concept of "inclusiveness" involved in RRI is not well reflected in public participation in innovation projects and public debates. The authors also suggest that it is difficult to directly assess the direct impact of the RRI framework on China's national-level innovation policy because the RRI framework was developed in a high-income country.

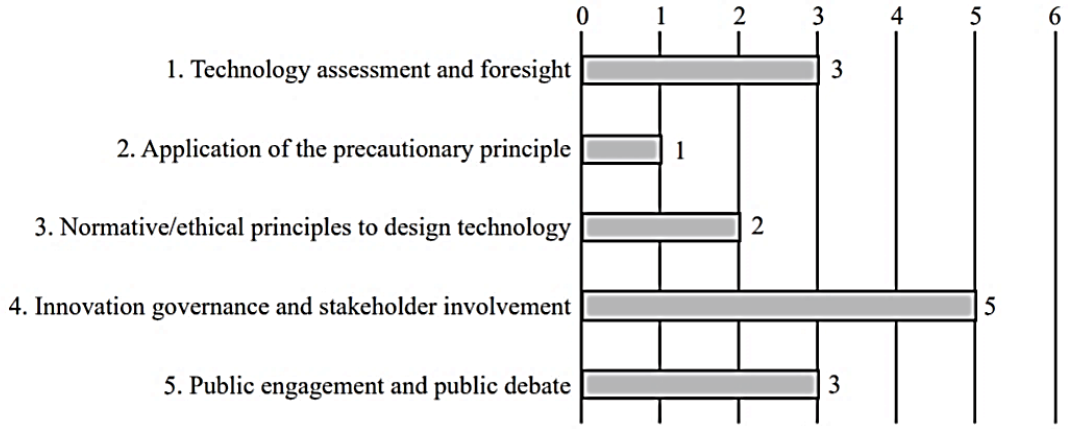

Figure 2. Growth Matrix for Responsible Research and Innovation in China (Yang, 2017, p132)

Yang (2017) argues that the RRI framework has both a push and a pull-on economic development, and then in Figure 2 assesses the enhanced effect of the RRI framework on innovation efficiency from five perspectives, ultimately arguing that developing countries like China should prioritize innovation governance and stakeholder engagement as a priority when initiating the RRI process.

Gao summarized the commonalities and contradictions of RRI in policy with China's science and technology governance system (Gao et al., 2019). The authors argue that there are entry points for RRI in China for government, entrepreneurs, and the scientific community that are appropriate to the Chinese context, which is undoubtedly a driving factor for RRI implementation in China. However, the absence of mechanisms for dialogue and communication at different levels appropriate to the RRI system in China, and the lack of consideration of shared responsibility of stakeholders, is one of the organizational factors that hinder the development of RRI in China. Gao also pointed out that the implementation process of RRI in China lacks implementation

details and relevant case studies (before 2020), which is a challenge to further analyze the enabling factors and obstacles.

There is a strong link between responsible innovation (RI) and responsible innovation and research (RRI), which are considered to be linked to liberal democratic values. Moreover, public participation in sustainable and technological is seen to draw on fundamental EU values such as consultative democracy. This calls for stakeholder deliberation on democracy in the process of research and innovation. However, Wong (Wong, 2016) argues that an overemphasis on the importance of democratic values in the implementation of RRI in China and East Asia, especially the emphasis on this as the only value to achieve the goals of RI (RRI) (Stilgoe, 2020), is not conducive to the implementation of a healthy and effective RRI system in these countries and regions. However, forcing a radical reform of the social value system also does not seem feasible. However, the authors repeatedly state that different values would not be a decisive impediment to RI or RRI implementation. Wittrock (Wittrock, 2021) also highlights the role of cultural identity as an enabler or hindrance to RRI implementation, i.e., if members of the organization perceive themselves to identify with RRI in terms of culture and values, then this integration will tend to be facilitated. But this fit is mostly seen in European countries, especially in Western Europe (Molen et al., 2018), rather than in Asia.

During the literature research, RRI studies for SMEs in developing countries have not received much attention compared to related studies in developed countries (Jamali & Karam, 2018). Tarek Bel Hadj (Hadj, 2020) tried to analyze the impact of responsible innovation (RI) on the competitiveness of SMEs in the case of North African countries, where Tarek argues that responsible innovation mediates the competitiveness of SMEs. The case study demonstrates that "inclusion," "anticipation," and "responsiveness" in the RRI system moderate the competitiveness of SMEs in emerging markets and North Africa through mediating benefits. The study demonstrates that "inclusion", "participation" and "responsiveness" in the RRI system moderate the competitiveness of SMEs in emerging markets and North Africa through mediating effects. Although this study only covers North African SMEs, other developing countries can refer to the moderators in the model.

Another limitation of RRI research in developing countries is that the concept has been researched and implemented mainly in the context of publicly funded research (Martinuzzi et al., 2018), underestimating the way it has been implemented in other

settings, such as industrial and business environments, especially small and medium-sized enterprises.

2.2.3 RRI implementation in SMEs

In order to investigate the potential drivers and barriers to RRI implementation by SMEs in specific contexts, sectors with high rates of innovation, high proportions of SMEs and high societal interest in "responsible business" will be analyzed. 2016 to date, researchers are increasingly interested in the practice of SMEs engaging in responsible innovation (Gonzales-Gemio, 2020). Although the concept of RRI is not widely known among SMEs, research on how SMEs should be socially responsible and use performance to incentivize RRI implementation is conducive to the start of the RRI concept in such contexts.

The implementation process of RRI has been studied much more in large or multinational organizations in the EU than in SMEs. In their study of incentives to implement RRI, Agata Gurzawska (Gurzawska, 2017) clearly suggest that both firm size and industry diversity affect the effectiveness of incentives. Although SMEs account for 99% of all firms in the EU, they face additional challenges in implementing the RRI framework. Among the problems faced by SMEs in implementing the RRI framework are the lack of financial support, the lack of human resources and the lack of brand creation. The lack of resources leads SMEs to focus their profitability goals and operational decisions on short-term interests. Therefore, SMEs should base their RRI implementation on helping them to create more competitive brands and maximize efficiency with a simple organizational structure (Tam, 2007).

The type of industry can also significantly influence the implementation of RRI in SMEs. Different industries encounter different resistance to RRI implementation depending on the knowledge context, stakeholders, and innovation players (Malerba, 2005). Chatfield (Chatfield, 2017) suggested that corporate social responsibility and market competitiveness are consistent in driving innovation activities in companies operating in industries that require consideration of general social impact, and that often the company's operations department takes on the primary role of perceived drivers and barriers. The key role of perceived drivers and barriers is often played by the company's operating divisions. The difficulty of innovating and managing technology varies across industries because of the degree of regulation and social responsibility (Van de Poel, 2017); for example, companies in synthetic biology and drones may have partially different RRI governance issues. The development of emerging technologies may raise social concerns about ethical issues, but may also bring broad

social value and governance convenience. This requires an increased sense of social responsibility on the part of SME operators.

Figure 3 shows the incentive matrix designed by Agata Gurzawska (Gurzawska, 2017, p1759) for implementing RRI based on the diversity of company types.

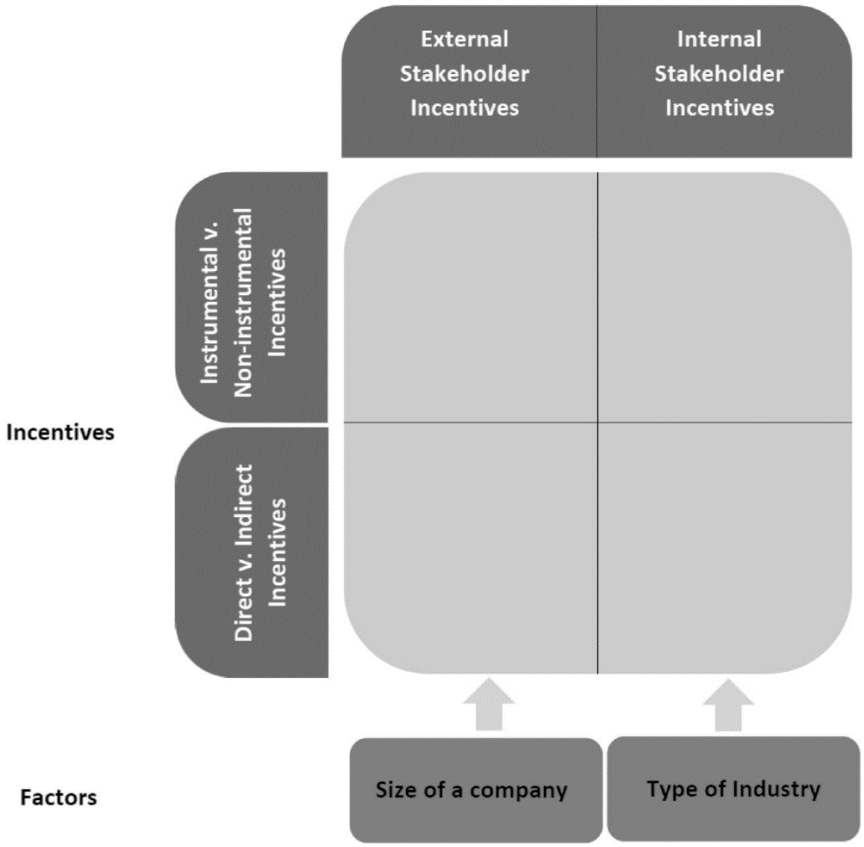

Figure 3. Categories of incentives and factors (Gurzawska, 2017, p1759)

2.3 Drivers and barriers of RRI implementation

During the literature research from last chapter, RRI studies for SMEs in developing countries have not received much attention compared to related studies in developed countries (Jamali & Karam, 2018). Therefore, this chapter will discuss the influencing factors of RRI implementation in developed countries, emerging economies and SMEs respectively. On the basis of theoretical compilation, experience in relevant fields will be selected as much as possible, and its feasibility will be analyzed to provide theoretical support for the RRI case study of small and medium-sized enterprises in my country.

2.3.1 Drivers and Barriers of RRI Implementation in Developed countries

Following a literature search, a study of RRI development in Austrian SMEs in the healthcare sector provides a reference framework for this study to sort out the enablers and impediments of RRI in Chinese SMEs in the healthcare technology sector (Auer & Jarmai, 2017). The study conducted interviews on potential drivers and impediments to RRI implementation in six dimensions: regulatory, financial, market positioning, customer knowledge, management structure, and external knowledge collaboration. From the findings, it was found that even in Europe, the birthplace of RRI, many SMEs in Austria are still ignorant of the RRI concept. However, this does not prevent them from quickly connecting the RRI concept to their daily operational activities. The only RRI element that is more difficult to understand and practice is "science education." If there is a high degree of alignment between the implementation of RRI and the current structure of the company's innovation practices, then RRI is more likely to be considered a beneficial factor for the implementation.

Comparing the authors' analysis of the current situation of Austrian SMEs in the healthcare sector, Chinese and Austrian SMEs in the healthcare sector have a similar industrial structure, dominated by low-tech equipment and a high demand for innovation. digitalization and ICT sectors. Therefore, the implementation of RRI in Austrian SMEs in the healthcare sector is considered to be relevant for a study in China in an equivalent context. Potential RRI drivers and barriers for Austrian healthcare SMEs are summarized in the Figure 4.

Factor Categories	Drivers Supporting Implementation of RRI	Barriers Obstructing Implementation of RRI
Regulatory framework	• RRI implementation required by law. • Threatened fines for not meeting RRI standards • Governments promote RRI and a comprehensible development strategy for SMEs. • Information about RRI and ethical support from regulatory bodies	• Unclear regulatory focus and changing regulatory framework at different geographical scales. • Theory-driven regulations divorced from reality. • Lack of information and support measures about RRI
Funding and finance	• European and national funding agencies require attention to societal and gender aspects • Increased access to European and national funding when considering RRI aspects	• Higher innovation costs expected from RRI implementation. • Additional financial resources required for RRI implementation
Market orientation	• Future economic value expected from taking up RRI. • Growth potential and benefits expected from taking up RRI. • Expected cost reductions from implementing RRI	• Lack of a qualified female workforce in the labor market • Cost and success pressures paired with uncertain outcomes from RRI. • Shareholder value and profit maximization thinking paired with unclear innovative and profit potentials
Customer knowledge	• Increased company reputation and visibility among (potential) customers expected from complying with RRI • Compliance with their customers' internal rules (certain RRI aspects)	• Increased customer engagement can hamper finding consensus among stakeholders
Management and organizational structures	• Ethical and responsible thinking and societal considerations of founder, managers or employees to comply with RRI aspects. • Employees transfer understanding of responsibility from previous companies. • Internal codes of conduct advocated by management require employees to comply with RRI	• Lack of knowledge about RRI and how to implement RRI aspects requires strong personnel efforts. • Personal attitudes and experiences of founders' conflicts with RRI aspects • Lack of governance structures in SMEs affects uptake of RRI • Long-established (sometimes conservative) governance structures prevent the introduction of structural change in companies • Implementation of RRI takes additional efforts and personnel resources
External knowledge from collaborations and networks	• Compliance with their innovation partners' responsibility rules or codes of conduct (large RRI advocates) • Increased company reputation and visibility among potential collaboration partners expected from complying with RRI	• Innovation partners advocate their own interests and affect decision making and the likelihood of resistance to RRI

Figure 4. Potential RRI drivers and barriers for Austrian healthcare SMEs (Auer & Jarmai, 2017)

2.3.2 Drivers and Barriers of RRI Implementation in Emerging Economics

In the previous section of the argument, the current status of RRI diffusion and implementation in developing countries varies, but there are still many commonalities to be found. Since this literature review chapter aims to provide theoretical support for RRI case studies of SMEs located in China, since the consideration of Drivers and barriers of RRI implementation in developing countries will be dominated by case studies and reports conducted in Asia.

In Korea (Ko, 2020), researchers used a hierarchical analysis model to rank the categories of barriers to RRI implementation in Korea, ultimately concluding that economic barriers and political policy barriers are the main obstacles to RRI implementa-

tion.

Overall barriers	Autonomous vehicle		Biotechnology		Overall	
	Priority weight	Rank	Priority weight	Rank	Priority weight	Rank
Increased innovation costs due to RRI implementation	0.178	1	0.151	1	0.165	1
Lack of economic incentive to participate in RRI	0.123	2	0.102	3	0.112	2
Lack of clear RRI policies and unclear focus on RRI regulation	0.091	4	0.111	2	0.101	3
Lack of both trust and political leadership to lead RRI change	0.103	3	0.093	5	0.099	4
Difficulty in identifying the impacts of emerging technologies on society	0.091	5	0.099	4	0.095	5
Lack of clarity and empirical RRI cases	0.066	7	0.076	6	0.071	6
Conflicts of interest and a lack of stakeholder networks	0.069	6	0.059	8	0.064	7
Difficulty in understanding the emerging technologies	0.061	8	0.059	9	0.060	8
Lack of organizational structure and suitable RRI culture	0.049	10	0.068	7	0.058	9
Increased bureaucracy with RRI implementation	0.051	9	0.046	11	0.049	10
Lack of RRI training and expertise	0.041	11	0.056	10	0.048	11
Lack of social acceptance and academic identity of RRI	0.039	12	0.039	13	0.039	12
Lack of experience with bottom-up governance	0.037	13	0.040	12	0.039	13

Figure 5. Overall RRI Implementation Barriers Ranking in South Korea (Ko, 2020, p633)

The study first compared the emerging technology industries in the European Union and South Korea to identify the industries in which the relevant research was conducted and determined that South Korea is sensitive to the introduction of RRI as a policy related to R&D and innovation. Ko argued that despite being a high R&D intensity country, Korea has a low rate of technological innovation and low profitability of technology commercialization. And Korea's industrial system is highly dependent on imported components and overseas license fees. This is why the introduction of RRI is economically sensitive in Korea. In addition, some experts surveyed believe that addressing economic barriers is more important than ensuring social acceptance of RRI, for the current stage of RRI implementation in Korea.

Political factors are considered the second major obstacle affecting RRI implementation in Korea. Due to the need for financial support, Korean companies are more influenced by government policy support in developing and commercializing new technologies. This factor is consistent with the general understanding of the political environment in East Asia. Therefore, consideration of political and policy factors is also seen as imperative in studying RRI implementation in China.

Category	Barriers	Priority Weight	Rank
Economic Barrier	Increased innovation costs due to RRI implementation	0.165	1
	Lack of economic incentive to participate in RRI	0.112	2
Implementation Barrier	Lack of clarity and empirical RRI cases	0.071	1
	Lack of RRI training and expertise	0.048	3
	Lack of organizational structure and suitable RRI culture	0.058	2
Policy/political Barrier	Increased bureaucracy with RRI implementation	0.049	3
	Lack of clear RRI policies and unclear focus on RRI regulation	0.101	1
	Lack of both trust and political leadership to lead RRI change	0.099	2
Social Barrier	Lack of social acceptance and academic identity of RRI	0.042	2
	Lack of experience with bottom-up governance	0.039	2
	Conflicts of interest and a lack of stakeholder networks	0.064	1
Technical Barrier	Difficulty in understanding the emerging technologies	0.060	2
	Difficulty in identifying the impacts of emerging technologies on society	0.095	1

Figure 6. RRI Implementation Barriers Category Ranking in South Korea (Ko, 2020, p631)

2.4 Summaries

A literature search did not find a significant amount of relevant literature on the implementation of responsible innovation and research concepts in Chinese SMEs. In fact, the current research on RRI in emerging countries, especially in China, is still focused on theoretical introduction and dissemination, and that most of the research on RRI implementation occurs in large organizations or multinational collaborations.

The literature review conducted for the first sub-question of this study found that the development of RRI in China is still at the stage of concept dissemination, and many leaders of innovation activities in enterprises and the scientific community are not familiar with the concept of RRI (Wang, 2016). However, many of the core policies of the Chinese government are consistent with the concept of RRI, and relevant concepts have already been used in innovation activities. Similar concepts to the concept of RRI include "sustainable development," "ecological civilization construction," and "mass entrepreneurship and innovation." The government, enterprises, and academic circles in China may not be able to describe a complete understanding of the RRI framework, but some policies and innovative actions that conform to the concept of RRI have already been implemented.

The author studied the implementation of RRI in emerging countries such as Hungary (Lukovics, 2017), Brazil (Lukovics, 2019), and Chile (Barton,2019), and found that different innovation policy backgrounds and cultural backgrounds strongly affect par-

ticipants' motivations. Ideology, economic support, and natural resources are also important factors that affect the successful implementation of RRI at the national level. However, since the RRI framework was developed in high-income countries, it is difficult to use the same RRI framework to govern innovation due to factors such as economic and natural resources and differences in national industrial structures. At the same time, since the existing policy system of the European Union has already adapted to the RRI framework, the implementation of the RRI concept in other countries may also face policy drawbacks such as a lack of multi-level dialogue mechanisms. But this does not mean that cases from developed countries are not worth learning from. Through a study of small and medium-sized medical enterprises in Austria (Auer, 2017), six potential drivers and obstacles were identified, namely regulation, finance, market positioning, customer knowledge, management structure, and external knowledge cooperation. In South Korea, economic and policy factors are seen as the main obstacles to the implementation of RRI. Moreover, RRI implementation activities in South Korea (Ko,2020) are seen as having greater economic sensitivity. This point is worth learning from for China, which has a similar cultural background in East Asia.

The current state of RRI diffusion and use is not only regionally distinct, but also not necessarily universal in terms of how RRI concepts are diffused, implemented, and incentivized, depending on the field of innovation technology. This study summarizes the factors influencing the implementation of the RRI framework for small and medium-sized healthcare companies that may be applicable to the Chinese context through a literature study to answer research sub-question 2. The specific categories and contents of the influencing factors are listed below.

Factor	Drivers for RRI Implementation	Barriers for RRI Implementation
Political	Government policies to promote RRI or similar concepts in SMEs, like tax credits and innovation subsidies.	Ideologically based resistance to the RRI concept Unclear regulatory focus and evolving regulatory regimes in different geographic contexts Lack of communication channels between SMEs and policy makers and policy implementers
Economics	Implementing RRI will bring in more innovative revenue. Implementing RRI can reduce the cost of fighting social problems	Implementing an RRI will consume higher innovation costs. Implementing an RRI requires additional financial investment in governance.

Market	The market recognizes the expected future economic value of RRI. Market acceptance of RRI's value orientation Expected cost reduction of implementing RRI	The market seeks to maximize profits. Imbalance in the gender structure of the labor market Free riding effect
Customer orientation	Customer acceptance of RRI's value orientation RRI framework facilitates the company's reputation and visibility among potential customers	Value orientation of customers against the RRI concept Too many stakeholders on board leading to unsatisfactory delivery results
Organization structure	Managers and employees understand and can practice RRI concepts. Employees inherit the organization's understanding of responsibility. Good communication channels exist within the organization	Lack of knowledge about RRI and how to implement it. Conflict between company culture and ethos and RRI concepts Long-established (and sometimes conservative) governance structures in SMEs prevent structural changes in the company.
External cooperation	Innovative partner interest and promotional moves for RRI (large RRI advocates) Increased company reputation and visibility among potential partners through RRI implementation	Potential for partners to advocate for their own interests and influence decision making and resistance to RRI Lack of knowledge about RRI within the collaborative network

Table 4. Influencing factors that may apply to the implementation of RRI in Chinese small and medium-sized healthcare enterprises

3. Methodology

This section will discuss feasible research methods to answer the research questions and meet the research objectives. A single case study approach will be used in this study to explore the factors influencing the introduction of the RRI concept and the implementation of the RRI framework in Chinese healthcare SMEs. To meet the research objectives, quantitative data will be collected for the defined research objectives.

3.1 Ethics Approval

The TU Delft Human Research and Ethics Committee approved the ethicality of this study on March 24th, 2023.

3.2 Research design

3.2.1 Case Description

This study will use the method of single case study, select a company that meets the research requirements, and conduct research within the company.

Case studies are very helpful in explaining why things develop in a limited sample and in helping researchers address the development of theory in priority areas (Yin, 1994). Quantitative research allows researchers to explore phenomena using a variety of data sources, making it valuable for scientific research. To properly study a case, researchers must consider its contextual conditions, which are intertwined with its political, social, and historical contexts (Stake, 1994). However, the biggest limitation of case studies is their inability to generalize findings to other cases, especially when the study involves a single case (Yin, 2009). Although case studies have limitations, they can contribute to theoretical development. Single case studies, in particular, can create more complex theories than multiple case studies because researchers can fit their theory to many details with a single case (Eisenhardt & Graebner, 2007, p. 30).

According to the research objects and research objectives, the author decided to select Gaush Teleon company as the subject of a single case study. One of the reasons the author chose Gaush Teleon for the single case study was that the authors' internship experience within the company made it easy to conduct the questionnaire and reach out to interview partners. After consultation with the company manager, the author has received permission and help to conduct the study on implementing the RRI framework within the company.

3.2.2 Case Description

Gaush Teleon is headquartered in the High-Tech Industrial Park in the Guangming District of Shenzhen, China, and employs approximately 200 people. As one of Gaush Medical Group's subsidiaries, Gaush Teleon manufactures Intraocular lenses (IOLs) that provide an advanced solution for cataract surgery. Its IOL products are sold in more than fifty countries in Europe, America, and Asia. As one of the few independent IOL manufacturers in the world, Gaush Teleon has its own R&D team and manufacturing facilities in China and the Netherlands.

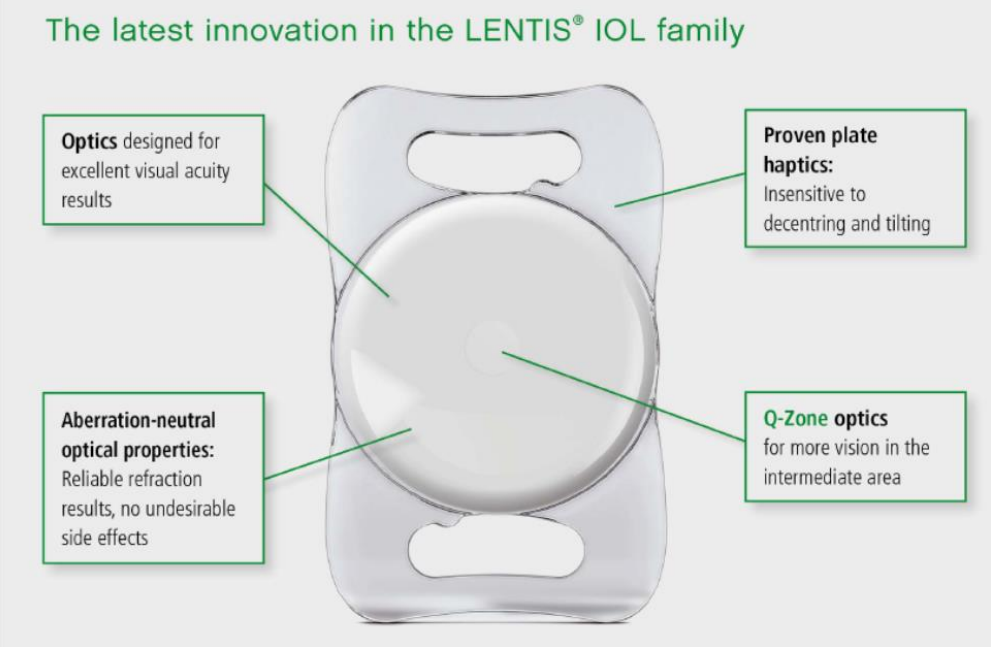

Figure 8. Teleon LENTIS intraocular lens

With the reform of China's public healthcare procurement policy, more and more public hospitals are choosing to purchase and use Chinese domestic medical devices and consumables. As an integrated procurement service provider with a large market share in the ophthalmic medical device niche market, Gaush Medical Group recognizes the need to transform the industry. In 2017, Gaush Group began purchasing or establishing its ophthalmic device manufacturing subsidiaries. In 2021, Gaush Group acquired the Netherlands-based Teleon IOL company and established Shenzhen Gaush Teleon to develop high-end cataract and refractive IOLs. Gaush Group now has five R&D and manufacturing facilities in China for ophthalmic The Gaush Group now has five centers in China for the development and manufacture of ophthalmic diagnostic equipment, surgical instruments and ophthalmic consumables. As a subsidiary of the Gaush Group, Gaush Teleon is an important part of the Gaush Group's strategy to become a leading ophthalmic total solutions provider with global reach.

Prior to the implementation of the strategic shift, Gaush Medical Group's business model could be summarized as a distributor model. Gaush Group was eager to complete the transformation of its industrial structure and to have more of its own brands and core technologies. Yin knit, after acquiring Teleon Netherlands and establishing Gaush Teleon in Shenzhen, Gaush Teleon was expected to establish its own R&D center and production as soon as possible. But the complexity of IOL production and the difficulty of technology transfer during the technology barrier covid-19, Gaush Teleon

needed to complete the localization of IOL production technology and R&D capabilities. In this context, efficient technology transfer and technology innovation management through the use of (partial) RRI framework is particularly important for the development of Gaush Teleon.

As the research subject on the factors affecting the implementation of RRI in small and medium-sized medical enterprises in China, Gaush Teleon fulfilled the following conditions as a research objective:

1. The size of the enterprise is less than 1,000 employees, which meets the Chinese standard for industrial small and medium-sized enterprises (Small and Medium-Sized Enterprise Classification Standard Regulations, 2011). Gaush Teleon currently has about 200 employees, of which more than 20% are engaged in R&D or technological innovation-related work.

2. Gaush Teleon is labeled as a High-tech company engaged in the manufacture of medical devices, which also conducts internal innovation activities such as product research and development, and Chinese government policies and legal regulations influence the innovation process.

3. Gaush Teleon's location in Shenzhen's Guangming District High-Tech Industrial Park is one of the best areas in China for innovation policies. The government supports high-tech enterprises in the industrial park with various policies such as tax exemptions, talent subsidies, and innovation incentives.

From the above-mentioned research conditions that Gaush Teleon possesses, this case meets the necessary factors to include a Chinese small and medium-sized healthcare enterprise as a research object. And since the company has a high need for innovation and subjective motivation, the case can be considered as conducive to studying responsible research and innovation enablers and drawing valuable conclusions.

3.2.3 Questionnaire Design

According to the research objectives, methodology and literature review mentioned in the previous chapters, the questionnaire was decided to be designed in the way of Likert scale. Likert scale is a type of rating scale that is commonly used in social science research to measure attitudes, opinions, and perceptions. Respondents are asked to rate their level of agreement or disagreement with a series of statements on a scale, typically ranging from 1 (strongly disagree) to 5 (strongly agree). The responses are

then scored and analyzed to provide insights into the attitudes, opinions, and perceptions of the respondents.

One of the main advantages of using Likert scales is that they are easy to administer and understand. Respondents can quickly and easily rate their opinions or attitudes on a scale that is familiar to them. Additionally, Likert scales can provide more nuanced data than simple "yes" or "no" questions. For example, instead of asking whether someone agrees or disagrees with a statement, a Likert scale can ask the respondent to rate the extent to which they agree or disagree (Barua, 2013). Another advantage of using Likert scales is that they can be used to measure multiple dimensions of an attitude or opinion. For example, a questionnaire could include multiple items that measure different aspects of RRI, such as financial factors, public engagement, and marketing. The responses to each item could then be analyzed separately or combined to provide an overall measure of RRI implementation.

All questions were designed to be mandatory to answer, so subjects were required to answer all questions before submitting the questionnaire. The entire questionnaire was designed as two parts. The first part will collect the respondents' work background and the subjects' knowledge of the RRI concept. Based on the literature review, it was found that there are concepts in Chinese policy advocacy that are similar to the RRI concept but have different names. Therefore, the questionnaire will ask the respondents if they are aware of concepts like RRI and use them in their innovation work. A short description of the RRI concept will then be given in the questionnaire. After gaining a basic understanding of RRI, subjects will answer questions about whether they think RRI is similar to other concepts. The first part of the questionnaire will focus on exploring the current diffusion of RRI and its similar concepts.

The second part of the questionnaire will be designed to explore the factors influencing the subjects' use of the RRI framework. Based on the influencing factors summarized in the previous literature review, Likert scale questions were designed for each influencing factor. There will be two specific statements under each question, a positive factor (advancing factor, which promotes the respondent's use of RRI) and a negative factor (hindering factor, which prevents the respondent from using RRI). Subjects will need to make a choice based on their understanding of the situation. The table below shows the classification of the influencing factors and the question codes. The complete questionnaires are presented in the appendix.

Factor category	**Drivers**	**Question**	**Barriers**	**Question**

Financial factors	Implementing RRI will bring in more innovative revenue	Q4_1	Implementing an RRI will consume higher innovation costs.	Q4_2
	Implementing RRI will reduce the subsequent governance costs	Q5_1	cause more governance expenses	Q5_2
Political factors	The government has financial or tax subsidies for companies that innovate using the RRI framework	Q6_1	Government's resistance to the RRI concept based on ideology	Q6_2
	Government incorporates RRI framework into regulation of medical manufacturing companies	Q7_1	Unclear regulatory focus and evolving regulatory regimes in different geographic contexts	Q7_2
Marketing factors	The market recognizes the expected future economic value of RRI.	Q8_1	Competitors with free-rider attitude exist in the market	Q8_2
	Competitive advantages	Q9_1	The lack of awareness among market participants of the value that RRIs bring.	Q9_2
Customer Orientation factors	Customer recognition of the RRI framework	Q10_1	Customers do not understand RRI concepts and values	Q10_2
Organization structure factors	Managers and employees understand and can practice RRI concepts	Q11_1	Lack of knowledge about RRI and the implementation methods.	Q11_2
	Employees inherit the organization's understanding of responsibility	Q12_1	Conflict between company culture and ethos and RRI concepts	Q12_2
	Good communication channels about innovation activities exist within the organization	Q13_1	Long-established (and sometimes conservative) governance structures in SMEs prevent structural changes in the company.	Q13_2
External factors	Increased company reputation and visibility among potential partners through RRI implementation	Q14_1	Lack of knowledge about RRI within the collaborative network	Q14_2
	Partner interest and support for the RRI concept	Q15_1	Potential for partners to advocate for their own interests and influence decision making and resistance to RRI	Q15_2

Table 5. Classification of influencing factors and problem coding

3.3 Sampling

The target population for this study was all employees currently working at Gaush Teleon. The link to the questionnaire was sent by the company supervisor only to a specific channel in the communication software used by the employees. During this process, the researcher did not have access to the specific subjects who participated in the study.

3.4 Data Collection

The study used the online questionnaire platform Qualtrics to design the questionnaire, create the link to the questionnaire and collect the data. Anonymous survey links without IP tracking were distributed to all study participants in a workgroup. The collected data and associated analysis results were stored and managed in the TU Delft student account OneDrive.

Data collection required anonymity of participants and simplicity of participation in the questionnaire in order to increase the response rate. First, the questionnaire was designed at Qualtrics in such a way that IP address tracking and other personal information was not enabled, and the researcher was not able to obtain any personal information about the participants in any way, other than the department in which they worked. Second, to avoid the questionnaire being blocked by local area networks, social media platforms, and email servers before reaching the audience (Evans & Mathur, 2005), the questionnaire distribution link was distributed directly to the workgroup by managers within the organization.

3.5 Data Processing

In this section the methods of data processing and analysis will be covered. This research will use the method of quantitative research to investigate the respondents in a single case. Therefore, we first discuss the reasons for using quantitative research and the methods of data processing.

3.5.1 Quantitative Research

Quantitative research methods involve the collection and analysis of numerical data to identify patterns and trends. These methods are highly structured and objective, making them ideal for analyzing complex data sets and identifying statistical relationships between variables (Heale, 2015). In the case of the RRI concept in the Chinese healthcare industry, quantitative research methods can be used to collect and analyze

data on various factors that affect the implementation of RRI in SMEs, such as financial resources, government policies, and industry regulations.

One advantage of using quantitative research methods is that they provide a standardized and systematic approach to data collection and analysis. This makes it easier to compare and contrast different factors and identify significant differences and similarities. Additionally, quantitative research methods allow for the use of statistical tests to identify significant relationships between variables, which can provide valuable insights into the factors that influence the implementation of the RRI concept in SMEs in the Chinese healthcare industry.

In conclusion, the use of quantitative research methods in a single case study of the drivers and barriers to the implementation of the RRI concept in SMEs in the Chinese healthcare industry can provide valuable insights into the factors that affect the adoption of ethical standards and innovation practices in this industry. By providing a standardized and systematic approach to data collection and analysis, quantitative research methods can help to identify significant relationships between variables and provide a more representative sample of the population.

3.5.2 AHP Analysis

AHP is an accurate method for quantifying the weights of decision criteria. The relative importance of factors is estimated by pairwise comparisons using respondents' experiences or perceptions. As a method for solving complex decision formulation problems, AHP allows decomposing the problem to be solved into several subproblems based on the criteria associated with each subproblem and deriving a hierarchical tree through this process. Once a hierarchy is established, decision makers systematically evaluate its various elements, comparing them to each other two at a time, to understand their impact on elements above them in the hierarchy. The advantage of the AHP model is that it makes the decision process more logical and intuitive, and thus easier to understand (Saaty, 1990 & 2008; Vaidya and Kumar 2006). Therefore, we used AHP analysis to rank the factors influencing the implementation of RRI.

In addition to this, this study also tried to use weight analysis (entropy method) to verify the results of the analysis (Qayyum, 2023). According to the definition of information entropy, for a certain indicator, the entropy value can be used to determine the discrete degree of a certain indicator, and the smaller the value of its information entropy, the greater the discrete degree of the indicator, the greater the influence (i.e., weight) of the indicator on the comprehensive evaluation, and if the values of a cer-

tain indicator are all equal, the indicator does not work in the comprehensive evaluation. Therefore, information entropy can be used as a tool to calculate the weights of each indicator to provide a basis for the comprehensive evaluation of multiple indicators.

Since the questionnaire was designed in the form of a five-point Likert scale, the ideal median value obtained by processing each group of data should be close to 3.0 if the respondents are neutral on one of the results of the influencing factor (León-Mantero, 2020). In this study, we will first average each item from the metadata and obtain the absolute value of the difference between the average and the ideal median 3.0 of each item. This value reflects how strongly the respondents responded to the influence. The higher the value, the greater the positive (or negative) feedback from the respondents. The author produced a statistical table of the absolute number of differences between the average and mean (3.0) for each item and then compared the values of each two items using SPSS software to obtain the final results of the AHP weighted analysis.

The processed data and analysis results will be stored in OneDrive until the end of the study.

4. Results

This chapter aims to validate and analyze the data obtained from the questionnaire survey. Firstly, an overall descriptive analysis was conducted, followed by testing the reliability and validity of the questionnaire design. Then, the Analytic Hierarchy Process (AHP) will be used to distinguish and rank the influencing factors on the determined RRI.

4.1 Descriptive Statistics

After distributing the questionnaire, we received a total of 182 responses. After being validated by Qualtrics, there were a total of 179 valid questionnaires. The average time to complete the questionnaires was 2 minutes and 33 seconds, but 3 questionnaires took less than 30 seconds to complete. The response time for these 3 questionnaires was much less than the average time taken and the questionnaire answers showed significant bias (only extreme options such as 1 or 5 were selected). Therefore these three questionnaires failed the Qultrics validation and will not be used in the data analysis.

The descriptive statistics for these questionnaires are shown in the table below. The percentage distribution of departments participating in the questionnaire is in line with the current organizational structure of the company.

Samples N=179			
		Frequency	Percentage
Department	Production	57	31.84%
	Sales	28	15.64%
	Marketing and Purchasing	26	14.53%
	R&D	22	12.29%
	Logistics and Warehousing	19	10.61%
	Operations（HR, Finance, etc.)	18	10.06%
	Quality Management	9	5.03%

Table 6. Departmental distribution statistics of samples

4.2 Validity Test

Validity analysis usually refers to the validity and correctness of the questionnaire scale, i.e., to analyze whether the questionnaire items are well designed. Validity anal-

ysis of questionnaires is based on principal component factor analysis, which is achieved by comparing whether the factor loading coefficients of question items perform best in the same principal component. The validity analysis will calculate the results of the KMO test and Bartlett's spherical test, which will be used to analyze whether factor analysis can be performed. If the KMO test passes (KMO>0.6), it means that there is the correlation between the question variables and the requirements of factor analysis are satisfied. If it passes the Bartlett's test: $p < 0.05$ and is significant, then factor analysis can be performed. The KMO test and Bartlett's spherical results are in the appendix.

The results of the KMO test showed that the value of KMO was 0.888, while the results of the Bartlett's spherical test showed that the significance p-value was 0.000***, presenting significance at the level, rejecting the original hypothesis that there is a correlation between the variables and the factor analysis is valid, and the suitability of conducting factor analysis. The detailed results of the validity analysis can be found in Appendix II.A.

4.3 Reliability Test

Reliability analysis is mainly used to examine the stability and consistency of the results measured by the scales in the questionnaire, i.e., it is used to test whether the sample of scales in the questionnaire is reliable and trustworthy. There is no unified standard for analyzing Cronbach's alpha coefficient (or half coefficient), but according to most scholars, generally speaking, if the Cronbach's alpha coefficient (or half coefficient) is above 0.9, the reliability of the test or scale is very good, between 0.8 and 0.9 indicates good reliability, between 0.7 and 0.8 indicates acceptable reliability, between 0.6 and 0.7 indicates fair reliability, and between 0.5 and 0.6 indicates less satisfactory reliability. If the reliability is below 0.5, we should consider reformatting the questionnaire.

The value of Cronbach's α coefficient for the model is 0.856, which indicates that the questionnaire has good reliability. The Cronbach's α coefficient table and the summary statistics of the deleted analysis items will be covered in detail in the Appendix II.B.

4.4 AHP Analysis

The following table shows the results of ranking all items using hierarchical analysis, where Q7_2, corresponding to "Unclear regulatory focus and evolving regulatory regimes in different geo-graphic contexts", has a high importance for the decision process of implementing RRI in the enterprise.

Item	Weights(%)	Rank	Categories
Q7_2	17.128	1	Political factors
Q12_2	9.051	2	Organization structure factors
Q7_1	4.281	3	Political factors
Q4 _2	4.116	4	Financial factors
Q13_2	4.056	5	Organization structure factors
Q4 _1	3.983	6	Financial factors
Q13_1	3.854	7	Organization structure factors
Q9_2	3.730	8	Marketing factors
Q14_1	3.572	9	External factors
Q10_1	3.548	10	Customer Orientation factors
Q14_2	3.545	11	External factors
Q15_1	3.469	12	External factors
Q5_2	3.443	13	Financial factors
Q15_2	3.380	14	External factors
Q11_1	3.305	15	Organization structure factors
Q11_2	3.305	16	Organization structure factors
Q8_1	3.218	17	Marketing factors
Q8_2	2.957	18	Marketing factors
Q9_1	2.898	19	Marketing factors
Q6_1	2.797	20	Political factors
Q5_1	2.735	21	Financial factors
Q12_1	2.673	22	Organization structure factors
Q10_2	2.575	23	Customer Orientation factors
Q6_2	2.380	24	Political factors

Table 7. AHP weights rank for all factors

The weight and ranking of the influencing factors for each category are then presented in the table below. It can be observed that political factors are the most important ones that influence firms to use responsible research and innovation frameworks in their innovation activities.

Categories	Weights (%)	Rank
Political factors	27.367	1
Organization structure factors	17.961	2

Financial factors	14.638	3
External factors	14.32	4
Marketing factors	13.133	5
Customer Orientation factors	12.581	6

Table 8. AHP weights rank for all categories

The following table shows the ranking of the categories of influencing factors for the use of the RRI framework in innovation activities by employees in the Production department. Political factors are the most important influencing factor, followed by organizational factors.

Categories	Weights (%)	Rank
Political factors	24.961	1
Organization structure factors	16.791	2
Financial factors	16.359	3
External factors	15.863	4
Marketing factors	13.115	5
Customer Orientation factors	12.911	6

Table 9. AHP weights rank for all categories in Production department

The following table shows how R&D department employees rank the categories of influencing factors for using the RRI framework in their innovation activities. In difference from the previous ranking, market factors are considered the most important influencing factor by R&D department employees, followed by policy factors.。

Categories	Weights (%)	Rank
Marketing factors	32.549	1
Political factors	31.133	2
Organization structure factors	15.266	3
External factors	9.726	4
Financial factors	7.027	5
Customer Orientation factors	4.3	6

Table 10. AHP weights rank for all categories in R&D department

The following table shows the ranking of the categories of influencing factors for the use of the RRI framework in innovation activities by employees in the Marketing department. Political factors are the most important influencing factors, followed by organizational and marketing factors.

Categories	Weights (%)	Rank
Political factors	26.699	1
Organization structure factors	16.646	2
Financial factors	15.39	3
External factors	14.342	4
Customer Orientation factors	13.656	5
Marketing factors	13.267	6

Table 11. AHP weights rank for all categories in Marketing department

The following table shows the ranking of the categories of influencing factors for the use of the RRI framework in innovation activities by employees in the Marketing department. Political factors play a dominant role in the decision of Logistics department employees to use the RRI framework or not.

Categories	Weights (%)	Rank
Political factors	34.037	1
Organization structure factors	20.076	2
Marketing factors	13.256	3
External factors	13.245	4
Financial factors	11.15	5
Customer Orientation factors	8.236	6

Table 12. AHP weights rank for all categories in Logistics department

The table below shows how employees in the quality management department ranked the factors that influence the use of a responsible research and innovation framework. In contrast to all previous results, employees in the quality management department tend to give more consideration to customer-oriented factors.

Categories	Weights (%)	Rank
Customer Orientation factors	25.67	1
Political factors	19.694	2
Marketing factors	15.142	3
Organization structure factors	14.271	4
External factors	13.69	5
Financial factors	11.532	6

Table 13. AHP weights rank for all categories in Quality Management department

The following table illustrates the attitudes of the Operations department towards the use of the RRI framework in new activities in the business. Of these, the Operations department is most concerned with factors related to policy and organizational structure.

Categories	Weights (%)	Rank
Political factors	26.609	1
Organization structure factors	16.949	2
Marketing factors	15.516	3
External factors	15.216	4
Financial factors	13.75	5
Customer Orientation factors	11.96	6

Table 14. AHP weights rank for all categories in Operations department

Figure 9 shows the results of the AHP analysis for all departments for different categories of influencing factors. We can conclude from this that most of the other departments, except the R&D and Quality management department, consider policy factors as the most important influencing factor affecting the use of the RRI framework in innovation activities.

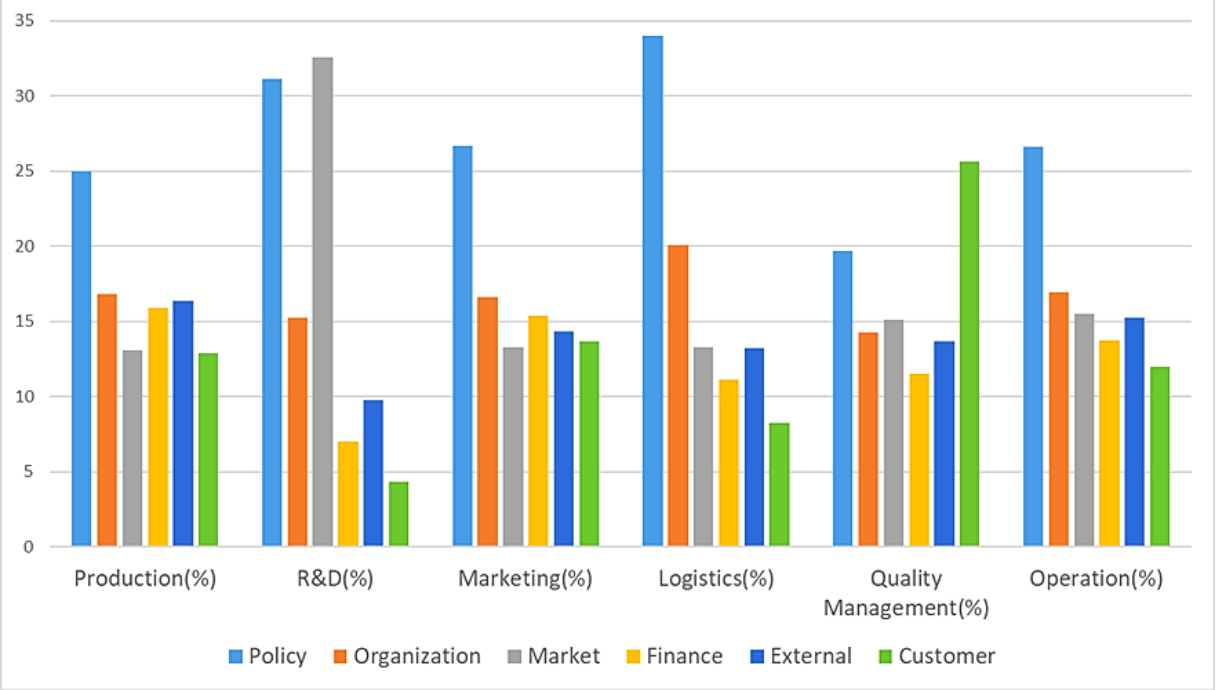

Figure 9. AHP weights rank for all categories within all department

For the Logistics department, it seems that policy-type factors are far more influential in deciding whether to use the RRI framework to manage innovation than other de-

partments. The quality management department also pays much more attention to customer-related influences than other departments.

4.5 Weight analysis

Entropy is a concept in information theory, which is a measure of uncertainty. The greater the amount of information, the smaller the uncertainty, the lower the entropy; the smaller the amount of information, the greater the uncertainty, the greater the entropy. According to the definition of information entropy, the entropy value can be used to judge the dispersion degree of a certain indicator, and the smaller the entropy value, the greater the dispersion degree of the indicator, and the greater the influence (i.e., weight) of the indicator on the comprehensive evaluation.

The figure below shows the importance ranking of the indicators in the form of a histogram (descending order). The higher the importance, the more the indicator contributes to the scale, i.e. the item corresponding to the indicator is the more important influencing factor. Details about the calculation of the weight analysis can be found in the appendix.

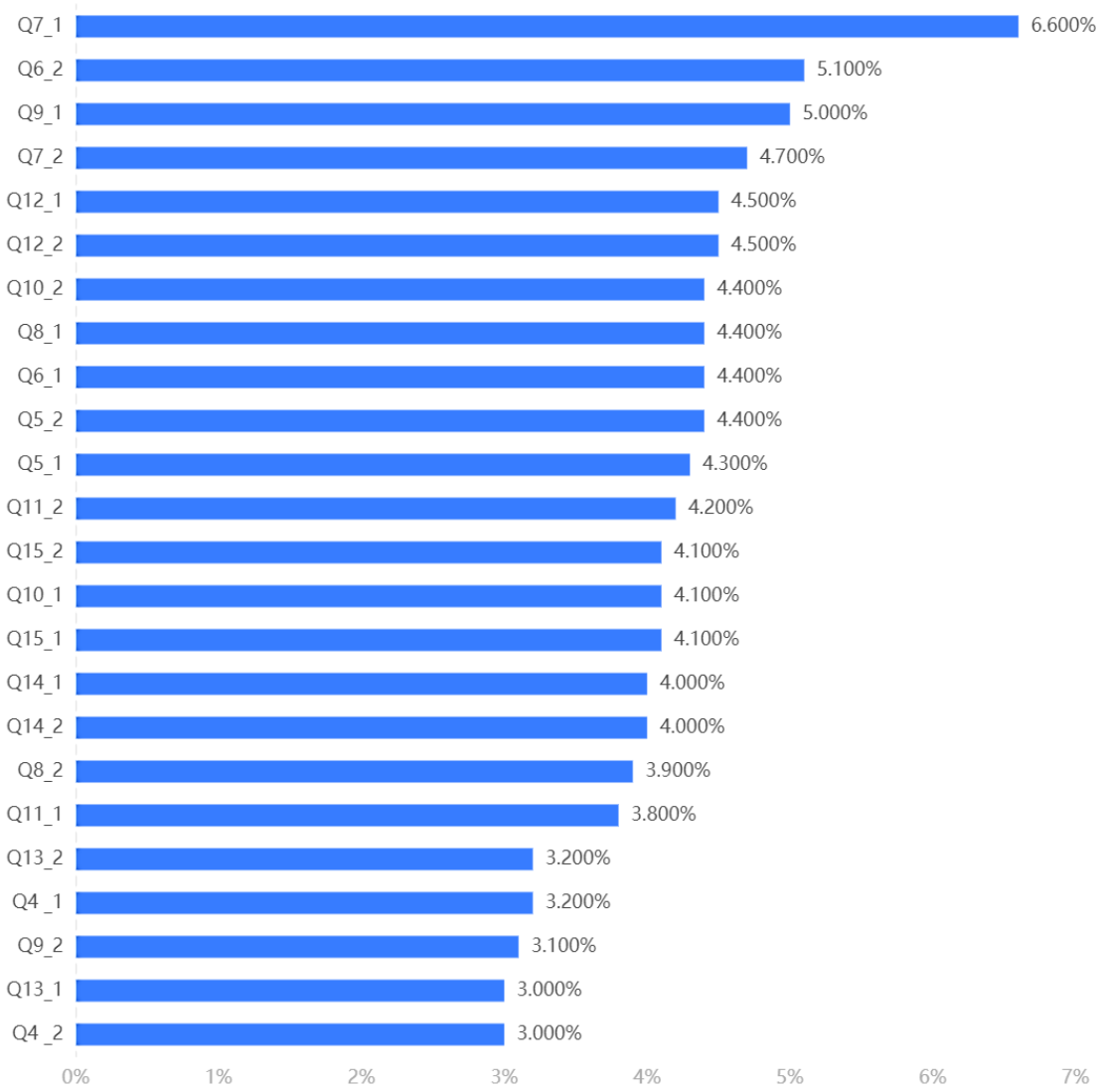

Figure 10. Indicator importance histogram

5. Discussions

In this chapter, we discuss the results obtained from the study in relation to the research questions. We first discuss the factors that influence the implementation of the RRI concept in the context of Chinese SMEs, and then we determine the order of importance of the influencing factors based on the results of the data analysis in the previous chapter and make recommendations for the implementation of the RRI framework in the context of Chinese SMEs in healthcare.

5.1 Research Findings

In Chapter 1.2 of this thesis, we identified the research questions and research sub questions. In this section, we will answer each of these questions.

Sub question 1: What is the current situation of RRI and similar innovation management concepts in Chinese healthcare SMEs?

Answers: At present, the development of RRI concept in China is still in the stage of concept dissemination. The research and discussion of RRI concept have received widespread attention in the academic community, but there are not many studies on RRI practice. Similar to other emerging economies or East Asian countries, the implementation of RRI in China currently lacks policy and institutional support, such as communication channels and regulatory systems among different stakeholders. However, the RRI framework is not contradictory to China's political and policy background. There are many political concepts that are highly consistent with the core of RRI, such as "green development", "construction of ecological civilization", "sustainable innovation", and "mass entrepreneurship and innovation initiative", which have been fully or partially adopted by China's governance system. Therefore, we can conclude that the dissemination and implementation of the RRI concept in China have prospects, despite the current lack of policy and institutional support.

Sub question 2: What are the factors that influence the presence of such innovation management concepts in Chinese healthcare SMEs?

Answer: Through literature review, six categories of influencing factors for the research and innovation framework suitable for implementation by leaders in small and medium-sized enterprises (SMEs) in the Chinese context were identified: financial, policy, marketing, customer orientation, organizational structure, and external factors.

In section 2.4, each category is further subdivided to provide detailed descriptions of the specific influencing factors. For example, "tax reductions and innovation subsidies for implementing RRI framework," "ideological resistance to the concept of RRI," and "ambiguous innovation regulatory laws and unclear regulatory priorities in different regions" are included as policy factors. Two opposing factors, "RRI implementation brings more profits to innovation activities" and "RRI implementation brings more expenses to innovation activities," have been categorized as financial factors.

Sub question 3: Which of these factors are identified as drivers and which are considered as barriers?

Answer: Based on the results of the literature, we first classified the known influences into drivers and barriers. A total of 24 factors were selected for the questionnaire design, of which 12 were drivers and 12 were barriers. a detailed breakdown of the factors can be found in Section 3.2.2. After the questionnaire survey and AHP data analysis we got the top 5 influencing factors as follows:

1. Barrier (17.128%): Unclear regulatory focus and evolving regulatory regimes in different geographic contexts.
2. Barrier (9.051%): Conflict between company culture and ethos and RRI concepts.
3. Driver (4.281%): Government incorporates RRI framework into regulation of medical manufacturing companies.
4. Barrier (4.116%): Implementing an RRI will consume higher innovation costs.
5. Barrier (4.056%): Long-established (and sometimes conservative) governance structures in SMEs prevent structural changes in the company.

We also note that the sum of the weight values of all the hindering factors equals 59.72%, which is much more than the sum of the advancing factors of 40.28%. This shows that when examining the importance ranking of single influencing factors, the negative effect of hindering factors on the decision of whether to use the RRI framework for innovation management is greater than the positive effect of advancing factors. After ranking the importance of all categories of influencing factors, we conclude that the political category of influencing factors has the highest weight (27.367%), i.e., political factors are the most important category of influencing factors that influence decision makers to use RRI in their innovation activities. The other categories in order of weight are Organization structure factors (17.961%), Financial factors (14.638%), External factors (14.320%), Marketing factors (13.133%), and Customer Orientation factors (12.581%).

Taking all of the above answers into consideration, we can now address the main research question.

Main research question: What are the drivers and barriers to implementing Responsible Innovation and Research (RRI) systems in Chinese small and medium-sized healthcare companies?

Answer: After the literature review and case study, in this case, we divided the factors influencing the use of RRI for innovation management in Chinese SMEs into six categories, totaling 24 factors. After AHP analysis, we derived the weight of each influencing factor in the decision-making process, and the gray part of the following table indicates the top 5 influencing factors in the categories of driving factors and hindering factors.

Factor category	Drivers	Weight (%)	Barriers	Weight (%)
Financial factors	Implementing RRI will bring in more innovative revenue	3.983	Implementing an RRI will consume higher innovation costs.	4.116
	Implementing RRI will reduce the subsequent governance costs	2.735	cause more governance expenses	3.443
Political factors	The government has financial or tax subsidies for companies that innovate using the RRI framework	2.797	Government's resistance to the RRI concept based on ideology	2.380
	Government incorporates RRI framework into regulation of medical manufacturing companies	4.281	Unclear regulatory focus and evolving regulatory regimes in different geographic contexts	17.128
Marketing factors	The market recognizes the expected future economic value of RRI.	3.218	Competitors with free-rider attitude exist in the market	2.957
	Competitive advantages	2.898	The lack of awareness among market participants of the value that RRIs bring.	3.730
Customer Orientation factors	Customer recognition of the RRI framework	3.548	Customers do not understand RRI concepts and values	2.575
Organization structure factors	Managers and employees understand and can practice RRI concepts	3.305	Lack of knowledge about RRI and the implementation methods.	3.305
	Employees inherit the organization's understanding of responsibility	2.673	Conflict between company culture and ethos and RRI concepts	9.051

	Good communication channels about innovation activities exist within the organization	3.854	Long-established (and sometimes conservative) governance structures in SMEs prevent structural changes in the company.	4.056
External factors	Increased company reputation and visibility among potential partners through RRI implementation	3.572	Lack of knowledge about RRI within the collaborative network	3.545
	Partner interest and support for the RRI concept	3.469	Potential for partners to advocate for their own interests and influence decision making and resistance to RRI	3.380

Table 15. Influencing factors and AHP weights

The answers to the research questions were obtained through literature research and a single case study. In the following sections, we will discuss and explain the generality and applicability of the results of this single case study, followed by a discussion of the theoretical implications of this research question.

5.2 Theoretical Implications

5.2.1 Generalizability and Applicability

Since this study is an interpretive single case study of Chinese SMEs in healthcare, it is necessary to discuss the representativeness of the results of this study, the accuracy of the data analysis, and to analyze the limitations and generalizability of the case study to ensure that the conclusions obtained are of practical application.

Based on the description of the case company in Section 3.2.2, we can understand that this study was conducted among SMEs in the healthcare sector in China. Compared to other companies in this context, the case study company also has several characteristics:

1. Gaush Teleon manufactures high-value-added consumables in the medical device sector. Influenced by China's centralized public healthcare procurement policy, domestic medical device brands such as Gaush Teleon are beginning to be sought after by the Chinese domestic market.

2. Gaush Teleon's Intraocular lens products have high technological barriers and requirements. For this reason, Gaush Teleon employs more than 20% of its workforce in research and development and related technological innovation activities and spends a

significant amount of money each year on product development. Gaush Teleon also actively seeks technical cooperation with outside organizations and shares some of its research and development results with the Teleon brand in the Netherlands.

3. Gaush Teleon is located in a high-tech industrial park in Shenzhen, China, and is recognized as a Shenzhen High-tech Enterprise. High-tech enterprises are entitled to preferential corporate income tax rates and other tax benefits. In Shenzhen, for example, high-tech enterprises can receive incentives of up to RMB 1.8 million and enjoy talent allowances and R&D subsidies. Shenzhen High-tech Industrial Park also facilitates the needs of high-tech enterprises for industrial land and other needs.

From this we can see that the company conducting this case study is a medical device manufacturer of high-tech, high value-added products and is strongly supported by regional innovation policies. Although the implementation of China's current policy of centralized public healthcare procurement has given a boost to the development of local Chinese medical device manufacturers as more and more public hospitals tend to purchase domestic brands. However, small and medium-sized enterprises in China's healthcare sector are limited by their technological research and development capabilities, and the manufacturing share of high-net-worth products is small. Given the three points of product, technology size and regional constraints, the following are the characteristics of Chinese SMEs in healthcare that can be represented in this case study:

1. Produce high technology and high value-added products
2. Have a high R&D investment and R&D staff ratio (at least 20% of all employees).
3. Located in the Guangdong-Hong Kong-Macao Bay area (Shenzhen for example), the Bohai Sea region and the Yangtze River Delta region of high-tech industrial parks. These three regions have similar innovation incentives and government subsidies for small and medium-sized enterprises with high technology and the regional regulatory or policy resistance is similar. Moreover, these three regions have concentrated research institutions and universities, which facilitate technology exchange between internal and external enterprises.

Small and medium-sized healthcare companies that meet conditions 1 and 2 can be considered as having similar internal drive for innovation and organizational structure as this study case. SMEs meeting condition 3 can be considered as having a similar policy and market context as this case. Therefore, we conclude that the results obtained from this case study, i.e., the drivers and barriers to the implementation of the RRI framework in Chinese small and medium-sized healthcare companies, are gener-

alizable and applicable when the study population meets the three conditions mentioned above and wants to use the RRI framework within the organization.

5.2.2 The state of RRI diffusion within the enterprise

During the study, we first explored the dissemination of RRI concepts within the firm. Among other things, we first focused on identifying the level of awareness of similar concepts of RRI among the employees in the company. Thus, concepts such as "sustainable innovation" and "green innovation" (Gao, 2019) were selected and included in the survey after literature research. After analyzing the data, approximately 50% of the employees chose to agree or strongly agree with the description "I understand the concepts of sustainable innovation" for question Q2_1 on the level of awareness. This survey suggests that concepts similar to RRI are better communicated within the companies involved in the case study. Some scholars (Macnaghten et al., 2014) have expressed concerns about the cultural and values colonization associated with the spread of RRI concepts, but based on current research in the literature and related policies, the current political context and policies in China do not express negative resistance to RRI, and Chinese policy planning has gradually incorporated conceptual political advocacy such as "sustainable development" into The Chinese policy planning has gradually incorporated conceptual political advocacy such as "sustainable development" into actual governance. Given that the core of the RRI concept is similar to the concepts of "sustainable development," "green innovation," and "innovation for all," it can be concluded that there should not be significant barriers to the content dissemination of the RRI concept in China. The RRI concept should not be a major barrier to content dissemination in China.

We found that although the RRI concept is considered academically similar to popular Chinese innovation concepts such as "sustainability strategy", there is no agreement among the employees interviewed within the company. Fifty percent of the employees disagreed with the similarity between the concepts, either by "disagreeing" or "not agreeing at all". This may be because, on the one hand, the questionnaire designed for this study does not explain the concept of RRI well enough for respondents to fully understand the concepts of responsible research and innovation in a short period; on the other hand, respondents may believe that, as a concept derived from a highly developed society, the core of RRI may not match the current concept of innovation management applicable to Chinese society, due to the difference in the level of development and understanding between the two societies. This perceived mindset may be widespread in traditional industrial or domestic industries, but may not be present in

emerging industries and in firms requiring large-scale international innovation collaboration (Xiao, 2017).

After linear regression analysis we found that the respondents' knowledge of concepts similar to RRI influenced the respondents' willingness to use RRI concepts in innovation activities to the greatest extent compared to other relevant terms, which is consistent with a priori experience and relevant studies. It is worth further exploring that the consistency of respondents' knowledge of RRI concepts and similar concepts tends to be negatively correlated with respondents' willingness to use RRI concepts in innovation activities. The reason (Liu, 2022) for this phenomenon is not only the bias in the questionnaire design and the corresponding process, but also the fact that people who agree that the RRI concept is similar to the concept of "sustainable development" are more likely to stick to the original innovation tool than to change to the RRI framework.

5.2.3 Factors influencing the implementation of RRI

In our previous study, we summarized 24 factors that influence the implementation of RRI concepts within companies and classified them into six categories. Through AHP analysis, the political category was the most important influencing factor on RRI implementation with a weight of 26.961%. the policy impediments corresponding to Q7_2 far exceeded the other influencing factors with a weight of 17.128%. This illustrates that respondents would be more likely to reject or abandon the implementation of the RRI framework in their innovation activities because of government policy opposition. This finding is consistent with the current context of government-oriented market and innovation activities in China. This is closely followed by organizational structure factors and financial factors.

Eunok Ko (Ko,2020) focused the main body of the study on emerging technologies such as autonomous driving and artificial intelligence, and consulted with experts and scholars from different fields and organizations, arguing that the Korean example reflects the current situation of RRI implementation in countries with high R&D intensity but low societal technology linkages. Unlike similar studies conducted in Korea, the implementation of the RRI framework in Chinese SMEs in the healthcare sector is not primarily economically sensitive. As emerging economies in the same East Asian context, there are many similarities in the process and status of emerging technology development in China and Korea. The reasons for the different findings are attributed to the following three points:

1. The different types of firms that the study focuses on lead to different decision processes corresponding to the implementation of the RRI framework within firms. Differences in industry and firm size may lead to different types or models of innovation within firms.
2. Ko's study involved large multinational organizations, which may have established complete innovation management models and communication channels within these organizations and may have a better understanding of RRI concepts within large multinational organizations.
3. Large organizations have longer innovation cost-benefit feedback chains and longer decision-making processes about innovation than the small and medium-sized healthcare companies that are the counterparts of this study.

Ko's study looked at emerging technology firms in areas such as autonomous driving. The regulatory systems and stakeholder interaction patterns of these emerging technologies are not the same compared to the healthcare industry covered in this study. For example, the AI industry relies heavily on technological advances to drive industry growth, and in contrast to the healthcare industry, the regulatory system and legal system for AI has evolved along with the technology. Technological innovation in the healthcare industry can be more constrained by the existing regulatory system. Their study focused on scholars with strong academic and industrial backgrounds, mainly experts with more than 10 years of experience or PhD holders. The study did not screen respondents for academic background, work experience, or their role in the company. For participants at different points in the decision chain, decision executors and decision makers may have different understandings of whether to implement the RR framework or under what circumstances to shift to the RRI framework.

We ranked each influencing factor separately using AHP and weight analysis, and there were some differences in the results of the analysis. In the weight analysis using the entropy weighting method, the item with the largest weight for the decision of whether to use the RRI framework is Q7_1. The result obtained by the AHP analysis is Q7_1. Although the results obtained by the two methods are not identical, the result is considered acceptable based on the policy-oriented market and political context in China.

Due to the limitations of using the entropy method with very small variations in indicator values, and the possibility of ignoring the subjective will of policy makers as an objective empowerment method (Zhu, 2020). Therefore, the data obtained from the 5-point Likert scale used in this study may be subject to large errors using the entropy

weighting method for weighting analysis. Therefore, only the entropy weighting method was used in this study as a test of the questionnaire design.

5.3 Suggestions for Chinese Healthcare SMEs' RRI implementation

As previously stated, the results obtained from this case study are that firms implementing the RRI framework to manage innovation activities are policy-sensitive, with other influencing factors ranked in order of organizational structure, financial factors, external factors, market factors and customer orientation factors. If Gaush Teleon has the intention to introduce RRI frameworks and tools into its future innovation management efforts for purposes such as improving the efficiency of innovation efforts and taking social responsibility, it can start with the following points.

The findings demonstrate the dependence of Chinese SMEs on innovation policies and regulations, especially in the healthcare sector. Unlike the EU (Owen, 2013), the implementation of the RRI framework in China does not necessarily imply the creation of a new policy system, but the existing policies are not sufficient to give firms sufficient incentive to shift to the use of the RRI framework for innovation management. This problem appears to be insurmountable until the Chinese government widely integrates the RRI concept into policy creation and practice. But this does not mean that firms will be helpless in the face of entrenched policies or unable to respond to a changing policy and regulatory system. On the contrary, keeping up with current changes and integrating deeply with social life will help companies incorporate the ethical, environmental, and gender implications of new technologies into their innovation management processes in an adaptive mode. For example, Gaush Teleon's parent company recognized the trend of the Chinese government's support for domestic medical device brands in the public healthcare procurement process after the government enacted centralized healthcare procurement terms. They then shifted their business strategy from primarily representing and selling overseas brands to developing their own domestic brands in order to improve their competitiveness in the domestic market. In the process of corporate strategy shift and self-owned brand development, this study suggests that Gaush Teleon could incorporate more of the current existing policies related to RRI in China into the daily business decision making process, such as the female childbirth subsidy policy and the childcare subsidy policy related to gender equality issues.

In terms of improving the organizational structure to implement the RRI framework, building good communication channels and innovation process support departments within the company is something that Gaush Teleon could improve to accommodate the RRI process. As a small and medium-sized enterprise, Gaush Teleon has a flat internal organizational structure, which helps to build innovative communication channels. However, the current division of labor within Gaush Teleon has resulted in the feedback of innovation activities within the company being concentrated only between R&D departments or department managers. Therefore, the establishment of an action group to collect, evaluate and give feedback on all innovation ideas could help Teleon to increase the motivation of employees to participate in innovation and innovation management activities.

Establishing in-house innovation management training and actively seeking cooperation with external organizations can help the company implement RRI or its equivalent concepts in terms of both organizational structure and external influences. For example, companies can organize regular employee training on ISO quality management systems and regional health care regulations, actively establish partnerships with external research institutions, and invite customers to participate in internal innovation monitoring. These approaches facilitate the dissemination of RRI and similar concepts within and outside the company. Once a basic understanding of RRI is established, the possibilities of innovation management using RRI, or similar concepts are greatly enhanced.

During this case study, it was also found that, given the same category of factors, barriers' negative impact on using the RRI framework in hospitals was stronger than the positive impact of drivers. For example, if "using RRI will increase innovation costs" and "using RRI will increase innovation revenue" occurred simultaneously, respondents were more likely to be influenced by the impediments and chose not to use the RRI framework for innovation management. The implication for internal implementers is that the process of implementing an RRI framework can focus on removing impediments rather than adding enablers. For instance, if a company wants to be socially responsible and enhance its intra-industry reputation by adopting the RRI framework in its innovation activities, then in promoting RRI from the top down, enablers can do more to promote the negative impact of not using the RRI framework on the company's reputation rather than just touting the role of RRI in creating a good corporate image.

According to our discussion in 5.2.1, SMEs with similar conditions and willingness to use the RRI framework as Gaush Teleon can adopt a similar approach to help their companies implement the RRI framework. Firms that do not fully meet the three conditions discussed in 5.2.1 can selectively draw on the recommendations mentioned in this study. For example, establishing an innovation management team in the enterprise to improve communication efficiency and motivation.

5.4 Limitations and Future Research Directions

5.4.1 Limitations

After analysis and discussion, the limitations of this study are as follows:

1. The single case study approach makes it difficult to scale up the results of this study in terms of commercial implementation. In fact, the company selected for this case study is located in one of the best regions in China in terms of innovation climate and policy support, and the company's development plan supports R&D-oriented large-scale technological innovation. However, in the same policy context, influenced by different regional innovation policies, other small and medium-sized medical companies in charge of adopt research and innovation concepts are likely to encounter more obstacles.

2. The survey participants are not all stakeholders in the internal decision to implement the RRI framework in innovation activities, so the results of the survey reflect to some extent the attitudes of the company community towards the implementation of the RRI framework rather than the decision orientation. Spreading RRI values within a company and trying to implement RRI activities is generally considered a top-down behavior. Considering whether to use the RRI framework to manage innovation activities from scratch is usually a decision made by the firm's management. This is one of the reasons why the results obtained in this study are somewhat different from other studies focused on academics or corporate managers.

5.4.2 Future studies

In the current context of increasing geopolitical gamesmanship, studying a concept of governance that is widely shared by Western societies in the Chinese political context may be seen as "dangerous research" with a tendency toward values migration. But examining the congruence of Chinese society with RRI at different levels and explor-

ing the feasibility of developing the concept of RRI in China should be seen as an opportunity rather than a challenge. It is the entry points for RRI in corporate innovation governance that this study reveals that can help developing countries like China to assess how emerging technologies and societies can evolve together. This study should be considered not only as a case study of RRI implementation in Chinese SMEs, but also as a case study of introducing new innovation management concepts in existing institutions to contribute to solving science and technology governance issues in the context of globalization.

For research on implementing the RRI framework in Chinese SMEs, this case study provides an example of future research in high-technology-oriented firms in innovation-friendly area. Future research can follow or draw on the questionnaire designed in this study to conduct surveys among different types of enterprises in other industries to obtain comprehensive opinions that influence the diffusion of the RRI framework.

In addition to investigating the influencing factors and ordering of enterprises' implementation of RRI, this study also conducted a relationship between the diffusion degree of the RRI concept and the willingness to use it. In this study, the item Q3_3, which corresponds to the question "whether the RRI framework will be used in future innovation work," was considered as the dependent variable, and questions Q2_1 to Q3_2 was listed as independent variables in turn. Through linear regression analysis, Q2_1 and Q2_4 have significant impacts on respondents' willingness to use the RRI framework. (Q2_1 indicates the extent to which the respondent is aware of similar concepts of RRI. Q2_4 indicates the support of the respondent's current organization for RRI similar concepts.）Since the focus of this study is on the analysis of influencing factors, future research can consider exploring the relationship between the diffusion degree of RRI concept and the intention to use it.

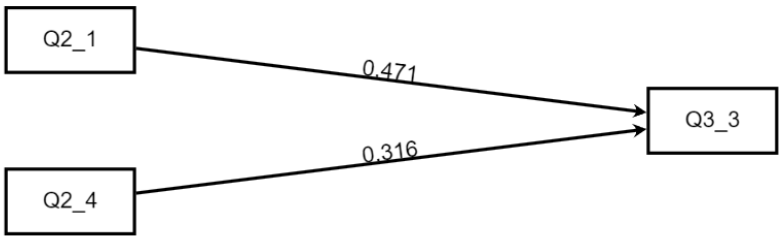

Figure 11. Model Roadmap for Q3_3

5.5 Conclusion

Responsible research and innovation (RRI) is a science policy term proposed by the European Commission to align scientific innovation with societal values. The RRI concept has six dimensions: ethical, societal engagement, gender equality, open access/science and science education, and governance. RRI is a "boundary object," which means that it will be defined differently by scholars with different social backgrounds, values, and interests as it spreads globally. However, there are relatively few studies on RRI implementation in developing countries, especially for SMEs. Most case studies on RRI focus on large or multinational organizations associated with the US and European markets. The lack of institutional support and enabling conditions makes it difficult for SMEs in emerging countries to fulfill their mission of responsible innovation. China, as a typical emerging country, has societal challenges in various areas and a broad distribution of SMEs in different industries. The paper argues that it is worthwhile to explore how the RRI framework can be promoted among SMEs in emerging economies in the Chinese context to address their social governance challenges and to provide lessons for other emerging countries to apply the RRI framework.

The main question of this research is “What are the drivers and barriers to implementing Responsible Innovation and Research (RRI) systems in Chinese small and medium-sized healthcare companies?” In order to answer this question, the author conducted extensive literature research to obtain possible applicable influencing factors, and designed a questionnaire to study the influence and weight of different factors on the decision to use RRI.

Literature research indicates RRI concept in China is still in the stage of concept dissemination, with limited studies on RRI practice due to the lack of policy and institutional support. However, China's political concepts are consistent with RRI, providing prospects for implementation. The literature review identified 24 factors in 6 categories of factors influencing the implementation of RRI in Chinese SMEs, which are financial, policy, marketing, customer orientation, organizational structure, and external factors. A questionnaire survey and AHP data analysis revealed the top 5 influencing factors: regulatory focus, conflict with company culture, government regulation, higher innovation costs, and conservative governance structures. In particular, when examining the importance ranking of individual influencing factors, the negative impact of hindering factors on whether to use the RRI framework for innovation management was greater than the positive impact of advancing factors. After ranking the

importance of all categories of influencing factors, we conclude that the political category of influencing factors has the highest weight, followed by organizational factors. This is consistent with China's current highly centralized social characteristics and ideology, as well as its policy-oriented market landscape.

The companies conducted in this single case study are characterized by products with high technology and high added value, strong intra-firm innovation drivers, and are supported by regional innovation policies. Therefore, the results of this case study are of high relevance for firms with similar backgrounds. This study suggests that similar small and medium-sized enterprises can start from keeping up with policy changes, improving internal innovation management and communication organization, and gradually adapt the concept of RRI within the enterprise.

The study highlights the limitations of using a single-case study approach and the survey participants being non-stakeholders in the internal decision-making process. However, it also presents opportunities for developing countries like China to assess how emerging technologies and societies can evolve together. Future research can follow the questionnaire designed in this study to conduct surveys among different types of enterprises in other industries to obtain comprehensive opinions that influence the diffusion of the RRI framework. The study also indicates the future study of exploring the relationship between the diffusion degree of the RRI concept and the intention to use it in future research.

Reference

Martinuzzi, A., Blok, V., Brem, A., Stahl, B., & Schönherr, N. (2018). Responsible Research and Innovation in Industry—Challenges, Insights and Perspectives. Sustainability 2018, Vol. 10, Page 702, 10(3), 702.

Owen, R. (2019). Responsible Innovation and Responsible Research and Innovation. Handbook on Science and Public Policy, 26–48.

Rip, A. (2016). The clothes of the emperor. An essay on RRI in and around Brussels. Journal of Responsible Innovation, 3(3), 290-304

Hadj, T. B. (2020). Effects of corporate social responsibility towards stakeholders and environmental management on responsible innovation and competitiveness. Journal of Cleaner Production, 250, 119490.

Macnaghten, P., Owen, R., Stilgoe, J., Wynne, B., Azevedo, A., de Campos, A., ... & Velho, L. (2014). Responsible innovation across borders: tensions, paradoxes and possibilities. Journal of Responsible Innovation, 1(2), 191-199.

Park, T., & Kim, J. (2020). Innovation Policy in Asia. Asian Development Bank: Mandaluyong City, Philippines

Yoshino, N., & Taghizadeh-Hesary, F. (2018). The role of SMEs in Asia and their difficulties in accessing finance.

www.chinabaogao.com. (2022). Research Report on the development status of China's small and medium-sized enterprises industry and research report on investment prospects 中国中小企业行业发展现状研究与投资前景调研报告. https://www.chinabaogao.com/baogao/202205/598225.html

Liu, H., & Fong, M. (2010). The Corporate Social Responsibility Orientation of Chinese SMEs. Journal of Law and Governance, 5(3), 27-44.

Wong, P. H. (2016). Responsible innovation for decent nonliberal peoples: a dilemma?. Journal of Responsible Innovation, 3(2), 154-168.

Doezema, T., Ludwig, D., Macnaghten, P., Shelley-Egan, C., & Forsberg, E. M. (2019). Translation, transduction, and transformation: expanding practices of responsibility across borders. Journal of Responsible Innovation, 6(3), 323-331.

Harsanto, B., Kumar, N., Zhan, Y., & Michaelides, R. (2020, June). Responsible Research and Innovation (RRI) in Emerging Economies: a Preliminary Review. In 2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC) (pp. 1-6). IEEE.

Lukovics, M., Flipse, S. M., Udvari, B., & Fisher, E. (2017). Responsible research and innovation in contrasting innovation environments: Socio-Technical Integration Research in Hungary and the Netherlands. Technology in Society, 51, 172–182.

Lukovics, M., Nagy, B., & Buzás, N. (2019). First steps in understanding the economic principles of responsible research and innovation. International Handbook on Responsible Innovation: A Global Resource, 134–149.

Barton, J. R., Román, Á., & Rehner, J. (2019). Responsible research and innovation (RRI) in Chile: from a neostructural productivist imperative to sustainable regional development?. European planning studies, 27(12), 2510-2532.

Yang, P., & Han, B. (2017). Responsible research and innovation and its implications for China. China & World Economy, 25(6), 120-138.

Gao, L., Liao, M., & Zhao, Y. (2019). Exploring complexity, variety and the necessity of RRI in a developing country: the case of China. Journal of Responsible Innovation, 6(3), 368-374.

Stilgoe, J., Owen, R., & Macnaghten, P. (2020). Developing a framework for responsible innovation*. The Ethics of Nanotechnology, Geoengineering and Clean Energy, 347–359.

Wittrock, C., Forsberg, E. M., Pols, A., Macnaghten, P., & Ludwig, D. (2021). Organisational Drivers for RRI. SpringerBriefs in Ethics, 23–36.

Molen, F., Consoli, L., Ludwig, F., Pols, A., & Macnaghten, P. (2018). Responsible Research and Innovation in Practice: Report from national case study, The Netherlands. Deliverable 9.1. Work Package 9.

Jamali, D., & Karam, C. (2018). Corporate Social Responsibility in Developing Countries as an Emerging Field of Study. International Journal of Management Reviews, 20(1), 32–61.

Gonzales-Gemio, C., Cruz-Cázares, C., & Parmentier, M. J. (2020). Responsible innovation in SMEs: A systematic literature review for a conceptual model. Sustainability, 12(24), 10232.

Gurzawska, A., Mäkinen, M., & Brey, P. (2017). Implementation of Responsible Research and Innovation (RRI) practices in industry: Providing the right incentives. Sustainability, 9(10), 1759.

European Commission. Growth. Available online: http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en (accessed on 30th May 2023).

Tam, F. Y., Moon, K. L., Ng, S. F., & Hui, C. L. (2007). Production sourcing strategies and buyer-supplier relationships: A study of the differences between small and large enterprises in the Hong Kong clothing industry. Journal of Fashion Marketing and Management: An International Journal.

Chatfield, K., Iatridis, K., Stahl, B. C., & Paspallis, N. (2017). Innovating responsibly in ICT for ageing: Drivers, obstacles and implementation. Sustainability, 9(6), 971.

Van de Poel, I., Asveld, L., Flipse, S., Klaassen, P., Scholten, V., & Yaghmaei, E. (2017). Company strategies for responsible research and innovation (RRI): A conceptual model. Sustainability, 9(11), 2045.

Auer, A., & Jarmai, K. (2017). Implementing responsible research and innovation practices in SMEs: Insights into drivers and barriers from the Austrian medical device sector. Sustainability, 10(1), 17.

Ko, E., Yoon, J., & Kim, Y. (2020). Why do newly industrialized economies deter to adopt responsible research and innovation?: the case of emerging technologies in Korea. Journal of Responsible Innovation, 7(3), 620-645.

Yin, R. K. (1994). Discovering the future of the case study. Method in evaluation research. Evaluation practice, 15(3), 283-290.

Von Schomberg, R. (2013). A vision of responsible research and innovation. Responsible innovation: Managing the responsible emergence of science and innovation in society, 51-74.

Stake, R. E. (1994). Case study: Composition and performance. Bulletin of the Council for Research in Music Education, 31-44.

Yin, R. K. (1994;2003;2009). Case study research: Design and methods. Thousand Oaks, CA: Sage.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. Academy of management journal, 50(1), 25-32.

Small and medium-sized enterprise classification standard regulations. (2011, June 18). Government Website of the People's Republic of China. Retrieved March 29, 2023, from http://www.gov.cn/gongbao/content/2012/content_2041870.htm

Barua, A. (2013). Methods for decision-making in survey questionnaires based on Likert scale. Journal of Asian Scientific Research, 3(1), 35-38.

Evans, J. R., & Mathur, A. (2005). The value of online surveys. Internet research, 15(2), 195-219.

León-Mantero, C., Casas-Rosal, J. C., Pedrosa-Jesús, C., & Maz-Machado, A. (2020). Measuring attitude towards mathematics using Likert scale surveys: The weighted average. PLoS One, 15(10), e0239626.

Saaty, T. L. (1990). How to make a decision: the analytic hierarchy process. European journal of operational research, 48(1), 9-26.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. International journal of services sciences, 1(1), 83-98.

Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. European Journal of operational research, 169(1), 1-29.

Qayyum, M., Yuyuan, Y., Bhatti, U. A., & Shijie, L. (2023). Evaluation of the one belt and one road (OBOR) in economic development and suggestions analysis based on SWOT analysis with weighted AHP and entropy methods. Multimedia Tools and Applications, 82(10), 14985-15006.

Dawes, R. M., & Corrigan, B. (1974). Linear models in decision making. Psychological bulletin, 81(2), 95.

Xiao, S. (2017). Dean of Tencent Research: Rule first on AI. 腾讯研究院院长司晓: AI 要规则先行) Accessed January, 20, 2018.

Liu, Z., Rao, P., Wang, X., & Yue, R. (2022). Peer Innovation Tone and Corporate Innovation Adjustments: Evidence from China. Asia-Pacific Journal of Financial Studies, 51(6), 945-980.

Zhu, Y., Tian, D., & Yan, F. (2020). Effectiveness of entropy weight method in decision-making. Mathematical Problems in Engineering, 2020, 1-5.

Owen, R., Bessant, J. R., & Heintz, M. (Eds.). (2013). Responsible innovation: managing the responsible emergence of science and innovation in society. John Wiley & Sons.

Yan, P., & Mitcham, C. (2022). Taking Responsible Innovation to China: The Dalian Port Development Case. Science and Engineering Ethics, 28(1), 4.

Zhang, Y. (2021). Greasing dirty machines: Evidence of pollution-driven bribery in China. Journal of Business Ethics, 170(1), 53-74.

Ma, Z., & Bu, M. (2021). A new research horizon for mass entrepreneurship policy and Chinese firms' CSR: Introduction to the thematic symposium. Journal of Business Ethics, 169, 603-607.

Fu, P., Sarpong, D., & Meissner, D. (2021). Recalibrating, reconfiguring, and appropriating innovation: a semantic network analysis of China's mass innovation and mass entrepreneurship (MIME) initiatives. The Journal of Technology Transfer, 1-18.

Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. Evidence-based nursing, 18(3), 66-67.

Appendix I Questionnaire

1. The department I am working in is____

A. Production

B. R&D

C. Operation (HR, Finance etc.)

D. Quality Management

E. Logistics

F. Sales

G. Market and Procurement

2. Please choose one of the following options that best describes your current understanding about each statement.

Sub questions	Totally disagree	Disagree	Not sure	Agree	Totally agree
I've heard of concepts like "green development", "construction of ecological civilization", "sustainable innovation", and "mass entrepreneurship and innovation initiative".					
My work involves the use of innovation concepts such as "green development", "construction of ecological civilization", "sustainable innovation", and "mass entrepreneurship and innovation initiative".					
I will have expertise and experience in implementing the concepts mentioned in the previous question.					
I know that the company I work for has a dedicated department or group responsible for					

executing the concepts such as "green development", "construction of ecological civilization", "sustainable innovation", and "mass entrepreneurship and innovation initiative".					

As a concept emerging in Europe, responsible research and innovation (RRI) is a term used to describe scientific research and technology development processes that take into account potential impacts on the environment and society. RRI advocates for high ethical standards for research, ensuring gender equality, engaging communities affected by innovation in the innovation process, and ensuring that they have the knowledge needed to understand the impact of innovation by promoting science education and open access. By now, you may have some basic ideas about RRI.

3. Please choose one of the following options that best describes your current understanding about each statement.

Sub questions	Totally disagree	Disagree	Not sure	Agree	Totally agree
I see similarities between the concepts mentioned in the previous question and the concept of responsible innovation and research (RRI).					
I think I have (partially) used the RRI framework for innovation in my current work, whether I had heard of the RRI concept before or not.					
I think I will use the RRI framework in my innovation work in the future, whether I now understand the RRI concept or not.					

4. If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
High innovation cost					
High innovation revenue					

5. RRI may reduce the most governance costs for innovation activities, such as reducing taxes related to environmental protection. RRI may incur the greatest governance cost, such as increasing additional system certification fees.

If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
Higher governance cost					
Lower governance cost					

6. If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
High government subsidies					
No political support					

7. If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
Chaotic public regulatory framework and communication channels					
Reasonable public regulatory frameworks and communication channels					

8. If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
No additional market recognition					
High market recognition					

9. If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
No competitive advantage					
High competitive advantage					

10. If I use RRI in my innovation work, it will bring ....

Options	Totally	Disagree	Not	Agree	Totally

	disagree		sure		agree
No help in attracting more customers					
Brings more customers					

11. I will use RRI in my innovation work when there are...

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
No relevant talent support					
Sufficient relevant talents to support					

12. I will use RRI in my innovation work when there are...

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
Contradictory company values					
Identical company values					

13. I will use RRI in my innovation work when there are...

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
Worse communication and training channels					
Better communication and training channels					

14. If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
No more influence within industry					
More industry reputation and influence					

15. If I use RRI in my innovation work, it will bring ....

Options	Totally disagree	Disagree	Not sure	Agree	Totally agree
No more influence within business partners					
More business partners and collaborations					

Appendix II

A. Validity Test

KMO test and Bartlett's test		
KMO		0.888
Bartlett test for sphericity	X^2	3125.85
	df	465
	P	0.000***

Table . Validity Analysis Result of the Questionnaire

The above table shows the results of the KMO test and Bartlett's spherical test, which are used to analyze whether factor analysis can be performed.

- If the KMO test is passed (KMO>0.6), it indicates that there is a correlation between the question variables and it meets the requirements of factor analysis.

- If it passes Bartlett's test: p<0.05, it is significant, then factor analysis can be performed.

The results of the KMO test showed that the value of KMO was 0.888, while the results of the Bartlett's spherical test showed that the significance p-value was 0.000***, presenting significance at the level, rejecting the original hypothesis that there is a correlation between the variables and the factor analysis is valid, and the suitability of conducting factor analysis.

B. Reliability Test

Cronbach's α coefficient	Standardized Cronbach's α coefficient	Items	Samples
0.856	0.865	31	179

The above table shows the results of the Cronbach's alpha coefficient of the model, including the value of Cronbach's alpha coefficient, the value of standardized Cronbach's alpha coefficient, the number of items, and the sample size, which are used to measure the confidence quality level of the data.

- Cronbach's alpha coefficient: To evaluate whether the collected data are true and reliable, and to check whether the questions are unreasonable or nonsense answers.

- Standardized Cronbach's alpha coefficient value: Standardization is used to transform scales with different scores into a uniform measure, and can be used when the scales are inconsistent, such as when scales with 5 and 10 scores need to be standardized for analysis together.

- Number of items: the number of variables involved in the calculation of reliability analysis.

The Cronbach's α coefficient value of the model is 0.856, indicating that the reliability of the questionnaire is good.

	Mean after removing items	Variance after removing terms	The correlation of the deleted item to the population after the item was deleted	Cronbach's αafter removing terms
Q2_1	96.743	312.248	0.397	0.852
Q2_2	96.838	310.047	0.394	0.852
Q2_3	96.872	316.113	0.265	0.855
Q2_4	96.872	311.371	0.362	0.852
Q3_1	96.911	319.644	0.182	0.857
Q3_2	96.76	314.363	0.311	0.854

	Mean after removing items	Variance after removing terms	The correlation of the deleted item to the population after the item was deleted	Cronbach's αafter removing terms
Q3_3	96.955	309.02	0.401	0.851
Q4 _1	97.721	306.764	0.541	0.848 (need to be checked)
Q4 _2	96.313	307.306	0.553	0.848
Q5_1	97.503	312.42	0.372	0.852 (need to be checked)
Q5_2	96.43	309.651	0.423	0.851
Q6_1	97.514	313.802	0.339	0.853
Q6_2	96.615	308.429	0.447	0.85
Q7_1	96.285	288.924	0.382	0.857 (need to be checked)
Q7_2	94.039	292.015	0.397	0.854
Q8_1	97.587	308.671	0.454	0.85
Q8_2	96.514	314.262	0.344	0.853
Q9_1	97.531	311.655	0.363	0.852
Q9_2	96.38	314.754	0.345	0.853
Q10_1	97.642	312.467	0.371	0.852
Q10_2	96.581	313.031	0.368	0.852
Q11_1	97.603	309.949	0.451	0.85
Q11_2	96.453	310.946	0.406	0.851
Q12_1	96.564	309.955	0.418	0.851
Q12_2	95.458	313.227	0.344	0.853
Q13_1	97.698	312.92	0.403	0.852
Q13_2	96.324	311.76	0.411	0.851
Q14_1	97.648	316.589	0.275	0.855 (need to be checked)

	Mean after removing items	Variance after removing terms	The correlation of the deleted item to the population after the item was deleted	Cronbach's αafter removing terms
Q14_2	96.413	311.558	0.391	0.852
Q15_1	97.631	312.56	0.372	0.852
Q15_2	96.441	310.259	0.417	0.851

The above table shows the results of the item total statistics of the model, and is used to assist in determining whether the scale questions should be revised by comparing the correlation and Cronbach's alpha coefficient before and after the deletion of a question through the control variable method.

Generally, we first determine whether the overall correlation is less than 0.3 after the deletion of a question item, and then determine whether the alpha coefficient is greater than the original coefficient after the deletion of a question item. If none of them is satisfied, the question item can be considered to be in good condition, otherwise it is necessary to check.

- Mean value after removing the item: This column is the new mean of the sum of the remaining items in the subscale after the variable of the item is removed.
- Variance after deleted item: This column is the new variance of the sum of the rest of the question items in the subscale after the variable of the question item is deleted.
- Correlation between the deleted item and the total after deleting the item: The data in this column is the correlation coefficient of the product difference between the question and the rest of the items. The higher this coefficient is, the higher the internal consistency between the changed item and the rest of the items, which can generally be used as one of the indicators for the retention or deletion of the item.

This column shows the change in Cronbach's alpha coefficient of the components of the remaining question variables after the deletion of the question item. In general, the more items there are, the higher the Cronbach's alpha coefficient will be. A decrease in the new alpha coefficient after the deletion of a question indicates that the question is more consistent with the rest of the items, while an increase in the alpha coefficient indicates that the question is less consistent with the rest of the items.

D. Linear regression analysis result

Linear regression analysis results n=179									
	unstandardized coefficient		standardized coefficient	t	P	VIF	R^2	Adjusted R^2	F
	B	Standard Error	Beta						
constant	0.107	0.236	-	0.452	0.652	-	0.541	0.525	F=33.725 P=0.000***
Q2_1	0.467	0.121	0.402	3.859	0.000***	4.053			
Q2_2	0.102	0.073	0.099	1.403	0.162	1.85			
Q2_3	0.1	0.077	0.095	1.303	0.194	2.006			
Q2_4	0.256	0.081	0.25	3.167	0.002***	2.33			
Q3_1	-0.022	0.076	-0.021	-0.289	0.773	2.062			
Q3_2	0.016	0.071	0.015	0.22	0.826	1.675			

E. AHP analysis results

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Q4 _1	1.076	3.983	24	0
Q4 _2	1.112	4.116		
Q5_1	0.739	2.735		
Q5_2	0.93	3.443		
Q6_1	0.756	2.797		
Q6_2	0.643	2.38		
Q7_1	1.157	4.281		
Q7_2	4.629	17.128		
Q8_1	0.87	3.218		
Q8_2	0.799	2.957		
Q9_1	0.783	2.898		
Q9_2	1.008	3.73		
Q10_1	0.959	3.548		
Q10_2	0.696	2.575		
Q11_1	0.893	3.305		
Q11_2	0.893	3.305		
Q12_1	0.722	2.673		
Q12_2	2.446	9.051		
Q13_1	1.041	3.854		
Q13_2	1.096	4.056		
Q14_1	0.965	3.572		
Q14_2	0.958	3.545		
Q15_1	0.937	3.469		
Q15_2	0.913	3.38		

Table . AHP analysis for all influencing factors

The largest characteristic root	CI	RI	CR	Consistency test result
24	0	1.65	0	Pass

Table . Consistency test result for all influencing factors

The calculation result of AHP showed that the largest characteristic root was 24.0, and the corresponding RI value was found to be 1.65 according to the RI table, so CR=CI/RI=0.0<0.1, which passed the consistency test.

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Finance	0.913	14.638	6	0
Policy	1.706	27.367		

Market	0.819	13.133		
Customer	0.784	12.581		
Organization	1.12	17.961		
External	0.893	14.32		

Table . AHP analysis for all influencing factors

The largest characteristic root	CI	RI	CR	Consistency test result
6	0	1.25	0	Pass

Table . Consistency test result for influencing factor categories

The calculation result of the AHP shows that the largest characteristic root is 6.0, and the corresponding RI value is 1.25 according to the RI table, so CR=CI/RI=0.0<0.1, passing the consistency test.

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Finance	0.976	15.863	6.003	0
Policy	1.536	24.961		
Market	0.807	13.115		
Customer	0.794	12.911		
Organization	1.033	16.791		
External	1.007	16.359		

Table. AHP analysis for different categories of influencing factors by staff in Production

The largest characteristic root	CI	RI	CR	Consistency test result
6.003	0.001	1.25	0	Pass

Table . Consistency test result for influencing factor categories by staff in Production.

The calculation result of the AHP shows that the largest characteristic root is 6.003, and the corresponding RI value is 1.25 according to the RI table, so CR=CI/RI=0.001<0.1, passing the consistency test.

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Finance	0.546	7.027	6	0
Policy	2.419	31.133		
Market	2.529	32.549		
Customer	0.334	4.3		

Organization	1.186	15.266		
External	0.756	9.726		

Table. AHP analysis for different categories of influencing factors by staff in R&D

The largest characteristic root	CI	RI	CR	Consistency test result
6	0	1.25	0	Pass

Table . Consistency test result for influencing factor categories by staff in R&D

The calculation result of the AHP shows that the largest characteristic root is 6, and the corresponding RI value is 1.25 according to the RI table, so CR=CI/RI=0<0.1, passing the consistency test.

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Finance	0.953	15.39	6	0
Policy	1.653	26.699		
Market	0.821	13.267		
Customer	0.845	13.656		
Organization	1.03	16.646		
External	0.888	14.342		

Table. AHP analysis for different categories of influencing factors by staff in Marketing

The largest characteristic root	CI	RI	CR	Consistency test result
6	0	1.25	0	Pass

Table . Consistency test result for influencing factor categories by staff in Marketing

The calculation result of the AHP shows that the largest characteristic root is 6, and the corresponding RI value is 1.25 according to the RI table, so CR=CI/RI=0<0.1, passing the consistency test.

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Finance	0.747	11.15	6	0
Policy	2.282	34.037		
Market	0.889	13.256		

Customer	0.552	8.236		
Organization	1.346	20.076		
External	0.888	13.245		

Table. AHP analysis for different categories of influencing factors by staff in Logistics

The largest characteristic root	CI	RI	CR	Consistency test result
6	0	1.25	0	Pass

Table . Consistency test result for influencing factor categories by staff in Logistics

The calculation result of the AHP shows that the largest characteristic root is 6, and the corresponding RI value is 1.25 according to the RI table, so CR=CI/RI=0<0.1, passing the consistency test.

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Finance	0.717	11.532	6.006	0.001
Policy	1.225	19.694		
Market	0.942	15.142		
Customer	1.597	25.67		
Organization	0.888	14.271		
External	0.852	13.69		

Table. AHP analysis for different categories of influencing factors by staff in Quality Management

The largest characteristic root	CI	RI	CR	Consistency test result
6.006	0.001	1.25	0	Pass

Table . Consistency test result for influencing factor categories by staff in Quality Management

The calculation result of the AHP shows that the largest characteristic root is 6.006, and the corresponding RI value is 1.25 according to the RI table, so CR=CI/RI=0<0.1, passing the consistency test.

Item	Eigenvector	Weights(%)	The largest characteristic root	CI
Finance	0.853	13.75	6	0

Policy	1.651	26.609		
Market	0.963	15.516		
Customer	0.742	11.96		
Organization	1.052	16.949		
External	0.944	15.216		

Table. AHP analysis for different categories of influencing factors by staff in Operations

The largest characteristic root	CI	RI	CR	Consistency test result
6	0	1.25	0	Pass

Table . Consistency test result for influencing factor categories by staff in Operations

The calculation result of the AHP shows that the largest characteristic root is 6, and the corresponding RI value is 1.25 according to the RI table, so CR=CI/RI=0<0.1, passing the consistency test.

F. AHP Indicator Index

Indicator	Q4 _1	Q4 _2	Q5_1	Q5_2	Q6_1	Q6_2	Q7_1	Q7_2	Q8_1	Q8_2	Q9_1	Q9_2	Q10_1	Q10_2	Q11_1	Q11_2	Q12_1	Q12_2	Q13_1	Q13_2	Q14_1	Q14_2	Q15_1	Q15_2
Q4 _1	1,00	0,97	1,45	1,16	1,43	1,67	0,93	0,23	1,23	1,35	1,37	1,06	1,12	1,54	1,20	1,20	1,49	0,44	1,03	0,98	1,12	1,12	1,15	1,18
Q4 _2	1,03	1,00	1,52	1,19	1,47	1,72	0,96	0,24	1,28	1,39	1,43	1,10	1,16	1,59	1,25	1,25	1,54	0,45	1,06	1,02	1,15	1,16	1,19	1,22
Q5_1	0,69	0,66	1,00	0,79	0,98	1,15	0,64	0,16	0,85	0,93	0,94	0,74	0,78	1,06	0,83	0,83	1,02	0,30	0,71	0,68	0,76	0,78	0,79	0,81
Q5_2	0,86	0,84	1,26	1,00	1,23	1,45	0,81	0,20	1,08	1,16	1,19	0,93	0,97	1,33	1,04	1,04	1,28	0,38	0,89	0,85	0,96	0,97	0,99	1,02
Q6_1	0,70	0,68	1,02	0,81	1,00	1,18	0,65	0,16	0,87	0,94	0,97	0,75	0,79	1,09	0,85	0,85	1,05	0,31	0,72	0,69	0,78	0,79	0,81	0,83
Q6_2	0,60	0,58	0,87	0,69	0,85	1,00	0,56	0,14	0,74	0,81	0,82	0,64	0,67	0,93	0,72	0,72	0,89	0,26	0,62	0,59	0,67	0,67	0,68	0,70
Q7_1	1,07	1,04	1,56	1,24	1,53	1,80	1,00	0,25	1,33	1,45	1,47	1,15	1,20	1,67	1,30	1,30	1,61	0,47	1,11	1,05	1,20	1,20	1,23	1,27
Q7_2	4,31	4,18	6,29	5,00	6,15	7,24	4,02	1,00	5,26	5,88	5,88	4,55	4,76	6,67	5,26	5,26	6,25	1,89	4,55	4,17	4,76	4,76	5,00	5,00
Q8_1	0,81	0,78	1,18	0,93	1,15	1,35	0,75	0,19	1,00	1,09	1,11	0,86	0,91	1,25	0,97	0,97	1,20	0,36	0,83	0,79	0,90	0,91	0,93	0,95
Q8_2	0,74	0,72	1,08	0,86	1,06	1,24	0,69	0,17	0,92	1,00	1,02	0,79	0,83	1,15	0,89	0,89	1,11	0,33	0,77	0,73	0,83	0,83	0,85	0,88
Q9_1	0,73	0,70	1,06	0,84	1,03	1,22	0,68	0,17	0,90	0,98	1,00	0,78	0,82	1,12	0,88	0,88	1,09	0,32	0,75	0,71	0,81	0,82	0,83	0,85
Q9_2	0,94	0,91	1,36	1,08	1,33	1,57	0,87	0,22	1,16	1,26	1,29	1,00	1,05	1,45	1,12	1,12	1,39	0,41	0,97	0,92	1,04	1,05	1,08	1,10
Q10_1	0,89	0,86	1,29	1,03	1,27	1,49	0,83	0,21	1,10	1,20	1,22	0,95	1,00	1,37	1,08	1,08	1,33	0,39	0,92	0,88	0,99	1,00	1,02	1,05
Q10_2	0,65	0,63	0,94	0,75	0,92	1,08	0,60	0,15	0,80	0,87	0,89	0,69	0,73	1,00	0,78	0,78	0,96	0,28	0,67	0,64	0,72	0,72	0,74	0,76
Q11_1	0,83	0,80	1,21	0,96	1,18	1,39	0,77	0,19	1,03	1,12	1,14	0,89	0,93	1,29	1,00	1,00	1,23	0,37	0,85	0,82	0,93	0,93	0,95	0,98
Q11_2	0,83	0,80	1,21	0,96	1,18	1,39	0,77	0,19	1,03	1,12	1,14	0,89	0,93	1,29	1,00	1,00	1,23	0,37	0,85	0,82	0,93	0,93	0,95	0,98
Q12_1	0,67	0,65	0,98	0,78	0,95	1,12	0,62	0,16	0,83	0,90	0,92	0,72	0,75	1,04	0,81	0,81	1,00	0,30	0,69	0,66	0,75	0,75	0,77	0,79
Q12_2	2,27	2,20	3,31	2,63	3,23	3,80	2,11	0,53	2,81	3,05	3,12	2,42	2,55	3,51	2,73	2,73	3,38	1,00	2,33	2,22	2,56	2,56	2,63	2,70
Q13_1	0,97	0,94	1,41	1,12	1,38	1,62	0,90	0,22	1,20	1,30	1,33	1,03	1,09	1,50	1,17	1,17	1,44	0,43	1,00	0,95	1,08	1,09	1,11	1,14
Q13_2	1,02	0,98	1,48	1,18	1,45	1,70	0,95	0,24	1,26	1,37	1,40	1,09	1,14	1,57	1,22	1,22	1,52	0,45	1,05	1,00	1,14	1,15	1,16	1,20
Q14_1	0,89	0,87	1,31	1,04	1,28	1,50	0,83	0,21	1,11	1,21	1,23	0,96	1,01	1,39	1,08	1,08	1,34	0,39	0,93	0,88	1,00	1,01	1,03	1,05
Q14_2	0,89	0,86	1,29	1,03	1,27	1,49	0,83	0,21	1,10	1,20	1,22	0,95	1,00	1,38	1,07	1,07	1,33	0,39	0,92	0,87	0,99	1,00	1,02	1,05
Q15_1	0,87	0,84	1,27	1,01	1,24	1,46	0,81	0,20	1,08	1,17	1,20	0,93	0,98	1,35	1,05	1,05	1,30	0,38	0,90	0,86	0,97	0,98	1,00	1,03
Q15_2	0,85	0,82	1,24	0,98	1,21	1,42	0,79	0,20	1,05	1,14	1,17	0,91	0,95	1,31	1,02	1,02	1,27	0,37	0,88	0,83	0,95	0,95	0,97	1,00

AHP Indicator Index for all influencing factors

Indicator	Finance	Policy	Market	Customer	Organization	External
Finance	1	0.535	1.111	1.163	0.82	1.02
Policy	1.87	1	2.083	2.174	1.515	1.923
Market	0.9	0.48	1	1.042	0.73	0.917
Customer	0.86	0.46	0.96	1	0.699	0.877
Organization	1.22	0.66	1.37	1.43	1	1.25
External	0.98	0.52	1.09	1.14	0.8	1

AHP Indicator Index for all influencing categories

Indicator	Finance	Policy	Market	Customer	Organization	External
Finance	1	0.654	1.205	1.235	0.943	0.943
Policy	1.53	1	1.852	1.887	1.449	1.695
Market	0.83	0.54	1	1.01	0.781	0.781
Customer	0.81	0.53	0.99	1	0.769	0.769

Indicator	Finance	Policy	Market	Customer	Organization	External
Organization	1.06	0.69	1.28	1.3	1	1
External	1.06	0.59	1.28	1.3	1	1

AHP Indicator Index for different categories of influencing factors by staff in Production

Indicator	Finance	Policy	Market	Customer	Organization	External
Finance	1	0.226	0.217	1.639	0.459	0.719
Policy	4.43	1	0.962	7.143	2.041	3.226
Market	4.61	1.04	1	7.692	2.128	3.333
Customer	0.61	0.14	0.13	1	0.282	0.444
Organization	2.18	0.49	0.47	3.55	1	1.562
External	1.39	0.31	0.3	2.25	0.64	1

AHP Indicator Index for different categories of influencing factors by staff in R&D

Indicator	Finance	Policy	Market	Customer	Organization	External
Finance	1	0.575	1.163	1.124	0.926	1.075
Policy	1.74	1	2	1.961	1.613	1.852
Market	0.86	0.5	1	0.971	0.794	0.926
Customer	0.89	0.51	1.03	1	0.82	0.952
Organization	1.08	0.62	1.26	1.22	1	1.163
External	0.93	0.54	1.08	1.05	0.86	1

AHP Indicator Index for different categories of influencing factors by staff in Marketing

Indicator	Finance	Policy	Market	Customer	Organization	External

Indicator	Finance	Policy	Market	Customer	Organization	External
Finance	1	0.329	0.84	1.351	0.556	0.84
Policy	3.04	1	2.564	4.167	1.695	2.564
Market	1.19	0.39	1	1.613	0.658	1
Customer	0.74	0.24	0.62	1	0.412	0.625
Organization	1.8	0.59	1.52	2.43	1	1.515
External	1.19	0.39	1	1.6	0.66	1

AHP analysis for different categories of influencing factors by staff in Logistics

Indicator	Finance	Policy	Market	Customer	Organization	External
Finance	1	0.61	0.649	0.467	0.84	0.877
Policy	1.64	1	1.351	0.769	1.389	1.429
Market	1.54	0.74	1	0.565	1.02	1.064
Customer	2.14	1.3	1.77	1	1.786	1.887
Organization	1.19	0.72	0.98	0.56	1	1.042
External	1.14	0.7	0.94	0.53	0.96	1

AHP analysis for different categories of influencing factors by staff in Quality Management

Indicator	Finance	Policy	Market	Customer	Organization	External
Finance	1	0.518	0.885	1.149	0.813	0.901
Policy	1.93	1	1.724	2.222	1.562	1.754
Market	1.13	0.58	1	1.299	0.917	1.02
Customer	0.87	0.45	0.77	1	0.704	0.787
Organization	1.23	0.64	1.09	1.42	1	1.111
External	1.11	0.57	0.98	1.27	0.9	1

AHP analysis for different categories of influencing factors by staff in Operations

G. Weight Analysis Calculation Results

Item	information entropy value	Information utility value	Weight(%)
Q4 _2	0.979	0.021	2.951
Q5_2	0.969	0.031	4.366
Q6_2	0.964	0.036	5.086
Q7_2	0.967	0.033	4.715
Q8_2	0.972	0.028	3.943
Q9_2	0.978	0.022	3.149
Q10_2	0.969	0.031	4.444
Q11_2	0.97	0.03	4.21
Q12_2	0.968	0.032	4.489
Q13_2	0.977	0.023	3.235
Q14_2	0.971	0.029	4.027
Q15_2	0.971	0.029	4.063
Q4 _1	0.977	0.023	3.23
Q5_1	0.97	0.03	4.276
Q6_1	0.969	0.031	4.373
Q7_1	0.954	0.046	6.567
Q8_1	0.969	0.031	4.399
Q9_1	0.965	0.035	5.005
Q10_1	0.971	0.029	4.057
Q11_1	0.973	0.027	3.833
Q12_1	0.968	0.032	4.505
Q13_1	0.979	0.021	2.99
Q14_1	0.971	0.029	4.037
Q15_1	0.971	0.029	4.052