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Measuring and Monitoring Flexibility of High-Tech Supply Chains – The Case of COROS

ZHENG Guohui

Doctor of Management

Supervisors:
PhD Teresa Cardoso de Gomes Grilo, Assistant Professor,
ISCTE University Institute of Lisbon
PhD CHEN Xu, Professor,
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Jury:

PhD Miguel Vieira, Assistant Professor,
Faculty of Engineering at Lusófona University
PhD Feng Yi, Associate Professor,
UESTC - University of Electronic Science and Technology of China
PhD Henrique O'Neill, Associate Professor with Habilitation,
ISCTE University Institute of Lisbon
PhD Teresa Grilo, Assistant Professor,
ISCTE University Institute of Lisbon
PhD Abilio Oliveira, Assistant Professor with Habilitation,
ISCTE University Institute of Lisbon

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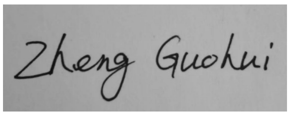
Signed: 

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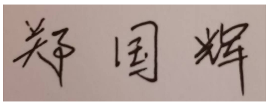
作者签名：

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姓名(拼音)：ZHENG Guohui

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Abstract

The measurement and monitoring of flexibility in high-tech supply chains (SC) have emerged as pivotal topics within supply chain management. This thesis specifically addresses the critical challenges associated with assessing the flexibility of SC and aiding managers in understanding how to enhance this flexibility within high-tech enterprises.

This thesis addresses the crucial challenge of measuring and enhancing the flexibility of SC in the high-tech sector, with a particular focus on private companies in China. Despite the growing body of literature on SC flexibility, significant gaps remain, notably in the context of the Chinese high-tech industry where comprehensive tools for measuring and monitoring SC flexibility are lacking.

The research proposes a novel measurement tool, designed through a systematic two-step process. Initially, a set of indicators critical to SC flexibility was identified through an extensive literature review. This set was further refined and expanded via a Fuzzy Web-Delphi study, incorporating insights from managers within the Chinese high-tech sector to ensure relevance and applicability. The measuring and monitoring tool is subsequently developed, featuring twenty-two distinct indicators that cover seven business areas. It was empirically tested in a case study involving COROS, a high-tech company operating in China. This practical application demonstrated the tool's effectiveness in real-world settings, validating its utility for improving SC flexibility.

The study's findings contribute significantly to both the academic understanding and practical management of SC flexibility in high-tech environments, particularly within the under-researched context of Chinese private enterprises. By providing a comprehensive framework for assessing and enhancing SC flexibility, this thesis offers valuable insights for managers seeking to navigate the complexities of today's dynamic high-tech industries.

Keywords: SC flexibility, high-tech enterprises, measurement tool, Fuzzy Web-Delphi, Chinese private companies

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Resumo

A medição e a monitorização da flexibilidade em cadeias de abastecimento (CA) de alta tecnologia emergiram como tópicos fundamentais na gestão de CA. Esta tese aborda especificamente os desafios críticos associados à avaliação da flexibilidade das CA e ao auxílio aos gestores em compreender como aprimorar essa flexibilidade em empresas de alta tecnologia.

Esta tese foca-se na medição e melhoria da flexibilidade nas CA no sector da alta tecnologia, com especial incidência nas empresas privadas da China. Apesar da crescente literatura sobre a flexibilidade das CA, subsistem lacunas significativas, nomeadamente no contexto da indústria chinesa de alta tecnologia, onde faltam ferramentas abrangentes para medir e monitorizar a flexibilidade das CA.

Esta pesquisa propõe uma ferramenta de medição inovadora, projetada através de um processo sistemático de dois passos. Inicialmente, um conjunto de dimensões críticas para a flexibilidade da CA foi identificado por meio de uma extensa revisão da literatura. Esse conjunto foi posteriormente refinado e ampliado através de um estudo Fuzzy Web-Delphi, incorporando perceções de gestores do setor de alta tecnologia na China para garantir a relevância e aplicabilidade. A ferramenta de medição e monitorização é depois construída, tendo na sua base vinte e duas dimensões distintas. Esta ferramenta foi testada empiricamente num estudo de caso envolvendo a COROS, uma empresa de alta tecnologia a operar na China. Esta aplicação prática demonstrou a eficácia da ferramenta em contextos reais, validando sua utilidade para melhorar a flexibilidade da CA.

Os resultados do estudo contribuem significativamente tanto para o entendimento académico quanto para a gestão prática da flexibilidade da CA em ambientes de alta tecnologia, especialmente no contexto pouco explorado de empresas privadas chinesas. Ao fornecer um quadro abrangente para avaliar e aprimorar a flexibilidade da CA, esta tese oferece *insights* valiosos para gestores que buscam navegar as complexidades das indústrias de alta tecnologia dinâmicas de hoje.

Palavras-chave: Flexibilidade das CA, empresas de alta tecnologia, ferramentas de medição e monitorização, Fuzzy Web-Delphi, empresas privadas Chinesas

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摘要

衡量和监控高科技供应链（SC）的弹性是近年来日益热门的话题。 特别是如何衡量供应链的弹性并帮助管理者了解如何提高高科技公司的供应链灵活性是本文提出要解决的关键挑战。

尽管过去几十年来关于供应链弹性测量和监控的文献不断增加，但仍然缺乏探索高科技领域，特别是中国民营企业的研究。 此外，大多数研究都严格集中于供应链弹性的部分测量和监控工具。 因此，本文旨在通过提出一种综合工具来衡量和监控高科技领域特别是中国民营企业供应链的弹性来填补这一空白。

这些指标的识别分两步进行：首先，通过系统的文献综述，根据该领域的现有文献收集一组指标；随后进行模糊网络德尔菲研究，根据中国民营高科技行业管理者的经验和观点，进一步评估和补充这组初始指标。

基于这种方法，获得了包含二十个测量和监控指标的最终工具，并使用 COROS 作为在中国运营的高科技公司的真实案例研究进行了测试。该案例研究验证了所提出工具的适用性和有用性，代表了一种有效的衡量和监测高科技领域供应链弹性的方法，旨在促进供应链的弹性。

关键词：供应链弹性，高科技企业，测量和监控工具，模糊德尔菲法，中国民营企业

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I am also grateful to these 89 experts who involved in the questionnaire survey, they all come from the 8 high-tech industry area, academia, and stakeholders for their strong support during my empirical research, including Dr. Liang Guizhao, Dr. Wang Lixin, Dr. Xin Tong, Dr. Cai Jinxin, Dr. Qian Boyi, Dr. Yang Kejun, Dr. Yang Ling, Doctoral candidate Huang Xiaofei, Doctoral candidate Yang Jun, Doctoral candidate Zhang Feng and other company owner or top management members (order by surname in alphabetical) Bao Yaqun，Chai Jinbin，Chai Xiaobing，Chao Meng，Chen Binyan，Chen Gang，Chen Lingli，Chen Tingdong，Chen Weigang，Chen Xiaoqun，Chen Xiaoshuo，Chen Yong，Chen Zhong，Chen Zhonghe，Chi Chubin，Ding Cong，Du Huifang，Fan Wei，Feng Wei，Ge Jinhui，Guo Yuebo，Huang Sangsang，Huang Weiyu，Huang Xing，Lang Ye，Li Gang，Li Jinyu，Li Yizhang，Li Zhen，Li Zheng，Liang Xushen，Lin Fuxin，Linda Zhang，Ling Ling，Liu Chao，Liu Xin，Liu Yu，Lv Jinfeng，Mai Jianguang，Mao Guofei，Miao Zhifeng，Nie Xinyu，Niu Haotian，Ou Yu，Pan Qiujun，Peng Zhuchun，Qiu Tinghua，Qiu Zejun，Qu Xiaohua，Quan Yuwen，Rao Xuan，Ren Guoguang，Sheng Zhang，Shi Chenyang，Shi Jing，Shi Pengchang，Tang Ling，Tang Yu，Wang Cong，Wang Fangde，Wang Gang，Wang Jianghua，Wang Peilin，Wang Xiaohu，Wang Xuanlin，Wu

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These 89 experts are coming from 48 high-tech companies in China, most of them holds the top companies background in high-tech, such as Everwin, Lens, Lingyi, DJI, Jinlong, Yisheng, COROS and so on. Some of them are the professional and senior managers with extensive experience and knowledge in the supply chain field from China private high-tech company, and some experts are the stakeholders of high-tech consulting company, all of them gather together formed an extremely professional team. In addition to contribute the dedicating precious time, the 89 experts also contributed their valuable practical experiences and knowledge which accumulated in their career life for many years. Their contributions and efforts make the research have high practical value. The research is harvesting the supply chain best practice of private high-tech enterprises, at the same time considering the context of the national situation, country culture, regional laws and business environment of China who plays as a global manufacturing center. The fruit of the research - the Chinese private high-tech SC flexibility measurement and monitoring, which not only expanded the academic research theory, closed the gap in current literature, but also can be directly applied by the company managers for decision-aiding reference and used as a real time monitoring tool, consequently the research contributes to the SC flexibility improvement of the high-tech industry in both theory and practice.

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I hope all my efforts can contribute to the development of high-tech supply chain management in China and the world!

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这89位专家来自国内48家高科技企业，大多拥有高科技顶尖企业背景，如长盈、

蓝思、领益、大疆、金龙、亦盛，高驰等。他们中有些是来自中国民营高科技公司在供应链领域拥有丰富经验和知识的专业高级管理人员，有些是高科技咨询公司企业家，他们聚集在一起组成了一支极其专业的团队。89位专家除了奉献宝贵的时间外，还贡献了他们在职业生涯中多年积累的宝贵实践经验和知识。他们的贡献和努力使得该研究具有很高的实用价值。该研究在收获民营高科技企业供应链最佳实践的同时，考虑了中国作为全球制造中心的国情、国家文化、区域法律和营商环境。研究产生的成果—中国民营高科技供应链柔性测量与监控，不仅拓展了学术研究理论，弥补了现有文献的空白，而且可以直接为企业管理者提供决策参考。并作为实时监控工具，从理论和实践上为高新技术产业供应链灵活性的提高做出了贡献。

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希望我的一切努力能够为中国乃至世界高科技供应链管理的发展做出贡献！

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List of Abbreviations

ACA - Alliance Capability

AI – Artificial Intelligence

AMT - Advanced Manufacturing Technology

BOM - Bill of Materials

BSC - Balanced Scorecard

BTO - Build to Order

CAD - Computer-Aided Design

CAE - Computer-Aided Engineering

CAM - Computer-Aided Manufacturing

CAPP - Computer-Aided Process Planning

COGS - Cost of Goods Sold

CRM - Customer Relationship Management

DAC - Data Analytic Capability

DSR - Design Science Research

ERP - Enterprise Resources Planning

FDM - Fuzzy Delphi Method

FMS - Flexible Manufacturing Systems

FP - Full Postponement

GPS - Global Positioning System

GSI - Green Supplier Integration

IT - Information Technology

JCR - Journal Citation Reports

KPIs - Key Performance Indicators

MPLS - Manufacturing Postponement and Logistics Speculation

NPS - Net Promoter Score

PFP - Product Financial Performance

PLM - Product Lifecycle Management

Power BI - Power Business Intelligence

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-Analyses

R&D - Research and Development

SC - Supply Chain

SCI - Supply Chain Integration

SCM - Supply Chain Management

SCOR - Supply Chain Operation Reference

SKUs - Stock Keeping Units

SLR - Systematic Literature Review

SMEs - Small and Medium Enterprises

SOEs - State Owned Enterprises

SRM - Supplier Relationship Management

TFN - Triangular Fuzzy Number

Chapter 1: Introduction

1.1 Research background

Since 2010, China has ascended to the position of the world's preeminent manufacturing powerhouse, maintaining its lead as the foremost global exporter for eleven consecutive years up to 2021 (Government White Paper, 7th December 2011, The Central People’s Government of the People’s Republic of China). In this context, a burgeoning number of Chinese private enterprises have experienced rapid growth while concurrently encountering severe competition in global markets. Traditionally, these enterprises have leveraged China's demographic dividend to produce cost-effective products. However, this strategy has become less viable in recent years, necessitating a strategic pivot towards enhancing product value and management capabilities to sustain profitability and competitiveness.

This strategic transformation is imperative for private firms striving to augment their flexibility to adapt to and thrive within the fiercely competitive international arena and to exploit global sales opportunities. Enhanced supply chain (SC) flexibility is crucial for adapting to market fluctuations—characterized by increasingly global and technologically advanced markets, reduced product life cycles, and rapidly evolving customer expectations (Fayezi et al., 2016). Therefore, augmenting SC flexibility is not merely beneficial but essential for fostering rapid and sustainable growth and enhancing competitive advantage in dynamic markets (Esmaeilikia et al., 2016; Fayezi et al., 2016; Gosling et al., 2010).

Current scholarship in SC management underscores the importance of SC flexibility as a strategic asset in dynamic environments (Rojo et al., 2018). The concept of dynamic capability, which enables firms to maintain competitive advantages in evolving environments, supports this perspective (Araceli et al., 2020). Moreover, the development of dynamic system models to increase supply chain agility and flexibility is a focal area of ongoing research (P. Liu et al., 2023).

Nevertheless, there is no one-size-fits-all solution to enhancing SC flexibility, as situational and contextual differences across regions and industries necessitate tailored strategies. This is particularly true for the high-tech sector, where the rapid pace of technological innovation and market demands pose unique challenges.

This thesis specifically addresses the challenges faced by Chinese private high-tech companies in enhancing their SC flexibility to better navigate the complexities of the global market landscape.

Private enterprises, as delineated by the "Provisions on Classifying Types of Enterprise Registration" issued on August 28, 1998, by the State Administration for Market Regulation, are defined as profit-oriented economic organizations that are established and funded or controlled by natural persons, utilizing wage labor as their operational foundation. As of the end of August 2022, the number of private enterprises in China reached approximately 47 million, constituting 28.8% of the total 163 million registered market entities. This statistic underscores the substantial role of private companies within the Chinese market, as reported by People's Daily on October 12, 2022.

In China, the designation "high and new technology enterprise" refers to resident enterprises that operate within the sectors outlined in the "High and New Technology Fields supported by the State," a directive issued by the government. These enterprises are engaged in ongoing research and development activities and the transformation of technological achievements into commercial applications, thereby establishing core independent intellectual property rights. They are recognized as knowledge-intensive and technology-intensive economic entities.

According to a document issued by the Ministry of Commerce of the People's Republic of China on May 15, 2008, the state-supported high and new technology fields encompass eight sectors: electronic information technology, biology and new medical technologies, aerospace technology, new materials technology, high-tech service industry, new energy and energy-saving technologies, resource and environment technology, and the transformation of traditional industries through high and new technologies.

Chinese high-tech enterprises confront significant challenges such as "Financing Difficulties" and "Expensive Financing," which impede sustainable development reliant on innovation and Research and Development (R&D). Market failures often arise due to the uncertainties associated with these sectors (Xiang et al., 2021). The innovation activities of private firms are particularly vulnerable to financial constraints, which are exacerbated by the high complexity, specificity, and uncertainty of innovation projects (Mateut, 2018). In comparison, most Chinese high-tech companies lag behind their international counterparts in adopting advanced technologies and business models. State-owned enterprises (SOEs) benefit from robust bureaucratic networks, facilitating access to preferential resources, contracts, and subsidies (Xia & Liu, 2017). Furthermore, the stability of Chinese private enterprises is relatively lower compared to SOEs, with an average lifespan of less than ten years (Tan & Zhao, 2019). These private enterprises often struggle with outdated information technology and management practices (Farooq et al., 2019).

In an increasingly dynamic global environment marked by rapid technological advancements, disruptive innovations, and intense global competition, high-tech companies must develop dynamic capabilities to respond effectively to these changes (Du & Chen, 2018). Chinese private high-tech companies, in particular, face financial constraints, limited resources, and technological lag, all within a context of dynamic uncertainty. To address these challenges, it is imperative for these companies to accelerate their R&D efforts, rapidly meet market demands, enhance operational efficiency, and increase profitability.

This thesis focuses on the flexibility of SC within Chinese private high-tech companies, using a Chinese private high-tech company - COROS, as a case study to explore methods for measuring, monitoring, and enhancing flexibility in high-tech supply chains.

1.2 Research problem

1.2.1 Research problem description

Numerous privately owned high-tech companies in China continuously grapple with challenges such as volatile demand, insufficient raw material supply (notably in integrated circuits), and power shortages. There exists a notable deficit in the power supply, particularly during peak demand periods across several provinces (Y. Liu et al., 2020). Furthermore, more than ten provinces implemented industry shutdowns and enforced household electricity restrictions during the summer of 2021 to mitigate shortages (B. Wang et al., 2022). Consequently, developing adaptable SC to effectively manage such a volatile and challenging environment is critical for these companies. Collaboration with supply chain partners to enhance flexibility and manage uncertainty has become a common strategy among these enterprises (Dubey et al., 2021). In the context of today's fiercely competitive environment, the necessity for firms to possess the capacity for efficient and effective responses to heightened levels of uncertainty, complexity, and unpredictability is imperative (Christofi et al., 2021). The presence of uncertainty in SC introduces significant risks, where increased flexibility in supply and manufacturing processes plays a pivotal role in mitigating such risks (Sreedevi & Saranga, 2017).

This scenario is notably applicable to many Chinese high-tech firms, including COROS.

COROS, a brand of Guangdong COROS Sports Technology Co., Ltd., engages in the production of professional sports wearable devices and is classified as a private enterprise within China. Initially, the company manufactured low-end wearable smart bracelets known as “Weloop” from 2014 to 2017. Subsequently, due to unsustainable profit margins from these low-end products, the strategy shifted towards the production of higher-end devices starting in 2017. In May 2018, the brand was launched in the USA under the name “COROS” and “GAOCHI” in Chinese. Since its introduction, the COROS brand has established a formidable reputation in the global professional sports watch market. Notably, the COROS Pace3 product was recognized as the best GPS running watch by The New York Times on October 24, 2023 (https://www.nytimes.com/wirecutter/reviews/best-running-watch/) and the COROS heart strap, used for heart rate monitoring, was listed among the top 200 inventions of 2023 by Time magazine (https://time.com/collection/best-inventions-2023/6324406/COROS-heart-rate-monitor/). The company now aspires to be ranked among the top two brands of professional sports wearable products globally by 2025. This market, however, is characterized by intense dynamism. Significant competition arises from Garmin, its principal rival, which consistently launches over ten new products annually worldwide. In contrast, COROS maintains a portfolio of five to six products, with two to three new products introduced each year. Other challenges stem from major consumer electronics giants like Apple and Huawei, who have recently ventured into the professional sports wearable market. For instance, Apple launched its professional sports watch, Ultra, and Huawei continuously updates its GT runner series.

These market dynamics introduce several operational challenges for COROS. For example, there are reported difficulties in meeting the rapidly growing market demand due to shortages of mechanical and electronic components. These issues are exacerbated by significant fluctuations in market forecasts, the presence of numerous stock-keeping units (SKUs) with relatively low utilization rates per SKU, and inadequate technical capabilities of existing suppliers. Additionally, approximately 70% of the company's revenue is generated from overseas markets, primarily in the USA and Europe. The company employs both online and offline sales channels in the USA, whereas offline channels, such as Decathlon, are preferred in Europe. This diversity in sales channels contributes to greater uncertainty, impacting demand forecasts and, consequently, the company's ability to respond effectively to market needs.

Addressing these challenges necessitates ensuring high flexibility within high-tech SC, representing a substantial challenge for any SC, particularly in the case of COROS. Literature suggests that enhancing SC performance generally begins with the measurement and monitoring of key performance indicators, enabling companies to direct performance improvements based on these metrics, with various tools proposed for this purpose (Agami et al., 2012; Kurien & Qureshi, 2011). A foundational principle in management asserts that elements that cannot be measured remain unmanageable (Nica et al., 2021). Performance measures afford organizations a detailed view of their supply chain's operational efficiency over time, facilitating the development of strategies and action plans aimed at comprehensive improvement and the attainment of strategic business objectives (Pham, 2021). The Supply Chain Operation Reference (SCOR) model and the Balanced Score Card (BSC) are extensively utilized tools for performance evaluation. However, they adopt a top-down approach primarily suited for driving the implementation of corporate strategies, thereby exhibiting limited flexibility. The SCOR model, widely acknowledged and utilized across industries, supports tactical and operational management in executing strategic decisions (Lima-Junior & Carpinetti, 2020). Despite its widespread use, the literature reveals a scarcity of studies focusing on the measurement of flexibility specifically. Both the BSC and SCOR models are potentially effective in fostering strategically focused organizations and achieving excellence in SC management. Nevertheless, the SCOR model operates within a rigid framework that strictly emphasizes a predefined set of metrics for evaluating, comparing, and enhancing SC operations, with some model elements potentially losing validity over time (Chorfi et al., 2018). The BSC presents a static approach, suitable for business scenarios but lacks the capacity to support the formulation, communication, and implementation of policies. Despite its industry dominance, the BSC prescribes only a theoretical framework and does not facilitate operational policymaking (Saleheen et al., 2018). Given the unique challenges faced by the high-tech sector, such as significant demand uncertainty, rapid market response requirements, imperfect management systems, incomplete Information Technology (IT) infrastructure, and funding shortages, this thesis endeavors to bridge the gap in the literature by exploring which tools, among those generally employed for performance measurement, are suitable for assessing and monitoring flexibility in high-tech SC.

1.2.2 Research question

Based on the research context provided, your key research question is: "How can Chinese private high-tech companies measure, monitor, and guide the improvement of its SC flexibility?"

1.2.3 General objective

Consistent with the research question articulated previously, the overarching goal of this dissertation is to develop and validate analytical tools that will enable the measurement and monitoring of SC flexibility for Chinese private high-tech enterprise, exemplified by COROS. These instruments are intended to not only quantify and oversee the flexibility metrics but also to identify strategic opportunities for enhancing the adaptability of the supply chain.

1.2.4 Partial objectives

In pursuit of the primary objective articulated above, this dissertation delineates several subsidiary goals to facilitate a comprehensive understanding and operationalization of SC flexibility within the context of a Chinese private high-tech enterprise:

i. Ascertain the critical indicators of SC flexibility pertinent for Chinese private high-tech companies, identifying which aspects are most crucial for enhancing operational adaptability.

ii. Design and validate a quantitative tool tailored to measure and monitor these identified indicators of flexibility, ensuring that the tool is specifically suited to the operational realities of private high-tech enterprises in China.

iii. Deploy the developed tool within a practical case study setting (COROS) to evaluate its effectiveness and utility. This deployment aims not only to refine the tool further based on real-world application feedback but also to demonstrate how it can generally guide the identification of opportunities for enhancing flexibility within high-tech SC.

1.2.5 Research contributions

Theoretical Contributions: This dissertation advocates for the creation of innovative tools tailored to measure and monitor the flexibility of private high-tech supply chains within the Chinese context. While the literature on performance measurement tools is extensive, with significant explorations by researchers such as Kurien and Qureshi (2011) and Agami et al. (2012), there remains a notable gap in adapting these tools to specifically measure flexibility indicators. This gap is particularly pronounced in the high-tech sector in China. A foundational management principle posits that effective management hinges on the ability to measure (Nica et al., 2021). Thus, by developing metrics that provide a comprehensive and nuanced view of supply chain performance, organizations can formulate strategies and action plans that enhance overall operational efficacy and achieve strategic objectives (Pham, 2021).

Practical Contributions: The tool developed through this research will be designed as a versatile instrument applicable across various high-tech enterprises in China, aiming to assess SC flexibility. This general applicability ensures that any high-tech company can evaluate its SC flexibility and use such evaluations to foster improvements. By integrating and analyzing selected flexibility indicators that align with their specific operational contexts, companies can enhance their adaptability and responsiveness to dynamic market conditions.

1.3 Research method

This thesis adopts the Design Science Research (DSR) methodology, which is geared towards the creation and utilization of artifacts with the goal of resolving identified problems. The artifact in question is a tool designed to enhance the measurement, monitoring, and promotion of flexibility within private high-tech supply chains in China, referencing the foundational frameworks by Peffers et al. (2007), Gregor et al. (2013), and Johannesson and Perjons (2014).

The study is structured around six sequential steps:

i. Problem Identification: This initial phase involves recognizing the primary challenge, which centers on the absence of adequate tools to facilitate enhancements in SC flexibility among private high-tech firms in China.

ii. Objectives of Solution: The solution, conceptualized as the artifact, aims to both measure and monitor SC flexibility. This tool is also designed to pinpoint opportunities that could lead to greater flexibility within the high-tech sector in China.

iii. Design and Development: The artifact is crafted through a structured process that includes:

1. Identification of key flexibility indicators via a systematic literature review coupled with a web-based Fuzzy Delphi method.

2. Operationalization of these indicators through face-to-face focus groups.

3. Construction of the measurement tool integrating the identified and operationalized indicators.

iv. Demonstration: The utility and effectiveness of the tool are demonstrated using COROS as a real-world case study, thereby providing practical insights into the tool's application and potential enhancements.

v. Evaluation: This stage assesses the tool's performance to determine if it meets the pre-established criteria and effectively addresses the identified problem.

vi. Communication: The final step involves the dissemination of the research findings and insights gained from the application of the tool, aimed at informing both academic audiences and industry practitioners.

1.4 Thesis structure

Seven chapters included in this thesis:

Chapter 1: Introduction. This initial chapter sets the stage for the research by providing an overview of the research background, delineating its significance, and articulating the research problem and questions. It also outlines the research methods that will be employed throughout the study.

Chapter 2: Literature Review. This chapter conducts a comprehensive review of the existing literature to identify key indicators of supply chain (SC) flexibility, evaluate tools currently utilized for measuring and monitoring SC flexibility, and explore strategies for improving SC flexibility.

Chapter 3: Research Methodology Detailed documentation of the research methodology applied in this thesis is presented in this chapter, outlining the Design Science Research approach and the specific methods used for data collection and analysis.

Chapter 4: Design and Development of Measuring and Monitoring Tools. This chapter details the process followed in designing and developing the tools proposed for measuring and monitoring SC flexibility. It covers all steps from conceptualization through to the operationalization of the tools.

Chapter 5: Demonstration with Application to a Real Case Study (COROS). A practical application of the developed tools is demonstrated through a case study involving COROS, a private high-tech company in China. This chapter assesses the tools' applicability and utility in a real-world context.

Chapter 6: Evaluation of the Proposed Measuring and Monitoring Tools. This chapter presents an evaluation of the proposed tools, discussing their validity, benefits, and the challenges encountered during their implementation in practice.

Chapter 7: Conclusion and Future Research Directions. The final chapter summarizes the thesis findings, discusses the theoretical and practical contributions of the study, addresses the research questions, and lists the limitations of the study. Additionally, it proposes directions for future research that could build upon the findings of this thesis.

Chapter 2: Literature review

This chapter undertakes a detailed examination of the existing research concerning the measurement and improvement of supply chain (SC) flexibility. The analysis initiates with a focused exploration of the crucial indicators identified in the literature for assessing SC flexibility. Special attention is given to those indicators that are particularly pertinent to high-tech supply chains, providing a nuanced understanding of the specific challenges and requirements within this sector (section 2.1). The discourse then transitions to a comprehensive review of the diverse array of tools currently employed to measure and monitor SC flexibility. This includes an evaluation of their applicability and effectiveness in a high-tech context (section 2.2). The chapter culminates with a critical analysis of various strategies that have been advocated in scholarly studies to enhance SC flexibility. This synthesis highlights approaches that hold particular relevance for high-tech supply chains, aiming to delineate how these strategies can be tailored and implemented to meet the unique demands of this dynamic sector (section 2.3).

2.1 SC flexibility

2.1.1 SC flexibility definition

There are many different definitions of supply chain flexibility (SCF) in the literature, but all refer in some way to it being an ability of the supply chain function to react to changes in the environment (Duclos et al., 2003; Lummus et al. 2005; Martínez-Sánchez and Pérez (2005).

Supply chain management (SCM) encapsulates the entirety of operations necessary for transforming raw materials into final products. This transformation process spans from sourcing and component manufacturing through final assembly to distribution to the end markets, encompassing all requisite material handling and storage activities, collectively termed logistics (Zijm et al., 2019). Increasingly, SCM also integrates the management of return flows of products and potential reuse of materials and components, leading to the concept of closed-loop supply chains. The multifaceted nature of these operations typically spans multiple industries, forming a complex network of companies and organizations that operate collaboratively in an end-to-end supply chain system.

The concept of SC flexibility has evolved significantly since its initial articulation by Slack (1983), who defined it as the range of states a system can adopt, the cost of transitioning between states, and the time required to affect such transitions, particularly within manufacturing organizations. This perspective on flexibility underscores the integrative, customer-oriented approach necessary for SCM, where the emphasis is on flexibilities that enhance customer value and involve collaborative efforts across various supply chain functions, both internal and external (Vickery et al., 1999).

Flexibility in SCM refers to the network of interrelated external and internal flexibilities, including inbound and outbound logistics and manufacturing, which collectively enhance the focal company's performance from a customer-centric viewpoint (Malhotra & Mackelprang, 2012). It encompasses the capability of the supply chain to adapt swiftly to unforeseen changes in customer demands and competitive actions, and to specific customer requirements (Moon et al., 2012; Yi et al., 2011). SC flexibility thus measures a system's capacity to accommodate fluctuations in volume and schedule from suppliers, manufacturers, and customers (Beamon, 1999).

Furthermore, SC flexibility extends beyond internal organizational boundaries to include all partners within the chain. This encompasses not only inter-departmental flexibility within an organization but also spans external partners such as suppliers, carriers, third-party companies, and information systems providers. It involves the capability to gather and exchange market demand information efficiently across organizational boundaries, reflecting the system's overall responsiveness to internal and external changes (Duclos et al., 2003; Garavelli, 2003).

Das and Abdel-Malek (2003) characterize SC flexibility as the resilience of the buyer-supplier relationship under varying supply conditions, where flexibility implies minimal deterioration in Procurement prices and penalties under different supply scenarios. In logistics systems, flexibility is a critical component that facilitates stable performance under changing conditions (Barad & Sapir, 2003). Moreover, SC flexibility enables supply chain partners to reconfigure their operations, align their strategies, and collaboratively respond to customer demands across the supply chain, thereby producing a variety of products in desired quantities, costs, and qualities while maintaining high performance (Kumar et al., 2006).

Stevenson and Spring (2007) suggest that SC flexibility should be viewed above manufacturing flexibility in the hierarchy of flexibility, incorporating all non-manufacturing services and external sources of flexibility at the network level, including sourcing, Procurement, and logistics. SC flexibility thus becomes a measure of how well the supply chain as a whole can adapt to changing business conditions (Blome et al., 2014; Choy et al., 2008).

From a strategic standpoint, SC flexibility enables companies to respond more swiftly to shifts in supply and demand, embedding process innovation into SCM operations and proactively managing supply-demand fulfillment (Hock-Soon & Mohamed, 2011; Merschmann & Thonemann, 2011). It measures the extent to which the supply chain can respond to random fluctuations in demand and supply changes, playing an increasingly vital role in today's complex, continuously changing, and uncertain business environment (Agus, 2011; Araceli et al., 2020).

The literature reveals that the definition of SC flexibility has expanded significantly over the past two decades, transitioning from a focus primarily on manufacturing flexibility to encompassing a broader scope that includes finance, sourcing, Procurement, information systems, and more. It has evolved from a single-firm focus to collaborative actions among upstream and downstream partners, extending from the outcome of individual actions to joint efforts across the supply chain. Thus, SC flexibility is critical for gaining competitive advantages in a dynamic environment, with an emphasis on a holistic system capable of adapting flexibly to cope with such dynamics, including both inter-organizational and intra-organizational activities. This comprehensive approach to SCM flexibility forms the core focus of this thesis.

2.1.2 Indicators for measuring SC flexibility

From subchapter 2.1 on supply chain definitions, it is evident that the supply chain is a complex system encompassing the entire process from sales to procurement, involving collaboration among various internal departments of a company and between the company and its customers and suppliers (Choi et al., 2001; Surana et al., 2005). The indicators of interest vary among companies of different sizes within the same industry, as well as across different industries and regions with distinct legal and regulatory frameworks. Therefore, the selection of appropriate indicators to measure a company's SC flexibility, and the identification of the specific differences in SC flexibility within Chinese privately-owned high-tech enterprises, become crucial.

Literature classifies flexibility into seven business areas pertinent to supply chains: Organization, Manufacturing, Information, Logistics, Procurement, Marketing, and Product Development.

"Organization" refers to organizational flexibility, organizational flexibility is critical for adapting to dynamic market demands and evolving customer needs. Lummus et al. (2005)

define this indicator of flexibility as the organization's capability to realign both management and labor in response to customer demands and service requirements. Further expanding on this concept, Stevenson and Spring (2007) emphasize the importance of developing and sustaining collaborative relationships both upstream and downstream, which is essential for an organization to effectively adapt to changes in the business environment. Yi et al. (2011) contribute to this discourse by highlighting the necessity for organizations to adapt to changing conditions through strategic management of relationships, organizational structures, and capacity control. Collectively, these studies underscore the imperative for organizations within the supply chain to maintain flexibility not only internally but also in their external interactions, thereby ensuring responsiveness and adaptability in a volatile market landscape.

"Manufacturing" encompasses indicators of flexibility related to manufacturing processes, the concept of manufacturing flexibility is multifaceted, encompassing several critical indicators that enable adaptive manufacturing processes. Nair (2005) articulates this flexibility as the capability to effectively manage production resources to align with customer demands, ensuring that production output meets specific customer requirements. Expanding upon this framework, Stevenson and Spring (2007) identify the flexibility to augment system capacity as essential for accommodating fluctuations in demand without compromising operational efficiency. Additionally, Vokurka and O’Leary (2000) define manufacturing flexibility as the ability to execute manufacturing activities through various alternative process plans and utilize different processes and assets. This indicator of flexibility is crucial for manufacturers to adapt their operations to changing market conditions and technological advancements. Collectively, these perspectives highlight the importance of adaptable manufacturing processes in enhancing the responsiveness and competitiveness of supply chains in a dynamic business environment.

"Information" pertains to informational flexibility, informational flexibility in supply chain management involves the dynamic alignment of information systems with evolving organizational and customer needs. Lummus et al. (2005) emphasize the necessity for information system architectures to adapt promptly to shifting demands, ensuring effective responses to customer requirements. Further, Zhang et al. (2006) and Nair (2005) highlight the crucial role of organizational capabilities in the collection, storage, and dissemination of information. This facilitates robust horizontal connections across the supply chain, thereby enhancing value creation for customers. Collectively, these insights underscore the importance of agile information systems in supporting the strategic adaptability of supply chain operations.

"Logistics" encompasses indicators of flexibility related to manufacturing transportation, logistics flexibility within supply chain management encapsulates several key aspects crucial for adapting to consumer demands and market changes. Swafford et al. (2000), Nair (2005), and Hock-Soon and Mohamed (2011) define it as the capability to align and adjust the processes of goods flow—both inbound and outbound activities, including storage—to meet evolving customer requirements. Koste and Malhotra (1999) and Stevenson and Spring (2007) discuss the flexibility to route different products between processing centers using multiple paths, enhancing system resilience. Furthermore, Lummus et al. (2003), Zhang et al. (2005), and Singh et al. (2011) highlight the adaptability of inventory and transport systems to ensure broad product access and meet specific customer needs. Stevenson and Spring (2007) and Skintzi (2007) note the importance of responding to changes in delivery requests, including adjustments to locations and dates. Lastly, Schütz and Tomasgard (2011) and Martínez-Sánchez and Pérez (2005) emphasize the flexibility to modify storage capacities and relocate stock efficiently to ensure timely goods transfer.

"Procurement" covers flexibility in procurement and sourcing, procurement flexibility in supply chain management involves the adaptive capabilities in sourcing and purchasing operations. Manders et al. (2016) articulate this as the capacity to adjust procurement strategies in response to evolving sourcing requirements and supply dynamics. Similarly, Mendonça Tachizawa and Giménez Thomsen (2007) emphasize the need to adapt to changes in location and delivery dates. Manders et al. (2016) further extend this concept to the flexibility in managing the entire process of ordering, delivery, and receipt of goods, ensuring responsiveness to fluctuating supply needs and conditions. These capabilities are critical for maintaining supply chain efficiency and responsiveness.

"Marketing" denotes flexibility related to marketing activities, marketing flexibility within supply chain management refers to the strategic capacity to adapt marketing efforts to shifts in the market environment and customer preferences. Vokurka and O'Leary (2000), Lummus et al. (2003), and Stevenson and Spring (2007) discuss the ability to customize marketing approaches and foster close customer relationships. Additionally, Vickery et al. (1999) and Martínez-Sánchez and Pérez (2005) highlight the agility required to rapidly introduce new products or variations to meet market demands. Lummus et al. (2003) further emphasize the responsiveness to specific target market needs, underpinning effective marketing strategies.

"Product Development" captures the flexibility indicators involved in product development activities, product development flexibility within supply chain management encompasses the capacity to innovate and modify offerings in response to consumer demands. Zhang et al. (2002) emphasize the ability to adapt by developing new products and altering existing ones. Stevenson and Spring (2007) discuss the competence to design and seamlessly integrate new products into existing systems. Additionally, Vickery et al. (1999) and Lummus et al. (2003) highlight the capability to customize standard products to fulfill specific customer requirements, demonstrating the critical role of flexibility in sustaining competitive advantage through tailored product strategies.

Subsequent indicator selection within the scope of each business area is thus of paramount importance, involving rigorous assessment of data sources, collection of existing measurement indicators, confirmation of their relevance to the actual circumstances of the studied enterprises, identification of any missing indicators, and elimination of survey noise. Different tools can thus be used for collecting this information.

2.1.3 Data gathering

Previous work has examined how receptive learners are to feedback, highlighting the importance of sources (*e.g.*, anonymous sources versus those from peers or authorities), and the nature and content of feedback. Anonymous feedback sources are also considered to be more honest and objective (Ez-zaouia et al., 2020). An appropriate data availability is the important step for constructing a indicator (Maroosi et al., 2019). Various tools can be used to collect data, such as survey, interview with experts, database, report. Among those tools survey, Delphi survey and interview with experts are more prevalent, since they are easy to collect data which are qualitative or in form of opinions. However, for company data, it can collect quantitative data against real case items of the company, such as KPIs, measurements, etc. Although accurate and reliable performance measurements are important, the tool is often difficult to use because the data is considered confidential (Lehyani et al., 2021).

Interviews

Many authors had used interview in their items. A qualitative study was conducted using semi-structured interviews to identify the main barriers and facilitators to accessing weight management services (Holt & Hughes, 2021). The strength of interviews is that we are able to ask respondents specific, tailored questions to explore their personal perspectives and insights into the research questions, but interview have the limited nature of retrospective, while interviews are semi-structured and use topic guides, allowing for a conversational approach to explore issues that we anticipate will be important, while enabling respondents to raise areas that are important to them (Biggane et al., 2019). McKenna (1994) found in his research that it was more beneficial to use face-to-face interviews in the first round, as it helped to improve response rates in those round and subsequent rounds.

There are several advantages associated with interviews:

✓ Detailed Insights: Interviews can provide deep insights into complex topics like flexibility, capturing the nuanced understanding and experiences of participants (Voss, 2010).

✓ Contextual Richness: They allow researchers to understand the context in which flexibility is applied or needed, which is crucial for developing relevant metrics and indicators (Pettigrew, 1990).

✓ Exploratory Tool: Interviews are excellent for exploring new areas where predefined metrics may not exist, helping to identify and define new indicators of flexibility (Eisenhardt, 1989).

Nevertheless, some disadvantages can also be identified:

✓ Subjectivity and Bias: The data collected can be subjective, influenced by the interviewer's perceptions or the interviewee's desire to conform to social expectations (Yin, 2014).

✓ Time-Consumption: Conducting and analyzing interviews is often time-consuming, which may limit the number of indicators or metrics that can be explored within project timelines (Bell et al., 2022).

✓ Non-generalizability: Results from interview studies may not be generalizable to wider populations, particularly if used to define flexibility metrics that are context-specific (Kozlowski & Bell, 2003).

Wieland and Wallenburg (2013) explore how relational competencies contribute to supply chain resilience, a key aspect of flexibility. It uses interviews to gather detailed insights from industry professionals. Brandon-Jones et al. (2014) uses interviews to identify critical resources that enhance the resilience and flexibility of supply chains, analyzing how organizations adapt to disruptions. Through interviews, Tachizawa and Wong (2015), examine how green supply chain practices contribute to overall supply chain flexibility, particularly in managing environmental complexities.

Delphi survey

The Delphi method is widely recognized as a robust instrument for eliciting expert opinion through iterative surveys. According to Dalkey and Helmer (1963), the Delphi technique may be defined as a method used to obtain the most reliable consensus of opinion of a group of experts, by a series of intensive questionnaires interspersed with controlled feedback, and Delphi is an iterative, multi-stage process designed to combine opinions into a group consensus (McKenna, 1994). The initial questionnaire can also collect qualitative comments, which are fed back to the participants in quantitative form via a second questionnaire. Alternatively, qualitative data can be collected through focus groups or interviews and used to inform the first round of Delphi quantitative analysis. As with all good surveys, pilot tests should be conducted on a small group of people before implementation (Hasson, 2000). Delphi survey is a group facilitation technique, it is an iterative multi-stage process that aims to translate opinions into group consensus and it is flexible (Hasson, 2000).The Delphi survey, used alone or in combination with other methods, is the most popular method for promoting participation. These methods involve iterative questionnaires that list the results and ask participants to rate the importance of each result, while Delphi surveys are relatively inexpensive to create, manage and analyze (Biggane et al., 2019). The availability of Delphi's online survey platform allows for the collection of large numbers of samples and ensures that they are relevant on a global scale.

There are several advantages associated with the use of Delphi:

✓ Consensus Building: It helps in achieving a converged opinion among a group of experts through iterative rounds, minimizing the influence of dominant individuals (Foth et al., 2016).

✓ Anonymity: Participants remain anonymous, reducing the effects of peer pressure or the influence of dominant personalities (Niederberger & Spranger, 2020).

✓ Geographical Dispersion: Allows for the participation of experts located in diverse geographical locations without the need for physical meetings (Riddell et al., 2017).

✓ Flexibility: The method is flexible in terms of structure and can be adapted to different kinds of research questions (Strand et al., 2017).

Some disadvantages also exist:

✓ Time-Consuming**:** It can be a lengthy process, requiring several rounds to reach consensus (Warner, 2014).

✓ Dependence on Expertise: The outcome is heavily dependent on the selected panel of experts. Misjudgment in selecting panelists can skew results (Von Der Gracht, 2012).

✓ Limited Interaction: The lack of direct interaction among experts can prevent the beneficial dynamics of live discussions (Graham, 2003).

✓ Response Fatigue**:** Participants may lose interest over multiple rounds, potentially leading to dropout or reduced response quality (Warner, 2014).

Turoff and Linstone (2002) discussed applications of the Delphi method across fields, including its use in developing indicators for various phenomena. Ho et al. (2010) reviews the use of Delphi in supplier selection within supply chains, focusing on criteria development and flexibility assessment. Seuring and Gold (2012) discussed using Delphi in systematic literature reviews within supply chain management, touching on aspects like flexibility in supply chain practices.

Fuzzy Delphi method (FDM)

According to Kozarević and Puška (2018), who cited from Zadeh (1965) and Bojadziev a nd Bojadziev (1995), the use of fuzzy logic began in 1965. Professor Zadeh of the University of Berkeley laid the foundations of fuzzy logic in his paper "Fuzzy Sets" published in the journal Information and Control, emphasizing that if we want to overcome very complex problem solving, we don't have to go in the direction of rigor and precision in our description and thinking, but we can go in the opposite direction. And allow for imprecision in the spirit of natural language. Fuzzy logic allows for subtle differences in the membership level of elements for a particular set, *i.e.*, each element is associated with a real number as the indicator of that element's membership level for the set. Fuzzy set theory provides a broader framework than classical logic, and it aims to develop the ability to reflect human thinking in the real world (Ertuğrul & Tuş, 2007). Fuzzy set theory is used to model imprecise information generated by human thinking (Ashrafzadeh et al., 2012). Fuzzy Delphi is the result of the combination of traditional Delphi technology and fuzzy set theory. It is proposed for the first time to improve the fuzziness and ambiguity of the original Delphi technology (Bouzon et al., 2016). Due to the lack of complete information, in order to make decisions, in addition to considering the objective probability of events, human subjectivity and fuzzy logic must be considered (Kozarević & Puška, 2018). The fuzzy algorithm of supply chain management performance input variables is implemented in three main stages: fuzzy, inference and defuzzy. In the fuzzification stage, the real-world sensory input in the final domain is represented on the closed interval [0, 1] according to its membership level in the fuzzy set. The names of these sets use easy-to-understand language terms to express the quality of the input variables. Linguistic variables refer to variables related to language (colloquial words and statements). Variables in mathematics usually take numerical values, while in fuzzy logic, non-numerical linguistic variables are often used to facilitate the expression of rules and facts (Dashore & Sohani, 2013). Numerical values for qualitative performance measures do not exist. Therefore, the opinion of the decision-maker (as a measurement tool) must be translated into numerical values. Because of this ambiguity in the investigation process, fuzzy set theory is a suitable method to deal with uncertainty (Omar et al., 2015.).

The Fuzzy Delphi Method shows several advantages:

✓ Reduces the number of rounds needed to reach consensus**:** By incorporating fuzzy logic, FDM can achieve consensus with fewer rounds compared to traditional Delphi methods

(Chen et al., 2006).

✓ Handles uncertainty and ambiguity in expert responses: FDM effectively manages the ambiguity and variability in expert opinions, making it particularly useful in scenarios where precise data are scarce (Khalili-Damghani et al., 2013).

✓ Cost-effective and Efficient for Geographic Dispersed Experts: FDM allows experts to participate remotely, reducing the need for physical meetings and thus saving time and resources (Lee et al., 2009).

A few disadvantages can also be identified:

✓ Complexity in setting up and analyzing fuzzy sets: The integration of fuzzy logic with the Delphi method introduces additional complexity, requiring more expertise to set up and analyze the results effectively (Kumar et al., 2017).

✓ Requires deep understanding of fuzzy logic: Accurate interpretation of fuzzy data demands specialized knowledge of fuzzy set theory, limiting its accessibility to researchers familiar with the field (Rolstadås et al., 2014).

✓ Potential for Over-Specification: The precision of fuzzy logic might lead to over-specification in cases where broader consensus-based guidance would suffice (Ho et al., 2010).

✓ Response and Participation Issues: The complexity and iterative nature of FDM can lead to response fatigue among experts, potentially affecting the quality of the final consensus (Linstone & Turoff, 2011).

Chen et al. (2006) applied FDM for evaluating suppliers, focusing on flexibility among other criteria in supply chain management. Ho et al. (2010) discussed various decision-making methods including Fuzzy Delphi for assessing supplier performance, particularly looking at flexibility. Tavana et al. (2016) utilized a combination of Analytic Network Process and FDM to manage risks in supply chain integration, highlighting the role of flexibility.

Considering the geographical dispersion of experts across various provinces, the involvement of nearly one hundred participants, and the urgent nature of the research, along with the varying interpretations of the same indicators, the Fuzzy Delphi technique is the most appropriate method for this study. This technique efficiently handles large, geographically dispersed expert panels, addresses time constraints, and effectively manages the ambiguity and variability in expert opinions. By incorporating fuzzy logic, it allows for a more precise consensus, making it particularly suitable for the complex and dynamic nature of supply chain flexibility research. Comparison among interviews, Delphi survey and Fuzzy Delphi method refer to Table 2.1.

Table 2.1 The comparison among interviews, Delphi survey and Fuzzy Delphi method

Method	Advantages	Disadvantages	References
Interviews	Provides detailed insights into complex topics. Offers contextual richness. Good for exploratory research.	Subject to bias and subjectivity. Time-consuming to conduct and analyze. Results may not be generalizable.	Voss (2010), Pettigrew (1990), Eisenhardt (1989), Yin (2014), Bell et al. (2022), Kozlowski and Bell (2003)
Delphi Survey	Builds consensus through iterative rounds. Participants remain anonymous. Suitable for geographically dispersed experts.	Time-consuming due to multiple rounds. Dependent on the quality of expert selection. Limited direct interaction.	Foth et al. (2016), Niederberger and Spranger (2020), Riddell et al. (2017), Strand et al. (2017), Warner (2014), Von Der Gracht (2012), Graham (2003), Warner (2014)
Fuzzy Delphi Method	Achieves consensus with fewer rounds. Manages uncertainty and ambiguity well. Cost-effective for dispersed experts.	Complex setup and analysis. Require knowledge of fuzzy logic. Potential for over-specification.	C. T. Chen et al. (2006), Khalili-Damghani et al. (2013), Lee et al. (2009), D. Kumar et al. (2017), Rolstadås et al. (2014), Ho et al. (2010), Linstone and Turoff (2011)

2.2 Tools for measuring and monitoring flexibility within supply chains

This study conducted a thorough literature review from 2017 to 2022, utilizing b-on, Web of Science, and Google Scholar databases. The search focused on keywords "SC flexibility" and "measure or monitor" in document titles, and "tools or dashboard or Excel or scorecard" in abstracts. Only peer-reviewed scientific journals and conference proceedings in English, with full text available, were included. Furthermore, only studies ranked in Q1 and Q2 according to the JCR ranking were selected. Duplicated studies were excluded using the literature management software Zotero. Due to space constraints in the text box, the abbreviation "T" is employed to denote "Tools".

The review identified 66 relevant studies, with 26 cited in this thesis. Among these, 12 studies were related to high-tech areas. The 26 studies cited mentioned a total of 32 measuring tools, due to some authors mentioning multiple tools and several studies citing the same tools. These 32 cited tools were categorized into 6 distinct tools. Refer to Figure 2.1.

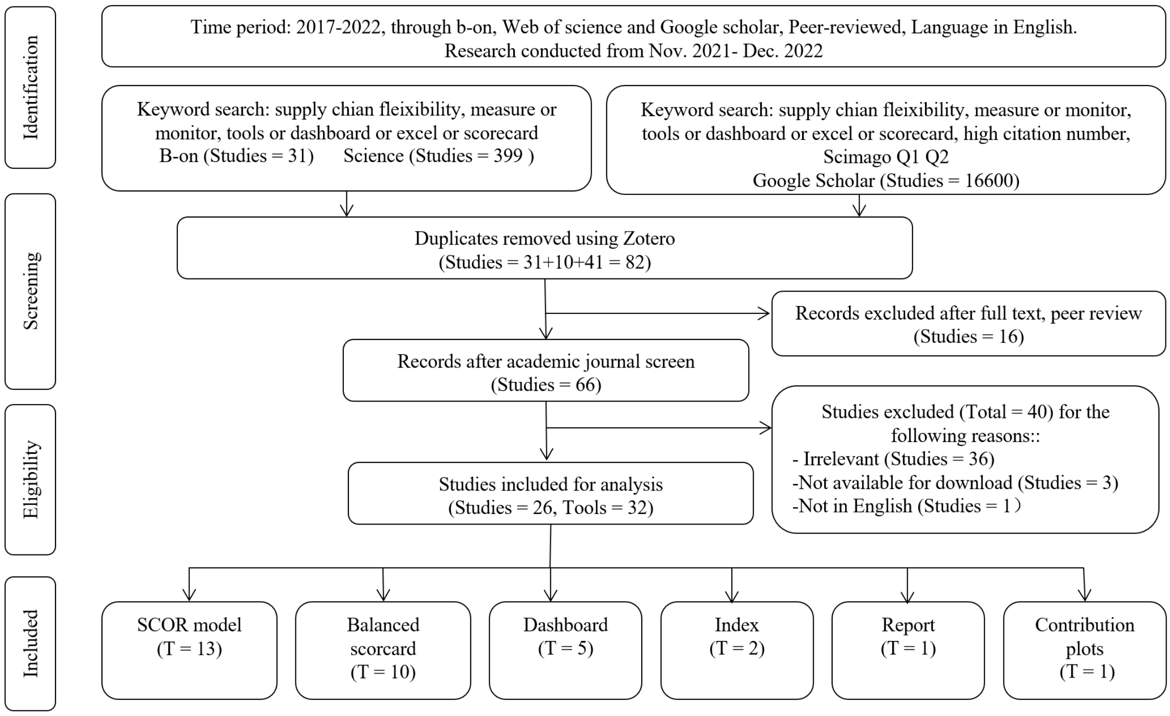

Figure 2.1 SLR steps to identify these tools to measure the SC flexibility

The SLR illustrates the distribution of measuring tools for SC flexibility. The SCOR model accounts for 13 out of 32 items (representing 41% of the total), balanced scorecards account for 10 items (31%), dashboards account for 5 items (16%), index accounts for 2 items (6%), and reports and contribution plots account for 1 item each (3% each). Therefore, the SCOR model, balanced scorecards, and dashboards are the most commonly used tools for measuring and monitoring SC flexibility. Refer to Table 2.2.

Table 2.2 Distribution of measuring tools for SC flexibility

MM Tools	Items	Percentage	#Items of High-tech area related	Percentage	#Items of SC flexibility related	SC flexibility percentage
SCOR model	13	41%	4	13%	0	0%
Balanced scorecard	10	31%	7	22%	1	3%
Dashboard	5	16%	4	13%	1	3%
Index	2	6%	0	0%	0	0%
Report	1	3%	1	3%	0	0%
Contribution plots	1	3%	0	0%	0	0%
	32	100%	16	50%	2	6%

Table 2.3 demonstrates that the measuring and monitoring tools mentioned earlier have primarily been utilized in the manufacturing sector, accounting for 50% of the overall items. Additionally, 19% of the high-tech items are focused on the manufacturing field. Specifically related to SC flexibility, there are only 2 items, 1 in manufacturing and 1 in the retail field.

Table 2.3 SC flexibility measuring and monitoring tools applied field

Field	Items	Percentage	#Items in High-tech	Percentage	#Items of SC flexibility related	SC flexibility percentage
Manufacturing	16	50%	6	19%	1	3%
Agricultural	3	9%	1	3%	0	0%
Exploratory study	3	9%	2	6%	0	0%
Public healthcare	3	9%	3	9%	0	0%
Literature review	2	6%	0	0%	0	0%
Retail	2	6%	2	6%	1	3%
All business field	1	3%	1	3%	0	0%
Banking	1	3%	1	3%	0	0%
Education	1	3%	0	0%	0	0%
	32	100%	16	50%	2	6%

Although various tools possess distinct characteristics and are applicable in diverse scenarios, it is essential to investigate the primary features of each tool. Detailed reference list of each tool please refer to Annex A, and for the benefits and drawbacks of each tool please refer to Annex B.

SCOR model

The SCOR model serves as a systematic approach for measuring a company's performance, offering a short implementation time through the application of best practices (Chorfi et al., 2018). SCOR establishes standards that assist companies in developing their own performance measurement criteria. It can serve as a diagnostic tool for companies operating in complex and highly competitive fields, aiding in the verification and enhancement of their supply chain performance (Lemghari et al., 2018). By utilizing the SCOR framework, various manufacturers can tailor their supply chain performance measurement by adjusting their measures, attributes, and metrics to suit their specific requirements (Dissanayake & Cross, 2018). The SCOR model provides common, pre-defined indicators that help prevent misunderstandings and disputes (Kusrini et al., 2019). Utilizing metrics suggested by the SCOR model contributes to better alignment, standardization, and integration of performance measures across different supply chain layers (Lima-Junior & Carpinetti, 2019). SCOR metrics are compatible with the SCOR mark database, enabling benchmarking through the comparison of estimated performance figures with performance databases from various supply chains worldwide (Lima-Junior & Carpinetti, 2020). In the systematic literature review (SLR), 13 studies were identified, with 4 studies related to the high-tech area.

The SCOR model is a comprehensive, process-based model designed to measure the performance processes of the supply chain. It is closely linked with the SCOR process and utilizes pre-defined indicators to prevent misunderstandings. Moreover, it aligns strategic and operational goals. However, its implementation may be influenced by changes in strategy, and it is best suited for customized cases.

Balanced scorecard

Balanced Scorecard (BSC) was introduced by Kaplan and Norton (2001) to promote a balanced approach in organizational metrics, considering four perspectives: short-term and long-term objectives, financial and non-financial measures, lagging and leading indicators, and internal and external performance perspectives. Its value lies in daily routine evaluation of supply chain management (SCM) performance, coordinating various business operations simultaneously. Companies benefit from a systematic framework based on predefined goals and measures at all decision levels (Bhagwat & Sharma, 2007). The BSC framework helps in understanding strategy and developing a balanced performance measurement system according to decision makers' preferences (Chorfi et al., 2018). By integrating financial and non-financial measures, BSC provides managers with more relevant information about organizational performance (Pakurár et al., 2019). Proposed metrics within the BSC framework's standard perspectives can signal potential disruptions, serving as early warning indicators (Pham, 2021). The primary purpose of a scorecard is to align business activities with a common strategic plan, monitoring execution in real time and reporting results in line with the strategy, with Key Performance Indicators (KPIs) as its fundamental indicator (Nica et al., 2021). From the systematic literature review (SLR), 10 studies were identified that utilized the balanced scorecard, with 7 of them related to the high-tech area. The Balanced Scorecard is a comprehensive tool for measuring overall organizational performance, aiding in aligning operational objectives with strategic targets. However, it primarily offers frameworks and lacks a formal implementation methodology.

Dashboard

Dashboard and graphical displays assist stakeholders in monitoring and evaluating strategy execution in the education field (Okfalisa et al., 2018). Dashboards can be customized to display Key Performance Indicator (KPI) indicators for analyzing supply chain sector work in retail companies to meet business requirements (Iliashenko et al., 2019). They offer intuitive, interactive reading and interpretation, with visualizations and filters fulfilling business needs (Freire, 2020). The goal of dashboards is to improve perception without complicating, hindering, or biasing it (Bréant et al., 2020). They are essential for monitoring changes in organizations, especially with increasing data in management. Dashboards help managers easily capture important information and present an overview of company results (Nica et al., 2021). From the systematic literature review (SLR), 5 studies were identified that applied dashboards for measurement, with 4 of them related to the high-tech area. Dashboard is a measuring tool that focuses on automatically monitoring the results of operational objectives. It is easy to implement in terms of cost and time and provides real-time data and multi-indicator performance monitoring. However, dashboards require a full set of operational data, data cleaning, and skilled use of Excel or Power BI to present the results.

Indexes

In the domain of supply chain management, particularly within the manufacturing sector, two studies have been instrumental in leveraging indices to measure supply chain flexibility. Singh et al. (2020) develop an Excel-based template that simplifies the process for managers and departments to identify key issues related to flexibility. This template facilitates the quantification of discrepancies between actual and target indices across various flexibility indicators, allowing managerial staff to implement necessary adjustments. The versatility of the index format is tailored to meet diverse company requirements, and the template's questions and choice numbers can be easily modified to align with the specific needs of the soap manufacturing industry.

Furthermore, Ramezankhani et al. (2018) introduce an index system where values range from 0 to 1, with higher values indicating superior performance in specific indicators. This index provides a straightforward method to assess performance levels, with numerical outputs derived from formulas established based on managerial specifications tailored to different measurement needs within the supply chain. These indices not only serve as practical tools for performance evaluation but also enhance the adaptability and responsiveness of supply chains by providing clear metrics that guide strategic decision-making in manufacturing contexts.

Reports

Reports are among the most prevalent tools in business intelligence (BI). They range from simple, static formats like sales lists over a period to sophisticated tables that include grouped data, pivots, and in-depth analyses. These reports excel in transforming raw data into formats that are easy to read and interpret, making them invaluable for users needing to perform direct data analysis. According to Nica et al. (2021), the true potential of reports is realized when they are integrated with scorecards and dashboards. This combination enhances user access to raw data, which is essential for defining critical metrics such as units of measure and key performance indicators (KPIs). Such integration not only facilitates a comprehensive overview of organizational performance but also streamlines the decision-making process by presenting crucial data points in a coherent and accessible manner. This synergy between different BI tools ensures that reports not only present data but also empower users to derive meaningful insights effectively.

Contribution plots

Contribution plots serve as a pivotal analytical tool in the identification of variables exhibiting abnormal behavior, particularly when one or more statistical measures surpass predefined thresholds. According to J. Wang et al. (2020), these plots are instrumental in both interpreting and pinpointing abnormalities within datasets. The utility of contribution plots extends across various applications, significantly aiding in the isolation of variables potentially associated with faults, as highlighted by Yoon and MacGregor (2001). This method effectively narrows down the range of variables under consideration, streamlining the process of fault diagnosis.

Furthermore, MacGregor and Cinar (2012) notes that the employment of contribution plots can be regarded as an indirect method for fault diagnosis. This approach allows for a systematic examination of deviations in operational data, facilitating early detection of irregularities that could indicate underlying problems. By providing a clear visual representation of data contributions, these plots enable researchers and practitioners to focus their investigative efforts more efficiently and make informed decisions based on empirical evidence.

In summary, contribution plots are a valuable tool in the arsenal of diagnostic techniques, offering a methodical approach to the detection and analysis of anomalies within complex datasets. Their application is crucial for maintaining operational integrity and enhancing the reliability of systems in various industrial and research settings.

From the preceding analysis, it is evident that the SCOR model, Balanced Scorecard, and dashboard are the primary measurement tools utilized, accounting for 41%, 31%, and 16% respectively of the total 32 tools selected from 26 cited studies. In the high-tech sector, these tools also predominate in the evaluation of company performance, with distribution among the tools being 13%, 22%, and 13% respectively.

Within the high-tech sector, only 2 out of 16 tools specifically addressed SC flexibility, representing 6% of the total 32 tools. Of these, one study employed a dashboard, while another utilized a Balanced Scorecard as the measurement tool.

Furthermore, no tools developed by Chinese companies were identified among the 32 tools selected from the 26 studies. This observation suggests a significant gap in the research dedicated to developing tools for measuring and monitoring SC flexibility, particularly within the context of Chinese high-tech sectors. These sectors face unique challenges such as financial constraints, resource limitations, technological gaps, and dynamic market uncertainties, which underscore the urgency for targeted tool development to enhance research and development, meet market demands promptly, improve operational efficiencies, and increase profitability.

Consequently, there is an unequivocal need for research aimed at creating tools specifically designed for this sector. Given the attributes, advantages, and limitations of the existing tools, dashboards are proposed as particularly suitable for this purpose. Dashboards are effective in continuously monitoring the achievement of operational objectives, offer ease of implementation considering cost and time, support real-time data access, and facilitate multi-indicator performance monitoring.

2.3 Strategies towards SC flexibility

2.3.1 Strategies towards SC flexibility by indicators

This section delineates the methodologies utilized in previous research to bolster SC flexibility. Building on established research protocols, a new systematic literature review (SLR) was undertaken to compile and scrutinize pertinent strategies.

This study undertook an exhaustive literature review spanning 2017 to 2022, leveraging b-on and Google Scholar databases. The search was centered on the keywords "SC flexibility" and "strategies" within document titles. Inclusion criteria were limited to peer-reviewed scientific journals and conference proceedings published in English and available in full text. Additionally, only studies categorized within Q1 and Q2 according to the Journal Citation Reports (JCR) rankings were selected, Duplicated studies were excluded using the literature management software Zotero. Due to space constraints in the text box, the abbreviation "S" is employed to denote "Strategies."

The review identified 57 pertinent studies, 43 of which are referenced in this thesis. Of these, 14 studies pertain to high-tech sectors. The 43 studies collectively reference 46 supply chain improvement strategies, organized into six business areas: organization, information, manufacturing, Procurement, marketing, and logistics. Notably, no strategies relating to the product development area were identified. The discrepancy between the number of cited studies and strategies arises from instances where authors referenced multiple tools and several studies cited the same tools. For further details, refer to Figure 2.2

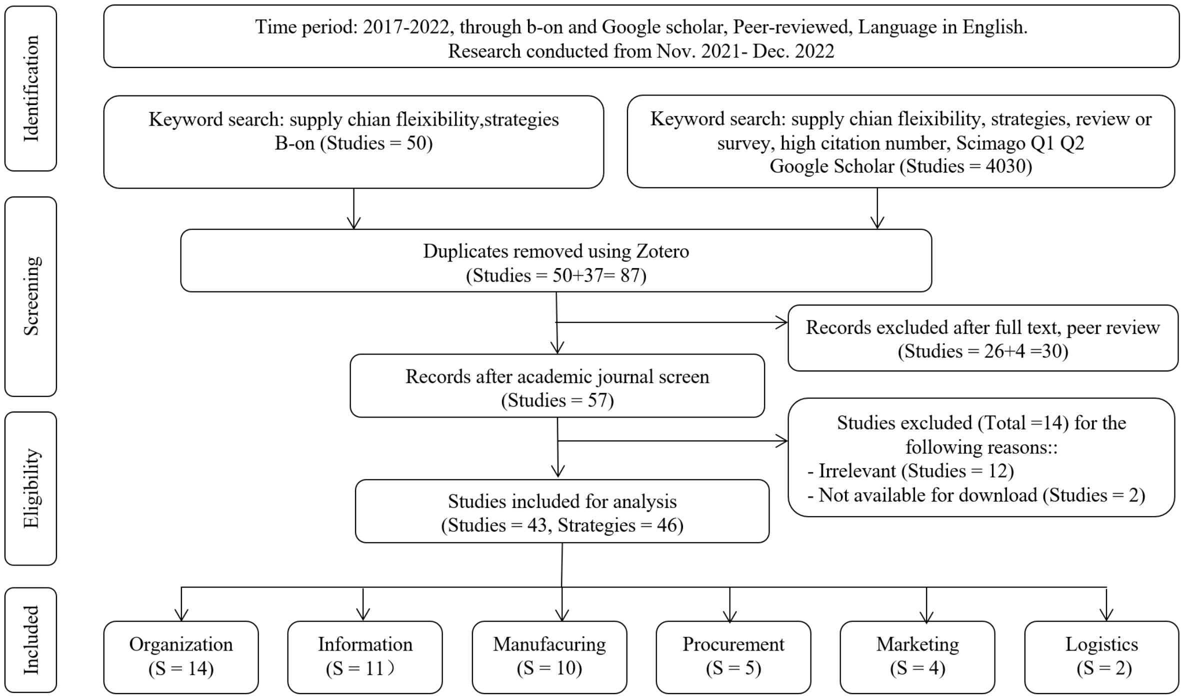

Figure 2.2 SLR steps to identify these strategies to improve SC flexibility

Following the established systematic literature review protocol, 43 studies were identified that propose strategies targeting specific indicators of SC flexibility. Notably, some studies suggest strategies that span multiple indicators of flexibility, resulting in a total of 46 strategic items enumerated within the table. Analysis of these items reveals a concentrated focus on enhancing organizational, informational, and manufacturing flexibility within supply chains. Specifically, 14 items (30%) are aimed at improving organizational flexibility, 11 items (24%) address informational flexibility, and 10 items (22%) enhance manufacturing flexibility. Additionally, strategies concerning Procurement, marketing, and logistics flexibility are represented by 5 (11%), 4 (9%), and 2 (4%) items, respectively. Upon reviewing the cited literature from the SLR, it was observed that no strategies specifically related to product development were identified.

Among these items, 15 items (33%) are related to the High-tech sector, while only 2 items (4%) specifically target Chinese High-tech companies. Detailed distributions and classifications of these strategies can be reviewed in Table 2.4, which categorizes the strategic items according to their respective indicators of SC flexibility.

Table 2.4 SC Flexibility strategies

Business area	Strategies	Percentage	Strategies in High-tech	Percentage	Strategies in China High-tech	Percentage
Organization	14	30%	3	7%		
Information	11	24%	7	15%	1	2%
Manufacturing	10	22%	1	2%	1	2%
Procurement	5	11%	2	4%		
Marketing	4	9%	2	4%		
Logistics	2	4%				
	46	100%	15	33%	2	4%

2.3.2 Organizational flexibility strategy

This analysis delineates fourteen strategic initiatives aimed at enhancing organizational effectiveness within supply chains. These strategies are categorized into three main types: external integration, internal integration, and a combination of both. A total of fourteen strategies were identified.

External Integration Strategies: These strategies primarily involve the alignment and integration with external entities such as customers, suppliers, and broader societal stakeholders. Key components of external integration include supplier integration, customer relationship management, external flexibility, external knowledge transfer, establishment of long-term strategic partnerships with vendors, and the incorporation of smart supply chain management and innovation practices. Altogether, nine items fall under this category.

Internal Integration Strategies: This category focuses on fostering cohesion and synergy across different departments within an organization. Strategies under this umbrella include enhancing internal integration, boosting internal flexibility, and developing operational absorptive capabilities, which together comprise three strategic items.

Combined External and Internal Integration: Additionally, two strategic items bridge both external and internal aspects, aiming to create a holistic framework that enhances overall SC flexibility.

Several scholars emphasize the importance of external integration strategies, particularly focusing on fostering relationships with suppliers to enhance network-wide flexibility and mitigate uncertainties within supply chains. Extensive research underscores the significant benefits of developing collaborative relationships across supply chains. Stevenson and Spring (2007), Fayezi et al. (2016), Y. Liu et al. (2019), Gupta et al. (2019)), and Chirra et al. (2021) detail key advantages of these partnerships, including just-in-time deliveries, cost reductions, and shared risks. Blome et al. (2014) further assert that knowledge transfer among suppliers can substantially improve overall SC flexibility. Zhu et al. (2021)) advocate for long-term relationships with suppliers and strategic logistics outsourcing as effective strategies to enhance supply chain operations.

Moreover, Cui et al. (2021) argue that customer relationship management and a deep understanding of customer expectations are pivotal for innovating within green supply chain management in the energy industry. Um (2017) contrasts the effectiveness of close customer relationships and supplier partnerships in different customization contexts, finding that close customer relationships significantly increase SC flexibility in high-customization scenarios, while partnerships with suppliers enhance supply chain agility more effectively.

Three scholars have underscored the importance of internal integration in boosting SC flexibility. Esmaeilikia et al. (2016) argue that employing tactical supply chain planning models that incorporate multiple flexibility options can enhance operational efficiency and effectiveness, thereby improving supply chain resilience in the face of environmental uncertainties. Rojo et al. (2018) explore the relationship between environmental dynamism, operational absorptive capacity, and organizational learning, noting that these dynamic capabilities are positively associated and collectively foster SC flexibility. They also point out that SC flexibility is partially mediated by these capabilities, suggesting that managers should develop these aspects to enhance SC flexibility, especially in highly dynamic environments.

Further, Tarigan et al. (2021) examine how internal integration, particularly through interdepartmental data sharing, impacts supply chain partnerships, agility, and resilience. They highlight the critical role of effective communication and data sharing among departments in strengthening the overall supply chain structure.

Integrating both internal and external elements significantly enhances SC flexibility. Almeida et al. (2018) highlight that flexibility in supply, manufacturing, and distribution is crucial for achieving supply chain resilience. Furthermore, Al-Zabidi et al. (2021) emphasize the importance of prioritizing the development and integration of core competencies to address cross-functional and cross-enterprise challenges within the supply chain framework.

2.3.3 Informational flexibility strategy

This research addresses eleven strategic elements centered on enhancing supply chain management through the integration of information systems and digitalization, aiming to improve operational flexibility and responsiveness.

Seven strategic elements focused on leveraging information system applications to augment flexibility within supply chain management. Han et al. (2017) elucidate that transactional IT flexibility significantly impacts operational IT flexibility, which in turn influences strategic IT flexibility. Kopanaki et al. (2018) further detail how IT utilization enhances operational efficiencies, reduces time-to-market, supports robust information-sharing, and facilitates cooperation across organizational boundaries, thus fostering operational, structural, and strategic flexibility within supply chains.

Luo et al. (2020) advocate for the critical importance of sharing information resources and strengthening the capability to access and discern valuable internal and external information within the supply chain to bolster product manufacturing innovation. S. Ahmed et al. (2021) recognize the emergent necessity for technology-based sustainable education platforms, such as online classes, that were not prevalent before. Additionally, Kuo et al. (2021) demonstrate that collaborative data-driven analytics in material resource management within smart supply chains can achieve up to a 90 percent customer material fulfillment rate, significantly enhancing supply chain responsiveness.

Moreover, Baah et al. (2022) find that information sharing profoundly and positively impacts supply chain visibility, collaboration, agility, and overall performance. The advancement of sensor and tracking technologies has escalated consumer expectations for real-time tracking of products or services throughout the entire supply chain process, necessitating organizations to implement comprehensive end-to-end communication strategies across their supply chains K. S. Ahmed et al. (2022).

Four strategic elements are dedicated to advancing data treatment to augment SC flexibility. Dubey et al. (2021) emphasize that enhancing data analytics capabilities within organizations can significantly improve information processing under uncertain scenarios, thereby enabling more effective management of uncertainties. Sharma et al. (2021) argue that retail supply chains, amid ongoing crises, must leverage advanced digital technologies to develop more robust and resilient systems. Additionally, Hussain et al. (2021) highlight the potential of the Internet of Things (IoT) as a transformative technology that allows businesses to monitor, track, and manage products and processes across their value chains, thereby increasing SC flexibility. Furthermore, Modgil et al. (2022) suggest that AI-powered supply chains, with improved information processing capabilities, can enhance resilience and adaptability in dynamic environments.

2.3.4 Manufacturing flexibility strategy

Within the discourse on supply chain management, ten strategic items have been delineated, concentrating on enhancing manufacturing processes through avenues such as manufacturing flexibility, product modularity, adherence to ISO9001 standards, and the optimization of facilities and equipment. Malik and Sarkar (2020) and Karimi et al. (2022) posit that managing and reducing production lead times can substantially decrease inventory levels, which consequentially improves customer service and boosts the profitability of the overall system. Furthermore, Swafford et al. (2006) establish that manufacturing flexibility is intrinsically linked to supply chain agility.

Alkahtani et al. (2021) advocate for a proactive strategy that leverages optimal resource utilization and controllable production rates to address emergencies, notably in pandemic contexts. Baral et al. (2021) suggest that small and medium enterprises, to thrive in unstable economic climates, must address human resource deficits to better respond to unpredictable demand patterns. Ivanov (2021) underscores the efficacy of a gradual capacity increase before anticipated demand surges as a potent strategy for inventory management, facilitating recovery and enhancing supply chain coordination.

Z. Wang and Zhang (2020) argue that product modularity significantly contributes to SC flexibility. Barman et al. (2021) note that maintaining employee safety and adapting workplace conditions can preempt production halts and secure food SC flexibility. Chitrakar et al. (2021) discuss how integrating automation and smart technologies in manufacturing processes can minimize human involvement, thus improving operational efficiency.

In the realm of quality standards, ISO 9001's impact on SC flexibility has been a subject of debate. Araceli et al. (2020) illustrate that ISO 9001 can indeed support the development of certain SC flexibility indicators, particularly when integrated with an ambidextrous supply chain strategy, thereby advising managers to not view ISO certification as a barrier but as a facilitator of SC flexibility.

2.3.5 Procurement flexibility stragety

Five strategic indicators are identified as pivotal to the Procurement processes within supply chains, specifically focusing on Procurement operations, sourcing flexibility, and supplier selection. Gosling et al. (2010) contend that an agile and flexible supply chain is essential for managing high levels of uncertainty, particularly in the construction industry, and highlight sourcing and vendor flexibility as key antecedents to SC flexibility. Wagner et al. (2018) explore the nuanced relationship between sourcing flexibility and delivery performance, noting that while sourcing flexibility is curvilinearly related to delivery performance, the latter significantly impacts the financial performance of a product. Good sourcing flexibility, therefore, enhances overall company performance.

Zhu et al. (2021) discuss the stability that domestic Procurement of shipping materials can provide, helping to mitigate supply chain uncertainty. Kuo et al. (2021) further elaborate on strategies during supply disruptions, suggesting that manufacturers might need to alter product types and select new suppliers that can meet the requirements of the modified product to minimize profit losses. Finally, Bai et al. (2019) argue that companies can achieve competitive advantage by developing unique resources that are valuable and challenging for competitors to replicate, thereby differentiating themselves in the market.

2.3.6 Marketing flexibility stragety

Four strategic items are centered on enhancing marketing within supply chain management, focusing on customer relationships, market, and demand variability. According to Jangga et al. (2015), SC flexibility has become a pivotal management strategy to address evolving customer requirements effectively. Almeida et al. (2018) explore the trade-off relationship between demand variability and service level, positing that increasing flexibility to accommodate demand variability necessitates some level of service sacrifice. Chirra et al. (2021) discuss how sales promotion schemes, prevalent in today's business environment, augment sales and profits yet introduce significant demand uncertainty into the supply chain. Furthermore, Lehyani et al. (2021) highlight that market orientation, as an external influence, plays a substantial role in fostering agile supply chain strategies.

2.3.7 Logistics flexibility stragety

Two strategic items primarily focus on logistics and supply chain delivery strategies. According to Hatani et al. (2016), delivery flexibility plays a predominant role in depicting SC flexibility. Yeh et al. (2016) further elucidate that superior delivery quality from airline companies significantly enhances the operational efficacy and development capabilities of travel agencies.

2.3.8 Flexibility stragety in high-tech sector (particular context in China)

In a survey of 43 studies, 14 were associated with high-tech sectors, encompassing a total of 15 indicators. Among these, 7 indicators targeted informational improvements as detailed by Han et al. (2017), Kopanaki et al. (2018), Luo et al. (2020), Hussain et al. (2021), Dubey et al. (2021), Kuo et al. (2021), and Modgil et al. (2022). Three indicators focused on organizational improvements, as observed in works by Chirra and Kumar (2018), Rojo et al. (2018), and Tarigan et al. (2021); two indicators addressed marketing strategies, highlighted in studies by

Chirra and Kumar (2018) and W. Ahmed and Huma (2021); two indicators concerned Procurement enhancements, discussed by Wagner et al. (2018) and Bai et al. (2019); and one indicator was related to manufacturing field advancements, proposed by Z. Wang and Zhang (2020).

Of these studies, only two specifically addressed Chinese high-tech companies. Z. Wang and Zhang (2020) discussed improving product modularity to enhance SC flexibility, while Luo et al. (2020) emphasized the importance of sharing information with both internal and external partners in the supply chain. Despite the technological advancements as mentioned in "Data China 2022" (p. 46), which outlines the construction of Digital China enhancing the foundation for modernization and providing impetus for national competitiveness, the penetration of digital transformation within Chinese enterprises remains low. According to "Digital China 2022" (appendix p. 3), only 24.9% of enterprises have implemented digital transformations in supply chain management, while 35.5% seldom utilize digital technologies, and 39.6% have never used them. This gap underscores the critical need for further exploration of digitalization in the supply chain sector among Chinese companies.

2.4 Conclusion

The forthcoming chapters will ascertain the indicators of SC flexibility pertinent to Chinese privately-owned high-tech enterprises through a systematic literature review and the Delphi method.

The principal methodologies for measuring and monitoring SC flexibility encompass the SCOR model, the balanced scorecard, and dashboards, which constitute 41%, 31%, and 16% of the 32 tools surveyed, respectively. Within the high-tech sector, 16 tools are identified, with dashboards, balanced scorecards, and the SCOR model, the balanced scorecard, and dashboards being the most prevalent, accounting for 13%, 22%, and 13% of the total tools, respectively. Among these, two tools are specifically associated with Chinese firms, where one is dashboard, and the other one is a balanced scorecard.

The primary strategies to enhance SC flexibility focus on organizational structure, information management, manufacturing, and Procurement, representing 30%, 24%, 22%, and 11% of the 46 strategic improvement strategies, respectively. In the high-tech sector, 15 strategic items are identified, with the main areas of improvement being information, organization, Procurement, and marketing, accounting for 15%, 7%, 4%, and 4% of the strategic items, respectively. Of these, two items are pertinent to Chinese high-tech companies, with one each in the information and manufacturing sectors.

In conclusion, there is a discernible paucity of research dedicated to the development of tools for the measurement and monitoring that facilitate the enhancement of SC flexibility, particularly with only two studies targeting the specificities of the high-tech sector in Chinese private enterprises. This thesis aims to bridge this gap.

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Chapter 3: Methodology

3.1 Overview of the methodology

The methodology followed in this thesis is the Design Science Research (DSR), and aims at designing, building, and evaluating an artifact (Peffers et al., 2007; Wang & Zhang, 2020).

The DSR should be employed under the following circumstances (Collatto et al., 2018; March & Storey, 2008): i) when there is a lack of adequate solutions to solve the problem under analysis; ii) when the artifact proposed to solve the problem is designed, developed and evaluated; iii) when the research adds value to existing theoretical knowledge, contributing both to the scientific literature and also to practice; and iv) when the implications of the proposed solution (*i.e.*, the artifact) are analyzed in a real context. Within this setting, the DSR represents an adequate approach to be employed within the scope of this thesis because it proposes to build a dashboard to measure, monitor and guide the improvement of the SC flexibility for those Chinese private high-tech companies – representing this the artifact – which, according to the literature review presented in Chapter 2, has not been developed to date. Furthermore, this new tool is planned to be developed and applied in real practice in a high-tech organization, which will then translated in a contribute to the real practice.

The dashboard will reflect the running status of different indicators in real time. By reading the dashboard, managers could well understand the company status and take action to fix problems. A systematic literature review will be done to find out indicators currently used in previous studies to measure SC flexibility, and then COROS will be used as a case study to validate those indicators as well as to identify any new indicators that are considered to fit in the particular case of Chinese high-tech companies.

The six steps of this methodology as proposed by Peffers et al. (2007) is shown in Figure 3.1.

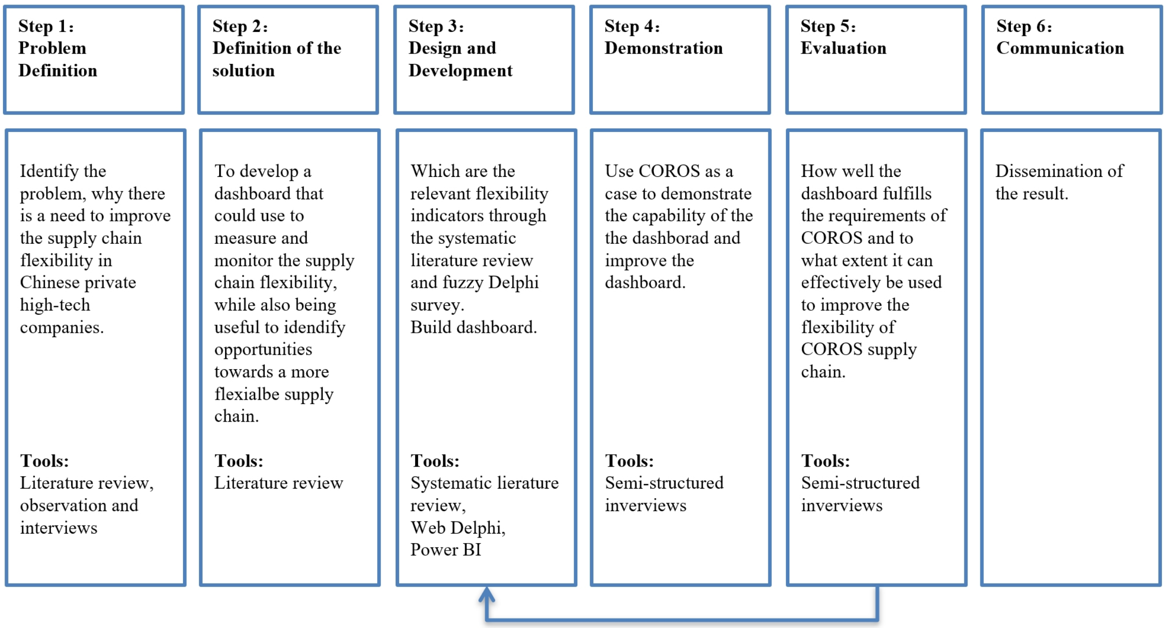

Figure 3.1 Six steps of methodology

3.2 Step 1: Define the problem

The problem under analysis of this thesis is as follows: How can Chinese private high-tech companies measure, monitor and improve its SC flexibility? To the author's knowledge, and according to the literature reviewed in Chapter 2, there is a lack of research focused on the development of measurement and monitoring tools that can be used to guide the improvement of flexibility of SC, and no study was identified focused on the specificities of the private high-tech sector.

3.3 Step 2: Identify the solution

The solution proposed in this thesis in order to deal with the problem defined under Step 1 is to develop a tool to measure and monitor the SC flexibility of Chinese private high-tech companies. Following the literature review presented in Chapter 2, a dashboard is selected for this purpose, which should allow for an easy visualization and analysis of multiple flexibility indicators, thus fostering for improvements in the SC flexibility of Chinese private high-tech companies.

3.4 Step 3: Design and development

This step is aimed at designing a dashboard for measuring the SC flexibility of Chinese private high-tech companies. This is achieved through the three key stages: Stage A, in which the flexibility indicators are selected; Stage B, in which the previously selected indicators are operationalized; and Stage C, in which the indicators will be used to build the proposed dashboard.

3.4.1 Stage A: Selecting flexibility indicators

The flexibility indicators that might be useful to measure the flexibility of SC in the high-tech sector are identified as follows:

i. Stage A1: A Systematic Literature Review (SLR) is followed to identify the SC indicators that are referred in the literature as being adequate to measure SC flexibility in general, and in the high-tech sector in particular.

ii. Stage A2: The web-Delphi method and the Fuzzy Set Theory are integrated so as to validate the set of flexibility indicators identified under Stage A1, as well as to find additional indicators of interest according to a large group of professionals with expertise in the high-tech sector. This integration of methods results in what is hereafter called as Fuzzy web-Delphi method. The reasons why the Fuzzy web-Delphi method fits for the purpose of this thesis are as follows:

First, it allows to bring together a large and diverse group of experts with a multiplicity of opinions and perspectives without requiring their presence in a face-to-face format. In fact, these experts might be found in different locations around the world, which result in some challenges in what concerns bringing them together. But using the Web-Delphi method as a participatory method to collect information from a group of experts under these circumstances represent a potential alternative since it is increasingly being explored in the literature due to its reliance on technological platforms that do not require face-to-face contact, remove geographical barriers, and allow the involvement of a large number of experts (Vieira et al., 2020). By using this convenience way, a higher number of experts could be invited to join the survey around the world.

Second, different experts might have different opinions for one topic, and they might even have different understandings about similar concepts, which makes this process somehow subjective and vague. This justifies the integration of the web-Delphi method with the fuzzy set theory, which will then allow to better deal with this subjectivity and vagueness, as well as to reduce the high drop rates that often characterize Delphi processes through the reduction of the number of rounds required to reach a consensus (K. S. Ahmed et al., 2022).

3.4.1.1 Stage A1: Systematic literature review

A systematic literature review (SLR) was employed in this thesis, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. SLR is different from traditional narrative reviews in that it uses a replicable, scientific, and transparent process (Tranfield et al., 2003). This aims to minimize bias by conducting exhaustive literature searches of published studies and by providing an audit trail of the reviewers' decisions, procedures, and conclusions.

For the purpose of this thesis, a SLR was used to identify the SC flexibility indicators that are most widely used in the literature.

It was performed by conducting searches both on B-on and Google scholar using as keywords "Flexibility or Flexible" and "Supply chain". Only scientific journals and conference proceedings written in English, peer reviewed and published between 2017-2022 were selected. Only Q1 and Q2 studies according to the JCR ranking were selected.

Several searching ways used to find out those related literatures:

i. Using b-on. b-on is the professional literature searching web site of the University Institute of Lisbon. There are three filters; in the first filter, choose TI title and input "Flexibility or Flexible". In the second filter, choose TI title and input "Supply chain". In the third filter, choose TI title and input "Review or survey". After that choose the filters in the side bar, first choose "2017-2022", second choose "Academic Journals", third choose "English". When searching out those literatures, the quality of those journals need to be double confirm in the website (Tranfield et al., 2003), input the name of journals, then you may see the journal ranking information, choose only Q1 and Q2 in the "Quartiles", since Q3 and Q4 are not high quality journal per the ranking.

ii. Using google scholar, the website is https://scholar.google.com, input "flexibility or flexible, supply chain", and from the side bar to choose the time limit "since 2017". choose those thesis and academic journals with high citation number. Then using the website scimagojr to check the quality as mentioned above.

3.4.1.2 Stage A2: Fuzzy Web-Delphi

The Fuzzy Web-Delphi developed within the scope of this thesis is two-fold: it aims at evaluating the list of flexibility indicators identified under Stage A1; and it also aims at identifying additional indicators that are considered as relevant according to the perspective of professionals working in the high-tech sector, although not identified based on the literature. A minimum number of two rounds are required, with a different questionnaire being implemented through WJX (https://www.wjx.cn) for each one of those rounds, an online survey platform operating and providing survey service in China.

Panel of participants

This research phase initiates with the critical process of participant selection, employing the Delphi technique, which significantly influences the validity of the findings (Powell, 2003). The literature does not prescribe a definitive rule regarding the size of the panel, acknowledging instead that a balance must be struck between the number of participants and their collective expertise (Salgado et al., 2020).

For this study, a non-probability purposive sampling method was utilized to select participants, comprising 89 experts from 48 high-tech companies across all eight recognized high-tech sectors in China. The majority of these individuals hold pivotal roles within their organizations, possessing substantial industry experience ranging from 10 to 30 years in the field of supply chain management. The demographic breakdown of the panel includes 3 PhD holders, 7 doctoral candidates, 12 with master's degrees, 62 with bachelor's degrees, 2 with college diplomas, and 3 with high school diplomas.

Upon their selection, all participants were provided access to the survey via WeChat, a platform chosen due to its ubiquity and central role in professional communications in China. WeChat's widespread use is attributed to its efficiency and reliability, making it an ideal medium over email for distributing the survey link. This method likely enhances both the speed of feedback and the response rate. At the outset of each survey round, participants receive comprehensive details about the study's objectives, the confidential nature of their responses, and the expected timelines for completion. Anonymity is maintained throughout the survey process, as the platform does not reveal the real names of respondents, thereby ensuring unbiased and genuine feedback.

Questionnaire Description: Round 1

A first questionnaire (see Annex E) is designed to validate the flexibility indicators identified under stage A1, as well as to ask for additional indicators. This first questionnaire is structured into three parts: the first part is devoted to presenting the aim of the questionnaire; the second is devoted to identify basic data of the respondents, including personal and professional details (company, title, field, e-mail address, if still engaged in high-tech industry, years of experience in the sector, academic qualification, position, how many staff in the company, revenue in 2022, how many years the company engaged in this sector, how many years working in the current company, which high-tech sector the company belong to); and the third part is finally aimed at asking for the agreement in relation to the flexibility indicators identified under Stage A1 (*i.e.*, it is asked if the participants agree that each of these indicators should be used for measurement and monitoring of the flexibility of high-tech supply chains).

Concerning the third part of the questionnaire, participants are expected to give their opinions in different ways:

1. Participants should show their agreement concerning each flexibility indicator through the use of a Five-point Likert scale (1: Strongly disagree, 2: Not agree, 3: Not sure, 4: Agree, 5: Strongly agree).

2. If they wish, participants can also leave comments for each indicator of flexibility. This might be useful if, for instance, a indicator is not clearly explained (according to the opinion of the participant), being thus possible to give that feedback, thus allowing for further explanations in future rounds.

3. Participants are also expected to identify additional indicators of flexibility that are missing in the list and that they consider as relevant (through open-ended questions).

The respondents are given seven days to reply to this first round.

This first questionnaire should be submitted to a pre-test to verify how clear are the questions asked, and also to check its organization. This is especially relevant to ensure that the flexibility indicators are clearly explained, which is essential for participants being able to state if they agree (or not) with the selection of each of those indicators for the monitoring and measuring of SC flexibility in high-tech companies. This pre-test was performed with four people.

Questionnaire Description: Round 2

A second questionnaire (see Annex F) is used to share the feedback based on the results of the first round with the participants. This feedback is provided in different ways: a) percentages and absolute values for the answers gathered related to the agreement with each of the flexibility indicators presented under Round 1; b) a summary of the comments that might be given by respondents under Round 1 (these comments are essential to promote learning and communication amongst all participants, which is a key feature of Delphi studies). And using as a basis this feedback, this round also gives participants the opportunity to adjust their opinions concerning their agreement to each of the flexibility indicators, as well as to indicate their agreement with the new indicators proposed by participants in Round 1 (again, using the

Five-point Likert scale). The respondents are given seven days to reply to this second round.

Data Analysis

Once gathered, the data collected through the different questionnaires should be analyzed. And following the Fuzzy Web-Delphi method, four key steps should be followed for that purpose, as detailed below.

Step 1 - Convert the Likert linguistic scale into equivalent triangular fuzzy numbers (Fuzzification)

All the answers given using the Likert scale are associated with an equivalent triangular fuzzy number (TFN). In this thesis, the interval that has been used is the one proposed by Dawood et al. (2021). Refer to Table 3.1.

Table 3.1 Five-point Likert scale and equivalent fuzzy scale

Likert Scale	Linguistic scoring scale	Fuzzy Scale
5	Strongly agree	0.6, 0.8, 1.0
4	Agree	0.4, 0.6, 0.8
3	Neither agree nor disagree	0.2, 0.4, 0.6
2	Disagree	0.0, 0.2, 0.4
1	Strongly disagree	0.0, 0.0, 0.2

After converting the numerical values into TFNs, the average of the fuzzy scores must be calculated as shown in Eq. (3.1).

$$F_{av} = \frac{1}{n}\left(\sum a_{1i}, \sum a_{2i}, \sum a_{3i}\right) \tag{3.1}$$

where F_{av} is the fuzzy mean of average participant opinion, a_1, a_2, a_3 are the fuzzy scores, and i=1, 2…, n corresponds to the set of participants.

Step 2 - Compute the threshold value (d)

To calculate the threshold value (d) the vertex method is applied, which consists of calculating the distance between two fuzzy numbers (Dawood *et al.*, 2021). (Eq. (3.2))

$$d\left(\tilde{m},\tilde{n}\right) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]} \tag{3.2}$$

where m_1, m_2, m_3 represent the average fuzzy number of individual participant's fuzzy number for each indicator, and n_1, n_2, n_3 represent the individual participant's fuzzy number. Once the individual participant threshold value is obtained, a global threshold value (also known as d-construct) can be computed (Eq. (3.3)).

$$\text{ThresholdValue}\,(\text{D} - \text{construct}) = \text{AverageThreholdValue}\,(\text{d}) \tag{3.3}$$

Where d is the set of participants.

Based on the d-construct, the acceptability of the construct (which in our case will be a set of flexibility indicators belonging to a given indicator) will be confirmed if the d-construct is lower than or equal to 0.2. The acceptance of each item (which are represented by each flexibility indicator) will be based on the expert agreement with the same threshold value (d) (Dawood et al., 2021). Within this context, the indicators whose threshold value (d) are greater than 0.2 are supposed to be eliminated.

Step 3 - Determine participants' consensus

The group consensus should be measured based on the participants' consensus on each flexibility indicator. If any indicator does not achieve the group consensus which was set as minimum, a new Delphi round should be followed until the group consensus is achieved, or until the result of consecutive rounds become stable (Von Der Gracht, 2012). The overall group consensus should thus be computed as shown by Eq. (3.4) (Dawood et al., 2021).

$$\mathbf{Groupconsensus} = \frac{\mathbf{Number\ of\ dimensions\ with\ d \leq 0.2}}{\mathbf{Number\ of\ Experts}} \times \mathbf{100\%} \quad (3.4)$$

According to several authors (*e.g.*, Dawood et al., 2021) a group consensus greater than or equal to 75% is needed to accept a indicator, and otherwise it must be eliminated. Furthermore, global consensus also gives information about the requirement for an additional Delphi round – if it is lower than 75%, additional rounds are needed until consensus is reached.

Step 4 - Defuzzification

Defuzzification aims at determining the value of the fuzzy score (A_{max}), which represents the average of a fuzzy number. The fuzzy score value (Eq. (3.5)) must be greater than or equal to a given threshold value α, with α depending on the specific context of the study.

$$\mathbf{A_{max}} = \frac{\mathbf{1}}{\mathbf{3}} \times (\mathbf{m_1} + \mathbf{m_2} + \mathbf{m_3}) \quad (3.5)$$

For the purpose of this thesis, and following the recommendations of different authors (*e.g.*, Bodjanova, 2006), it is considered that Amax should be greater than or equal to 0.5, representing this the third requirement to accept a indicator (Dawood et al., 2021).

Summing up, the acceptance of each flexibility indicator (so as to be used in the construction of the dashboard) depends on the verification of the following cumulative conditions (Dawood et al., 2021): (i) threshold value (d) ≤ 0.2, (ii) experts' consensus ≥75%, and (iii) fuzzy score value (Amax) ≥ 0.5.

3.4.2 Stage B: Operationalizing flexibility indicators

All the flexibility indicators need to be operationalized to allow for their measurement and monitoring throughout time. Such an operationalization should be performed by defining a descriptor of performance for each indicator, and this should be done jointly with a group of experts (Costa & Beinat, 2005). In this thesis this is achieved by involving four experts out of the participants involved in the Fuzzy web-Delphi study - one purchasing head, one operation head, one manufacturing head and one finance manage. This was done through a face-to-face focus-group.

Costa and Beinat (2005) define a descriptor of performance as "*an ordered set of plausible impact levels associated with a given criterion*" (pp.12). Descriptors can be measured quantitatively or qualitatively, it should describe the indicators as objective as possible while assuring independence between indicators (if any dependency is detected, the indicators should be adjusted). In addition to being defined as quantitative or qualitative indicators, these should also be distinguished in continuous or discrete indicators, and in direct or constructed (Costa & Beinat, 2005).

3.4.3 Stage C: Building the dashboard

The dashboard used to measure and monitor the flexibility of high-tech SC is built under Stage C. This stage starts by building the dashboard using the Microsoft power BI. Power BI allows for data refreshing automatically, its visualization is intuitive, Power BI has a powerful data editor that allows users to transform and modify data within their model, Power BI could serve as a bridge between analysis workflows, adding the degree of interactivity that makes presentations more dynamic and interactive. Power BI provide a suite of desktop, cloud, and mobile application, that could ensure managers to check the data via their mobile phone in real time (Carlisle, 2018). At this stage, the experts involved include only experts from COROS (total of 4 experts, including the head of purchasing, the head of operation, the head of manufacturing and the head of finance). The dashboard building process will then translate the process that should be employed if a similar development needs to take place in other high-tech companies in China.

The dashboard was built as follows:

i. First, an individual page for each of the selected flexibility indicators was built. Each page needs to have the description panel to explain the definition or formula associated with each indicator, as well as the associated target and current state. In addition, a traffic light was added in each page promoting a quick understanding for the level of each indicator and how far it is from the desired target.

ii. Secondly, a summary page for the different flexibility indicators/categories are built. The summary page fosters a better understanding of each category in one picture and could guide users to go into one specific indicator if that indicator is not performing well.

iii. Finally, the main page is built, where one can find all the flexibility indicators/categories. One button will be included for each indicator, thus facilitating the navigation between different pages. This main page also includes the traffic light information associated with each flexibility indicator, thus fostering a better understanding on the global flexibility performance for the company in one single page.

It should be noted that, in order to promote the best possible utilization of the proposed dashboard, it is essential that the company provides detailed information allowing to measure all the indicators as well as the desired targets.

Concerning the graphical and visual aspect of the dashboard, it is of great importance since it influence how the information will be perceived by the user. The visual content of dashboards should be as simple as possible to make it easier to interpret the large amount of information presented (Scholtz et al., 2018). The colors used in this type of tool should be chosen with a view to their effectiveness (Scholtz et al., 2018). Few (2006) describes nine rules for using colors in graphics. Refer to Table 3.2.

Table 3.2 Rules to use colors in graphics

Rules to use colors in graphics (Few, 2006)
1. Use a consistent background color when you want different objects in a graphic
2. Use a contrasting background color to make it easier to see the elements of a table or graph
3. Apply a different color only when it is necessary to communicate information for a specific purpose
4. Only use different colors when they correspond to different meanings in the data shown
5. Use soft, natural colors to present most data. Use lighter colors to highlight information that requires more attention from the user's attention
6. For quantitative values in a sequential range, use a single matrix of colors, or a small set of closely related colors, varying the intensity from light to dark/bright respectively
7. Elements that are not part of the data presented in tables or graphs should be displayed in a way that is just visible enough. Excessive highlighting of these elements can distract users from the information presented
8. Avoid using green and red in the same presentation to ensure the distinction of color-coded data groups for the majority of color-blind people
9. Visual effects (*e.g.,* shadows or 3D effects) should be avoided in graphs and tables

In addition, Park and Jo (2019) state that the Gestalt principles should be considered when developing dashboards. These principles can be categorized as follows (Rusu et al., 2011):

1. Proximity - objects that are close together are perceived collectively, unlike those that are far apart.

2. Similarity - visualizations that present similarities also create associations between them, such as color, shape or size.

3. Enclosure - elements that are incomplete or darkened tend to be completed by the human mind.

4. Symmetry - regardless of distance, symmetrical objects create an association with each other.

5. Continuity - when two or more elements cross or overlap, each is perceived in isolation and uninterruptedly.

6. Common destination - the same speed between several elements causes them to be captured together.

7. Figure-ground - the distinction between an object and everything that surrounds it can be created by foreground and background.

All these principles help in the construction of the dashboard, making it possible to distinguish between elements that are accessories or produce visual pollution, and those that are essential to present and transmit information to the end user.

3.5 Step 4: Demonstration

Step 4 is focused on demonstrating the applicability of the proposed dashboard to real cases. According to Peffers et al. (2007) such a demonstration can be done in different ways, such as through experiments, simulations or even case studies. Accordingly, for the purpose of this thesis, a single case study relying on a real Chinese private high-tech company (COROS) will be used to demonstrate and validate the applicability of the proposed dashboard concerning its usefulness to measure and monitor the flexibility of SC in the high-tech sector (Yin, 2014). Two main steps are followed for the purpose of this demonstration, as illustrated below.

3.5.1 Step 4.1 Data gathering and adjustments to the reality of the selected case study

The first step under this demonstration relies on the collection of real data from the case study, thus allowing to apply and test the developed dashboard. This data can be gathered through interviews and official company documents and databases. The data should be collected to be used as input to the developed dashboard.

Also, since the proposed dashboard includes a set of flexibility indicators that are useful to measure the flexibility of SC in the high-tech sector, and being recognized that each company might have its own particularities, it is essential to start by reviewing and validating the set of indicators obtained under Stage 3 (Design and Development), so that only those flexibility indicators reflecting the reality of the selected case study are included.

3.5.2 Step 4.2 Identify opportunities of improvement towards a more flexible supply chain

Using as a starting point the strategies identified in the literature review, this stage relies on the analysis of the flexibility for the selected supply chain and aims at identifying potential strategies that might enhance the improvement of flexibility for the most critical indicators, or even for the indicators for which the company might have established particular targets.

3.6 Step 5: Evaluation

Step 5 is aimed at evaluating how well the dashboard fulfills the requirements of the selected company, and to what extent it can effectively be used to improve the flexibility of their supply chain. This evaluation might have two main consequences:

i. One may decide to go back to the design and development stage in order to improve the dashboard using as a basis the concerns identified during the evaluation stage.

ii. One may decide to proceed with the current version of the dashboard.

For the purpose of this thesis, this evaluation is performed by face-to-face interviews with 4 experts, the head of purchasing, the head of operation, the head of manufacturing and the head of finance.

The interviews were divided into two main parts:

i. A general presentation of the dashboard along with all its functionalities, as well as possible interactions between the various visualization elements.

ii. Five questions that according to Few (2013) meet the validation of the artifact:

1. Do the groupings of information make sense?
2. Are the indicators arranged appropriately?
3. Can the most important information be easily identified?
4. Is the information presented enough to support an informed decision-making?
5. Do you suggest any changes to the dashboard design?

3.7 Step 6: Communication

This final step involves the dissemination of results within the high-tech sector and also through publications in scientific journals in the area.

Chapter 4: Design and Development of the Dashboard

The purpose of this chapter is to design and develop the dashboard as described under the Step 3 of the methodology (Chapter 3).

4.1 Stage A1: Systematic literature review

A Systematic Literature Review (SLR) is used to explore in detail how such flexibility has been measured in previous studies. This SLR followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021), as shown in Figure 4. 1.

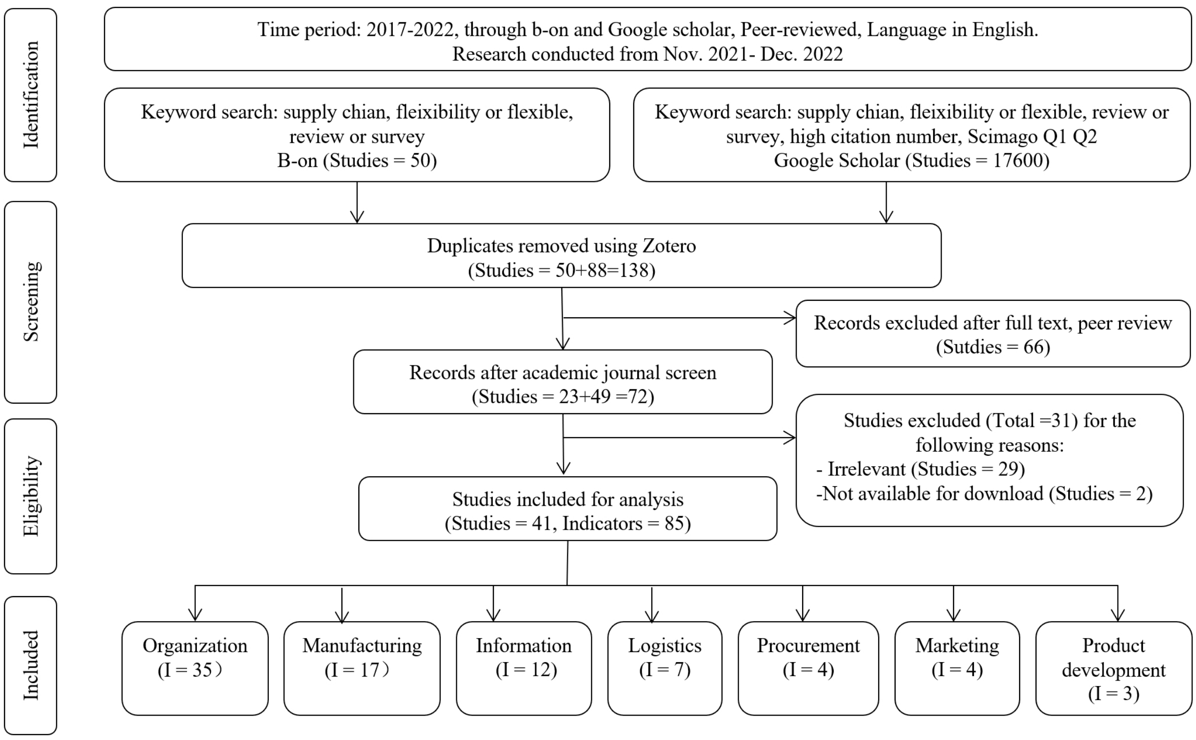

Figure 4.1 SLR steps to identify these indicators to measure the flexibility of SC

This SLR utilized the B-on and Google Scholar databases with the keywords "Supply chain" and "Flexibility or Flexible" within document titles, and "review and survey" in the abstracts. The review spanned 2017 to 2022 for B-on and 2018 to 2022 for Google Scholar. Inclusion criteria were restricted to peer-reviewed scientific journals and conference proceedings in English, available in full text. Only publications ranked in Q1 and Q2 according to the Journal Citation Reports (JCR) were considered. Duplicated studies were excluded using the literature management software Zotero. Due to space constraints in the text box, the abbreviation "I" is employed to denote "Indicators."

Following these steps allowed to depart from 138 studies, and after applying all the filters a total number of 41 studies were analyzed to identify how flexibility is measured within the scope of supply chains, and total 85 indicators identified, due to some authors mentioning multiple tools and several studies citing the same tools.

From Table 4.1, we could see the total collected flexibility indicators are 85, 25 indicators are related with high-tech area and it takes 29.4% of overall indicators, only 6 indicators come from Chinese high-tech companies and it takes only 7.1% of overall indicators.

Table 4.1 Indicator distribution list

Business area	Citied indicators	Percentage	High-tech related indicators	Percentage	Chinese Company related	Percentage
Organization	35	41%	5	6%	3	4%
Manufacturing	17	20%	8	9%	1	1%
Information	12	14%	3	4%	1	1%
Logistics	7	8%	3	4%		0%
Procurement	7	8%	3	4%		0%
Marketing	4	5%	1	1%	1	1%
Product development	3	4%	2	2%		0%
	85	100%	25	29.4%	6	7.1%

Each business area encompasses several indicators of flexibility, references to Annex D.

Thirty-five indicators are identified that focus on enhancing organizational structures within supply chain management, segmented into external and internal integration, with certain indicators intersecting both areas.

External Integration: This involves collaboration with external stakeholders such as customers, suppliers, and societal groups. It includes centralized decision-making to streamline processes and improve responsiveness, developing capabilities for sustained engagement with external partners, and fostering robust supplier partnerships to ensure flexibility and resilience. Additionally, it entails promoting supplier adaptability to meet dynamic market demands, facilitating the transfer of external knowledge to spur innovation, and strategically managing risks to mitigate supply chain disruptions. It also emphasizes designing adaptable supply networks capable of responding swiftly to changes in operational conditions.

Internal Integration: Focuses on enhancing synergy across various departments within the organization. This includes promoting cross-functional collaboration to optimize efficiency, ensuring effective knowledge transfer within the organization to enhance informed decision-making, cultivating a culture of continuous learning and process improvement, and implementing targeted training programs to equip employees with necessary skills.

Combined External and Internal Integration: Four studies specifically explore the integration of both external and internal aspects, highlighting the importance of a holistic approach in supply chain management. These studies discuss merging internal operational strategies with external interactions to streamline the entire supply chain, as well as developing comprehensive strategies that incorporate both internal efficiencies and external collaborations.

Leading corporations disclose demand information to downstream vendors to centralize supply, thereby potentially diminishing the aggregate cost of the supply chain (Malik & Sarkar, 2020). Coercive power pertains to the forewarning of negative sanctions or punitive measures if suppliers do not adhere to the principal firm's directives; for instance, the firm might threaten to cease future transactions unless suppliers conform to revised delivery schedules (P. Liu et al., 2023). Engagement capability denotes the facility to involve partners consistently across all phases of service delivery, enhancing the co-design and co-production of services significantly (Bag & Rahman, 2021). Firms are encouraged to collaborate with supply chain partners to mitigate potential disruptions rather than addressing such issues in isolation (Skipper & Hanna, 2009).

External integration is conceptualized as a second-order construct that encapsulates the integration with key customers and suppliers, fostering responsiveness to dynamic market demands. Volume flexibility allows a firm to adjust its production output without adversely affecting process costs or capabilities (Braunscheidel & Suresh, 2009). The alignment of core supply chain processes - plan, source, make, deliver, return, and enable， with both customers and suppliers underscores the criticality of cultivating robust, interactive relationships (Oliveira-Dias et al., 2022).

This includes sharing information with key suppliers regarding sales forecasts, production plans, order tracking and tracing, delivery statuses, and inventory levels, and developing collaborative strategies such as supplier development, risk/revenue sharing, and long-term contracts. It also involves joint decision-making with key suppliers on product and process design modifications, quality enhancement, and cost management. System integration with key suppliers may include practices such as vendor-managed inventory, just-in-time systems, Kanban, and continuous replenishment (Chaudhuri et al., 2018).

External knowledge transfer is defined as the firm's capacity to harness external expertise to augment its products and processes (Blome et al., 2014). External integration enhances SC flexibility. The benefits of external collaboration via integration often materialize when partners willingly share information and resources to attain common objectives. This requires various competencies to amalgamate a firm's internal capabilities with those of its external partners, enhancing trust and facilitating rapid responses to customer needs through cross-functional team integration (Um, 2017).

Relationship flexibility is the mutual expectation in a trading relationship to adapt and adjust to novel insights without resorting to extensive contract renegotiations (Yu et al., 2018). Smart supply chains are characterized by their ability to adapt and reconfigure in real time, making decisions that not only address current conditions but also preemptively adjust for future operations (Gupta et al., 2019).

Supplier integration involves the coordination between suppliers and manufacturers concerning inventory management, collaborative planning, forecasting, replenishment, and resource flows (He et al., 2014). It includes information sharing, collaboration, joint decision-making, and system integration (Shou et al., 2018). Maintaining a flexible supply base and engaging in collaborative practices with key suppliers can significantly enhance supply network flexibility, which is the capacity of a firm to manage, reconfigure, or reinvent relationships with suppliers effectively and efficiently (Fernandez-Giordano et al., 2021). Vendor flexibility pertains to the adaptability of individual vendors that support manufacturing, warehousing, or transport operations (Gosling et al., 2010).

Green supplier integration indicates the extent to which firms collaboratively manage environmental issues with their suppliers, playing a pivotal role in boosting environmental performance (Ji et al., 2020). Legal-legitimate power involves using contractual agreements to ensure supplier compliance, with the principal firm potentially leveraging legal threats to enforce order quantity adjustments (G. Liu et al., 2022).

Risk management strategies such as selecting reliable suppliers, implementing clear safety procedures, conducting preventive maintenance, and detecting risks through internal, or supplier monitoring are critical. Responsive measures include securing backup suppliers, increasing capacity, and employing alternative transportation modes, while recovery strategies may involve forming task forces, developing contingency plans, and assigning clear responsibilities. Effective management and control of these risks are imperative to enhance SC flexibility (Chaudhuri et al., 2018).

Internal integration encompasses a spectrum of activities including cross-functional integration, knowledge transfer, organizational learning, and employee training. Effective coordination of internal processes through tools like information systems or enterprise resources planning (ERP) systems is essential for assimilating data from various departments, thereby increasing organizational flexibility (Riley et al., 2016). Internal integration is defined as the extent to which manufacturers harmonize their organizational strategies, practices, and processes to fulfill customer requirements and interact efficiently with suppliers, recognizing that all departments should operate as part of a cohesive system (Moyano-Fuentes et al., 2016).

The degree of interaction, communication, information sharing, and coordination across different functions significantly contributes to enhancing the supply chain's flexibility (Yang & Tsai, 2019). Furthermore, internal integration involves the cross-functional collaboration and information sharing through interconnected and synchronized processes and systems, aligning intra-firm goals, which substantially improves a company's adaptability (Chaudhuri et al., 2018). Additionally, internal integration facilitates a more coordinated response to marketplace changes and disruptions through inter-functional and interdepartmental cohesion (Braunscheidel & Suresh, 2009).

Knowledge transfer within a firm can be conceptualized as the process through which the experience of one-unit influences another. This internal knowledge transfer capability allows for the sharing of information across various functions within the firm (Blome et al., 2014). Operational absorptive capacity is defined as the ability of a firm's operational units to acquire, assimilate, transform, and exploit knowledge from operations management. This concept is extended to include the supply chain department, enhancing the organization’s knowledge system and increasing flexibility in responding to changes (Rojo et al., 2018).

Supply chain learning is described as the ongoing management of the learning process by the firm, its suppliers, and customers, focusing on supply chain management issues. A firm with a high level of supply chain learning continually evaluates and seeks to improve its organizational processes (Willis et al., 2016). The planning, support, patience, and leadership from management are crucial as many programs can otherwise become significant drains on time, effort, and resources (Skipper & Hanna, 2009).

Training plays a pivotal role in facilitating knowledge transfer, enabling managers to educate employees on identifying risks and managing anomalies, thus preparing the organization to handle uncertainties flexibly (Riley et al., 2016).

Four studies highlight the dual focus on both external and internal integration within supply chains, such as through strategies and integration measures that enhance overall supply chain functionality. Each member within a supply chain alliance can leverage multiple strengths, contributing uniquely to the collective efficacy (Skipper & Hanna, 2009). Integration with suppliers and customers facilitates a seamless synchronization of internal and external operations, thereby enhancing visibility, augmenting information processing capabilities, and strengthening relationships across the supply chain (Ramos et al., 2021).

Supply Chain Integration (SCI) is conceptualized as the extent to which a manufacturer collaboratively manages intra- and inter-organizational processes. This synchronization across the supply chain enhances flexibility, making SCI a multi-indicator construct that typically encompasses both external (e.g., customer and supplier integration) and internal aspects (Z. Wang & Zhang, 2020). Firms are advised to allocate adequate resources and time to cultivate the indicators of flexibility that align with their strategic objectives (Aissa et al., 2009).

Seventeen studies focus on manufacturing flexibility, encompassing a variety of aspects including agile production, modular production, mix flexibility, routing flexibility, volume flexibility, postponement flexibility, product flexibility, lean production, standardized production, and safety stock.

Agile production is characterized by its adaptability, aiming to eliminate as much waste as possible while maximizing flexibility. This type of production system is capable of managing internal and external variances such as volume, variety, delivery, and supplier capabilities, thereby leveraging the benefits of flexibility (Qamar et al., 2018). Manufacturing flexibility refers to the capacity of a manufacturing process to exploit a range of options effectively, thereby responding adaptively to changes in product characteristics, material supply, and demand, or to incorporate technological advancements (Swafford et al., 2006). The implementation of flexible manufacturing systems enables a firm to operate multiple plants for diverse products, enhancing flexibility (Tang & Tomlin, 2008). Additionally, maintaining excess capacity and labor can further increase production flexibility (Sreedevi & Saranga, 2017).

Product modularity, defined as a design strategy that reduces complexity through the use of interchangeable components within a hierarchical system, facilitates flexibility during the assembly stage. This strategy allows for component changes without altering interfaces, thus enhancing manufacturing flexibility (Um, 2017; Z. Wang & Zhang, 2020). Mix flexibility enables the economic and effective production of diverse product combinations within existing capacities (Braunscheidel & Suresh, 2009).

Routing flexibility, which involves processing parts through multiple routes using alternative machinery and flexible transport networks, mitigates the impact of environmental uncertainties and production inefficiencies (Martínez-Sánchez & Pérez, 2005). Volume flexibility allows an organization to operate efficiently at various output levels without compromising cost, quality, or service, necessitating close coordination with suppliers, especially under fluctuating demand (Braunscheidel & Suresh, 2009; Martínez-Sánchez &

Pérez, 2005).

Postponement flexibility emphasizes the ability to maintain products in a generic state until late in the production process to tailor them to specific customer requirements. This flexibility is distributed across the supply chain and is critical for meeting or exceeding customer expectations (Martínez-Sánchez & Pérez, 2005). Product flexibility entails the capability to handle complex, customized orders and produce a wide array of features, options, sizes, and colors, requiring effective collaboration across marketing, product design, development, and engineering functions (Martínez-Sánchez & Pérez, 2005).

Lean production, identified as a continuous improvement-based management system, minimizes resource usage both internally and among key supply chain partners (Maqueira et al., 2021). Standardizing production, for instance through the implementation of ISO 9001, enhances operational effectiveness and flexibility (Rojo et al., 2018). Lastly, maintaining safety stocks of raw materials and finished goods prepares a firm for unforeseen disruptions, such as those caused by events like the COVID-19 pandemic (Mohammaddust et al., 2017).

Twelve studies have concentrated on information flexibility, encompassing aspects such as data analytic capabilities and information sharing systems.

Big data analytics capabilities enable executives and managers to monitor corporate performance in real-time, facilitating swift and cost-effective investigations of anomalies and providing appropriate interventions and actions (Cheng et al., 2021). Analytics capability is understood as the amalgamation of tools, techniques, and processes that allow an organization to process, organize, visualize, and analyze data to derive actionable insights. This capability empowers managers to make efficient and effective decisions pertinent to business operations (Dubey et al., 2021). Data analytics in supply chain management encompasses the application of descriptive, predictive, and prescriptive analytics, necessitating robust analytics knowledge within the company (Bag & Rahman, 2021).

Sharing intra-firm information and integrating data access across operating and planning databases enhances visibility in the supply chain through the implementation of supplier relationship management systems, thereby increasing flexibility to adapt to changes (Wagner et al., 2018). The capacity for groups of specialists to share information and integrate knowledge effectively for common tasks is a critical organizational attribute (Fernandez-Giordano et al., 2021). Efficient information sharing within groups enhances work efficiency. By scientifically integrating business processes and data processing, firms can realize a seamless connection between online and offline activities, improving employee proficiency with information systems and platforms (Luo et al., 2020). Flexibility in information system development enhances system responsiveness, as cognizance among team members optimizes system performance (Gupta et al., 2019). Employing IT methods in the supply chain can significantly increase agility in information handling (Skipper & Hanna, 2009). When employees within a firm and supply chain partners share information, it reduces uncertainty in behaviors, thereby improving decision-making processes (Riley et al., 2016). IT-enabled sharing capabilities allow firms to identify which suppliers can best meet price and delivery requirements, determine available production facilities, and enable customers to access production lead times and order statuses (Jin et al., 2014). Spanning flexibility in supply chains focuses on developing the capacity for disseminating information crucial for collecting and diffusing various data, and on creating strategic development flexibility that transforms competencies into customer value (Zhang et al., 2006). IT flexibility allows organizations to adapt to both incremental and revolutionary changes in business processes with minimal impact on current time, effort, cost, or performance (Han et al., 2017).

Seven studies have focused on various aspects of logistics flexibility, encompassing delivery flexibility, distribution flexibility, logistics flexibility, and trans-shipment flexibility.

Delivery flexibility refers to a company's ability to tailor lead times according to customer requirements. A prime example of high delivery flexibility is the just-in-time system, where suppliers deliver products in the precise quantity, place, and time as needed by the customer (Martínez-Sánchez & Pérez, 2005). This flexibility is indicative of a firm's customer-facing performance, specifically in terms of product availability, delivery reliability, and the capability to meet the quantities demanded by customers (Wagner et al., 2018).

Distribution and logistics flexibility allows a firm to adjust its delivery schedules to accommodate unpredictable or rapidly changing customer demands, thereby enhancing its competitive position through superior delivery performance (Swafford et al., 2006). Supporting this flexibility are multimodal, multicarrier, and multi-route transportation systems, which are essential for robust logistics operations (Sreedevi & Saranga, 2017). Logistics flexibility, which is primarily unilateral, enables an organization to swiftly respond to customer needs in delivery, support, and service (Yu et al., 2018). An example of extensive distribution flexibility is demonstrated by Seven-Eleven stores, which employ a variety of transportation means—including trucks, motorcycles, boats, and helicopters—to distribute products from various distribution centers to retail locations, significantly enhancing their logistics capabilities (Tang & Tomlin, 2008).

Trans-shipment flexibility involves the movement of stock between locations within the same echelon level, particularly when the physical distances between the demand and supply locations are minimal (Martínez-Sánchez & Pérez, 2005).

Seven studies concentrate on aspects of procurement flexibility, including alliance capability, sourcing flexibility, and supplier selection flexibility.

The capacity to forge alliances is a critical strategic asset, contributing significantly to a firm's competitive advantage. Specific training programs are implemented for managers and partners to enhance alliance capabilities, which are pivotal for maintaining and leveraging strategic partnerships (Bag & Rahman, 2021). The ability to provide extensive or intensive distribution coverage, facilitated by close coordination of downstream activities, whether internal or external to the firm, underscores the strategic importance of integrated supply chain operations (Martínez-Sánchez & Pérez, 2005).

Sourcing and procurement flexibility involve the availability of multiple sourcing options and the capability of the purchasing process to utilize these options effectively in response to evolving requirements related to the supply of purchased components (Swafford et al., 2006). Sourcing flexibility, defined as the ability to identify alternative suppliers for specific components or raw materials, is crucial for firms aiming to enhance competitiveness through flexibility (Martínez-Sánchez & Pérez, 2005). This flexibility may include reconfiguring the supply chain network through the strategic selection and deselection of vendors (Gosling et al., 2010).

Procurement flexibility extends to include aspects such as supplier commitment to environmentally sustainable products, supplier dependency, and control over supplier operations, which collectively contribute to the strategic procurement capabilities of a firm (Chirra et al., 2021).

Supplier selection flexibility encompasses the ability to evaluate and choose suppliers based on criteria such as cost, quality, delivery, innovation, and flexibility. Selecting competitive suppliers plays a pivotal role in enhancing SC flexibility (Wagner et al., 2018).

Four studies concentrate on various aspects of marketing flexibility, encompassing customer relationships, price flexibility, product lifecycle, and product financial performance.

Marketing flexibility within supply chains involves each participant adding value by delivering the optimal product or service from the customer's perspective. Effective and efficient management of the entire supply chain from the procurement of raw materials to the final point of consumption is crucial. It ensures that the product and service value meet the end-consumer’s requirements. Firms need to implement market strategies that minimize unwanted product variety. This can be achieved through establishing closer relationships with customers to align current products with customer needs and eliminating products that no longer yield benefits (Um, 2017).

Adjusting product prices to guide customer consumption patterns enhances flexibility, enabling firms to respond more dynamically to market demands (Tang & Tomlin, 2008).

Product financial performance evaluates a product line's performance relative to main competitors in terms of growth, market share, and profitability. Superior performance in these areas can confer greater flexibility in competitive contexts (Wagner et al., 2018).

The product lifecycle reflects the life cycle stage of a company's major product or product line, as well as the dynamics of competition within the external environment where the manufacturer operates (Z. Wang & Zhang, 2020).

Three studies have concentrated on indicators of product development flexibility, including the adoption of additive manufacturing, the use of advanced manufacturing technologies, launch flexibility, and product financial performance.

Additive manufacturing, a pivotal component of modern manufacturing, involves a suite of process technologies that construct parts through the incremental addition of material layers, typically based on 3D computer models. This approach significantly shortens production lead times, particularly for new product sampling, by enabling direct and rapid prototyping and manufacturing (Delic & Eyers, 2020).

Advanced manufacturing technology encompasses a set of mostly programmable technologies that enhance the efficiency and flexibility of various operations within product development. This includes activities related to design, planning, execution, and control, utilizing tools such as Computer-Aided Design (CAD), Computer-Aided Engineering (CAE), and Computer-Aided Process Planning (CAPP). These technologies facilitate the product development process, offering substantial agility and adaptability in manufacturing operations (Moyano-Fuentes et al., 2016).

Within a corpus of 41 studies, merely three address the unique context of Chinese high-tech companies. These studies delineate six pivotal indicators of supply chain and operational flexibility, which are essential for navigating the complexities of the high-tech industry in China: Reference as Table 4.2.

Table 4.2 References of China high-tech company related indicators

Business area	Flexibility indicators	Source
Organization flexibility	Logistics flexibility	Yu et al. (2018)
Organization flexibility	Relationship flexibility	Yu et al. (2018)
Information flexibility	Information system	Luo et al. (2020)
Marketing flexibility	Product lifecycle	Z. Wang & Zhang (2020)
Manufacturing Flexibility	Product modularity	Z. Wang & Zhang (2020)
Organization flexibility	Supply chain integration (customer,	Z. Wang & Zhang (2020)

		supplier, internal integration)	

Logistics Flexibility and Relationship Flexibility: Investigated by Yu et al. (2018), these indicators emphasize the capability to adapt logistical operations dynamically and maintain effective relationships, both of which are vital for rapid response to market changes and complex supply chain demands.

Information System: Luo et al. (2020) highlight the critical role of advanced information systems in supporting real-time decision-making and enhancing the integration and efficiency of operations, which are particularly crucial in high-tech environments where rapid data processing and responsiveness are required.

Product Lifecycle, Product Modularity, and Supply Chain Integration: Z. Wang and Zhang (2020) explore these interrelated indicators, noting the importance of managing the entire lifecycle of products efficiently, employing modular designs to facilitate customization and quick adaptations, and achieving deep integration across the supply chain to optimize overall performance and drive innovation.

These studies collectively underscore a strategic emphasis on flexibility and integration, highlighting their critical importance in maintaining competitive advantage and responding adeptly to the fast-paced changes characteristic of the high-tech sector in China. The findings suggest that embracing these indicators can significantly contribute to the agility and resilience of Chinese high-tech firms, enabling them to better meet global standards and customer expectations.

According to the data presented in Table 4.1, a total of 85 SC flexibility indicators have been identified in the research. Of these, twenty-five indicators are pertinent to the high-tech sector, constituting 29.4% of the overall indicators studied. Notably, only six indicators are derived from studies specifically focusing on Chinese high-tech companies, which represents a mere 7.1% of the total flexibility indicators identified. This highlights a significant gap in research focusing on flexibility indicators within Chinese high-tech companies compared to the broader high-tech industry.

Among the 85 SC flexibility indicators identified above, several indicators either duplicated existing concepts or fell within similar thematic scopes. To consolidate these indicators, we grouped overlapping indicators, reducing the total count to 38. For detailed information, see T able 4.3.

Table 4.3 Indicators of SC flexibility from SLR

No.	Business area	Indicators of SC flexibility	Author & Year of publication
1	Manufacturing	Safety stock	Mohammaddust et al. (2017)

2	Manufacturing	ISO 9001	Araceli et al. (2020)
3	Manufacturing	Lean production	Maqueira et al. (2021), Qamar et al. (2018)
4	Manufacturing	Postpone flexibility	Martínez-Sánchez and Pérez (2005), Sreedevi and Saranga (2017)
5	Manufacturing	Product modularity	Z. Wang and Zhang (2020), Um (2017), Martínez-Sánchez and Pérez (2005)
6	Manufacturing	Routing flexibility	Martínez-Sánchez and Pérez (2005), Swafford et al. (2006)
7	Manufacturing	Volume flexibility	Martínez-Sánchez and Pérez (2005), Tang and Tomlin (2008), Kim et al. (2013), Braunscheidel a nd Suresh (2009)
8	Organization	Information sharing with vendors	Malik and Sarkar (2020)
9	Organization	Coercive power	G. Liu et al. (2022)
10	Organization	External integration	Moyano-Fuentes et al. (2016), Bag and Rahman (2021), Skipper and Hanna (2009), Braunscheidel and Suresh (2009), Chaudhuri et al. (2018), Um (2017), Yu et al. (2018), Gupta et al. (2019), He et al. (2014), Shou (2018), Z. Wang and Zhang (2020), Ramos et al. (2021), Aissa et al. (2009), Sreedevi and Saranga (2017), Fernandez-Giordano et al. (2021)
11	Organization	External knowledge transfer	Blome et al. (2014)
12	Organization	Green supplier integration	Ji (2020)
13	Organization	Internal integration	Braunscheidel and Suresh (2009), Yang and Tsai (2019), Riley et al. (2016), Moyano-Fuentes et al. (2016), Chaudhuri et al. (2018), Ramos et al. (2021), Gosling et al. (2010)
14	Organization	Internal knowledge transfer	Blome et al. (2014)
15	Organization	Organizational learning	Rojo et al. (2018)
16	Organization	Supply chain learning	Willis et al. (2016)
17	Organization	Supply chain risk management	Chaudhuri et al. (2018)
18	Organization	Top management support	Skipper and Hanna (2009)
19	Organization	Training	Riley et al. (2016)
20	Information	Data analytics capability	Dubey et al. (2021), Cheng et al. (2021), Bag and Rahman (2021)
21	Information	Information system's use	Luo et al. (2020), Riley et al. (2016), Gupta et al. (2019), Skipper and Hanna (2009)
22	Information	IT flexibility	Han et al. (2017), Jin et al. (2014), Q. Zhang et al. (2006)
23	Information	The integration of information system at buyer-supplier interface	Wagner et al. (2018), Fernandez-Giordano et al. (2021)
24	Procurement	Alliance	Bag and Rahman (2021)

		capability (ACA)	
25	Procurement	Procurement flexibility	Swafford et al. (2006), Chirra et al. (2021)
26	Procurement	Sourcing flexibility	Gosling et al. (2010), Martínez-Sánchez and Pérez (2005), Wagner et al. (2018)
27	Logistics	Delivery flexibility	Martínez-Sánchez and Pérez (2005)
28	Logistics	Delivery performance	Wagner et al. (2018)
29	Logistics	Distribution flexibility	Swafford et al. (2006)
30	Logistics	Logistics flexibility	Sreedevi and Saranga (2017), Yu et al. (2018), Tang and Tomlin (2008)
31	Marketing	Market distribution flexibility	Martínez-Sánchez and Pérez (2005)
32	Marketing	Customer relationships	Um (2017)
33	Marketing	Price flexibility	Tang and Tomlin (2008)
34	Marketing	Product financial performance	Wagner et al. (2018)
35	Marketing	Product lifecycle	Z. Wang and Zhang (2020)
36	Product development	Additive manufacturing adoption (3D printing)	Delic and Eyers (2020)
37	Product development	Advanced manufacturing technology (AMT) adoption	Moyano-Fuentes et al. (2016)
38	Product development	Launch flexibility	Martínez-Sánchez and Pérez (2005)

In the subsequent chapter, the 38 refined supply chain indicators are analyzed in a Web-Delphi survey.

4.2 Stage A2: Fuzzy Web-Delphi

4.2.1 Questionnaire Round 1: Responses

The first round of the questionnaire comprises three segments: an introduction outlining the purpose, a section collecting basic participant information, and a section devoted to the main inquiries. The basic information section includes nine questions, while the main section consists of 52 questions. Of these, 38 are single-choice questions derived from the literature review, and fourteen are open-ended questions designed to elicit new ideas. The distribution of the single-choice questions is as follows: seven pertain to manufacturing, twelve to organizational aspects, four to information management, three to purchasing, four to logistics, five to marketing, and three to product development. Each of these thematic sections concludes with two open-ended questions, replicated across all seven sections, totaling fourteen open questions.

The survey was administered from February 16th, 2023, to February 27th, 2023, spanning 11 days. It was distributed via WeChat to 89 participants (see Annex C – List of experts to invite), achieving a response rate of ninety percent with eighty collected responses. Respondents were from six provinces, indicating a broad geographical spread across China's economically advanced regions: 54 experts from Guangdong province, seven from Anhui, four each from Zhejiang and Sichuan, and two each from Hunan and Fujian provinces.

All eight high-tech regions have been included in the data collection, ensuring that the findings may be considered representative of China's high-tech sector, despite some regions having a low response rate. For detailed questionnaire round 1, please refer to Annex E. The feedback on basic participant information is as Table 4.4.

Table 4.4 Questionnaire1 basic participant information

Question	Option	Number	Percentage
1. Are you still working in the high-tech industry?	Yes	75	94%
	No	5	6%
	Total valid responses	80	
2. How many years of experience do you have in the high-tech industry?	1-5 years	7	9%
	6-10 years	8	10%
	11-15 years	19	24%
	16-20 years	25	31%
	20+ years	21	26%
	Total valid responses	80	
3. What is your education level?	High school	0	0%
	College degree	11	14%
	Bachelor's degree	38	48%
	Master's degree	28	35%
	Doctor degree	3	4%
	Total valid responses	80	
4. What is your position in the company?	Chairman or General manager	17	21%
	Vice President	22	28%
	Director or Head of department	23	29%
	Other management or technical position	16	20%
	Staff	2	3%
	Others	0	0%
	Total valid responses	80	
5. How many workers work in the company?	1-20 persons	2	3%
	20-300 persons	26	33%
	300-1000 persons	19	24%
	1000-5000 persons	14	18%
	5000+ persons	19	24%
	Total valid responses	80	
6. What is the revenue of your company in 2022 (Unit: Million RMB)?	0-3 million	2	3%
	3-20 million	2	3%
	20-400 million	26	33%
	400-1000 million	9	11%
	1000 + millions	41	51%
	Total valid responses	80	

7. For how many years is the company operating in the sector?	1-5 years	8	10%
	6-10 years	25	31%
	11-15 years	9	11%
	16-20 years	8	10%
	20+ years	30	38%
	Total valid responses	80	
8. How many years have you been working in your current company?	1-5 years	8	10%
	6-10 years	25	31%
	11-15 years	9	11%
	16-20 years	8	10%
	20+ years	30	38%
	Total valid responses	80	
9. Which is the sector/area in which the company belongs?	Electronic information technology	45	56%
	Biology and new medical technologies	1	1%
	Aerospace technology	1	1%
	New material technology	12	15%
	High-tech service industry	6	8%
	New energy and energy-saving technologies	4	5%
	Resource and environment technology	1	1%
	High and new technologies transform traditional industries	10	13%
	Total valid responses	80	

4.2.2 Questionnaire Round 1: Data analysis

Transforming the responses from the questionnaire from a linguistic scoring scale to a Likert scale according to the following mapping rules: 'Strongly Agree' corresponds to 5, 'Agree' to 4, 'Not Sure' to 3, 'Disagree' to 2, and 'Strongly Disagree' to 1.

Inputting the Likert scale scores for the thirty-eight questions into the Round 1 Fuzzy Delphi data sheet. The worksheet is programmed to automatically generate the fuzzification outcomes. Subsequently, it will display the average threshold (d), the defuzzification value (Amax), the consensus per criterion, and the global consensus value. Refer to the Table 4.5. for the round 1 Fuzzy Delphi result.

Table 4.5 Round 1 questionnaire Fuzzy Delphi result

Business Area	Item	Indicators	d	Amax	Consensus	Result
Manufacturing	1	Safety stock	0.179	0.621	83%	Accepted
	2	ISO 9001	0.090	0.710	94%	Accepted
	3	Lean production	0.189	0.611	81%	Accepted
	4	Postpone flexibility	0.188	0.588	61%	Accepted
	5	Product modularity	0.057	0.658	94%	Accepted
	6	Routing flexibility	0.150	0.650	89%	Accepted
	7	Volume flexibility	0.072	0.673	95%	Accepted
Organization	8	Information sharing with vendors	0.060	0.660	94%	Accepted
	9	Coercive power	0.130	0.530	70%	Accepted
	10	External integration	0.018	0.583	73%	Accepted
	11	External knowledge transfer	0.040	0.640	94%	Accepted

	12	Green supplier integration	0.013	0.613	81%	Accepted
	13	Internal integration	0.092	0.693	99%	Accepted
	14	Internal knowledge transfer	0.072	0.673	96%	Accepted
	15	Organizational learning	0.095	0.705	99%	Accepted
	16	Supply chain learning	0.105	0.695	98%	Accepted
	17	Supply chain risk management	0.093	0.708	98%	Accepted
	18	Top management support	0.103	0.698	98%	Accepted
	19	Training	0.072	0.673	99%	Accepted
Information	20	Data analytic capability	0.093	0.708	100%	Accepted
	21	Information system's use	0.085	0.715	100%	Accepted
	22	IT flexibility	0.082	0.683	96%	Accepted
	23	The integration of information system at buyer-supplier interface	0.103	0.497	71%	Rejected
	24	Alliance capability (ACA)	0.012	0.613	81%	Accepted
	25	Procurement flexibility	0.040	0.640	91%	Accepted
	26	Sourcing flexibility	0.010	0.610	86%	Accepted
Logistics	27	Delivery flexibility	0.045	0.645	93%	Accepted
	28	Delivery performance	0.065	0.665	98%	Accepted
	29	Distribution flexibility	0.045	0.645	93%	Accepted
	30	Logistics flexibility	0.043	0.643	91%	Accepted
Marketing	31	Customer relationships	0.070	0.670	94%	Accepted
	32	Price flexibility	0.019	0.581	73%	Accepted
	33	Product financial performance	0.048	0.648	94%	Accepted
	34	Product lifecycle	0.065	0.665	98%	Accepted
	35	Market distribution flexibility	0.010	0.610	86%	Accepted
Product development	36	Additive Manufacturing Adoption (3D printing)	0.144	0.544	80%	Accepted
	37	Advanced Manufacturing Technology (AMT) Adoption	0.007	0.607	83%	Accepted
	38	Launch flexibility	0.200	0.600	49%	Rejected

Two indicators were excluded based on the stopping criteria as detailed below:

i. The indicator 'the integration of information systems at the buyer-supplier interface' was initially listed as question number 27 in the questionnaire. However, it appears as number 23 in the Fuzzy Delphi data sheet due to the presence of four initial statement questions that lack Likert scale scoring and are excluded from Fuzzy Delphi calculations. The Amax value for this indicator is 0.497, falling below the stopping criterion threshold of 0.5, indicating a lack of consensus among experts on its suitability for measuring supply chain flexibility.

ii. The indicator 'launch flexibility' was question number 50 in the questionnaire and changed to 38 in the Fuzzy Delphi data sheet, following twelve statement questions that also do not incorporate Likert scale assessments and are thus excluded from the analysis. The average threshold (d) for this indicator is 0.20. According to the stopping criteria, any indicator with a threshold equal to or greater than 0.2 is rejected, signifying expert disagreement on the applicability of this indicator in measuring supply chain flexibility.

Several indicators recorded consensus values below 75%, as detailed below:

1. Question 4 in the questionnaire, concerning 'postpone flexibility', achieved a consensus value of 61.25%.

2. Question 11 in the questionnaire, regarding 'coercive power', listed as number 9 in the Fuzzy Delphi data sheet, had a consensus value of 70%.

3. Question 12 in the questionnaire, on 'external integration', listed as number 10 in the Fuzzy Delphi data sheet, had a consensus value of 72.5%.

4. Question 50 in the questionnaire, on 'launch flexibility', listed as number 38 in the Fuzzy Delphi data sheet, had a consensus value of 48.75%.

According to the stopping rules, a consensus value below 75% necessitates an additional round of inquiry (Abdulkareem et al., 2021). Despite the global consensus reaching 88.09%, this value falls below the desired threshold of 90%, indicating the need for a further round of the questionnaire.

In terms of the fourteen open questions, and upon reviewing the feedback from the expert panel, several modifications are proposed for the next round of the questionnaire. Specifically, two indicators are recommended for elimination, four require more detailed explanations to clarify ambiguities, and five new indicators have been suggested for inclusion:

i. Indicators recommended for elimination:

1. Top Management Support: This indicator is considered a general prerequisite for all company activities. Given its ubiquitous nature, it is advised to be excluded from the list as its absence universally impedes performance.

2. IT Flexibility: This aspect is already encompassed by Question 25 ("Information System Use") in the questionnaire, covering identical scope; thus, repetition is unnecessary.

ii. Indicators requiring further explanation:

1. Postpone Flexibility: Current queries suggest confusion with modularity. The revised description will define it as the "Capability to maintain products in generic form as long as feasible to incorporate customer requirements during later stages." An additional note will clarify that product differentiation primarily occurs at the assembly's end, contrasting with modularity, which spans the entire production process.

2. Sourcing Flexibility: Some experts have indicated that the current description lacks clarity. An additional statement will specify that "There are ample qualified resources available for selection."

3. Logistics Flexibility: The revision will expand the definition beyond multi-modal, multi-

carrier, and multi-route transportation to include "the capability to deliver products to various locations."

4. Distribution Flexibility: The emphasis will be on the importance of inventory levels within sales channels. The updated description will outline "The ability to offer extensive or intensive distribution coverage, facilitated by coordinated downstream activities, whether internal or external to the firm. Attention should also be paid to channel inventory levels.

iii. New indicators proposed for addition:

1. Multi-skilled Worker: Described as workers possessing diverse skills capable of operating across different stations or lines, enhancing operational flexibility.

2. Production Line Configuration Flexibility: This entails having adaptable production lines or mechanisms to meet customization and diverse, minimal demands, supporting product individualization.

3. Device Normalization: Advocates for the use of standardized materials across different products to streamline development.

4. Configurable Product Functions: Encourages flexibility in product functions to meet varied and unforeseen business needs through various configurations, specifically within the product development domain.

4.2.3 Questionnaire Round 2: Responses

The second round of the questionnaire is structured into three main parts. The first part solicits basic personal and professional information from the participants. The second part reevaluates the participants' levels of agreement based on the feedback from the first round, and the third part gauges agreement with the newly proposed measurement indicators introduced in the first round:

i. Part I contains three questions aimed at collecting basic personal and professional information from the respondents.

ii. Part II consists of 37 questions, forming the core section for feedback collection. This includes 35 single-choice questions and two open-ended questions designed to gather new ideas and opinions. The single-choice questions are distributed across seven thematic sections:

Section 1: Seven questions related to the manufacturing field.

Section 2: Eleven questions pertaining to the organizational field.

Section 3: Three questions concerning the information field.

Section 4: Three questions about the purchasing field.

Section 5: Four questions related to logistics.

Section 6: Four questions focused on marketing.

Section 7: Two questions on product development.

A noteworthy oversight in Part II is Question 21, titled "The integration of information system at buyer-supplier interface - Share intra-firm information and data access," which should not have been included due to its Amax value of 0.497 from the first round, indicating insufficient consensus. The error was identified post-survey; however, no modifications were made. The question will remain in the questionnaire and thesis to maintain consistency but will be excluded from the Fuzzy Delphi analysis to ensure data accuracy.

iii. Part III includes seven questions: five single-choice and two open-ended questions. These are intended to evaluate the additional indicators identified from the first round's feedback. However, there was a late realization regarding Question 42, "Product Configuration - Make product functions flexible and configurable," which overlaps significantly with product modularity and postponement. Although it was initially added based on first-round feedback, subsequent expert opinion suggested exclusion from the analysis. This has been communicated and agreed upon with the supervising professor, and while it will remain in the documentation for consistency, it will be excluded from the Fuzzy Delphi calculations.

The questionnaire was distributed on March 2nd, 2023, and concluded on March 14th, 2023, spanning a period of 12 days.

A total of 84 participants were invited, with 68 providing feedback, resulting in a response rate of 81%. The survey was distributed via WeChat, with participants completing it on the Wenjuanxin website through the provided link. For detailed questionnaire for round 2, please refer to Annex F. The basic participant information for the second round is shown in Table 4. 6.

Table 4.6 Questionnaire2 basic participant information

Question	Option	Number	Percentage
1. How many years of experience do you have in the high-tech industry?	1-5 years	3	4%
	6-10 years	14	21%
	11-15 years	15	22%
	16-20 years	21	31%
	20+ years	15	22%
	Total valid responses	68	
2. What is your position in the company?	Chairman or General manager	14	21%
	Vice President	17	25%
	Director or Head of department	24	35%
	Other management or technical position	12	18%
	Staff	1	1%
	Others	0	0%
	Total valid responses	68	
3. Which is the sector/area in	Electronic information technology	35	51%
	Biology and new medical technologies	1	1%

which the company belongs?	Aerospace technology	1	1%
	New material technology	7	10%
	High-tech service industry	9	13%
	New energy and energy-saving technologies	3	4%
	Resource and environment technology	1	1%
	High and new technologies transform traditional industries	11	16%
	Total valid responses	68	

4.2.4 Questionnaire Round 2: Data analysis

Transforming the responses from the questionnaire from a linguistic scoring scale to a Likert scale according to the following mapping rules: 'Strongly Agree' corresponds to 5, 'Agree' to 4, 'Not Sure' to 3, 'Disagree' to 2, and 'Strongly Disagree' to 1.

Inputting the Likert scale scores for the thirty-eight questions into the Round 2 Fuzzy Delphi data sheet. The worksheet is programmed to automatically generate the fuzzification outcomes. Subsequently, it will display the average threshold (d), the defuzzification value (Amax), the consensus per criterion, and the global consensus value. Refer to the Table 4.7 for the round 2 Fuzzy Delphi result.

Table 4.7 Round 2 questionnaire Fuzzy Delphi result

Business Area	Item	Indicators	d	Amax	Consensus	Result
Manufacturing	1	Safety stock	0.012	0.588	71%	Accepted
	2	ISO 9001	0.056	0.744	94%	Accepted
	3	Lean production	0.012	0.612	87%	Accepted
	4	Postpone flexibility	0.033	0.633	96%	Accepted
	5	Product modularity	0.045	0.645	97%	Accepted
	6	Routing flexibility	0.045	0.645	94%	Accepted
	7	Volume flexibility	0.042	0.642	96%	Accepted
Organization	8	Information sharing with vendors	0.019	0.619	93%	Accepted
	9	Coercive power	0.023	0.577	75%	Accepted
	10	External integration	0.024	0.576	87%	Accepted
	11	External knowledge transfer	0.015	0.615	94%	Accepted
	12	Green supplier integration	0.000	0.600	66%	Accepted
	13	Internal integration	0.085	0.685	100%	Accepted
	14	Internal knowledge transfer	0.065	0.665	99%	Accepted
	15	Organizational learning	0.105	0.695	97%	Accepted
	16	Supply chain learning	0.125	0.675	94%	Accepted
	17	Supply chain risk management	0.087	0.713	99%	Accepted
	18	Training	0.057	0.657	99%	Accepted
Information	19	Data analytic capability	0.102	0.698	99%	Accepted

	20	Information system's use	0.096	0.704	99%	Accepted
Procurement	21	Alliance capability (ACA)	0.006	0.594	84%	Accepted
	22	Procurement flexibility	0.035	0.635	93%	Accepted
	23	Sourcing flexibility	0.026	0.626	94%	Accepted
Logistics	24	Delivery flexibility	0.019	0.619	96%	Accepted
	25	Delivery performance	0.044	0.644	99%	Accepted
	26	Distribution flexibility	0.029	0.629	94%	Accepted
	27	Logistics flexibility	0.038	0.638	96%	Accepted
Marketing	28	Customer relationships	0.059	0.659	99%	Accepted
	29	Price flexibility	0.032	0.568	84%	Accepted
	30	Product financial performance	0.012	0.612	91%	Accepted
	31	Product lifecycle	0.029	0.629	93%	Accepted
	32	Market distribution flexibility	0.015	0.615	94%	Accepted
Product development	33	Additive Manufacturing Adoption (3D printing)	0.142	0.542	84%	Accepted
	34	Advanced Manufacturing Technology (AMT) Adoption	0.009	0.609	87%	Accepted
Manufacturing	35	Multi-skilled employee	0.059	0.659	91%	Accepted
	36	Production line configuration flexibility	0.079	0.679	99%	Accepted
Product development	37	Material selection flexibility	0.053	0.653	91%	Accepted
	38	Material normalization	0.076	0.676	96%	Accepted

Based on the data derived from the second round of the Fuzzy Delphi method, it was observed that no indicators were terminated by the established stopping criteria. Among the evaluated indicators, only the consensus value for the safety stock (Question 1) was below the 75% threshold, registering at 70.59%, in contrast to a global consensus of 91.95%. Furthermore, discussions from the expert panel indicated no emergence of new indicators in the round 2 questionnaire. Consequently, given the absence of new indicators arising and the current Fuzzy Delphi data, further rounds of the survey are deemed unnecessary.

4.2.5 Fuzzy Web-Delphi overview

Following the outcomes derived from two rounds of questionnaire surveys, thirty-eight indicators have been validated for measuring and monitoring the flexibility within a high-tech company. It is imperative to delineate the operationalization of these indicators, which are categorized into seven distinct areas as follows:

i. Manufacturing Area (9 indicators): Safety stock, ISO9001 certification, lean production techniques, postponement flexibility, product modularity, routing flexibility, volume flexibility, workforce multi-skilling, and flexibility in production line configuration.

ii. Organization Area (11 indicators): Vendor information sharing, coercive power utilization, external integration, transfer of external knowledge, integration of green suppliers, internal integration, transfer of internal knowledge, organizational learning, supply chain learning, supply chain risk management, and training programs.

iii. Information Area (2 indicators): Data analytic capabilities and usage of information systems.

iv. Procurement Area (3 indicators): Alliance capability, procurement flexibility, and sourcing flexibility.

v. Logistics Area (4 indicators): Delivery flexibility, delivery performance, distribution flexibility, and overall logistics flexibility.

vi. Marketing Area (5 indicators): Management of customer relationships, price flexibility, financial performance of products, product lifecycle management, and market distribution flexibility.

vii. Product Development Area (4 indicators): Adoption of additive manufacturing (3D printing), adoption of advanced manufacturing technology (AMT), flexibility in material selection, and material standardization.

4.3 Stage B: Operationalizing flexibility indicators

The purpose of operationalization is to systematically define the procedures for quantifying each indicator. This encompasses selecting appropriate data types for measurement, establishing computational methodologies, and determining the accuracy of the results. Furthermore, it necessitates assessing whether established measurement techniques from existing scholarly literature can be adapted, or if unique methods need to be developed specifically suited to the context of the case study company, COROS.

A panel comprising six experts was convened to deliberate on the methodologies for measuring the 38 identified indicators of flexibility within a high-tech company. This panel included two CEOs， one from a consulting firm and another from a supply chain company along with the heads of COROS's purchasing, operations, manufacturing, and finance departments. The discussions were structured in two phases: an initial round conducted online involving all six experts, followed by a face-to-face session with four of these experts. Prior to these meetings, preparatory materials were disseminated to each expert to facilitate a thorough understanding of the topics to be discussed.

4.3.1 Operationalization round 1: Review of indicators

Following comprehensive deliberations, the expert panel identified redundancies and overly broad constructs within the proposed indicators of flexibility. Consequently, they recommended a reconfiguration of these indicators, which includes the elimination of five indicators and the consolidation of eleven indicators. Additionally, the panel proposed the introduction of two new indicators, synthesized from the existing ones, to better encapsulate the requisite flexibility aspects.

The panel of experts has recommended the deletion of five indicators based on their overlapping nature and breadth, which complicates specific measurement. These indicators are:

i. Lean Production: Originally quantified through the reduction in manufacturing costs (e.g., labor reduction, automation), this indicator was deemed too broad, encompassing aspects of inventory management, process improvement, and skilled workforce. It overlaps significantly with safety stock, product modularity, material normalization, and multi-skilled workforce indicators.

ii. Distribution Flexibility: Defined as the ability to adapt delivery schedules to fluctuating customer demands and closely monitor stock levels, this indicator was found redundant with 'delivery performance', which focuses more on outcomes rather than processes.

iii. Production Line Configuration Flexibility: This indicator, involving adaptable production setups to meet diverse market needs, closely mirrors the 'routing flexibility' indicator, making it redundant.

iv. Product Lifecycle Management (PLM): While PLM is a holistic strategy focusing on capturing and reallocating wasted resources to bolster product and process improvements, it was not recognized as a distinct indicator due to its overlap with lean-thinking principles and other existing indicators.

v. Market Distribution Flexibility: Originally classified under logistics, this indicator's focus on the breadth or intensity of distribution coverage and channel inventory management was deemed more relevant to logistics and delivery performance, thus leading to its removal.

The expert panel has advised consolidating 11 indicators into broader categories as follows:

i. Information Sharing with Vendors: This indicator, defined as the leading company sharing demand information with downstream vendors to reduce overall supply chain costs, falls under the scope of external integration. It is suggested to be merged into the external integration indicator.

ii. Organization Learning: Described as the transformation of individual knowledge into organizational knowledge systems, this indicator aligns with internal knowledge transfer. The panel recommends its integration into the internal knowledge transfer indicator.

iii. Supply Chain Learning: With a focus on internal process evaluation and improvement, this indicator closely mirrors internal knowledge transfer. The panel advises merging it into the internal knowledge transfer indicator.

iv. Training: This indicator facilitates knowledge transfer from managers to employees, focusing on risk identification and management. The panel suggests incorporating it into internal knowledge transfer.

v. Procurement Flexibility: Highlighting the ability to respond to changes in supply requirements, this indicator is seen as part of the broader purchasing flexibility and is recommended for integration.

vi. Sourcing Flexibility: Defined by the ability to reconfigure supply networks and select suppliers, this indicator is recommended to be merged into purchasing flexibility due to its focus on the initial stages of purchasing activities.

vii. Logistics Flexibility: Emphasizing diverse transportation methods and routes, this indicator is suggested to be integrated into delivery performance, reflecting its operational outcomes.

viii. Delivery Flexibility: Focusing on adapting lead times to meet customer requirements, this indicator is also recommended for integration into delivery performance due to its logistical focus.

ix. Internal Knowledge Transfer: This indicator involves sharing information across different functions within a company, which is essentially a form of knowledge transfer. It is recommended to be consolidated under a broader knowledge transfer category.

x. External Knowledge Transfer: Focused on leveraging external expertise for organizational benefit, this indicator is also suggested to be merged into a broader knowledge transfer category.

xi. Additive Manufacturing Adoption (3D Printing): As this represents an advanced manufacturing technology, and given the existence of an AMT adoption indicator, it is suggested to be consolidated under AMT adoption.

The expert panel has synthesized two new indicators from existing ones to streamline the measurement framework and enhance coherence:

i. Knowledge Transfer: This consolidated indicator merges the internal and external knowledge transfer indicators to eliminate redundancy in measurement content. The new indicator will utilize diverse methodologies to measure knowledge transfer activities, recognizing both internal and external aspects under a unified framework. This approach simplifies the assessment process by reducing the duplication of similar concepts across different indicators.

ii. Purchasing Flexibility: Created by amalgamating the procurement flexibility and sourcing flexibility indicators, this new indicator addresses the entire purchasing process. Procurement flexibility focuses on the latter stages of purchasing, ensuring material availability, while sourcing flexibility concerns the initial stages, ensuring adequate supply and qualification of vendors. This comprehensive indicator reflects the full spectrum of purchasing activities, from vendor selection through to material procurement.

The comprehensive reevaluation and restructuring of the indicators, including those that were eliminated, merged, or newly formulated, are meticulously cataloged in.

Table 4.8 provides a detailed summary, enabling a clear understanding of the adjustments made to enhance the measurement framework's efficacy and coherence.

Table 4.8 Operationalization round 1 result

No.	Business area	38 indicators from FD survey	Result
1	Manufacturing	Safety stock	Keep
2	Manufacturing	ISO 9001	Keep
3	Manufacturing	Lean production	Deleted
4	Manufacturing	Postpone flexibility	Keep
5	Manufacturing	Product modularity	Keep
6	Manufacturing	Routing flexibility	Keep
7	Manufacturing	Volume flexibility	Keep
8	Organization	Information sharing with vendors	Combined to external integration
9	Organization	Coercive power	Keep
10	Organization	External integration	Keep
11	Organization	External knowledge transfer	Combined as knowledge transfer
12	Organization	Green supplier integration	Keep
13	Organization	Internal integration	Keep
14	Organization	Internal knowledge transfer	Combined as knowledge transfer
15	Organization	Organizational learning	Combined as knowledge transfer
16	Organization	Supply chain learning	Combined as knowledge transfer

17	Organization	Supply chain risk management	Keep
18	Organization	Training	Combined as knowledge transfer
19	Information	Data Analytic capability	Keep
20	Information	Information system's use	Keep
21	Purchasing	Alliance Capability (ACA)	Keep
22	Purchasing	Procurement flexibility	Combined as purchasing flexibility
23	Purchasing	Sourcing flexibility	Combined as purchasing flexibility
32	Marketing	Market Distribution Flexibility	Deleted
24	Logistics	Delivery flexibility	Combined to delivery performance
25	Logistics	Delivery performance	Keep
26	Logistics	Distribution flexibility	Deleted
27	Logistics	Logistics flexibility	Combined to delivery performance
28	Marketing	Customer relationships	Keep
29	Marketing	Price flexibility	Keep
30	Marketing	Product financial performance	Keep
31	Marketing	Product lifecycle management	Deleted
33	Product development	Additive Manufacturing Adoption (3D printing)	Combined to AMT
34	Product development	Advanced Manufacturing Technology (AMT)	Keep
35	Manufacturing	Multi-skilled workforce	Keep
36	Manufacturing	Production line configuration flexibility	Deleted
37	Product development	Material selection flexibility	Keep
38	Product development	Material normalization	Keep
39	Organization	Knowledge transfer	New added
40	Purchasing	Purchasing flexibility	New added

From an initial 38 indicators, 24 were selected in the first round of operationalization to measure and monitor the SC flexibility in Chinese private high-tech companies. These indicators are organized across seven business areas:

i. Manufacturing: Includes safety stock, ISO9001, postponement flexibility, volume flexibility, product modularity, routing flexibility, and a multi-skilled workforce.

ii. Organizational: Comprises coercive power, internal integration, external integration, knowledge transfer, green supplier integration, and supply chain risk management.

iii. Information: Features data analytic capability and information system usage.

iv. Purchasing: Consists of alliance capability and purchasing flexibility.

v. Marketing: Covers marketing strategies, customer relationships, price flexibility, and product financial performance.

vi. Logistics: Focuses on delivery performance.

vii. Product Development: Encompasses advanced manufacturing technology adoption, material selection flexibility, and material normalization.

4.3.2 Operationalization round 2: Defining how to operationalize flexibility indicators

The 24 indicators previously identified are generally applicable to a wide range of Chinese private high-tech enterprises. However, given the distinct characteristics of individual companies, it may be necessary to tailor these indicators based on the specific realities of each enterprise. This phase of the process aims to select, from the existing 24 indicators, those that are most appropriate for evaluating the SC flexibility of the case study company, COROS.

A panel of four experts from COROS has been convened to deliberate on the operationalization of the 24 indicators identified for measuring and monitoring supply chain flexibility. The panel comprises the heads of the Purchasing, Operations, Manufacturing, and Finance departments at COROS. The rationale for selecting only internal experts from COROS for this discussion is that these indicators are to be validated and assessed specifically within the context of a case study focused on COROS. This approach ensures that the insights and adjustments proposed are directly relevant and tailored to the operational realities of the company.

COROS, a private high-tech company based in Dongguan City, Guangdong Province, specializes in sports watches. As of 2022, COROS employs 360 individuals, generating revenues of 340 million RMB and projecting an increase to 500 million RMB in 2023. The company operates in the electronic information technology sector, with products and services reaching over 100 countries globally.

Despite its success, COROS faces operational challenges, including inaccurate demand forecasts and supply inconsistencies that fail to meet demand fluctuations. Occasionally, excessive material stock results in financial burdens due to unsold inventory. Given these issues, there is a critical need to closely measure and monitor supply chain flexibility in real-time and implement necessary improvements. This makes COROS an ideal candidate for a case study focused on enhancing supply chain responsiveness and efficiency.

In manufacturing area:

Safety stock

Tan and Tang (2006) and Rădăşanu (2016) address the strategic importance of maintaining appropriate safety stock levels within supply chain management, especially in contexts involving new products. Tan and Tang (2006) argues that safety stock is essential for enterprises to effectively manage the uncertainties associated with demand and supply fluctuations, ensuring that product availability aligns with strategic goals. He outlines several methods for calculating safety stock, including approaches based on specific replenishment policies, desired customer service levels (CSL), and fill rates (FR). On the other hand, Rădăşanu (2016) links safety stock levels directly to service levels within a company, advocating for a balance that covers vendor delivery times and customer demand without leading to excessive carrying costs. He points out the financial risks and operational challenges of overstocking, such as increased storage costs, potential for product expiration, and the need for price reductions due to over-supply. Rădăşanu (2016) highlights that many retailers and manufacturers strive for a 95% service level to foster customer loyalty and maximize sales, despite the high costs and risks involved. He notes that safety stock can be calculated using either historical demand patterns or projected demand forecasts (forecast error), with the standard formula incorporating a safety factor that represents the number of standard deviations needed to achieve a specified service level, assuming normally distributed demand during the replenishment period. This approach allows companies to tailor their inventory practices to meet both current and future consumer demands effectively, thereby enhancing overall supply chain resilience.

Based on the theoretical frameworks discussed, the expert panel at COROS has recommended utilizing the fill rate and customer service level as metrics to measure safety stock, aligning with the company's make-to-stock strategy. This approach ensures sufficient finished goods are available to meet unexpected customer demands, aiming for a 100% target to align with COROS's aggressive sales strategy.

The methodology for measuring safety stock encompasses both finished goods and kitting raw materials:

1. Finished Goods: The stock in the factory is compared against the average sales quantity over the past three months. The target is set at 100%, being computed as shown below:

$$\mathbf{X} = \frac{\textbf{Actual stock quantity}}{\textbf{Average sales quantity over the past 3 months}} \tag{4.1}$$

For instance, if the actual stock quantity is 18,000 and the average sales quantity over the past three months is 20,000, the fill rate is calculated as:

$$\mathbf{X} = \frac{\mathbf{18{,}000}}{\mathbf{20{,}000}} = \mathbf{90\%}$$

2. Kitting raw materials involves grouping and packaging all the necessary components needed for assembling a specific product into a single unit called a kit. This process streamlines assembly by ensuring all parts are readily available at the assembly point, thus improving efficiency and accuracy in production.

The target for kitting raw materials is also set at 100%. This measure calculates the proportion of kitting raw material items available within a 10–15-day period compared to the total required kitting raw material items for the same period. For example, if there are 600 kitting raw material items available within 10-15 days out of a total of 700 requested, the kitting raw material rate is:

$$X = \frac{600}{700} = 85.75\%$$

This structured approach enables COROS to closely monitor and adjust their inventory levels, ensuring operational efficiency and high customer satisfaction through accurate and responsive supply chain practices.

ISO9001

This indicator is quantitatively straightforward to assess. It is measured as a binary variable, assigned a value of 1 if the company possesses ISO9001 certification, and 0 if it lacks such certification.

Postpone flexibility

Saghiri and Barnes (2016) explore the concept of manufacturing postponement, which involves delaying product customization processes such as fabrication, assembly, and packaging to the latest possible point in the supply chain to enhance flexibility and reduce costs. This strategy allows for product customization, risk management, and reductions in finished goods and work-in-process inventory expenses. It relies on robust coordination with suppliers to adapt to last-minute changes due to shorter lead times in manufacturing processes.

Lin and Wang (2011) discuss the Manufacturing Postponement and Logistics Speculation (MPLS) strategy, which operates on a build-to-order (BTO) basis. This strategy involves sourcing common components and building modules that are universal across products, which are then stored at field warehouses. Differentiated components are added only when orders are received, maintaining economies of scale in module production while slightly increasing the cost for assembling differentiated components. This method helps reduce risks associated with product obsolescence and dead stock. They also describe the Full Postponement (FP) strategy that integrates both manufacturing and logistics postponements, holding modules and differentiated components in central warehouses and assembling products as orders are placed, which reduces inventory levels and repositioning costs but may reduce production economies of scale.

Given these insights, the panel of experts recommends adopting these concepts to measure COROS's manufacturing postponement. They suggest quantifying the time products remain in a general status as a proportion of the total production time, differentiated by product line. The suggested formula for this metric is as follows:

$$\textbf{Manufacturing postponement flexibility} = \frac{\textbf{Days product kept in general status}}{\textbf{Total production lead time}} \# \qquad (4.2)$$

For example, if a product line is kept in general status for 7 days out of a total production lead time of 8 days, the manufacturing postponement efficiency would be:

$$X = \frac{7}{8} = 87.5\%$$

This metric will help COROS monitor and optimize their manufacturing postponement strategy across different product lines.

Volume flexiblity

Jack and Raturi (2009) reference Stigler's 1939 assertions on volume flexibility, proposing that a firm with a flatter cost curve, indicating lower marginal costs associated with output changes, exhibits greater volume flexibility. They suggest practical measurement of this flexibility through the second derivative of the average cost curve, highlighting a fundamental trade-off between sales fluctuations and inventory variations. A firm capable of minimizing inventory fluctuations in response to sales variability is considered more volume flexible.

The experts propose three ways to measure volume flexibility:

1. Proposition 1: Measures volume flexibility as the ratio of fluctuations in sales to fluctuations in inventory, suggesting a direct relationship between sales variability and inventory management effectiveness.

2. Proposition 2: Suggests measuring volume flexibility as the ratio of sales fluctuations to fluctuations in cost-of-goods-sold (COGS), indicating that a firm that maintains lower variability in production costs in response to sales variations demonstrates higher flexibility.

3. Proposition 3: Combines the insights of the first two propositions, measuring volume flexibility as the ratio of sales fluctuations to the combined fluctuations of inventory and COGS, offering a comprehensive view of a firm's responsiveness to market changes.

The panel recommends adopting the first proposition, which uses the ratio of sales to inventory fluctuations for measurement. They suggest a simplification by directly using the ratio of sales amount to inventory amount without standard deviations, where volume flexibility is calculated as shown in Eq. (4.3):

$$\textbf{Volume fleixibility} = \frac{\textbf{Sales amount}}{\textbf{Inventory amount}} \qquad (4.3)$$

If the sales amount in a given month is 300 million and the inventory amount is 800 million, then the volume flexibility would be:

$$\textbf{Volume flexibility} = \frac{\textbf{300}}{\textbf{800}} = \textbf{37.5\%}$$

This metric will help assess how effectively a company can manage its resources in response to sales demands.

Product modularity

Gershenson et al. (2004) discuss a modularity measurement approach that accounts for both common and unique interfaces, while Gu et al. (1997) utilize interaction analysis, assigning values to design objectives to construct an interaction matrix between components, scaled between 0 and 10. This method allows for a weighted average calculation of interactions, providing flexibility for different life-cycle processes.

Despite extensive literature searches, no specific measurement method has been identified as universally applicable. Consequently, the panel recommends a tailored approach for COROS, focusing on the cost share of modular components relative to the total product Bill of Materials (BOM) cost, specifically at the final assembly stage (excluding packaging due to SKU variability). This method reflects actual flexibility more accurately.

The proposed metric for measuring product modularity is the ratio of the cost of modular components to the total product BOM cost. For instance, if the modular components cost is 300 RMB and the product BOM cost is 500 RMB, then the Product Modularity is calculated using Eq. (4.4):

$$\textbf{Product modularity} = \frac{\textbf{Modular components cost}}{\textbf{Total product BOM cost}} = \frac{\textbf{300}}{\textbf{500}} = \textbf{60\%} \tag{4.4}$$

This approach provides a concrete measure of modularity, directly reflecting the percentage of a product's cost attributable to modular components, with a target set at 60% to suit COROS's specific circumstances.

Routing flexibility

Chang (2007) and various other scholars have proposed multiple methods to measure routing flexibility, which assesses the adaptability of production processes within manufacturing systems. These methods include:

1. Average Number of Routes: Initiated by Chatterjee et al. (1984) and further developed by Chung et al. (1989), Zahran et al. (1990), and Sinha and Wei (1992), this method calculates the average number of routing options available for each part or product.

2. Ratio of Links: Carter (1986) suggested measuring the ratio of existing to possible links between machines in a system, providing insight into the connectivity and potential flexibility of the system.

3. Actual to Ideal Paths Ratio: Primrose and Leonard (1984) extended the concept of range measurement by comparing the ratio of actual paths utilized to ideal paths within the system.

4. Feasible Routes to Total Parts Ratio: Chung and Chen (1990) proposed quantifying routing flexibility by the ratio of feasible routes for a part to the total number of parts, indicating the relative routing freedom for each part.

5. Potential and Actual Routing Flexibility (PRF and ARF): Chen and Chung (1996), following Bernardo and Mohamed (1992), differentiated between PRF and ARF. PRF represents the total available routes for making a part, while ARF reflects the number of routes actually used, showing utilized versus potential flexibility.

6. Impact of Machine Breakdowns: Buzacott (1982) and Chung et al. (1989) emphasized the effect of machine breakdowns on production efficiency, suggesting metrics like the percentage decrease in throughput and job completion times, as well as increased flexibility from avoiding fixed routes.

The concept of routing flexibility in manufacturing emphasizes the importance of backup machines, labor, and logistical alternatives to maintain production flow. However, given COROS's reliance on skilled labor with minimal machine usage, the panel of experts suggests that traditional measures of routing flexibility may not be applicable for assessing COROS's specific production environment. They recommend omitting this indicator from COROS's flexibility assessment due to its limited relevance to the company’s operational structure.

Multi-skilled workforce

G. Liu et al. (2022) discuss the impact of multi-skilled worker turnover on manufacturing flexibility, noting that higher turnover rates could hinder the acquisition of such flexibility. Their study quantifies multi-skilled worker turnover by comparing a firm’s turnover rate with the industry average, acknowledging that this method might not yield perfectly accurate results due to variability in public data availability. They suggest that refining this measure could be a fruitful area for future research.

However, the expert panel advises against using the turnover rate of multi-skilled workers as a metric for assessing COROS's manufacturing flexibility. Instead, they recommend focusing on the proportion of multi-skilled workers relative to the total workforce, arguing that maintaining a high percentage of multi-skilled workers is more indicative of a flexible manufacturing capability than turnover rates.

The proposed measurement method follows Eq. (4.5):

$$\textbf{Multi-skilled workforce ratio} \tag{4.5}$$

$$= \frac{\textbf{Number of multi} - \textbf{skilled workers}}{\textbf{Total number of direct labor workers}}$$

This ratio focuses exclusively on direct labor workers, those directly involved in production, to provide a more accurate reflection of the operational flexibility at COROS. This approach aligns with the notion that a workforce skilled in multiple areas enhances a firm's adaptability and responsiveness to changing production demands, thus better supporting the goals of operational efficiency and flexibility.

In organization area:

Coercive power

Zhang et al. (2020) discuss the role of coercive power in supply chain management, noting that while it can enforce supplier compliance to meet a firm’s demands, it often results in an unsatisfactory normative commitment (Chae et al., 2017; Flynn et al., 2008; Ireland & Webb, 2007). They argue that the use of penalties or enforcement measures by a focal firm indicates a perception of the supplier relationship as purely transactional, rather than based on trustful cooperation (John, 1984; Zhuang et al., 2010).

Despite the sparse literature on precise measurement methods for coercive power, it is generally represented by the constraints imposed on suppliers. For COROS, coercive power is manifested through the signing of penalty contracts with suppliers, ensuring compliance with production standards and timelines. To effectively measure this indicator, COROS could consider the proportion of their top suppliers (based on purchasing volume) that have entered into such contracts, reflecting the extent of coercive power exercised.

For instance, if COROS has signed penalty contracts with 25 out of the top 40 suppliers (representing the top 80% of suppliers by purchase volume), the coercive power index can be calculated as shown below:

$$\textbf{Coercive power}$$
$$= \frac{\textbf{Number of vendors with penalty contracts}}{\textbf{Total number of top 80\% vendors}} = \frac{\textbf{25}}{\textbf{40}} = \textbf{62.5\%} \quad (4.6)$$

This ratio provides a quantitative measure of the extent to which COROS relies on coercive mechanisms to manage its supplier relationships, potentially highlighting areas for strategic adjustments to enhance cooperation and trust.

Internal integration

Moyano-Fuentes et al. (2016), citing Flynn et al. (2010), propose a comprehensive approach to measure internal integration within organizations, focusing on multiple aspects of intra-organizational communication and coordination. Their method encompasses several key indicators:

1. Data Integration between internal functions.

2. Enterprise Application Integration between internal functions.

3. Integrative Inventory Management, which includes:

a. Real-time searching of inventory levels.

b. Real-time searching of logistics-related operating data.

4. Periodic Inter-Departmental Meetings among internal functions.

5. Cross-Functional Teams used in process improvement.

6. Cross-Functional Teams used in new product development.

7. Real-Time Integration and Connection among all internal functions, from raw materials management through production, shipping, and sales.

On the other hand, Chaudhuri et al. (2018) suggest a more focused approach, emphasizing information sharing and joint decision-making primarily within the purchasing and sales departments. Their method includes:

1. Sharing Information with purchasing and sales departments regarding sales forecasts, production plans, production progress, and stock levels.

2. Joint Decision Making with these departments about sales forecasts, production plans, and stock levels.

Given the comprehensive nature of the measures proposed by Moyano-Fuentes et al. (2016), the expert panel recommends adopting their seven-point framework to assess internal integration at COROS. This framework not only covers the critical elements of integration but also ensures a holistic view of the organizational connectivity and responsiveness:

Internal Integration Measure: This is quantified by scoring each of the seven areas on a binary scale (1 for implemented, 0 for not implemented), summing these scores, and then dividing by the total number of areas (7). This method provides a percentage that reflects the level of internal integration within COROS.

For instance, if COROS has implemented five out of the seven integration measures (with partial implementation counting as 0.5), the calculation for internal integration might look like this:

$$\textbf{Internal integration} = \frac{\mathbf{(1+1+0.5+1+1+0+1)}}{\mathbf{7}} = \mathbf{78.57}\%$$

The target for internal integration is set at 100%, indicating full implementation across all measures. This goal supports a strategic vision of fully integrated internal functions, enhancing overall organizational efficiency and responsiveness.

External integration

Rai et al. (2006) have developed a model to assess external integration in supply chains, distinguishing between financial flow integration and physical and information flow integration. This model captures the degree of collaboration and synchronization between a firm and its supply chain partners in managing financial transactions, material flows, and information sharing.

Financial Flow Integration

This aspect evaluates the automation of financial transactions between the firm and its supply chain partners, emphasizing efficiency and timeliness:

Accounts receivable: The process is automated such that receivables are triggered immediately when shipments are made to customers. The integration level can be quantified by Eq. (4.7):

$$\textbf{Financial flow integration (receivables)} = \frac{\textbf{Total amount of automatically triggered account receivable}}{\textbf{Total amount of receivable}} \tag{4.7}$$

Accounts payable: Similarly, payables are automated to ensure that payments are triggered upon the receipt of supplies, as shown in Eq. (4.8):

$$\textbf{Financial flow integration (payables)} = \frac{\textbf{Total amount of automatically triggered account payable}}{\textbf{Total amount of payable}} \tag{4.8}$$

Information Flow Integration

This indicator focuses on the real-time sharing and updating of operational data across the supply chain, enhancing collaborative decision-making:

Customer Data Sharing: Using Customer Relationship Management (CRM) systems to manage real-time supply data sharing with customers, measured by Eq. (4.9):

$$\textbf{Information Flow Integration} - \textbf{CRM} = \frac{\textbf{Number of customers using CRM}}{\textbf{Total number of customers}} \tag{4.9}$$

Vendor Data Sharing: Employing Supplier Relationship Management (SRM) systems to facilitate real-time demand data sharing with vendors, computed using Eq. (4.10):

$$\textbf{Information Flow Integration} - \textbf{SRM} = \frac{\textbf{Number of customers using SRM}}{\textbf{Total number of vendors}} \tag{4.10}$$

Given these detailed metrics, the expert panel recommends focusing on financial and information flow integration while eliminating the physical integration measures, as these overlap with other assessed indicators such as safety stock and purchasing flexibility. This focused approach ensures a streamlined evaluation of the most critical aspects of external integration that directly impact the efficiency and responsiveness of the supply chain.

Knowledge transfer

Blome et al. (2014) propose a method for evaluating both internal and external knowledge transfer within organizations. They define specific metrics for assessing the effectiveness of information sharing and collaboration both within a company and between the company and its external partners.

Blome et al. (2014)'s methodology, as adopted and expanded by COROS, includes several measures to gauge the effectiveness of knowledge sharing among internal departments:

1. Effective Information Exchange: This measure assesses whether departments effectively exchange information relevant to each other's functions.

2. Common Understanding: This measure checks whether there is a mutual understanding among departments regarding the importance of the information shared.

3. Cross-functional Product Development: This measure evaluates the intensity of collaboration on new product development across different functions.

4. Best Case and Knowledge Sharing: Added by COROS, this measure examines the frequency and quality of sharing best practices and relevant professional knowledge within the company.

5. Effective Training: Also added by COROS, this measure evaluates the availability and effectiveness of training related to employees' specific job functions.

The methodology also includes measures for assessing the transfer of knowledge from external suppliers to the company:

1. Supplier Expertise Sharing: This measures the ability of suppliers to share their expertise in new technologies with COROS.

2. Frequent Development Meetings: This assesses the frequency of meetings with suppliers aimed at developing new knowledge.

3. Technical Know-How Conversion: This evaluates how effectively the technical know-how from suppliers is converted into COROS's new products and processes.

COROS conducted two surveys:

1. Survey 1: Sent to all staff via the company's WeChat account using the WJX survey tool. It was conducted between May 13th and 15th, 2023, with a 38.5% response rate (77 out of 200 employees responded). The survey revealed varying levels of effectiveness in internal knowledge transfer practices and highlighted generally low effectiveness in external knowledge

transfer. The feedback from this survey led to a second, more focused survey.

2. Survey 2: Targeted only employees from the purchasing and hardware development departments, as they are more frequently in contact with external partners. Conducted between May 18th and 19th, 2023, with a 45% response rate (9 out of 20 employees responded), this survey showed a higher effectiveness in external knowledge transfer among these targeted groups.

The results from these surveys indicate that while internal knowledge transfer is effectively implemented in certain areas, external knowledge transfer initially appeared to be less effective. This discrepancy was addressed with a more targeted approach in the second survey, which provided more insightful feedback from departments directly involved with external partners. The findings from both surveys are being used to develop a dashboard that will help monitor and improve knowledge transfer processes continuously within COROS, especially focusing on areas identified as needing improvement.

Green supplier integration

Ji et al. (2020) build on the work of Vachon and Klassen (2008) and Wu (2013) to develop a set of six questions that gauge the effectiveness of green supplier integration (GSI) within supply chains. This measure assesses the collaborative efforts between a company and its suppliers to enhance environmental performance. The questions address various aspects of environmental management, including goal setting, understanding responsibilities, and joint efforts to mitigate environmental impacts.

The following questions are designed to assess the extent of integration on environmental issues between a company and its suppliers:

1. Achieving Environmental Goals Collectively (GSI1): This question evaluates whether the company and its suppliers set and work towards shared environmental targets.

2. Developing a Mutual Understanding of Responsibilities (GSI2): Assesses whether there is a clear mutual understanding of each party's responsibilities in terms of environmental performance.

3. Working Together to Reduce Environmental Impact (GSI3): Measures the collaborative efforts to lessen the environmental impact of their joint activities.

4. Conducting Joint Planning for Environmental Issues (GSI4): Examines the extent to which the company and its suppliers engage in joint planning to foresee and solve environmental issues.

5. Making Joint Decisions to Reduce Environmental Impact (GSI5): Assesses joint decision-making processes regarding the reduction of environmental impacts of products or

services.

6. Accumulating and Sharing Environmental Knowledge (GSI6): Measures the effectiveness of accumulating and sharing knowledge about environmental practices and technologies.

Based on discussions among the panel of experts, it was noted that most of these aspects are typically covered in environmental agreements with suppliers. Therefore, COROS has chosen to measure green supplier integration by examining the proportion of suppliers that have signed environmental agreements incorporating standards such as RoHS, REACH, and California Proposition 65. The measurement follows Eq. (4.11):

$$\textbf{Green supplier integration} = \frac{\textbf{Number of suppliers which have signed environmental agreements}}{\textbf{Total number of suppliers}} \quad (4.11)$$

For instance, if 30 out of 200 suppliers have signed such agreements, the green supplier integration score would be:

$$\textbf{Green supplier integration} = \frac{\textbf{30}}{\textbf{200}} = \textbf{15}\%$$

This metric provides a quantitative assessment of how well environmental considerations are integrated with COROS's supplier interactions and reflects the company's commitment to environmental stewardship through its supply chain management.

Supply chain risk management

Chaudhuri et al. (2018) offer a comprehensive framework for measuring supply chain risk management by examining the processes involved in preventing, detecting, responding to, and recovering from operational risks. Drawing from various scholars' contributions to the field, they propose a multi-indicator approach that includes:

1. Preventing Operations Risks: Strategies like selecting reliable suppliers, implementing clear safety procedures, and carrying out preventive maintenance are essential to mitigate potential disruptions (Tomlin, 2006).

2. Detecting Operations Risks: This involves monitoring and inspecting operations both internally and across suppliers to identify risks early (Manuj & Mentzer, 2008; Raj et al., 2004; Zsidisin et al., 2004).

3. Responding to Operations Risks: Employing backup suppliers, increasing capacity, or using alternative transportation modes are vital for maintaining operations despite disruptions (Sheffi & Rice Jr, 2005).

4. Recovering from Operations Risks: Establishing task forces, creating contingency plans,

and clarifying responsibilities help in quickly restoring operations after an incident (Norrman & Jansson, 2004).

Considering the extensive nature of these measures and their varied applicability across different types of suppliers, the panel of experts at COROS has decided to simplify the approach and focus specifically on key suppliers who have a significant impact on the supply chain's risk profile. The rationale is that these suppliers represent critical points where potential disruptions could have the most significant adverse effects. Thus, the assessment has been condensed into three key questions:

1. Strategic Supplier Proportion: This metric assesses the percentage of strategic suppliers relative to the total number of suppliers to determine the concentration of critical supply sources.

2. Supplier Audits per Year: Measures the frequency of supplier audits conducted annually to monitor compliance and performance.

3. Alternative Supplier Availability: Evaluates whether there is at least one alternative supplier for critical commodities such as plastic tooling and metal parts machining, ensuring that there are contingency options available in case of supply chain disruptions.

This focused approach allows COROS to specifically address the areas where risk management is most crucial, thereby efficiently utilizing resources and maximizing the impact of their risk management strategies. By concentrating on key suppliers, COROS ensures that the backbone of their supply chain remains robust against potential disturbances, maintaining operational continuity and minimizing the likelihood of significant supply chain failures.

In information area:

Data analytic capability (DAC)

Drawing from the frameworks proposed by Akter et al. (2016) and Srinivasan and Swink (2018), the measure of data analytic capability (DAC) in an organization can be delineated into specific actionable aspects. These aspects encompass the utilization of advanced analytical tools and techniques, integration and visualization of data for informed decision-making, and the connectivity of these systems to managerial communication devices. Here's an elaborate breakdown based on the proposed measures, adapted for COROS's current practices:

1. Advanced Analytical Tools Usage (DAC1): This involves the application of simulation, optimization, regression, and other advanced tools to facilitate decision-making.

2. Integration of Varied Data Sources (DAC2): This measure assesses the capability to aggregate and synthesize information from diverse data sources to support decision processes.

3. Data Visualization Techniques (DAC3): Utilization of dashboards and other visual tools

to help decision-makers understand complex data sets effectively.

4. Dashboard Information Relevance (DAC4): Ensures that the dashboards display relevant information necessary for diagnosing and addressing issues.

5. Connectivity and Accessibility (DAC5): The degree to which dashboard applications or informational tools are integrated with managerial communication devices for timely and effective communication.

Although COROS has not fully implemented dashboards to monitor the above aspects, they are currently engaged in activities akin to data analytic capabilities:

1. Weekly Active Quantity Monitoring: Tracking the activation rates of sold watches to gauge usage trends.

2. Weekly Inventory Monitoring: Regular checks on inventory levels to manage stock efficiently.

3. Weekly Sales Volume Tracking: Monitoring sales data to adapt marketing and sales strategies.

4. Weekly Production Output Monitoring: Assessing production metrics to align manufacturing with demand.

Each activity is scored on a binary scale, where "1" indicates the activity is performed, and "0" indicates it is not. For instance, if COROS performs the first, third, and fourth activities but not the second, the score would be calculated as follows:

$$\textbf{Data analytic capability} = \frac{(\mathbf{1}+\mathbf{0}+\mathbf{1}+\mathbf{1})}{\mathbf{4}} = \mathbf{75}\%$$

The target set by COROS for full implementation of data analytic capabilities is 100%. This systematic approach not only ensures operational alignment with market demands but also sets a benchmark for continuous improvement in data utilization and decision-making processes.

Information system usage

As literature on measuring the usage of information systems within organizations is sparse, the panel of experts at COROS has proposed a pragmatic approach to evaluate the extent of information system adoption across various functional departments. This measurement method aims to capture the coverage rate of information system implementation across eleven key departments within COROS, which include Sales, Planning, Purchasing, Production, Logistics, Warehouse, Quality, Finance, Research and Development, After Sales Service, and Human Resources.

The measure is calculated as the ratio of the number of departments actively using information systems to the total number of departments: Information system usage = Number of departments using information systems / 11

If the departments of Sales, Planning, Purchasing, Production, Warehouse, and Finance are currently utilizing information systems, this would be represented as:

$$\textbf{Information system usage} = \frac{\mathbf{6}}{\mathbf{11}} \approx \mathbf{54.5}\%$$

Although achieving a 100% adoption rate is ideal, a target of 80% is considered more practical and financially feasible. This target acknowledges that while information systems significantly enhance operational efficiency, the substantial investment required may not justify full implementation across all departments. Thus, an 80% adoption rate is deemed sufficient to robustly support the business operations of COROS, balancing cost with the benefits of digital integration.

In purchaing area:

Alliance capability (ACA)

According to Bag and Rahman (2021), alliance capability is typically assessed through five key indicators:

1. Experience with Alliances: Evaluates the firm's historical involvement and success with strategic alliances aimed at achieving its strategic objectives.

2. Evaluation of New Partner Opportunities: Assesses how frequently and thoroughly the firm evaluates potential new partners for contributions to its core business.

3. Contribution to Competitive Advantage: Focuses on the firm's efforts to forge alliances that enhance its competitive edge in the market.

4. Training Programs: Looks at whether the firm has dedicated training programs for managers and partners to maximize the benefits of alliances.

5. Institutionalized Routines: Measures whether there are established procedures within the firm to regularly evaluate the performance and effectiveness of alliances

However, the panel of experts at COROS considers these conventional measurements unsuitable for the company's current operational context. Instead, they propose a more tailored approach to gauge alliance capability. This approach prioritizes practical outcomes such as the partner's willingness to prioritize COROS's orders when capacity is constrained, willingness to invest in support of COROS's demand increases, and collaboration in developing new technologies like Global Positioning System (GPS) integrated circuits.

The measurement is proposed to be the ratio of the number of allied suppliers who demonstrate such support behaviors to the total number of suppliers, as shown in Eq. (4.12):

$$\textbf{Alliance capability (ACA)} = \frac{\textbf{Number of allied suppliers}}{\textbf{Total number of suppliers}} \quad (4.12)$$

For instance, if COROS has 30 suppliers who meet the criteria for being considered "allied suppliers" out of a total of 200 suppliers:

$$\textbf{Alliance capability (ACA)} = \frac{\mathbf{30}}{\mathbf{200}} = \mathbf{15\%}$$

This tailored measurement approach better aligns with the strategic needs and real-world operational challenges faced by COROS.

Purchasing flexibility

Swafford et al. (2006) propose eight criteria for assessing purchasing flexibility, which encompasses a company's adaptability in managing supplier interactions to handle fluctuations and changes in the procurement process efficiently. These criteria are:

1. Influence on Supplier's Short-term Capacity: The ability to affect suppliers' production capabilities in the short term.

2. Global Volume Allocation Changes: Adjusting order quantities across different suppliers on a global scale.

3. Procurement as Required: The capability to locate and purchase necessary services and products on demand.

4. Order Quantity Modifications: Flexibility to change the quantity of orders placed with suppliers.

5. Adjustment of Delivery Timings: The ability to modify the delivery schedules of orders.

6. Engineering Change Orders: Influencing suppliers' ability to handle engineering modifications.

7. Global Demand Consolidation: Consolidating global requirements for components to optimize order volumes.

8. Global Supplier Changes: The capacity to switch suppliers on a global scale as needed.

Given the current strategic position of COROS within its industry, implementing all these measures is challenging. Particularly, actions like adjusting order quantities may not be feasible due to the company's limited influence over its suppliers, and such strategies might not foster healthy business relations.

Therefore, the expert panel recommends focusing on three revised measures more suited to COROS's current capabilities and business ethics:

1. Change in Volume Allocation Among Existing Suppliers:

Metric: The proportion of procurement spending that allows for volume reallocation among suppliers (Eq. (4.13)).

$$X = \frac{\textbf{Purchasing amount allowing for allocation change}}{\textbf{Total purchasing amount}} \tag{4.13}$$

2. Influence on Suppliers' Engineering Change Capabilities:

Metric: The extent to which COROS can mandate engineering changes in the procurement process (Eq. (4.14)).

$$X = \frac{\textbf{Amount of material purchased allowing for engineering changes}}{\textbf{Total amount of material purchased}} \tag{4.14}$$

3. Flexibility in Changing Delivery Times:

Metric: The portion of procurement that permits adjustments in delivery schedules (Eq. (4.15)).

$$X = \frac{\textbf{Purchasing amount allowing for schedule changes}}{\textbf{Total purchasing amount}} \tag{4.15}$$

X= Purchasing amount allowing for schedule changes / Total purchasing amount

These streamlined metrics align better with COROS's operational realities and strategic interests, focusing on enhancing flexibility without straining supplier relationships.

In maketing area:

Customer relationships

The customer relationship mechanisms within the framework provided by Um (2017). This framework is divided into four distinct aspects:

1. Anticipation and Response to Customer Needs (CS1): This aspect involves preemptively identifying and addressing changes in customer requirements, thereby ensuring adaptability and responsiveness in customer interactions.

2. Evaluation of Customer Complaints (CS2): This measures the effectiveness of mechanisms in place for handling both formal and informal customer grievances, which is crucial for maintaining service quality and customer trust.

3. Monitoring and Measuring Service Levels (CS3): This involves the continuous assessment of service delivery standards to ensure they meet predefined customer expectations and service commitments.

4. Feedback on Quality and Service (CS4): This aspect focuses on actively seeking and analyzing customer feedback on the quality of service and products provided, facilitating ongoing improvements.

Above framework centers around two pivotal metrics identified in the synthesis of customer relationship strategies:

1. Customer Complaint Rate: Calculated as the ratio of the total number of customer complaints to the total sales volume. This metric serves as an indicator of customer dissatisfaction and a barometer for the effectiveness of customer service practices within the supply chain (Eq. (4.16)).

$$\textbf{Customer complaint rate} = \frac{\textbf{Total number of complaints}}{\textbf{Total sales volume}} \tag{4.16}$$

2. Customer Satisfaction Rate: This metric is bifurcated to reflect different assessment methods across geographical markets:

✓ China Market: Measured using the Net Promoter Score (NPS), which quantifies the likelihood of existing customers recommending the company's products based on their satisfaction.

✓ Non-China Market: Utilizes a traditional customer satisfaction rate to gauge consumer contentment.

These metrics are essential for the strategic evaluation of customer relationship management across diverse market environments, providing a data-driven foundation for improving customer interaction and satisfaction within global supply chain operations.

Price flexiblity

Price flexibility, traditionally employed to modulate consumer purchasing behaviors through adjustments in sales prices, is minimally discussed in the literature concerning its measurement. In the context of COROS, this indicator is deemed to have negligible practical impact due to the infrequency of price changes. Instead, COROS prioritizes enhancing customer value through regular software updates, which serve to improve service quality and strengthen brand reputation. Based on expert consensus, it is recommended to omit the price flexibility indicator from performance metrics, redirecting focus towards service enhancement as a more effective strategy for fostering customer engagement and loyalty.

Product financial performance

The indicator of product financial performance (PFP), as delineated by Wagner et al. (2018) and based on earlier work by Joshi and Sharma (2004) and Song et al. (2011), is quantitatively measured through three key indicators: sales growth rate, market share, and profitability. Each of these metrics offers a specific lens to assess the competitive stance of a product line relative to its principal market competitors:

1. Sales Growth Rate: Calculated as the percentage change in sales volume over a specified period. This metric reflects the ability of the product to increase its market presence relative to the previous period (Eq. (4.17)).

$$\textbf{Sales growth rate} = \frac{\textbf{Current period sales volume} - \textbf{previous period sales volume}}{\textbf{previouse period sales volme}} \quad (4.17)$$

Example calculation for Q1 2023 sales growth rate: 2022 Q1 sales volume 40,000 sets, 2023 Q1 sales volume 60,000 sets.

$$\textbf{Sales growth rate} = \frac{(60000 - 40000)}{40000} = 50\%$$

2. Market Share: Originally considered for measurement via the ratio of COROS's annual sales to global sales, this approach was revised to better reflect the specialized consumer base of COROS products. The revised metric for assessing the market share of COROS products strategically focuses on their prevalence among participants in major marathon events. The 2023 analysis encompasses seven significant events, specifically in Boston, London, Tokyo, Xiamen, Wuxi, Chongqing, and Wuhan. This targeted approach allows for a more precise measurement of market penetration within the niche of sports enthusiasts, thereby providing a clearer understanding of the brand's impact and reach within this specific consumer segment (Eq. (4.18)).

$$\textbf{Market share} = \frac{\textbf{Number of COROS product users at events}}{\textbf{Totall number of events participants}} \quad (4.18)$$

The data is weighted equally between Chinese and Non-Chinese markets, with an assumption of a 50/50 distribution.

3. Profitability: Measured using the ratio of gross profit to total sales, which provides an indication of the financial efficiency and pricing strategy effectiveness of the product line, excluding the considerations of net profits due to confidentiality (Eq. (4.19)).

$$\textbf{Profitability} = \frac{\textbf{Gross profit}}{\textbf{Total sales amount}} \quad (4.19)$$

Example calculation for Q1 2023: 2022 Q1 gross profit 50 million while sales amount is 90 million.

$$\textbf{Profitability} = \frac{50}{90} = 55.56\%$$

These metrics collectively offer a comprehensive view of the financial performance of a product line, facilitating strategic adjustments and targeted interventions in product management and marketing strategies.

In logistics area:

Delivery performance

In light of the methodology outlined by Wagner et al. (2018) and further refined by Power et al. (2010) and Malhotra and Mackelprang (2012), the evaluation of delivery performance has been adapted to focus primarily on delivery reliability due to its direct impact on customer-facing performance. This adjustment reflects the operational strategy of COROS, which operates on a make-to-stock model, maintaining sufficient safety stock to reliably meet customer demand without the necessity to measure customer order lead time, fill rate, or overall satisfaction related to delivery specifics.

The recommended metric for assessing delivery performance centers on the economic impact of delivery losses and damages rather than their numerical occurrence, which provides a more accurate reflection of financial implications as shown in Eq. (4.20):

$$\textbf{Delivery performance} = \frac{\textbf{Total sales amount} - \textbf{Amount of actual product lost and damaged}}{\textbf{Total sales amount}} \qquad (4.20)$$

For example, given an actual product loss and damage amount of RMB 8,000 against a total shipping amount of RMB 10 million, the delivery performance would be calculated as follows:

$$\textbf{Delivery perfromance} = \frac{\textbf{10,000,000} - \textbf{8,000}}{\textbf{10,000,000}} = \textbf{99.92\%}$$

This measure offers a precise indicator of the effectiveness of the delivery system in preserving the integrity and financial value of shipped goods, thus ensuring high reliability in customer deliveries.

In product development area:

Advanced manufacturing technology adoption (AMT)

In adapting the measurement approach for Advanced Manufacturing Technology (AMT) implementation, COROS will utilize a modified version of the parsimonious scale proposed by Moyano-Fuentes et al. (2016). The focus will be on the following aspects:

1. Using computer-aided design (CAD)
2. Using computer-aided manufacturing (CAM)
3. Using computer-aided engineering (CAE)
4. Using enterprise resource planning (ERP)
5. Using 3D printing

The decision to exclude computer-aided process planning (CAPP) and flexible manufacturing systems (FMS) stems from their relevance primarily at the vendor's end in the manufacturing process, where COROS is not directly involved. Instead, COROS concentrates on final assembly. The inclusion of 3D printing reflects its growing importance in modern manufacturing processes.

The assessment will be binary, where “1” indicates adoption and “0” indicates non-adoption. The overall AMT implementation score is calculated as the average of these indicators, as shown in Eq. (4.21):

$$\textbf{AMTscore} = \frac{\textbf{Sum of adoption scores}}{\textbf{Number of technologies assessed}} \tag{4.21}$$

For example, if the adoption scores across the five assessed technologies are CAD=1, CAM=1, CAE=0, ERP=1, 3D Printing=0, then:

$$\textbf{AMT score} = \frac{(\mathbf{1+1+0+1+0})}{\mathbf{5}} = \mathbf{60\%}$$

This formula provides a clear, quantitative measure of AMT implementation within COROS, facilitating strategic decisions regarding further technology integration.

Material selection flexibility

The newly introduced indicator of material selection flexibility assesses COROS's ability to adapt to changes in supplier relationships and material availability. This indicator is crucial due to the limited literature available on its measurement and the specific challenges faced by COROS in influencing the technical direction and product evolution with suppliers, owing to its smaller business scale.

Given these constraints, COROS has strategically focused on monitoring the material selection trends of competitors to ensure that its hardware selection remains competitive. The pragmatic metric for this indicator measures the organization's responsiveness to supply chain disruptions, specifically its capacity to source alternative suppliers under conditions where existing suppliers fail to meet commitments within a predefined six-month period.

The metric is calculated using the financial value of purchases, which provides a more accurate reflection of material management effectiveness than sheer volume (Eq. (4.22)).

$$\textbf{Material selection flexibility} = \frac{\textbf{Purchasing amount of non} - \textbf{bottleneck material}}{\textbf{Total purchasing amount}} \tag{4.22}$$

For instance, if the purchasing amount for non-bottleneck materials totals RMB 40 million out of an overall purchasing amount of RMB 60 million, the material selection flexibility is calculated as:

$$\textbf{Material selection flexibility} = \frac{\mathbf{40}}{\mathbf{60}} = \mathbf{66.67\%}$$

This formula not only quantifies COROS's adaptability in material sourcing but also serves as an indicator of its strategic resilience against supply chain vulnerabilities.

Material nomalization

The newly incorporated indicator of material normalization focuses on the strategic use of common materials across different products in the product development process. This approach aims to streamline manufacturing and potentially reduce costs by leveraging economies of scale and minimizing inventory complexity.

Given the scarcity of literature on precisely measuring this indicator, the proposed metric assesses the financial proportion of common materials used across multiple products relative to the total material expenditure. This method emphasizes the economic impact of material standardization, accounting for the variance in component costs which might skew simpler volumetric or unit-based assessments (Eq. (4.23)).

$$\textbf{Material normalization} = \frac{\textbf{Purchasing amount of common materials}}{\textbf{Total purchasing amount of all materials}} \tag{4.23}$$

For instance, if the purchasing amount for common materials is RMB 16 million against a total material purchasing amount of RMB 35 million, the material normalization ratio would be:

$$\textbf{Material normalization} = \frac{\textbf{16}}{\textbf{35}} = \textbf{45.7\%}$$

This percentage reflects the extent to which an organization successfully implements a material standardization strategy, highlighting its efficiency in resource utilization and its potential impact on reducing manufacturing costs and complexity.

Operationalization round 2 summary

Based on the outcomes of the second round of operationalization, it has been determined that for the development of a comprehensive dashboard for the COROS case, 22 indicators will be incorporated. These indicators are selected to effectively capture and monitor various operational and strategic aspects of the organization, providing actionable insights through data visualization.

Additionally, two indicators - routing flexibility and price flexibility—have been excluded from this iteration of the dashboard development. The decision to omit these indicators likely stems from their limited applicability or impact in the context of COROS's current operational strategy or business model. This refinement ensures that the dashboard remains focused and relevant to the core operational metrics that drive decision-making and performance evaluation within COROS. Reference as Table 4.9.

Table 4.9 Operationalization round 2 result

No	Business area	Round 1 operationalization list	Round 2 Result
1	Manufacturing	Safety stock	Keep
2	Manufacturing	ISO 9001	Keep

3	Manufacturing	Postpone flexibility	Keep
4	Manufacturing	Product modularity	Keep
5	Manufacturing	Routing flexibility	Delete
6	Manufacturing	Volume flexibility	Keep
7	Manufacturing	Multi-skilled workforce	Keep
8	Organization	Coercive power	Keep
9	Organization	Internal integration	Keep
10	Organization	External integration	Keep
11	Organization	Knowledge transfer	Keep
12	Organization	Green supplier integration	Keep
13	Organization	Supply chain risk management	Keep
14	Information	Data Analytic capability	Keep
15	Information	Information system's use	Keep
16	Purchasing	Alliance Capability (ACA)	Keep
17	Purchasing	Purchasing flexibility	Keep
18	Logistics	Delivery performance	Keep
19	Marketing	Customer relationships	Keep
20	Marketing	Price flexibility	Delete
21	Marketing	Product financial performance	Keep
22	Product development	Advanced Manufacturing Technology (AMT)	Keep
23	Product development	Material selection flexibility	Keep
24	Product development	Material normalization	Keep

4.4 Stage C: Build the dashboard with Power BI

Stage C of the COROS case study focuses on developing a dashboard using Power BI, highlighting 22 strategic indicators.

The process includes designing an intuitive and responsive dashboard, utilizing Power BI for robust data visualization, and managing data through extraction, cleansing, and transformation. Data is then uploaded to Power BI, where visualizations for each indicator are created and organized logically with interactive elements for dynamic exploration. The project culminates with the presentation of the initial dashboard version, tailored for effective strategic decision-making and operational insight.

Visualization Principles

Data visualization facilitates the exploration of data by researchers, analysts, engineers, and non-experts, leveraging the human visual system's ability to quickly identify patterns (V anWijk, 2005). Dashboards are highly personalized in their design and should avoid including redundant data. Charts are more useful for identifying relationships (comparison, grouping, classification, prediction, or pattern recognition), while tables are more effective for extracting specific values and their combinations, providing a broader perspective. Dashboards should prioritize simplicity to minimize reading distractions or complexities (Scholtz et al., 2018). According Sarikaya et al. (2019), these data visualization tools offer three types of interactivity:

(i) highly personalized dashboards (allowing flexible placement of visual elements); (ii) data filtering and segmentation options; and (iii) modification of the data states presented in the dashboard (e.g., users selecting to view specific measurement data). Traditionally, dashboards consist of a single panel, but they may also switch between multiple pages to focus on a specific data context through particular visual elements. Dashboards present detailed information in visual formats, enhancing user comprehension and enabling deep analysis (Widjaja & Mauritsius, 2019). These dashboards improve the measurement of operational and decision-making processes by providing efficient, visible, accessible, and shareable information (Nabil et al., 2023).

Power BI

Developed by Microsoft, Power BI is a widely praised Business Intelligence (BI) system known for its robust interactive data visualization capabilities. Initially introduced in 2014 as part of the Microsoft Office365 suite, Power BI has since evolved into a standalone platform and has garnered significant popularity, emerging as one of the most prominent BI systems in use today (Nabil et al., 2023). Leveraging a collection of supply chain indicators, a Microsoft Power BI-based system enhances information transmission and management, thereby improving decision-making processes. Power BI serves as an analytical tool for data analysis and knowledge sharing, capable of integrating various databases, files, and services to facilitate quick data corrections or modifications (Widjaja & Mauritsius, 2019; Williams, 2016). Power Business Intelligence (Power BI) enables real-time tracking of Key Performance Indicators (KPIs) such as order fulfillment rates, inventory levels, lead times, and supplier performance. These visualizations aid in identifying inefficiencies and areas requiring improvement, enabling timely decision-making and initiatives (Becker & Gould, 2019). Power BI solutions are widely adopted by major corporations such as Heathrow, Hewlett-Packard, Meijer, Aston Martin, Rolls-Royce, among others, for various analytical tasks and crucial business growth decisions (Nabil et al., 2023). Power BI offers several advantages:

1. Automation and enhancement of information-intensive tasks such as repetitive business planning, performance management, variance analysis, root cause analysis, and corrective actions.

2. Just-in-time automation and acceleration, alongside unit business dashboards and KPIs, focus the company's attention on key customers and channels to drive desired results, measure performance against established KPI targets, and manage impact through exception strategies.

3. Automatic analysis of trade promotion effects and increased sales support through consumer advertising and marketing to achieve optimal outcomes.

4. Provision of standard and comprehensive historical business information as input to various corporate plans and budgets, enabling efficient planning and effective control within a short timeframe.

5. Timely and cost-effective monitoring of company's business and financial performance through standard but dynamic insights related to the profitability and performance of customers, market segments, categories, brands, products, plants, and networks significantly impacting sales, costs, service, and profit.

6. Provision of business information and analysis in an easily accessible format, allowing stakeholders to specify variables of interest and "current" dates in fast-executing reports and analyses.

7. Alteration of current warehousing and reporting processes to mitigate or eliminate performance issues in the current environment. Information Technology (IT) is tailored to provide a comprehensive framework to assist companies in achieving their corporate IT governance and management goals.

Data organization

The organization of dashboard data involves several critical steps to ensure effective data visualization and analysis:

i. Data Extraction:

1. From SAP Tools: Data is extracted from COROS using SAP tools that manage purchasing, storage, manufacturing, sales, and finance operations. This data is exported in multiple Excel files for research implementation.

2. From Company Servers: Manually retrieve specific data, such as marathon market share data, directly from company servers.

3. Manual Data Collection: Gather data manually, such as statistics on a multi-skilled workforce, which are provided by the production department based on completed multi-skill certifications.

4. From Market Surveys: Utilize existing market survey data, including overseas customer satisfaction results and domestic satisfaction ratings gathered from sales platforms.

5. From Surveys: Some data, such as external integration, are obtained through survey responses.

ii. Data Transformation:

Organize and prepare the provided data for analysis, which includes removing duplicates/incomplete entries, converting date/time formats, and standardizing data to ensure consistency across the dataset.

iii. Data Upload:

The transformed data is uploaded to Power BI via prepared Excel files. During this stage, links between different data variables are created, enabling the computation of selected metrics for the COROS SC flexibility assessment dashboard.

These steps are crucial for developing a comprehensive dashboard that can effectively support decision-making by providing clear, actionable insights derived from well-organized data.

The first version of the Dashboard was constructed in July 2023, reference to Annex G. F igure 4.2 is a big picture of COROS dashboard, and it offer an overall status overview for all 22 indicators.

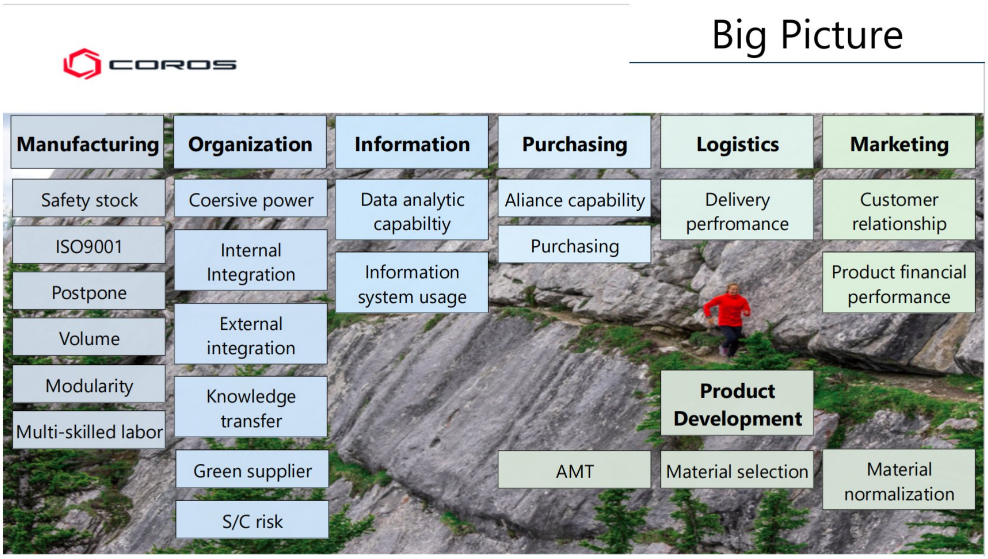

Figure 4.2 The big picture of COROS dashboard version 1

Figure 4.3 presents a comprehensive overview of flexibility across all indicators within the manufacturing sector, illustrating the current status of each indicator.

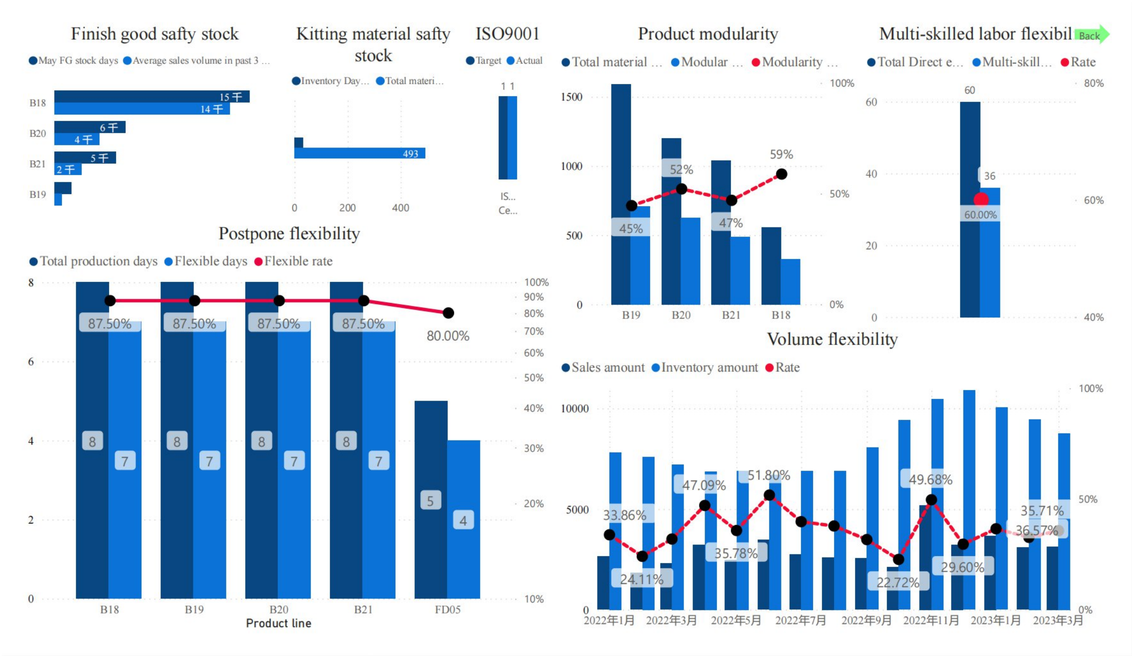

Figure 4.3 Flexibility overview in manufacturing area version 1

Figure 4.4 provides a detailed examination of the status specific to safety stock, encompassing both finished goods and kitting materials.

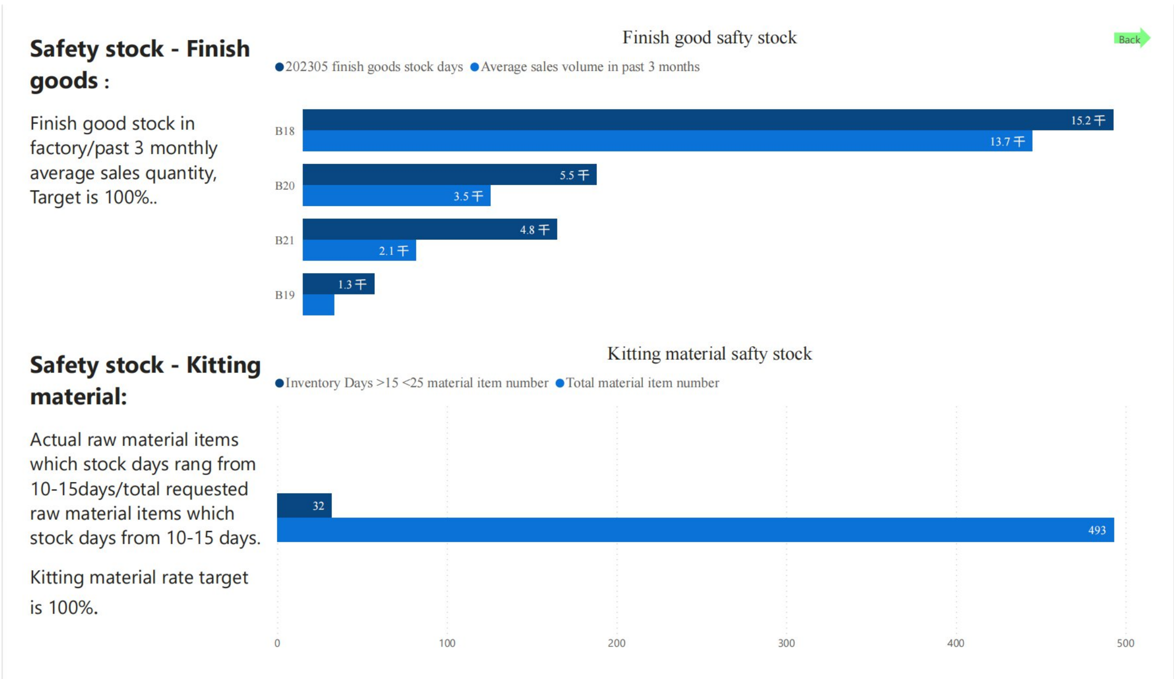

Figure 4.4 Safety stock – Finish good flexibility version 1

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Chapter 5: Demonstration

The objective of this chapter is to present the preliminary version of the dashboard to the COROS team, collect their feedback, and subsequently enhance the dashboard based on the feedback received to ensure it meets the specific needs and improves its operational effectiveness.

A panel of four senior experts from the finance, manufacturing, operations, and purchasing departments was convened for face-to-face discussions aimed at evaluating a set of semi-constructed questions. Two rounds of meetings were held between August and September 2023 to gather comprehensive feedback and insights from these leaders. Three semi-constructed questions in Table 5.1 were asked during the meeting.

Table 5.1 Key evaluation questions

Questions
What are the negative aspects of the proposed dashboard?
What are the positive aspects of the proposed dashboard?
What improvement proposals do you intend to make regarding the proposed dashboard?

5.1 Demonstration: Round 1

The evaluation framework will incorporate several components, including an ID number, the proposed enhancement, the category of the improvement, implementation status, the proposer, and associated indicators (see Table 5.2). The types of improvements are to be classified into three categories: visualization, information, and navigation.

These three types are essential elements in any dashboard, the visualization is one of the most important elements in the dissertation. The visualization techniques allow stakeholders to answer their questions about indicators in a given area and trigger new research that helps to increase the knowledge base, improve existing indicators, and also contribute to the emergence of new indicators (Al-Hajj et al., 2013; McLeod, 2010).

Another very important element is the information where the stakeholders are information consumers, this element is of extreme importance since they make decisions and change the strategies based on the presented information (Nogueira et al., 2017).

Finally, the element is navigability which has to be treated very carefully so as not to create an exaggerated overload of components, contents, and tabs to dashboards, they should only provide and be used to facilitate the necessary navigation to the dashboards without making it too confusing (Karami et al., 2017).

Table 5.2 Demonstration round 1 result

ID	Proposed enhancement	Improvement category	Implemented?	Proposer	Associated indicators
#1	Delivery performance change subtotal of the score and target to the average value.	Visualization, information, and navigation	Yes	Purchasing Head	Delivery flexibility
#2	Show up the traffic light criteria in the dashboard for each indicator. What range is red, what range is yellow and what range if green.	Information	Yes	Operation head	All indicators
#3	Mark the traffic light range for red, yellow, green in each dashboard.	Information	Not	Production head	All indicators
#4	Alliance flexibility should put the main suppliers as base not all vendors, company relay on allied relationship with key suppliers not all vendors.	Visualization	Yes	Purchasing Head	Alliance flexibility
#5	Add percentage for safety stock for finish good and raw material	Visualization	Yes	Production head	Safety stock
#6	Safety stock of finish good should add weighted percentage to reflect the real status and avoid the product line deviation	Visualization	Yes	Finance head	Safety stock
#7	Coercive flexibility should measure key suppliers which have the annual business revenue keep above 1 million RMB.	Information	Yes	Purchasing Head	Coercive flexibility
#8	External integration should separate into two pages since the measurement indicator is different.	Visualization	Not	Operation head	External integration
#9	Knowledge transfer should use 100% not weighted percentage for easy understanding	Visualization	Yes	Purchasing Head	Knowledge transfer-internal
#10	Supply chain risk, the measurement of strategic supplier should measure key suppliers not all vendors.	Information	Not	Purchasing Head	Supply chain risk flexibility
#11	Information flexibility should change the graph type for easy understanding.	Visualization	Yes	Operation head	Information flexibility
#12	AMT flexibility should change the graph type for easy understanding.	Visualization	Not	Purchasing Head	Advanced manufacturing technology adoption

#13	Coercive flexibility rate 22% and the traffic light is red, then what's the target and why it is red.	Visualization	Yes	Academic consultant	Coercive flexibility
#14	Internal integration, instead of using two bars per indicator, why not using a line or something similar for the target? Something more visible. This applies to many other examples.	Visualization	Yes	Academic consultant	Internal integration flexibility External integration flexibility Knowledge transfer-internal Knowledge transfer-external Data analytic flexibility Advanced manufacturing technology (AMT) adoption.
#15	Some graphs have too much text in the description coercive power, internal integration flexibility - do not include references in the dashboard	Visualization	Yes	Academic consultant	Coercive flexibility Internal integration Flexibility External integration flexibility Knowledge transfer-internal Knowledge transfer-external Data analytic flexibility Purchasing flexibility
#16	It is strange to have the red value (percentage) on the top of the two blue bars - maybe add it as a separate graph? Same suggestion for the other similar graphs.	Visualization	Yes	Academic consultant	Material selection flexibility

Improvement Proposal #1

The initial dataset inaccurately aggregated the scores and targets into subtotals. This aggregation method was incorrect as it failed to reflect the distinct yearly differences between the data for January to April in 2022 and 2023. Consequently, this approach has been revised to utilize mean values instead of total sums. Calculating the average provides a more accurate representation of the delivery performance indicator, allowing for a straightforward comparison with set targets.

Improvement Proposal #2

A traffic light color-coding system has been implemented to indicate performance levels across different indicators. This system categorizes performance data into three distinct ranges: red signifies poor performance, yellow indicates moderate performance, and green represents optimal performance. This enhancement, which has already been applied, facilitates a clearer understanding by readers of the current status of each indicator, enabling them to discern the performance level at a glance.

Improvement Proposal #3

The implementation of a color-coded traffic light system within each dashboard visually delineates performance levels. This system has been integrated across all dashboards, with the color ranges for red, yellow, and green explicitly defined at the bottom of each dashboard. This enhancement, which has already been implemented, facilitates easier interpretation of performance data, allowing readers to quickly assess the status and compare performance across different metrics and time periods.

Improvement Proposal #4

The evaluation of alliance flexibility has been refined to focus on primary suppliers rather than the entire vendor pool, acknowledging the company's significant reliance on key supplier relationships. This change has been implemented following the recommendation of the purchasing head. The rationale for this adjustment stems from the fact that main suppliers, who are difficult and resource-intensive to replace, pose potential unknown risks to the company if substituted. In contrast, smaller vendors can generally be replaced more easily.

Originally, when using the total vendor count of 238 as the base, the percentage of allied suppliers was only 4.2%. However, by recalculating this figure with the main suppliers, totaling 36, as the base, the rate significantly increases to 27.8%. This substantial disparity highlights the importance of focusing on primary suppliers to reflect the real ratio of critical vendor dependence more accurately.

For 2022, 'main suppliers' are defined as those with annual purchases exceeding 1 million

RMB. While criteria for defining main suppliers may vary across different contexts, this threshold has been deemed appropriate for the COROS case, according to the purchasing head's assessment.

Improvement Proposal #5

Enhancements to the dashboard now include an additional graph that delineates the rates for both finished goods and raw materials, supplementing the existing bar charts that were previously consolidated on a single page. This modification has been successfully implemented to address managerial challenges in interpreting safety stock levels directly from numerical data alone. The new graphical representation allows managers to immediately ascertain the adequacy of safety stock without the need for further calculations. This direct visual aid significantly enhances the ease with which managers can assess inventory levels, thereby improving decision-making efficiency concerning stock management.

Improvement Proposal #6

In the evaluation of safety stock, a weighted percentage approach has been integrated to more accurately reflect the actual status of stock and to mitigate discrepancies across product lines. This modification has been successfully implemented, focusing specifically on the main product lines B18, B19, B20, and B21, which predominantly influence stock assessments. Notably, product line B18 accounts for 69% of the overall finished goods inventory. A comparative analysis revealed that using an average percentage resulted in a rate of 180%, which could potentially mislead managerial decision-making due to its disregard for the varying significances of each product line. Conversely, applying a weighted average, which accounts for the proportional impact of each product line, adjusts the rate to 135%. This adjustment not only eliminates a substantial 45% discrepancy but also provides a more reliable basis for decision-making, better reflecting the true operational status.

Improvement Proposal #7

The metric of coercive flexibility has been refined to focus exclusively on key suppliers, as opposed to the entire supplier base. This amendment, which aligns with the logic of PI4, specifies that these key suppliers must have had a purchasing volume exceeding 1 million RMB in the last financial year. This change has been implemented to ensure that the measure accurately reflects the true state of the supplier relationship and avoids providing misleading information to stakeholders.

Originally, when the total vendor counts of 238 was used as the base, the percentage of contractually bound suppliers was only 3.4%. However, recalculating this figure using only the 36 main suppliers as the base resulted in a significantly higher rate of 22.2%. This substantial variance underscores the importance of focusing on key suppliers to more accurately represent their critical role within the company's operations.

The criteria for identifying a 'main supplier' are based on annual purchases exceeding 1 million RMB for the year 2022. While the criteria for defining main suppliers may vary in different contexts, for the COROS case, this threshold has been deemed appropriate according to the purchasing head's assessment, enhancing the relevance and accuracy of the coercive flexibility metric.

Improvement Proposal #8

The evaluation of external integration within the organization, a proposal to segment the metric into two separate pages was discussed but ultimately not implemented. External integration is comprised of two distinct flows: financial and information, each assessed using two specific measurement questions. The decision against the bifurcation of this metric into separate pages was made to prevent the over-fragmentation of the indicator. Instead, a more comprehensive explanation was incorporated into the dashboard's panel description. This approach aims to reinforce the evaluation by elucidating that external integration should be viewed and assessed from these two critical perspectives, totaling four questions for a holistic measurement. The expert panel has endorsed this method, agreeing that it maintains the coherence and integrity of the indicator's assessment.

Improvement Proposal #9

The evaluation of internal knowledge transfer, the methodology for measuring each of the five designated questions has been revised to utilize a full 100% scale for each question, rather than distributing a weighted percentage of 20% to each. This adjustment, which has been implemented, is predicated on the premise that each question contributes uniquely and equally to the understanding of knowledge transfer effectiveness. This approach aims to provide a clearer and more direct understanding by affirming that each question stands independently, rather than as a fractional part of a larger question. Consequently, this method helps to mitigate any potential confusion among readers by emphasizing the equal importance of all questions in the assessment of knowledge transfer.

Improvement Proposal #10

Supply chain risk, the focus centers on three critical questions that gauge the robustness of supplier relationships. These include: (1) the number of strategic suppliers, (2) the frequency of supplier audits per year, and (3) the availability of alternative suppliers for each commodity. A suggestion to limit the scope of the first question to key vendors exclusively was raised but ultimately not adopted by the expert panel. The rationale for this decision is twofold.

Firstly, the panel contended that not only key suppliers, but all suppliers collectively contribute to the supply chain's vulnerability to disruptions. This is underscored by the necessity for consistent material supply through kitting processes, where even non-key materials' unavailability could precipitate production downtimes. Secondly, consistency in measurement standards across different assessment questions was deemed critical. The panel argued that if key suppliers were solely evaluated in the first question, a similar selective approach should logically extend to the second question concerning supplier audits. However, historical instances where non-key suppliers have precipitated production stoppages underscore the importance of maintaining a comprehensive overview that includes all suppliers. Thus, the decision was made to continue monitoring the entire supplier base to mitigate potential risks effectively.

Improvement Proposal #11

Information flexibility, an enhancement in the visualization of information flexibility has been effectively implemented to facilitate a more intuitive understanding of the data. The previously utilized bar chart has been replaced with a radar chart, which collectively presents all 11 functional teams. This new visualization strategy employs a distinctive dark color to denote the indicators where the related information systems have been implemented in actual operational processes. Conversely, indicators without such system adoption remain unmarked, or blank. This contrast distinctly highlights the adoption status across different teams, thereby making it significantly easier for stakeholders to visually assess the extent of information system integration within the organization.

Improvement Proposal #12

AMT advanced manufacturing, the proposal to modify the graph type for presenting Advanced Manufacturing Technology (AMT) adoption was considered but ultimately not adopted. A variety of alternative visualizations, including various radar charts, horizontal bar charts, and pie charts, were evaluated for their potential to enhance clarity and understanding. Despite these considerations, the decision was made to retain the original vertical bar chart format. This decision was informed by the vertical bar chart's ability to juxtapose target and actual data effectively, facilitating direct comparison in a clear and unambiguous manner. Radar and pie charts, while visually distinct, were found inadequate for simultaneously displaying target and actual data, potentially leading to confusion. However, to aid in the interpretation of the data, a pie chart was introduced to display the rate of adoption separately, enhancing the overall presentation without compromising the clarity provided by the vertical bar chart.

Improvement Proposal #13

In the evaluation of coercive flexibility within the organization, a rate of 22% has been recorded, which falls under the 'red' category in the traffic light system implemented to visually represent performance metrics. This classification is based on the established target of achieving a 60% rate for coercive flexibility. The criteria for categorizing the performance rates are defined as follows: a rate from 0% to just above 30% is marked red, indicating underperformance; from 30% up to but not including 60% is marked yellow, denoting moderate performance; and from 60% to 100% is marked green, signifying optimal performance. Given these parameters, the 22% rate is categorized within the red range, highlighting a significant shortfall from the target and underscoring the need for strategic interventions to enhance this aspect of flexibility.

Improvement Proposal #14

Concerning the visualization of internal integration, a significant modification has been adopted to enhance the clarity and visibility of performance metrics. Previously, two bars per indicator were used to represent target and actual data, which could lead to visual clutter and make comparisons less intuitive. The improvement involves the incorporation of additional graphical elements to separately depict rates, while retaining bar charts for juxtaposing target and actual data. This change has been implemented across six indicators: internal integration flexibility, external integration flexibility, internal and external knowledge transfer, data analytic flexibility, and advanced manufacturing technology (AMT) adoption.

The introduction of line graphs or similar visual tools for targets provides a clearer, more distinct representation, facilitating easier and more immediate comparison. This adjustment not only simplifies data presentation but also enhances interpretability, ensuring that stakeholders can quickly grasp the comparative status of targets versus actual outcomes.

Improvement Proposal #15

In response to concerns over excessive textual clutter in the dashboard graphics, a streamlined approach has been implemented across several indicators, including coercive power and internal integration flexibility. Previously, charts were overburdened with extensive descriptions from the evaluation of multiple questions, which compromised the visual clarity and cleanliness of the graphics. To address this, the original verbose descriptions within the graphs have been replaced with succinct numerical references.

These numbers correlate directly to specific questions detailed in the dashboard's descriptive section, allowing readers to easily reference and understand the data without overcrowding the visual presentation. This method of simplification has been applied consistently across various indicators, such as internal and external integration flexibility, both internal and external knowledge transfer, data analytic flexibility, and purchasing flexibility. This enhancement not only improves aesthetic appeal but also enhances the usability of the dashboard by making information more accessible and easier to digest.

Improvement Proposal #16

The presentation of data within the dashboard has undergone significant refinement, particularly concerning the visual integration of percentage values with bar graphs. Originally, red percentage values were placed atop blue bars, which was considered visually incongruent. To enhance clarity and aesthetic coherence, a suggestion was made to separate these elements into distinct graphical representations. This change has now been implemented across all relevant indicators, with the exception of ISO9001, postpone flexibility, product modularity, and volume flexibility.

The decision to maintain the original combined line and bar chart format for these exceptions was based on positive feedback from a panel of experts, who found that the combined format adequately conveyed the results. This selective application ensures that each indicator's unique characteristics are effectively communicated while maintaining overall consistency in data presentation across the dashboard.

5.2 Demonstration: Round 2

In round 2 demonstration, the panel has proposed eight enhancements, reference as Table 5.3.

Table 5.3 Demonstration round 2 result

ID	Proposed enhancement	Improvement category	Implemented?	Proposer	Associated indicators
#1	Separate knowledge transfer of internal and external by different pages	Visualization	Yes	Purchasing Head	Knowledge transfer
#2	Highlight the formular/definition of each indicator and show the target and actual score/rate in the description panel.	Visualization	Yes	Purchasing Head	All indicators
#3	Aline the consequence number between two graphs.	Navigation	Yes	Finance Head	Safety stock - finish good
#4	Move the traffic light marker right after the title of each indicator in the description panel.	Visualization	Yes	Purchasing Head	All indicators
#5	Cancel the weighted measurement and change them using 100% for each question, that could help for easy	Information	Yes	Purchasing Head	External integration flexibility

	understanding.				Knowledge transfer-external
#6	Adjust the upper marker setting range from >=150% - < 300% to >=150% for safety stock finish good, since <300% is could not cover all the case.	Informat ion	Yes	Purchasi ng Head	Safety stock - finish good
#7	Correct the upper measurement limit from >100% to <=100% for each indicator.	Informat ion	Yes	Operatio n Head	All indicators
#8	Using mathematical expression [0%,50%) to replace" >=0% - >50%". "["means bigger and contain, ")" means smaller. This change applies for all dashboards.	Visualiz ation	Yes	Purchasi ng Head	All indicators

Improvement Proposal #1

Knowledge transfer has been revised to present internal and external knowledge transfer metrics on separate pages. Previously, combining both metrics on a single page resulted in a crowded and difficult-to-understand layout. The new design, which splits the metrics into two distinct pages, facilitates the addition of an extra graph to display rates for each type of knowledge transfer. This reorganization significantly enhances clarity, enabling readers to better comprehend the specific aspects of internal and external knowledge transfer. Each page now clearly and concisely presents the relevant data, improving overall understanding.

Improvement Proposal #2

The formula or definition for each indicator, along with the target and actual score/rate, has been highlighted in the description panel for all indicators. This enhancement has already been implemented. This adjustment is intended to help readers quickly grasp the key points of each indicator, improving comprehension and efficiency in data interpretation.

Improvement Proposal #3

The alignment of sequence numbers between the two graphs within a single dashboard has been implemented. This adjustment primarily pertains to the safety stock of finished goods. Previously, the bar chart and rate graph displayed data based on the sequence of data entries rather than product lines. By reordering the sequence numbers according to production lines, both the data chart and rate graph now follow the same sequence. This change facilitates easier comparison for readers, allowing them to effectively evaluate data per product line.

Improvement Proposal #4

The traffic light marker has been relocated to immediately follow the title of each indicator in the description panel. This modification has already been implemented. Originally, the marker was placed at the right corner of each dashboard, adjacent to the traffic light range bar at the bottom. This placement required readers to spend additional time locating the traffic marker. The revised positioning allows readers to quickly and clearly understand the performance level of each indicator immediately upon reading the title, enhancing the efficiency of data interpretation.

Improvement Proposal #5

The weighted 25% measurement has been replaced with a 100% measurement for each question. This modification has already been implemented, specifically affecting external integration flexibility and external knowledge transfer. Previously, external integration was measured by evaluating four questions, each contributing 25% to the overall score. This weighted approach required readers to understand the underlying logic, which was not straightforward. Changing each question to 100% allows readers to clearly understand the score for each question independently. Similarly, external knowledge transfer, which consisted of three questions with varying weighted percentages, has been simplified by assigning 100% to each question, thereby enhancing clarity and ease of understanding.

Improvement Proposal #6

The upper marker setting range for safety stock-finished goods has been adjusted from '>=150% - <300%' to '>=150%'. This change has been implemented to ensure the range accurately encompasses all cases. The previous range of '<300%' was inadequate, as it did not cover all scenarios. By modifying the range to '>=150%', all possible cases are now appropriately accounted for.

Improvement Proposal #7

The upper measurement limit for each indicator, except for safety stock-finished goods, has been corrected from '>100%' to '<=100%'. This modification has already been implemented. As explained in PI6, the safety stock-finished goods indicator cannot be restricted to a 100% limit. This adjustment ensures accurate representation of the upper measurement limits across all relevant indicators.

Improvement Proposal #8

Mathematical expressions have been standardized to replace the original range notations. The expression '[0%, 50%)' is now used instead of '>=0% - <50%', where '[' denotes 'greater than or equal to' and ')' denotes 'less than'. This change has been applied across all dashboards. For instance, in the safety stock-finished goods indicator, the original red range '>=0% - <50%' has been replaced by '[0%, 50%)', the yellow range '>=50% - <80%' by '[50%, 80%)', the green range '>=80% - <120%' by '[80%, 120%)', the yellow range '>=120% - <150%' by '[120%, 150%)', and the red range '>=150%' by '[150%, ∞)'. This logical standardization applies to all traffic light settings in the traffic light bar.

5.3 Demonstration: COROS SC flexibility dashboard final version

The COROS Supply Chain Flexibility Dashboard is structured across three informational tiers.

First Tier - Overview of Flexibility Indicators: This tier presents a comprehensive 'big picture' view of resilience across 22 measured indicators, encapsulated within a single-page layout. It features an intuitive panoramic chart with color-coded indicators—red for below target, yellow for close to target, and green for meeting targets. Each indicator's color dynamically updates based on conditionally formatted links to individual metric values. This visualization effectively conveys the current state of COROS's overall supply chain flexibility, providing managers with a clear snapshot of areas needing attention, particularly those marked in red and yellow. Refer to Figure 5.1 for a graphical representation.

Second Tier - Business Area-Specific Overviews: Spanning seven pages, this level disaggregates the flexibility indicators by business areas including manufacturing, organization, information, purchasing, marketing, logistics, and product development. Each page offers detailed data for the respective business area, allowing managers to delve deeper into the specific flexibility metrics of each segment. Refer to Figure 5.2 for detailed illustrations.

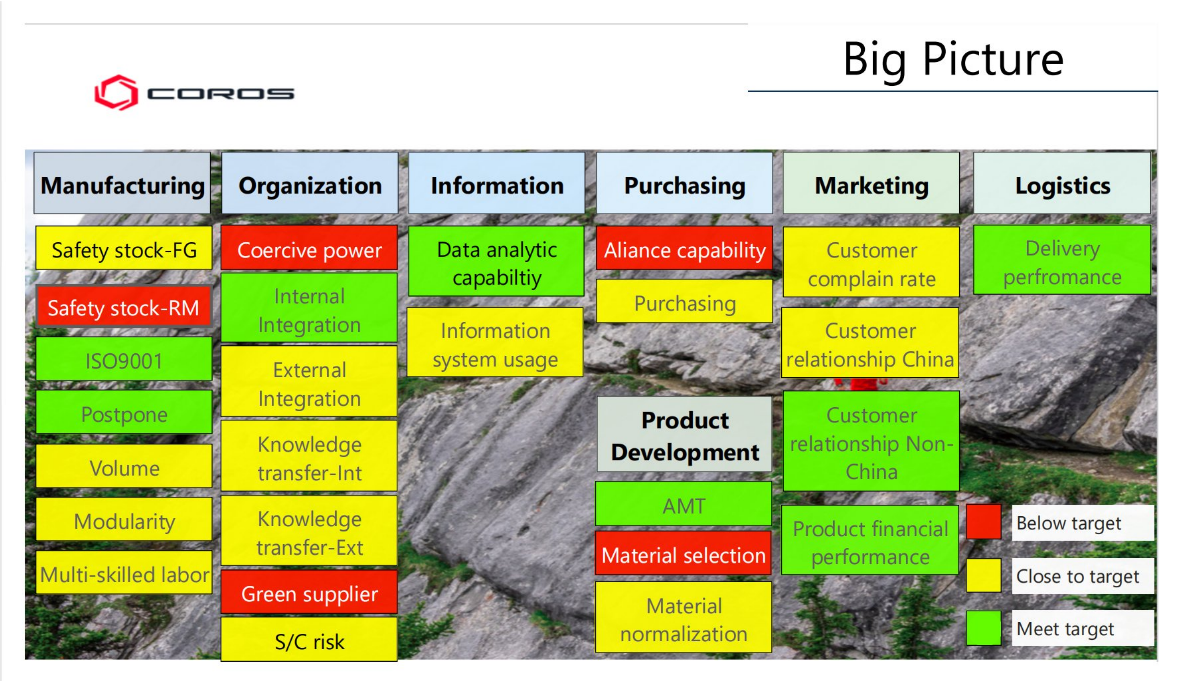

Figure 5.1 Big picture of COROS dashboard final version

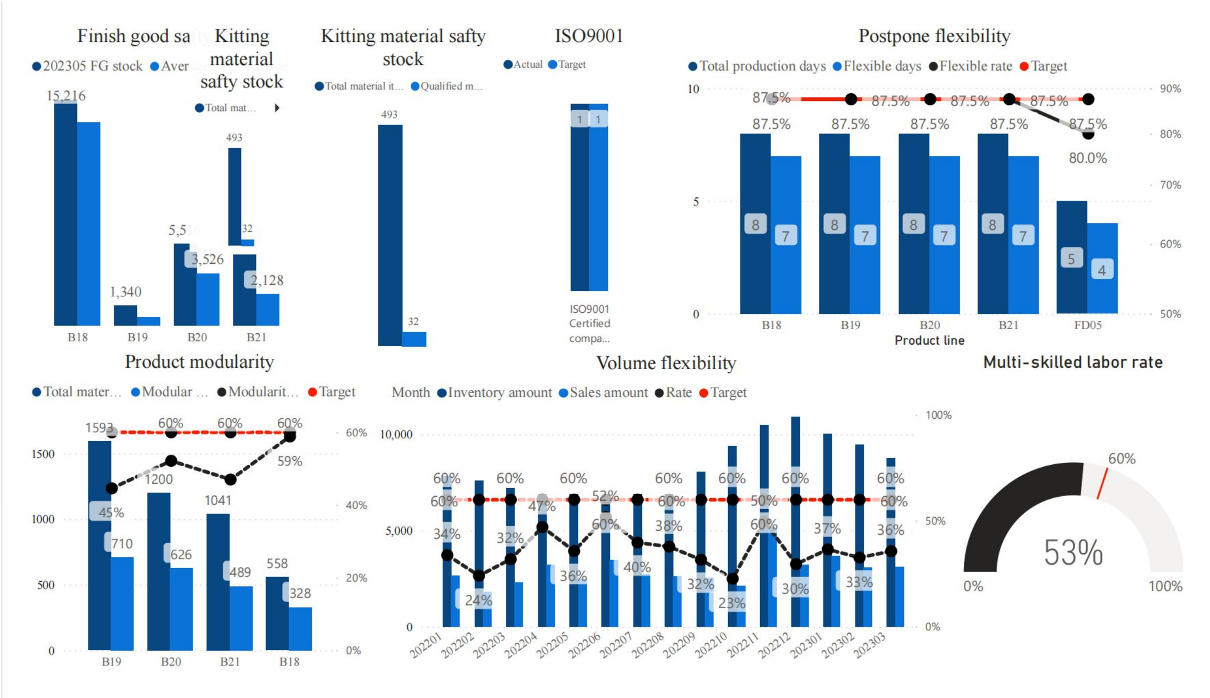

Figure 5.2 Flexibility overview in manufacturing area

Third Tier - Detailed Metrics per Flexibility Indicator: Comprising 26 pages due to spatial constraints necessitating multiple pages for certain indicators, this tier details individual flexibility indicators and their performance metrics. For instance, 'safety stock' is divided into two pages covering finished goods and raw materials (kitting materials), while 'knowledge transfer' and 'customer relationship' are split into internal and external, and customer complaints, customer satisfaction rate in China and Non-China, respectively. Each page includes:

1. A indicator explanation panel detailing the name, status, formula, target, and performance data for the indicator.

2. A left-hand chart displaying actual data versus targets.

3. A right-hand graphical representation of goal achievement, illustrating the gap between actuals and targets.

4. A color-coded target range at the bottom of each page, clarifying the specific target achievements.

5. A navigation arrow labeled 'back' in the top right corner of each page, allowing users to return to the first page of the dashboard for ease of navigation between pages. Pressing 'Control + back' activates this feature.

For further details, see Figure 5.3.

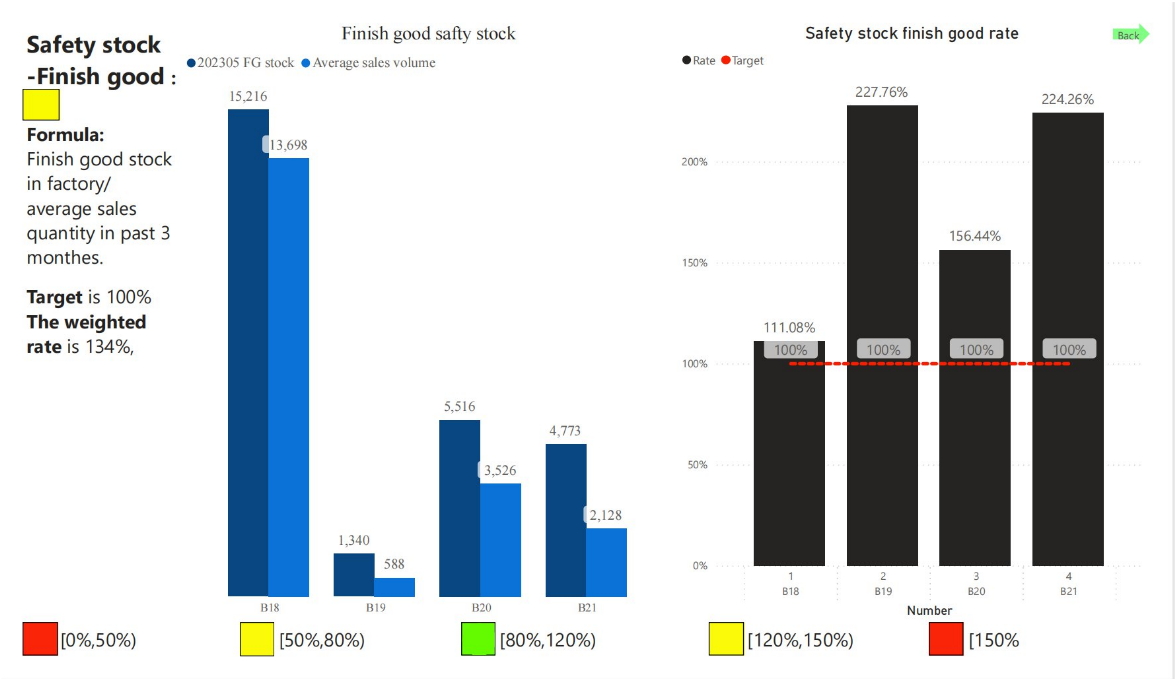

Figure 5.3 Safety stock – Finish good flexibility

For the complete visual representation (final version) of the COROS dashboard, refer to Annex H.

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Chapter 6: Evaluation of the Measurement Tool

How well the dashboard fulfills the requirements of COROS and to what extent it can effectively be used to improve the flexibility of COROS supply chain.

This evaluation might have two main consequences:

i. One may decide to go back to the design and development stage in order to improve the dashboard using as a basis the concerns identified during the evaluation stage.

ii. One may decide to proceed with the current version of the dashboard.

For the purpose of this thesis, this evaluation is performed by face-to-face interviews with 4 experts, the head of purchasing, the head of operation, the head of manufacturing and the head of finance.

The interviews were divided into two main parts:

i. A general presentation of the dashboard along with all its functionalities, as well as possible interactions between the various visualization elements.

ii. Five questions that according to Few (2013) meet the validation of the artifact:

1. Do the groupings of information make sense?
2. Are the indicators arranged appropriately?
3. Can the most important information be easily identified?
4. Is the information presented enough to support an informed decision-making?
5. Do you suggest any changes to the dashboard design?

The evaluation was made in Dec 2023 and the experts' response to each question as detailed below.

1. Do the groupings of information make sense?

It is great to see the big pictures in one page, it gives an overview of the whole flexibility of COROS supply chain status. Classifying different measurement indicators according to different business areas can allow us to clearly know where the problem lies. Using red, yellow, and green to distinguish the current status of different indicators can allow us to quickly know which indicators are problematic and worthy of immediate action.

In addition to the big picture, each business area has a summary page, that could guide us to see specific information about the indicators in each business area, making it easier for relevant managers to directly enter the area we are responsible for and take a detailed look at problematic indicators.

2. Are the indicators arranged appropriately?

Manufacturing head mentioned the indicator "ISO9001", it should be put at the end in the manufacturing area because it appears at low frequency and does not need to be placed in a conspicuous position. "Postpone flexibility" is also the same case, since the assembly method of this indicator has been determined during product design, and the frequency of subsequent changes is very low. Therefore, it is an indicator of low-frequency changes, so it is more appropriate to put it behind the dashboard.

3. Can the most important information be easily identified?

Through the color labels represented by each indicator, we can easily know the current status of each indicator. Through the information in the introduction column, we can also know what this indicator measures. Through the comparison of the target and actual data, including text description and graphic comparison, we can clearly know which product has the problem. This is very helpful.

4. Is the information presented enough to support an informed decision-making?

For simple indicators, we can make judgments through this dashboard information directly, such as the usage of information system, ISO9001 application. For complex indicators, we feel that we need to analyze more detailed excel data and make improvement suggestions, such as safety stock for both finished goods and raw materials, product modularity and so on. But this dashboard narrows down the problematic indicators and really helpful for our daily works.

5. Do you suggest any changes to the dashboard design?

The dashboard looks clear and straight forward, no suggestion for big change. But for the frequency of data refresh, we recommend that we treat it differently. Some indicators can be based on weekly intervals, such as safety stock, some indicators can be based on monthly intervals, such as product financial performance, multi-skilled labor, delivery performance and some indicators do not need to be updated after being updated once, such as ISO9001.

As a conclusion, the measuring and monitoring tool of SC flexibility for Chinese private high-tech companies is capable and practical for case tested company COROS. This tool can also be used as a reference by other companies.

Chapter 7: Conclusion and Further Research

Considering the research question addressed in this thesis – "Measuring and monitoring flexibility of high-tech supply chains" – a decision-aiding tool based on a dashboard that allows to measure and monitor the flexibility of suppy chain for Chinese private high-tech companies was developed. The developed tool contain 22 indicators and covered 7 business areas. Those indicators collected from the scientific literature in the area and the practitioner view and opinions of supply chain experts from Chinese private high-tech area. In the end, the tool was tested by one Chinese private high-tech company – COROS, which comfirms the usefulness of the proposed tool to aiding them to measure and monitor their SC flexibility and make improvement toward the better performance in dynamic business enviroment.

The development of this tool benefit from integrating scientific knowledge in the area with real industry data and practitioner group's opinions, thus forstering both practical and theoretical advancement in the area SC flexibility.

Through the reaserch and diligent works, the objectives defined for this thesis have been achieved:

1. Review of indicators, tools and strategy used in the literature to measure and monitor the SC flexibility in both non-high-tech area and high-tech area.

2. Collecting these indicators on how to measure and monitor SC flexibility from practitioners of Chinese private high-tech area.

3. Development of a decision-aiding tool for measuring and monitoring the flexibility of SC and accounts for the multiplicity of indicators suggested by existing literature in the area and also by high-tech companies.

4. Application of the developed tool to a case study based on a Chinese private high-tech company - COROS.

7.1 Contributes of the thesis

This dissertation advances both theoretical and practical knowledge within the field of supply chain management (SCM), specifically targeting the high-tech industry in China. It addresses a notable gap in SCM research by developing a nuanced measurement tool designed to evaluate and enhance flexibility in high-tech supply chains. This tool not only enriches theoretical frameworks but also proves its utility in practical applications.

Theoretical Contribution

The research identifies a critical shortfall within existing literature - namely, the lack of specific frameworks tailored to measure and monitor SC flexibility in the high-tech sector, with a particular emphasis on Chinese private enterprises. This gap is significant given the rapid evolution and unique challenges within this sector, which demands dynamic supply chain strategies to maintain competitiveness.

Also, the thesis introduces a novel tool that facilitates the comprehensive assessment of SC flexibility. This innovation is particularly crafted to cater to the complexities of the high-tech industry in China. It incorporates traditional flexibility metrics while introducing two novel indicators: material normalization flexibility and material selection flexibility. These indicators are pivotal for adapting to rapid technological changes and supply chain disruptions typical in high-tech environments.

Practical Contribution

The tool covers seven critical business areas: manufacturing, organization, information systems, purchasing, logistics, marketing, and product development. It integrates 22 measurement indicators that collectively provide a holistic view of SC flexibility. This extensive coverage ensures that managers can identify and address flexibility bottlenecks across all facets of the supply chain.

To better illustrate its practical application, this thesis employs the tool to analyze product market share in specialized segments, particularly examining user participation in major marathon events. This innovative application highlights the tool's versatility and its ability to provide strategic insights into market penetration and consumer behavior.

Summing up, this thesis makes significant contributions to the theoretical foundations of SC flexibility measurement and offers a practical tool that has been empirically tested within the high-tech industry. Its implications extend beyond academia, providing valuable insights and methodologies that can significantly benefit supply chain practitioners, particularly in high-tech sectors where flexibility and rapid response are paramount. This work not only fills a crucial gap in supply chain research but also sets a precedent for future studies aimed at enhancing supply chain resilience and adaptability in high-tech contexts.

7.2 Limitations

While the thesis makes substantial contributions to both theory and practice in SC flexibility, particularly within the Chinese high-tech sector, several limitations warrant consideration for a comprehensive understanding and future research directions.

i. Composition and Engagement of Expert Group.

The expert panel involved in validating the tool through a web-based questionnaire exhibited limitations in its composition and engagement level. Feedback durations from some experts were notably brief, suggesting a potential lack of thorough consideration in their responses. This raises concerns about the depth of the insights provided and the overall validity of the feedback used to refine the tool.

ii. Geographical Coverage of Feedback.

The feedback obtained predominantly originates from companies located in the Pearl River Delta, which does not represent the broader economic zones of China, such as the Yangtze River Delta, the Beijing-Tianjin-Hebei economic zone, and the Chengdu-Chongqing economic zone. This geographical limitation restricts the generalizability of the study's findings across different regional markets within China, which may exhibit distinct industrial dynamics and supply chain challenges.

iii. Language Barrier and Literature Interpretation.

A personal limitation noted is the language barrier, as English is not the researcher's native language. This may have influenced the interpretation and understanding of the existing literature, potentially leading to misinterpretations that could affect the thesis's quality and accuracy. The nuanced concepts and complex terminologies typical in supply chain management research might not have been fully grasped or could have been misunderstood.

7.3 Future research

The findings and limitations of this thesis open several avenues for future research aimed at enhancing the robustness and applicability of the SC flexibility measurement tool, especially within the high-tech sector in China. The following research initiatives are recommended:

i. Indicator Weighting and Impact Analysis.

Future studies should focus on developing a systematic approach to assign weights to the 22 indicators of the SC flexibility tool. Recognizing that not all indicators exert equal influence on the flexibility of a SC, it is essential to quantify the impact of each indicator. This can be achieved through advanced statistical techniques such as factor analysis or regression modeling to determine the relative importance of each indicator in contributing to overall SC flexibility. This approach will refine the tool’s accuracy and enhance its strategic relevance by prioritizing areas that significantly impact flexibility.

ii. Geographical Expansion of Study Scope.

Considering that the initial feedback was predominantly sourced from companies located in the Pearl River Delta, there is a substantial opportunity to broaden the geographical scope of the research. Future studies should aim to include companies from the other three main economic zones in China: the Yangtze River Delta, the Beijing-Tianjin-Hebei economic zone, and the Chengdu-Chongqing economic zone. Expanding the research to these areas will not only enhance the diversity of the data but also allow for comparisons across different economic contexts within China, potentially uncovering regional differences in SC flexibility needs and practices.

iii. Multi-Case Study Approach.

While the current research utilized a single case study to validate the measurement tool, future research could benefit from a multi-case study approach. Employing multiple case studies across different sectors within the high-tech industry would provide a more comprehensive validation of the tool. This method would allow researchers to test the tool's versatility and adaptability across varying organizational sizes, operational complexities, and market dynamics. Additionally, a comparative analysis of these case studies could yield deeper insights into sector-specific challenges and how the tool can be customized to meet diverse operational needs.

iv. Longitudinal Studies for Tool Evolution.

Implementing longitudinal studies to observe the tool's performance over time could provide insights into its adaptability and sustainability in dynamic market conditions. Such studies would offer valuable data on how changes in the external environment, technological advancements, and internal organizational shifts influence the tool's effectiveness and the SC flexibility.

v. Integration of Advanced Technologies.

Research could also explore the integration of emerging technologies, such as artificial intelligence (AI) and machine learning, into the SC flexibility measurement tool. These technologies could enhance the tool's capability to process large datasets, provide predictive insights, and adapt to changing conditions in real-time, thereby offering a more dynamic and responsive tool for SC managers.

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Annex A: Tools Reference List for Measuring and Monitoring SC Flexibility

MM tools	Author (year)	Studies in High-tech area
SCOR model	Ahmad and Zabri (2018)	
	Chorfi et al. (2018)	Chorfi et al. (2018)
	Kamble and Gunasekaran (2020)	
	Lemghari et al. (2018)	Lemghari et al. (2018)
	Lima-Junior et al. (2019)	
	Maizi et al. (2020)	Maizi et al. (2020)
	Piotrowicz et al. (2015)	Piotrowicz et al. (2015)
	Rodríguez Mañay et al. (2022)	
	Saleheen et al. (2018)	
	Dissanayake and Cross (2018)	
	Kusrini et al. (2019a)	
	Lima-Junior et al. (2020)	
	Kusrini et al. (2019b)	
Balanced scorecard	Ahmad and Zabri (2018)	
	Bhagwat et al. (2007)	Bhagwat et al. (2007)
	Chorfi et al. (2018)	Chorfi et al. (2018)
	Cunha Callado and Jack (2015)	
	Nica et al. (2021)	Nica et al. (2021)
	Pakurár et al. (2019)	Pakurár et al. (2019)
	Pham (2021)	Pham (2021)
	Piotrowicz et al. (2015)	Piotrowicz et al. (2015)
	Saleheen et al. (2018)	
	Stefanovic and Stefanovic (2011)	Stefanovic and Stefanovic (2011)
Dashboard	Bréant et al. (2020)	Bréant et al. (2020)
	Iliashenko et al. (2019)	Iliashenko et al. (2019)
	Nica et al. (2021)	Nica et al. (2021)
	Okfalisa et al. (2018)	
	Freire (2020)	Freire (2020)
Index	Ramezankhani et al. (2018)	
	Singh et al. (2020)	
Report	Nica et al. (2021)	Nica et al. (2021)
Contribution plots	Wang et al. (2020)	

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Annex B: Measuring and monitoring tools benefits and drawbacks

Tools	Benefits	Drawbacks
SCOR model	Measurable Effective problem identification Linked to SCOR process Uses pre-defined SCOR indicators to ensure clear communication and avoid disputes Regularly updated to adapt to changes in supply chain business processes, making it suitable for various products Primarily used in manufacturing, but applicable to all companies, including services Comprehensive process-based model for measuring supply chain performance	SCOR partially fits special cases Changing strategic objectives may affect system accuracy Model application requires understanding and engagement from management Customized system not universally applicable
Balanced scorecard	Comprehensive view of organization's assets Aligns performance measures with mission and strategy Includes historical and leading indicators Aligns operational with strategic levels Key Performance Indicator (KPI) is basic indicator Real-time monitoring and alerting Flexibility, personalization, and customization Integrates with existing systems Includes predefined web parts and templates for knowledge and best practices	Requires strong IT support Lack of formal implementation methodology and metric selection subjectivity in BSC frameworks Changing strategic objectives may affect system accuracy Customized system not universally applicable Model application requires understanding and engagement from management
Dashboard	Dashboard focuses on presenting operational results Automatic monitoring Describes information easily, intuitively, and accurately Provides consolidated, unanimous view Minimal costs for implementation, training, and maintenance Multi-indicatoral performance monitoring in complex environments Sustainable and scalable Real-time monitoring Capable of processing large amounts of data	Complex Implementation not easy Requires larger IT memory system Requires stable operations Requires uniform data formats and nomenclature across different systems Processes become more complicated Requires complete data sets Not all required data is integrated in operational systems, requiring manual manipulation of data sources such as Excel files provided daily/weekly
Index	Monitors long-term and short-term horizons Identifies poor decision-making units (DMUs)	Lacks systematic approach

	Simple and easy to use Adaptable to change Based on facts Trackable Effective and efficient	
Report	Simple and static, ranging from basic sales lists to complex report tables with pivots and data analysis Best for analyzing raw data in a user-friendly format Combined with scorecards and dashboards, reports provide access to raw information for determining units of measure and KPIs	Not straightforward or intuitive
Contribution plots	Customizable tools Identifies variables with abnormal behavior when at least one statistic exceeds its limit Narrows the scope of potential fault-related variables	Specific case fit

Annex C: List of experts to invite

Number	Name spelling	中文名字	Title	Company name	High-tech sector
1	Bao Yaqun	包亚群	CEO	Yisheng Technology	New material technology
2	Cai jinxin	蔡金鑫	CEO	Fujian Natura Guide Biology Technology Co.,LTD	Biology and new medical technology
3	Chai jinbin	蔡晋斌	Director	Cosmo Supply Lab	High and new technologies transform traditional industries
4	Chai xiaobing	蔡晓兵	COO	Avove Technology	High and new technologies transform traditional industries
5	Chao meng	曹猛	CEO	Avove Technology	High and new technologies transform traditional industries
6	Chen Binyan	陈彬燚	Sales director	TDG Holding Co., LTD	New material technology
7	Chen Gang	陈刚	Manager	DG Grands Precision Manufacturing Co.,LTD	High and new technologies transform traditional industries
8	Chen lingli	陈玲丽	Director	Lens Technology	High and new technologies transform traditional industries
9	Chen Tingdong	陈庭东	Key account manager	Huawei Terminal Co.,LTD	Electronic information technology
10	Chen weigang	陈伟纲	GM	Avnet Electronics Technology	High and new technologies transform traditional industries
11	Chen xiaoqun	陈晓群	CTO	Lens Technology	High and new technologies transform traditional industries
12	Chen xiaoshuo	陈小硕	CEO	Everwin precision technoloty CO., LTD	High and new technologies transform traditional industries
13	Chen yong	陈勇	VP	Lens Technology	High and new technologies transform traditional industries
14	Chen Zhong	陈忠	Department GM	Wuxi Sharp Electronic Components Co.,LTD	New material technology
15	Chen Zhonghe	陈仲河	Director	Guangdong COROS	Electronic information technology

16	Chi chubin	池楚彬	GM	SZ Peicheng Technology Co.,LTD	Electronic information technology
17	Ding Cong	丁丛	Manager	Guangdong COROS	Electronic information technology
18	Du huifang	杜会芳	VP	Avove Technology	High and new technologies transform traditional industries
19	Fan wei	范伟	VP	LingYi iTECH(DG) Company	High and new technologies transform traditional industries
20	Feng wei	冯为	GM	DPT Electronic Company	High and new technologies transform traditional industries
21	Ge jinhui	葛金会	GM	DG Junda Touch Technology	High and new technologies transform traditional industries
22	Guo Yuebo	郭跃波	Executiv GM	TDG Holding Co., LTD	New material technology
23	Huang Sangsang	黄桑桑	Director	Guangdong COROS	Electronic information technology
24	Huang weiyu	黄炜瑜	Key account manager	Huawei Technologies Co.,LTD	Electronic information technology
25	Huang Xiaofei	黄小飞	CEO	China express	Aerospace technology
26	Huang xing	黄星	Superviso r	Guangdong COROS	Electronic information technology
27	Lang ye	朗烨	VP	Lens Technology	High and new technologies transform traditional industries
28	Li gang	李刚	Key account manager	Faith Long Crystal	New material technology
29	Li jinyu	李金玉	VP	Teleray Smart Technologies (Dongguan) Co. LTD	High and new technologies transform traditional industries
30	Li yizhang	李亦章	VP	Avove Technology	High and new technologies transform traditional industries
31	Li Zhen	李臻	Director	Guangdong COROS	Electronic information technology
32	Li zheng	李铮	Operator Director	Heyuan lianhong Toy and Gifts Co.,LTD	High and new technologies transform traditional industries
33	Liang Guizhao	梁桂肇	VP	Highpower International,Inc.	New energy and energy-saving technology
34	Liang xushen	梁旭森	Planning Expert	Huawei Terminal Co.,LTD	Electronic information technology
35	Lin fuxin	林福新	Senior PMC	Multek Flexible Circuit	High and new technologies transform traditional industries
36	Linda Zhang	张小林	Sales manager	BaiHong Fabrication Co.,	High and new technologies transform traditional

				LTD	industries
37	Ling ling	凌玲	Manager	Guangdong COROS	Electronic information technology
38	Liu Chao	刘超	VP	Yuanfeng Technology	Electronic information technology
39	Liu xin	刘新	Director	Guangdong COROS	Electronic information technology
40	Liu yu	刘宇	VP	Wuxi Sharp Electronic Components Co.,LTD	New material technology
41	Lv jinfeng	吕金锋	Director	Avnet Electronics Technology	High and new technologies transform traditional industries
42	Mai jianguang	麦建光	Director	Guangdong COROS	Electronic information technology
43	Mao guofei	毛国飞	GM	JinLong Machinery&Electronics Co.,LTD	High and new technologies transform traditional industries
44	Miao zhifeng	缪志峰	Chairman of board	Guangdong Fuyuan Technology Co.,LTD	High and new technologies transform traditional industries
45	Nie xinyu	聂新宇	VP	DJI-Innovations	Aerospace technology
46	Niu Haotian	牛浩田	CEO	Guangdong COROS	Electronic information technology
47	Ou yu	欧煜	Asset Manager	Guangzhou Industry Gas Co., LTD	New material technology
48	Pan qiujun	潘秋君	VP	Jiangsu Sidike New material Science & Technology Co.,LTD	New material technology
49	Peng Zhuchun	彭柱春	Sales GM	Wuxi Sharp Electronic Components Co.,LTD	New material technology
50	Qian Boyi	钱博一	CEO	Derui New material	New material technology
51	Qiu Tinghua	邱廷华	Director	Guangdong COROS	Electronic information technology
52	Qiu zejun	仇泽军	CEO	DPT Electronic Company	High and new technologies transform traditional industries
53	Qu xiaohua	瞿晓华	GM	Jujin Precision Moulds and Plastics	High and new technologies transform traditional industries
54	Quan yuwen	全钰雯	GM	Swiftronic Precision Manufacturing (SH) Co., LTD	High and new technologies transform traditional industries
55	Rao xuan	饶旋	Manager	Guangdong COROS	Electronic information technology

56	Ren guoguang	任国光	R&D GM	Truly opto-electronics LTD.	High and new technologies transform traditional industries
57	Sheng zhang	盛璋	Chairman of board	Huizhou China Eagle Electronic Technology Co., LTD	High and new technologies transform traditional industries
58	Shi Chenyang	史晨阳	Sales manager	Yuanxingcheng Technology	High and new technologies transform traditional industries
59	Shi Jing	施菁	Director	Guangdong COROS	Electronic information technology
60	Shi Pengchang	史鹏昌	CEO	Yuanxingcheng Technology	High and new technologies transform traditional industries
61	Tang ling	汤伶	Sales director	DG TaiYang Rubber Plastic industry Co., LTD	High and new technologies transform traditional industries
62	Tang yu	汤彧	Manager	Guangdong COROS	Electronic information technology
63	Wang Cong	王聪	Manager	Guangdong COROS	Electronic information technology
64	Wang Fangde	王方德	Director	Yuanfeng Technology	Electronic information technology
65	Wang Gang	王刚	Manager	Guangdong COROS	Electronic information technology
66	Wang Jianghua	王江华	Director	Guangdong COROS	Electronic information technology
67	Wang Lixin	王立新	VP	Sunmi Technology	Electronic information technology
68	Wang peilin	王培麟	VP	Teleray Smart Technologies (Dongguan) Co. LTD	High and new technologies transform traditional industries
69	Wang Xiaohu	王晓虎	Director	Guangdong COROS	Electronic information technology
70	Wang xuanlin	汪选林	GM	Sen Feng PVD	High and new technologies transform traditional industries
71	Wu Zheng	吴铮	CEO	COROS USA	Electronic information technology
72	Xie zhong	谢忠	Sales director	GoodIC Technology Co.,LTD	High-tech service industry
73	Xin Tong	辛童	Founder	SZ Xintong technology	High-tech service industry
74	Xu changping	许昌平	Marketing GM	DPT Electronic Company	High and new technologies transform traditional industries
75	Yan xiaowei	严孝为	Sales engineer	Avnet Electronics Technology	High and new technologies transform traditional industries
76	Yang bi	杨比	Executive VP	Jiangsu Sidike New material	New material technology

				Science & Technology Co.,LTD	
77	Yang guofeng	杨国凤	Director	Guangdong COROS	Electronic information technology
78	Yang Jun	杨君	CEO	Zhongzhi Yunhui	High-tech service industry
79	Yang Kejun	杨克军	VP	Huache Inspetion	High-tech service industry
80	Yang li	杨莉	CFO	Yuanfeng Technology	Electronic information technology
81	Yang Ling	杨凌	VP	Zhongke Dongxin	High-tech service industry
82	Yang Xi	杨曦	Director	Guangdong COROS	Electronic information technology
83	Yang yuefeng	杨越峰	Head of Supply chain	Shanghai CHINT Electrics International Trade Co.,LTD	New energy and energy-saving technology
84	Yuan yue	袁悦	Account manager	Everwin precision technoloty CO., LTD	High and new technologies transform traditional industries
85	Yuan Yunhang	袁运航	Superviso r	Guangdong COROS	Electronic information technology
86	Zhang Feng	张锋	COO	Next new energy	New energy and energy-saving technology
87	Zhang Lixin	张立新	Co-funder	Yisheng Technology	New material technology
88	Zhao jiantao	赵建涛	CEO	Shenzhen Jincheng Technology Co., LTD	Resource and environment technology
89	Zheng junlong	郑俊龙	President	Lens Technology	High and new technologies transform traditional industries

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Annex D: SC flexibility indicators source list

Business area	Flexibility indicators	Source
Organization	Centralized decision policy minimizes the SCM cost	Malik and Sarkaret (2020)
	Coercive power	G. Liu et al. (2022)
	Cross-functional integration	Yang and Tsai (2019)
	Engagement Capability (ENC)	Bag and Rahman (2021)
	External collaboration	Skipper and Hanna (2009)
	External integration	Braunscheidel and Suresh (2009)
	External integration	Moyano-Fuentes et al. (2016)
	External integration	Shou (2018)
	External integration	Chaudhuri et al. (2018)
	External knowledge transfer	Blome et al. (2014)
	Green supplier integration	Ji (2020)
	Internal integration	Braunscheidel and Suresh (2009)
	Internal integration	Chaudhuri et al. (2018)
	Internal integration	Moyano-Fuentes et al. (2016)
	Internal integration	Riley (2016)
	Internal knowledge transfer	Blome et al. (2014)
	Legal-legitimate power	Liu et al. (2022)
	Operational absorptive capacity (OAC)	Rojo et al. (2018)
	Organizational learning	Rojo et al. (2018)
	Partnership with suppliers	Um (2017)
	Relationship flexibility	Yu (2018)
	Resource alignment	Skipper and Hanna (2009)
	Smart supply chain management	Gupta et al. (2019)
	Supplier integration	He et al. (2014)
	Supply chain integration (customer, supplier, internal integration)	Z. Wang and Zhang (2020)
	Supply chain external integration	Ramos et al. (2021)
	Supply chain internal integration	Ramos et al. (2021)
	Supply chain learning	Willis et al. (2016)
	Supply chain risk management	Chaudhuri et al. (2018)
	Supply chain strategy	Aissa et al. (2009)
	Supply flexibility	Sreedevi and Saranga (2017)
	Supply network flexibility	Fernandez-Giordano et al. (2021)
	Top management support	Skipper and Hanna (2009)
	Training	Riley (2016)
	Vendor flexibility	Gosling et al. (2010)
Manufacturing	Agile production	Qamar et al. (2018)
	Emergency stock	Mohammaddust et al. (2017)
	Internal Variety management Strategy Modular	Um (2017)
	ISO 9001	Araceli et al. (2020)
	Lean production	Maqueira et al. (2021)
	Manufacturing flexibility	Sreedevi and Saranga (2017)
	Manufacturing flexibility	Swafford et al. (2006)
	Manufacturing flexibility	Tang and Tomlin (2008)

	Manufacturing flexibility	Kim et al. (2013)
	Mix flexibility	Braunscheidel and Suresh (2009)
	Postpone flexibility	Martínez-Sánchez and Pérez (2005)
	Product flexibility	Martínez-Sánchez and Pérez (2005)
	Product modularity	Wang and Zhang (2020)
	Response flexibility	Martínez-Sánchez and Pérez (2005)
	Routing flexibility	Martínez-Sánchez and Pérez (2005)
	Volume flexibility	Martínez-Sánchez and Pérez (2005)
	Volume flexibility	Braunscheidel and Suresh (2009)
Information	Big data analytics (BDA) capability	Cheng et al. (2021)
	Data Analytics capability	Dubey et al. (2021)
	Data Analytics Capability (DAC)	Bag and Rahman (2021)
	Information sharing	Riley (2016)
	Information system	Luo et al. (2020)
	Information system agility	Gupta et al. (2019)
	Information technology usage	Skipper and Hanna (2009)
	IT flexibility	Han et al. (2017) Jeong
	IT-enabled sharing capability	Jin et al. (2014)
	Spanning flexibility	Zhang et al. (2006)
	The integration of information system at buyer-supplier interface	Wagner et al. (2018)
	Transactive memory system	Fernandez-Giordano et al. (2021)
Logistics	Delivery flexibility	Martínez-Sánchez and Pérez (2005)
	Delivery performance	Wagner et al. (2018)
	Distribution/logistics flexibility	Swafford et al. (2006)
	Logistics flexibility	Sreedevi and Saranga (2017)
	Logistics flexibility	Tang and Tomlin (2008)
	Logistics flexibility	Yu et al. (2018)
	Trans-shipment flexibility	Martínez-Sánchez and Pérez (2005)
Procurement	Access flexibility	Martínez-Sánchez and Pérez (2005)
	Alliance Capability (ACA)	Bag and Rahman (2021)
	Procurement	Chirra et al. (2021)
	Procurement/sourcing flexibility	Swafford et al. (2006)
	Sourcing flexibility	Gosling et al. (2010)
	Sourcing flexibility	Martínez-Sánchez and Pérez (2005)
	Supplier election and selection	Wagner et al. (2018)
Marketing	Customer relationships	Um (2017)
	Price flexibility	Tang and Tomlin (2008)
	Product financial performance	Wagner et al. (2018)
	Product lifecycle	Z. Wang and Zhang (2020)
Product development	Additive Manufacturing Adoption (3D printing)	Delic and Eyers (2020)
	Advanced Manufacturing Technology (AMT)	Moyano-Fuentes et al. (2016)
	Launch flexibility	Martínez-Sánchez and Pérez (2005)

Annex E: SC flexibility indicators questionnaire round 1

供应链弹性指标调查 第一轮

Supply Chain Flexibility Indicators 1st Round

我叫郑国辉，这份问卷是我为了完成我的管理学博士论文而进行的一项研究而开发的，该论文的重点是测量和监测高科技行业的供应链灵活性，特别是关注中国私营高科技公司。

这是本研究的第一份问卷，旨在评估您对预先定义的供应链灵活性措施清单的同意程度，并确定您可能认为相关的其他措施。因此，问卷分为两部分:第一部分询问你的个人和职业细节;第二部分致力于收集您对上述措施的同意程度。

回答这些问题大约需要30分钟。答案是匿名的，这项研究的最终结果将在不透露受访者细节的情况下公布。

您的参与对这项研究的成功至关重要。

谢谢您的宝贵时间!

My name is Zheng Guohui, and this questionnaire is developed within the scope of a research I am developing for concluding my Doctor of Management thesis, which is focused on measuring and monitoring supply chain flexibility in the high-tech sector, particularly focusing on Chinese private high-tech companies.

This is the first questionnaire of this study, which is aimed at evaluating your agreement with a pre-defined list of supply chain flexibility measures, and also to identify additional measures that you might consider as relevant. The questionnaire is thus organized into two parts: one first part asking for your personal and professional details; and a second part devoted to the gathering of your agreement with the before mentioned measures.

It will take around 30 minutes to answer these questions. The answers are anonymous, and the final results of this study will be published without disclosing details about the respondents.

Your participation will be essential for the success of this study.

Thank you for your time!

第一节: 基本信息收集

Section 1: Basic Information Collection

你还在从事高科技行业吗? [单选题]*

Are you still working in the high-tech industry? [单选题] *

○是/Yes

○不是/No

您在高科技行业有多少年的经验? [单选题] *

How many years of experience do you have in the high-tech industry? [单选题] *

○1-5年/years

○6-10年/years

○11-15年/years

○16-20年/years

○20+ 年/years

您的学历程度是什么? [单选题] *

What is your education level? [单选题] *

○高中/High school

○大专/College degree

○学士/bachelor’s degree

○硕士/master’s degree

○博士/Doctor degree

你在公司的职位是什么? [单选题] *

What is your position in the company? [单选题] *

○董事长/总经理/CEO Chairman or General manager

○副总/Vice President

○总监/部门负责人/Director or Head of department

○其他管理或者技术职位/Other management or technical position

○职员/Staff

○其他/Others

你们公司有多少员工? [单选题] *

How many workers work in the company? [单选题] *

○1-20人/1-20 persons

○20-300人/20-300 persons

○300-1000人/300-1000 persons

○1000-5000人/1000-5000 persons

○5000+ 人/5000+ persons

贵公司2022年的营业额是多少 (单位: 百万人民币)? [单选题] *

What is the revenue of your company in 2022 (Unit: Million RMB)? [单选题] *

○0-3百万/0-3 million

○3-20百万/3-20 million

○20-400百万/20-400 million

○400-1000百万/400-1000 million

○1000 + 百万/1000 + millions

公司在该行业经营了多少年? [单选题] *

For how many years is the company operating in the sector? [单选题] *

○1-5年/1-5 years

○6-10年/6-10 years

○11-15年/11-15 years

○16-20年/16-20 years

○20+ 年/20+ years

你在现在的公司工作了多少年? [单选题] *

How many years have you been working in your current company? [单选题] *

□不到1年/Within 1 year

□1-3年/1-3 years

□3-5年/3-5 years

□5-10年/5-10 years

□10+ 年/10+ years

公司属于哪个高新技术行业/领域? [单选题] *

Which is the sector/area in which the company belongs? [单选题] *

○电子信息技术/Electronic information technology

○生物学与医学新技术/Biology and new medical technol

○航天技术/Aerospace technology

○新材料技术/New material technology

○高新技术服务业/High-tech service industry

○新能源及节能技术/New energy and energy-saving technologies

○资源与环境技术/Resource and environment technology

○高新技术改造传统产业/High and new technologies transform traditional industries

第二节:

为了评估高科技供应链的灵活性，请确认您对以下所示的灵活性措施(与**制造**问题有关)选择的同意程度。 (注:目的不是评估你是否有信息来衡量这些措施;目的是了解你是否相信它值得衡量，基于你所拥有的信息。)

Section 2:

Please identify your level of agreement with the selection of the flexibility measures (related to **manufacturing issues**) shown below for the purpose of evaluating the flexibility of high-tech supply chains.

(Note: the aim is not to evaluate if you have the information to measure these measures; the aim is to understand if you believe it is worthwhile to measure it, independently of the information you have available.)

1.安全库存

为了避免意外情况导致的缺货而提前准备的库存，意外情况例如新冠疫情。[单选题] *

1.Safety stock

- Stock prepared in advance to avoid stockouts caused by unexpected circumstances, such as Covid-19 isolation. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

2.ISO 9001

你们公司的生产制造有执行ISO 9001 标准吗？[单选题] *

2.ISO 9001

- Implement ISO 9001 standard [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

3.精益生产

它基于丰田的生产系统，专注于废物处理、库存减少、改进流程性能和人力资源嵌入，你们公司有应用精益生产吗？[单选题] *

3.Lean production

- It is based on Toyota’s production system and focuses on waste disposal, inventory reduction, improved process performance and human resource embedding. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

4.推迟灵活性

尽可能长时间保持产品通用形式的能力，以便在后期阶段纳入客户的产品要求。（补充说明：尽可能让产品差异化的部分在组装的后端发生，降低生产的复杂

度。这区别于产品模块化，产品模块化覆盖了产品的从前到后的整个过程）。[单选题] *

4.Postpone flexibility

- Capability of keeping products in their generic form as long as possible, in order to incorporate the customer’s product requirements in later stages. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

5.产品模块化

模块化产品是具有可互换组件的分层和整体系统，不同的产品可能具有不同级别的模块化。[单选题] *

5.Product modularity

- A modular product is a hierarchical and holistic system with interchangeable components. Different products might have different levels of modularity. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

6.工艺路线灵活性

通过使用替代机器、灵活的材料处理和灵活的运输网络，通过不同的工艺路线加工零件的能力。[单选题] *

6.Routing flexibility

- It is the capability of processing a part through varying routes by using alternative machines, flexible material handling, and flexible transporting network. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

7.产量灵活性

根据客户需求有效增减整体产量的能力。[单选题] *

7.Volume flexibility

- The ability to effectively increase or decrease aggregate production in response to customer demand. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

8.关于上面提到的灵活性度量，您还有什么想说的吗? (例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写"没有"。 [填空题] *

8.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题] *

____

9.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。 [填空题] *

9.Do you think there are additional flexibility measures thar are relevant to analysis? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题] *

____

第三节:

为了评估高科技供应链的灵活性，请确认您对以下所示的灵活性措施(与**组织**问题有关)选择的同意程度。 (注:目的不是评估你是否有信息来衡量这些措施;目的是了解你是否相信它值得衡量，基于你所拥有的信息。)

Section 3:

Please identify your level of agreement with the selection of the flexibility measures (related to **Organizational issues**) shown below for the purpose of evaluating the flexibility of high-tech supply chains.

(Note: the aim is not to evaluate if you have the information to measure these measures; the aim is to understand if you believe it is worthwhile to measure it, independently of the information you have available.)

10.与供应商信息共享

龙头企业与下游供应商共享需求信息，促进整个供应链总成本的降低。[单选题] *

10.Information sharing with vendors

- The leading company share the demand information with downstream vendors, promoting a reduction in the total cost of the whole supply chain. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

11.强制力

如果供应商不遵守核心公司的意愿，则侧重于警告未来的负面制裁或惩罚。 [单选题] *

11.Coercive power

- Focuses on warning of future negative sanctions or punishments if suppliers fail to comply with the focal firm’s wishes. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

12.外部整合

需要使供应链中每个公司的计划、采购、制造、交付、退货和启用流程与客户和供应商保持一致。[单选题] *

12.External integration

- The need to align the plan, source, make, deliver, return and enable processes of each firm in the chain with both customers and suppliers. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

13.外部知识转移

被定义为公司利用外部专业知识为公司产品和流程带来好处的能力。[单选题] *

13.External knowledge transfer

- Is defined as the firm's ability to utilize external expertise for the benefit of the firm's products and processes. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

14.绿色供应商整合

采用绿色供应商，涉及以提高环境绩效为重点的战略。[单选题] *

14.Green supplier integration

- It involves strategies focused on enhancing environmental performance. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

15.内部整合职能间和部门间的整合，使得对市场变化和中断做出相互关联和更加

协调的反应。 [单选题] *

15.Internal integration

- Inter-functional and interdepartmental integration, leading to a connected and more coordinated response to marketplaces changes and disruptions. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

16.内部知识转移公司在内部与其他职能部门共享信息的能力 。[单选题] *

16.Internal knowledge transfer

- Firm's ability to share information internally with other functions. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

17.组织学习

个人创造的知识以有组织的方式增加，并转化为组织知识体系的一部分。[单选题] *

17.Organizational learning

- The knowledge created by individuals is increased in an organized fashion and is transformed into part of the knowledge system of the organization. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

18.供应链学习

可以预期，供应链学习水平高的公司将积极质疑其组织流程的运作情况，并寻求更好的组织方式。[单选题] *

18.Supply chain learning

- It can be expected that firms with a high level of supply chain learning will actively question how well their organizational processes work and seek better ways to be organized. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

19.供应链风险管理

供应链需要预防风险(例如选择更可靠的供应商、使用明确的安全程序、预防性维护)、发现风险(例如内部或供应商监控、检查、跟踪)并响应风险并从中恢复 (例如备用供应商、额外产能、替代运输方式)。[单选题] *

19.Supply chain risk management

- Supply chains need to prevent risks (*e.g.,* select a more reliable supplier, use clear safety procedures, preventive maintenance), detect risks (*e.g.,* internal or supplier monitoring, inspection, tracking) and respond and recover from risks (*e.g.,* backup suppliers, extra capacity, alternative transportation modes). [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

20.最高管理层的支持

得到管理层的计划、支持、耐心和领导。[单选题] *

20.Top management support

- The planning, support, patience, and leadership from management. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

21.培训

指促进知识转移的过程，管理人员通过培训来教导员工如何识别风险并在出现异常情况时进行处理。[单选题] *

21.Training

- It refers to processes that facilitate knowledge transfer. Managers use training to teach employees how to identify risks and handle anomalies once materialized. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

22.关于上面提到的灵活性度量，您还有什么想说的吗? (例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。[填空题] *

22.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题] *

____

23.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。[填空题] *

23.Do you think there are additional flexibility measures thar are relevant to analysis? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题] *

____

第四节：为了评估高科技供应链的灵活性，请确认您对以下所示的灵活性措施(与**信息**问题有关)选择的同意程度。 (注:目的不是评估你是否有信息来衡量这些措施;目的是了解你是否相信它值得衡量，基于你所拥有的信息。)

Section 4:

Please identify your level of agreement with the selection of the flexibility measures (related to **Informational issues**) shown below for the purpose of evaluating the flexibility of high-tech supply chains.

(Note: the aim is not to evaluate if you have the information to measure these measures; the aim is to understand if you believe it is worthwhile to measure it, independently of the information you have available.)

24.数据分析能力

与使用工具、技术和流程的组合有关，这些工具、技术和流程使组织能够处理、组织、可视化和分析数据以获得有用的见解，从而使管理人员能够做出高效和有效的决策 业务及其相关业务。[单选题] *

24.Data Analytic capability

- Is related to the use of a combination of tools, techniques and processes that enable the organization to process, organize, visualize, and analyze data to derive useful insights, which enables managers to take efficient and effective decisions related to business and its related operations. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

25.信息系统的使用

科学结合实际工作中的业务和数据处理，实现线上线下无缝衔接，提高员工使用信息系统和信息平台的能力。[单选题] *

25.Information system's use

- Scientifically combine the business and data processing in actual work, realize the seamless connection between online and offline, and improve the ability of employees to use the information system and information platform. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

26.IT 灵活性

适应业务或业务流程中增量和革命性变化的能力，同时对当前时间、精力、成本或性能的损失最小。[单选题] *

26.IT flexibility

- The ability to adapt to both incremental and revolutionary changes in the business or business process with minimal penalty to current time, effort, cost, or performance. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

27.买卖双方的信息系统集成

买卖双方共享公司内部信息和数据访问。[单选题] *

27.The integration of information system at buyer-supplier interface

- Share intra-firm information and data access. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

28.关于上面提到的灵活性度量，您还有什么想说的吗？(例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。 [填空题] *

28.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题] *

____

29.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。[填空题] *

29.Do you think there are additional flexibility measures thar are relevant to analysis? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题] *

____

第五节:

为了评估高科技供应链的灵活性，请确认您对以下所示的灵活性措施(与**采购**问题有关)选择的同意程度。 (注:目的不是评估你是否有信息来衡量这些措施;目的是了解你是否相信它值得衡量，基于你所拥有的信息。)

Section 5:

Please identify your level of agreement with the selection of the flexibility measures (related to **Procurement**) shown below for the purpose of evaluating the flexibility of high-tech supply chains.

(Note: the aim is not to evaluate if you have the information to measure these measures; the aim is to understand if you believe it is worthwhile to measure it, independently of the information you have available.)

30.联盟能力 (ACA)

与合作伙伴形成联盟的能力有助于公司的竞争优势。 公司还为管理人员和合作伙

伴制定专门的培训计划，以培养联盟能力。[单选题] *

30.Alliance Capability (ACA)

- The ability to form alliances contributes to the competitive advantage of the firm. Firms also have specific training program for managers and partners to foster alliance capabilities. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

31.采购灵活性

采购流程有效响应与采购组件供应相关的不断变化的需求的能力。[单选题] *

31.Procurement flexibility

- The ability of the purchasing process to effectively respond to changing requirements related to the supply of purchased components. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

32.寻源灵活性

通过选择和取消选择供应商来重新配置供应链网络的能力。[单选题] *

32.Sourcing flexibility

- The ability to reconfigure a supply chain network through selection and deselection of vendors.

[单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

33.关于上面提到的灵活性度量，您还有什么想说的吗? (例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。 [填空题] *

33.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(e.g., the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题] *

____

34.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。 [填空题] *

34.Do you think there are additional flexibility measures thar are relevant to analysis? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题] *

____

第六节:

为了评估高科技供应链的灵活性，请确认您对以下所示的灵活性措施(与**物流**问题有关)选择的同意程度。 (注:目的不是评估你是否有信息来衡量这些措施;目的是了解你是否相信它值得衡量，基于你所拥有的信息。)

Section 6:

Please identify your level of agreement with the selection of the flexibility measures (related to **Logistics**) shown below for the purpose of evaluating the flexibility of high-tech supply chains. (Note: the aim is not to evaluate if you have the information to measure these measures; the aim is to understand if you believe it is worthwhile to measure it, independently of the information you have available.)

35.交货灵活性

公司根据客户要求调整交货时间的能力,例如：JIT。[单选题] *

35.Delivery flexibility

- It is the company’s capability to adapt lead times to the customer requirements. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

36.交付绩效

公司满足最终客户要求的能力，以产品可用性、交付可靠性、满足客户需求数量的能力表示。[单选题] *

36.Delivery performance

- How well the company is able to meet end-customer requirements, expressed in product availability, delivery reliability, ability to meet the quantities demanded by customers. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

37.分销灵活性

它使公司能够调整其交货时间表以适应不可预测或快速变化的客户需求。[单选题] *

37.Distribution flexibility

- It enables a firm to adapt its delivery schedules to unpredictable or rapidly changing customer requirements. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

38.物流灵活性

灵活的运输方式(多式联运、多承运人、多路线运输)。[单选题] *

38.Logistics flexibility

- Flexible modes of transportation (multi-modal, multi-carrier, multi-route transportation). [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

39.关于上面提到的灵活性度量，您还有什么想说的吗? (例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。 [填空题] *

39.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题] *

____

40.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。 [填空题] *

40.Do you think there are additional flexibility measures thar are relevant to analysis? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题] *

____

第七节:

为了评估高科技供应链的灵活性，请确认您对以下所示的灵活性措施(与**市场**问题有关)选择的同意程度。 (注:目的不是评估你是否有信息来衡量这些措施;目的是了解你是否相信它值得衡量，基于你所拥有的信息。)

Section 7:

Please identify your level of agreement with the selection of the flexibility measures (related to **Marketing**) shown below for the purpose of evaluating the flexibility of high-tech supply chains.

(Note: the aim is not to evaluate if you have the information to measure these measures; the aim is to understand if you believe it is worthwhile to measure it, independently of the information you have available.)

41.客户关系

公司需要一个市场策略来尽量减少不需要的产品种类，并提出两个策略：与客户建立更紧密的关系以确保当前产品反映客户需求，以及淘汰不再有益的产品。[单选题] *

41.Customer relationships

- Companies need a market strategy to minimize unwanted product variety and propose two strategies: closer relationships with customers to ensure current products reflect customer needs, and eliminating products that are no longer beneficial. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

42.价格弹性

调整产品价格，引导顾客消费。 [单选题] *

42.Price flexibility

- Adjust product price to guide customer consumption. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

43.产品财务业绩

主要产品线相对于主要竞争对手在增长、市场份额和盈利能力方面的表现。[单选

题] *

43.Product financial performance

- The performance of the main product line relative to the main competitor in terms of growth, market share, and profitability. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

44.产品生命周期的管理

公司是否对产品生命周期进行管理，因为它反映了公司主要产品/产品线的生命周期阶段和制造商所处的外部环境中的竞争动态。[单选题] *

44.Product lifecycle

- PLC reflects the life cycle stage of a company's major product/product line and competition dynamics in the external environment in which a manufacturer resides. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

45.市场分销灵活性

提供广泛或密集的分销覆盖的能力。这种灵活性得益于供应链下游活动的密切协调，无论是在公司内部还是外部进行的。[单选题] *

45.Market Distribution flexibility

- The ability to provide widespread or intensive distribution coverage. This flexibility is facilitated by the close coordination of downstream activities in the supply chain whether performed internally or externally to the firm. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

46.关于上面提到的灵活性度量，您还有什么想说的吗？(例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。[填空题] *

46.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题] *

____

47.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。[填空题] *

47.Do you think there are additional flexibility measures that are relevant to analysis? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题] *

____

第八节:

为了评估高科技供应链的灵活性，请确认您对以下所示的灵活性措施(与**产品开发**

问题有关)选择的同意程度。 (注:目的不是评估你是否有信息来衡量这些措施;目的是了解你是否相信它值得衡量，基于你所拥有的信息。)

Section 8:

Please identify your level of agreement with the selection of the flexibility measures (related to **Product development**) shown below for the purpose of evaluating the flexibility of high-tech supply chains.

(Note: the aim is not to evaluate if you have the information to measure these measures; the aim is to understand if you believe it is worthwhile to measure it, independently of the information you have available.)

48.增材制造采用(3D打印)

指的是一套工艺技术，可以使用3D计算机模型的数据，通过增加连接材料的材料层直接生产零件。[单选题] *

48.Additive Manufacturing Adoption (3D printing)

- Refers to a set of process technologies that can directly produce parts through the incremental addition of material layers of joining materials, using data from 3D computer models. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

49.先进制造技术(AMT)采用

主要是可编程技术的集合，加上高水平的效率，可以为涉及设计、计划、执行和控制操作的活动提供极大的灵活性。它包括各种各样的技术，如CAD， CAE和CAPP(设计)，CNC和FMS(执行)和ERP系统(计划和控制)。[单选题] *

49.Advanced Manufacturing Technology (AMT) Adoption

- Set of mostly programmable technologies which, together with high levels of efficiency, can provide great flexibility to the activities involved in the design, planning, execution and control of operations. It includes a wide variety of technologies, such as CAD, CAE and CAPP (design), CNC and FMS (execution) and ERP systems (planning and control). [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

50.产品发布灵活性

在市场上推出多种新产品的能力。[单选题] *

50.Launch flexibility

- The ability to introduce a high variety of new products in the market. [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

51.关于上面提到的灵活性度量，您还有什么想说的吗? (例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。[填空题] *

51.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题] *

____

52.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。[填空题] *

52.Do you think there are additional flexibility measures that are relevant to analysis? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题] *

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Annex F: SC flexibility indicators questionnaire round 2

供应链弹性指标调查 第二轮

Supply Chain Flexibility Indicators 2nd Round

我叫郑国辉。

感谢您参与完成本研究的第一轮问卷调查。

第二轮现在旨在与您分享第一轮之后获得的结果——特别是，您将看到专家组为每个灵活性措施选择的答案。 现在要求您分析这些答案，并确认您是否要保持或更改您对每个供应链灵活性措施的选择的同意程度.

此外，本轮还旨在评估您是否同意第一轮专家组提出的额外的供应链灵活性措施清单。因此，调查问卷分为三个部分：

第一部分询问您的个人和专业基本信息；

第二部分致力于以第一轮反馈结果为基础重新评估您的同意程度；

第三部分专门收集您对第一轮提出的新措施的同意程度。

与第一轮类似，答案是匿名的，本研究的最终结果将在不透露受访者详细信息的情况下公布。

您的参与对于本研究的成功至关重要。请在3月8号前完成反馈。

感谢您的时间！

My name is Zheng Guohui.

Thank you for completing the first round of questionnaires for this study.

The second round now aims to share with you the results obtained after the first round - in particular, you will see the answers chosen by the panel for each flexibility measure. You are now asked to analyze these answers and confirm whether you want to maintain or change your level of agreement with your choice of each supply chain flexibility measure.

In addition, the purpose of this round is to assess whether you agree with the list of additional supply chain flexibility measures proposed by the first round of expert groups.

Therefore, the questionnaire is divided into three parts:

The first part asks for your basic personal and professional information.

The second part focuses on reassessing your level of consent based on the first round of feedback.

The third section is dedicated to collecting your level of agreement with the new measures proposed in the first round.

Similar to the first round, the answers are anonymous, and the final results of this study will be published without disclosing details of the respondents.

Your participation is essential to the success of this study. Please complete the feedback by March 8.

Thank you for your time!

第一部分: 基本信息收集

Part I: Basic Information Collection

您在高科技行业有多少年的经验?

How many years of experience do you have in the high-tech industry? [单选题] *

○1-5 年/years

○6-10 年/years

○11-15 年/years

○16-20 年/years

○20+ 年/years

你在公司的职位是什么?

What is your position in the company? [单选题] *

○董事长/总经理/CEO Chairman or General manager

○副总/Vice President

○总监/部门负责人/Director or Head of department

○其他管理或者技术职位/Other management or technical position

○职员/Staff

○其他/Others

公司属于哪个高新技术行业/领域?

Which is the sector/area in which the company belongs? [单选题] *

○电子信息技术/Electronic information technology

○生物学与医学新技术/Biology and new medical technol

○航天技术/Aerospace technology

○新材料技术/New material technology

○高新技术服务业/High-tech service industry

○新能源及节能技术/New energy and energy-saving technologies

○资源与环境技术/Resource and environment technology

○高新技术改造传统产业/High and new technologies transform traditional industries

第二部分 第1节 （制造领域）：

第一轮的反馈结果如下供您参考，请您从新评估您的同意程度。

（请注意，您可以保留第一轮给出的相同答案，如果您认为合适，也可以更改。）

Part II Section 1 (Manufacturing Area):

The first round of feedback results are as follows for your reference. Please re-evaluate your agreement.

(Note that you can keep the same answers you gave in the first round or change them if you see fit.)

1.安全库存

为了避免意外情况导致的缺货而提前准备的库存，意外情况例如新冠疫情。

1.Safety stock

- Stock prepared in advance to avoid stockouts caused by unexpected circumstances, such as Covid-19 isolation. [单选题] *

选项	小计	比例
非常不同意	1	1.25%
不同意	3	3.75%
不确定	10	12.5%
同意	39	48.75%
非常同意	27	33.75%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

2.ISO 9001

你们公司的生产制造有执行ISO 9001 标准吗？

2.ISO 9001

- Implement ISO 9001 standard? [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	1	1.25%
不确定	4	5%
同意	25	31.25%
非常同意	50	62.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

3.精益生产

它基于丰田的生产系统，专注于废物处理、库存减少、改进流程性能和人力资源嵌入，你们公司有应用精益生产吗？

3.Lean production

- It is based on Toyota's production system and focuses on waste disposal, inventory reduction, improved process performance and human resource embedding. [单选题] *

选项	小计	比例
非常不同意	1	1.25%
不同意	5	6.25%
不确定	9	11.25%
同意	39	48.75%
非常同意	26	32.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

4.推迟灵活性

尽可能长时间保持产品通用形式的能力，以便在后期阶段纳入客户的产品要求。（补充说明：尽可能让产品差异化的部分在组装的后端发生，降低生产的复杂度。这区别于产品模块化，产品模块化覆盖了产品的从前到后的整个过程）

4.Postpone flexibility

- Capability of keeping products in their generic form as long as possible, in order to incorporate the customer's product requirements in later stages. （（Additional note: As much as possible, the product differentiation occurs in the back end of assembly to reduce the complexity of production. This is different from product modularity, which covers the entire process from front to back of the product) [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	8	10%
不确定	12	15%
同意	37	46.25%
非常同意	23	28.75%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

5.产品模块化

模块化产品是具有可互换组件的分层和整体系统，不同的产品可能具有不同级别的模块化。

5.Product modularity

- A modular product is a hierarchical and holistic system with interchangeable components. Different products might have different levels of modularity. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	5	6.25%
同意	47	58.75%
非常同意	28	35%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

6.工艺路线灵活性

通过使用替代机器、灵活的材料处理和灵活的运输网络，通过不同的工艺路线加工零件的能力。

6.Routing flexibility

- It is the capability of processing a part through varying routes by using alternative machines, flexible material handling, and flexible transporting network. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	3	3.75%
不确定	6	7.5%
同意	39	48.75%
非常同意	32	40%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

7.产量灵活性

根据客户需求有效增减整体产量的能力。

7.Volume flexibility

- The ability to effectively increase or decrease aggregate production in response to customer demand. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	1	1.25%
不确定	3	3.75%
同意	42	52.5%
非常同意	34	42.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

第二部分 第2节 （组织领域）：

Part II Section 2 (Organizational Areas):

8.与供应商信息共享

龙头企业与下游供应商共享需求信息，促进整个供应链总成本的降低。

8.Information sharing with vendors

- The leading company share the demand information with downstream vendors, promoting a reduction in the total cost of the whole supply chain. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	1	1.25%
不确定	4	5%
同意	45	56.25%
非常同意	30	37.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

9.强制力

如果供应商不遵守核心公司的意愿，则侧重于警告未来的负面制裁或惩罚。

9.Coercive power

- Focuses on warning of future negative sanctions or punishments if suppliers fail to comply with the focal firm’s wishes. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	11	13.75%
不确定	19	23.75%
同意	37	46.25%
非常同意	13	16.25%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

10.外部整合

需要使供应链中每个公司的计划、采购、制造、交付、退货和启用流程与客户和供应商保持一致。

10.External integration

- The need to align the plan, source, make, deliver, return and enable processes of each firm in the chain with both customers and suppliers. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	5	6.25%
不确定	14	17.5%
同意	44	55%
非常同意	17	21.25%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

11.外部知识转移

被定义为公司利用外部专业知识为公司产品和流程带来好处的能力。

11.External knowledge transfer

- Is defined as the firm's ability to utilize external expertise for the benefit of the firm's products and processes. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	1	1.25%
不确定	4	5%
同意	53	66.25%
非常同意	22	27.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

12.绿色供应商整合

采用绿色供应商，涉及以提高环境绩效为重点的战略。

12.Green supplier integration

- It involves strategies focused on enhancing environmental performance. [单选题] *

选项	小计	比例
非常不同意	1	1.25%
不同意	0	0%
不确定	14	17.5%
同意	43	53.75%
非常同意	22	27.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

13.内部整合

职能间和部门间的整合，使得对市场变化和中断做出相互关联和更加协调的反应。

13.Internal integration

- Inter-functional and interdepartmental integration, leading to a connected and more coordinated response to marketplaces changes and disruptions. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	1	1.25%
同意	41	51.25%
非常同意	38	47.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

14.内部知识转移

公司在内部与其他职能部门共享信息的能力。

14.Internal knowledge transfer

- Firm's ability to share information internally with other functions. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	3	3.75%
同意	45	56.25%
非常同意	32	40%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

15.组织学习

个人创造的知识以有组织的方式增加，并转化为组织知识体系的一部分。

15.Organizational learning

- The knowledge created by individuals is increased in an organized fashion and is transformed into part of the knowledge system of the organization. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	1	1.25%
同意	36	45%
非常同意	43	53.75%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

16.供应链学习

可以预期，供应链学习水平高的公司将积极质疑其组织流程的运作情况，并寻求更好的组织方式。

16.Supply chain learning

- It can be expected that firms with a high level of supply chain learning will actively question how well their organizational processes work and seek better ways to be organized. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	2	2.5%
同意	38	47.5%
非常同意	40	50%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

17.供应链风险管理

供应链需要预防风险(例如选择更可靠的供应商、使用明确的安全程序、预防性维护)、发现风险(例如内部或供应商监控、检查、跟踪)并响应风险并从中恢复 (例如备用供应商、额外产能、替代运输方式)。

17.Supply chain risk management

- Supply chains need to prevent risks (*e.g.,* select a more reliable supplier, use clear safety procedures, preventive maintenance), detect risks (*e.g.,* internal or supplier monitoring, inspection, tracking) and respond and recover from risks (*e.g.,* backup suppliers, extra capacity, alternative transportation modes). [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	2	2.5%
同意	33	41.25%
非常同意	45	56.25%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

18.培训

指促进知识转移的过程，管理人员通过培训来教导员工如何识别风险并在出现异常情况时进行处理。

18.Training

- It refers to processes that facilitate knowledge transfer. Managers use training to teach employees how to identify risks and handle anomalies once materialized. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	1	1.25%
不确定	0	0%
同意	48	60%
非常同意	31	38.75%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

第二部分 第3节 （信息领域）：

Part II, Section 3 (Information field):

19.数据分析能力

与使用工具、技术和流程的组合有关，这些工具、技术和流程使组织能够处理、组织、可视化和分析数据以获得有用的见解，从而使管理人员能够做出高效和有效的决策 业务及其相关业务。

19.Data Analytic capability

- Is related to the use of a combination of tools, techniques and processes that enable the organization to process, organize, visualize, and analyze data to derive useful insights, which enables managers to take efficient and effective decisions related to business and its related operations. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	0	0%
同意	37	46.25%
非常同意	43	53.75%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

20.信息系统的使用

科学结合实际工作中的业务和数据处理，实现线上线下无缝衔接，提高员工使用信息系统和信息平台的能力。

20.Information system's use

- Scientifically combine the business and data processing in actual work, realize the seamless connection between online and offline, and improve the ability of employees to use the information system and information platform. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	0	0%
同意	34	42.5%
非常同意	46	57.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

21.买卖双方的信息系统集成

买卖双方共享公司内部信息和数据访问。

21.The integration of information system at buyer-supplier interface

- Share intra-firm information and data access. [单选题] *

选项	小计	比例
非常不同意	2	2.5%
不同意	9	11.25%
不确定	30	37.5%
同意	27	33.75%
非常同意	12	15%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

第二部分 第4节 （采购领域）：

Part II Section 4 (Procurement Area):

22.联盟能力 (ACA)

与合作伙伴形成联盟的能力有助于公司的竞争优势。 公司还为管理人员和合作伙伴制定专门的培训计划，以培养联盟能力。

22.Alliance Capability (ACA)

- The ability to form alliances contributes to the competitive advantage of the firm. Firms also have specific training program for managers and partners to foster alliance capabilities. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	15	18.75%
同意	45	56.25%
非常同意	20	25%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

23.采购灵活性

采购流程有效响应与采购组件供应相关的不断变化的需求的能力。

23.Procurement flexibility

- The ability of the purchasing process to effectively respond to changing requirements related to the supply of purchased components. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	1	1.25%
不确定	6	7.5%
同意	49	61.25%
非常同意	24	30%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

24.寻源灵活性

通过选择和取消选择供应商来重新配置供应链网络的能力。（补充说明：有足够的合格供应商资源可供选择）

24.Sourcing flexibility

- The ability to reconfigure a supply chain network through selection and deselection of vendors. (Additional note: There are sufficient qualified supplier resources to choose from) [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	2	2.5%
不确定	9	11.25%
同意	52	65%
非常同意	17	21.25%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

第二部分 第5节 （物流领域）：

Part II Section 5 (Logistics Field):

25.交货灵活性

公司根据客户要求调整交货时间的能力,例如：JIT。

25.Delivery flexibility

- It is the company’s capability to adapt lead times to the customer requirements, such as JIT.

[单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	6	7.5%
同意	50	62.5%
非常同意	24	30%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

26.交付绩效

公司满足最终客户要求的能力，以产品可用性、交付可靠性、满足客户需求数量的能力表示。

26.Delivery performance

- How well the company is able to meet end-customer requirements, expressed in product availability, delivery reliability, ability to meet the quantities demanded by customers. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	2	2.5%
同意	50	62.5%
非常同意	28	35%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

27.分销灵活性

它使公司能够调整其交货时间表以适应不可预测或快速变化的客户需求

27.Distribution flexibility

- It enables a firm to adapt its delivery schedules to unpredictable or rapidly changing customer requirements. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	6	7.5%
同意	50	62.5%
非常同意	24	30%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

28.物流灵活性

灵活的运输方式(多式联运、多承运人、多路线运输)。（补充说明：增加多送货地点）

28.Logistics flexibility

- Flexible modes of transportation (multi-modal, multi-carrier, multi-route transportation). (Additional note: Add multiple delivery locations) [单选题] *

选项	小计	比例
非常不同意	1	1.25%
不同意	0	0%
不确定	6	7.5%
同意	47	58.75%
非常同意	26	32.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

第二部分 第6节 （市场领域）：

Part II Section 6 (Market Areas):

29.客户关系

公司需要一个市场策略来尽量减少不需要的产品种类，并提出两个策略：与客户建立更紧密的关系以确保当前产品反映客户需求，以及淘汰不再有益的产品。

29.Customer relationships

- Companies need a market strategy to minimize unwanted product variety and propose two strategies: closer relationships with customers to ensure current products reflect customer needs, and eliminating products that are no longer beneficial. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	0	0%
不确定	5	6.25%
同意	42	52.5%
非常同意	33	41.25%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

30.价格弹性

调整产品价格，引导顾客消费。

30.Price flexibility

- Adjust product price to guide customer consumption. [单选题] *

选项	小计	比例
非常不同意	1	1.25%
不同意	5	6.25%
不确定	11	13.75%
同意	47	58.75%
非常同意	16	20%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

31.产品财务业绩

主要产品线相对于主要竞争对手在增长、市场份额和盈利能力方面的表

31.Product financial performance

- The performance of the main product line relative to the main competitor in terms of growth, market share, and profitability. [单选题] *

选项	小计	比例
非常不同意	1	1.25%
不同意	0	0%
不确定	4	5%
同意	49	61.25%
非常同意	26	32.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

32.产品生命周期的管理

公司是否对产品生命周期进行管理，因为它反映了公司主要产品/产品线的生命周期阶段和制造商所处的外部环境中的竞争动态。

32.Product lifecycle

- PLC reflects the life cycle stage of a company's major product/product line and competition dynamics in the external environment in which a manufacturer resides. [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	2	2.5%
不确定	0	0%
同意	48	60%
非常同意	30	37.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

33.市场分销灵活性

提供广泛或密集的分销覆盖的能力。这种灵活性得益于供应链下游活动的密切协

调，无论是在公司内部还是外部进行的。（补充说明：同时要密切关注渠道库存水位）33.Market Distribution flexibility

- The ability to provide widespread or intensive distribution coverage. This flexibility is facilitated by the close coordination of downstream activities in the supply chain whether performed internally or externally to the firm. (Additional note: At the same time, pay close attention to the channel inventory level) [单选题] *

选项	小计	比例
非常不同意	0	0%
不同意	1	1.25%
不确定	10	12.5%
同意	53	66.25%
非常同意	16	20%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

第二部分 第7节 （产品开发领域）：

Part II Section 7 (Product Development Area):

34.增材制造采用(3D打印)

指的是一套工艺技术，可以使用3D计算机模型的数据，通过增加连接材料的材料层直接生产零件。

34.Additive Manufacturing Adoption (3D printing)

- Refers to a set of process technologies that can directly produce parts through the incremental addition of material layers of joining materials, using data from 3D computer models. [单选题] *

选项	小计	比例
非常不同意	2	2.5%
不同意	0	0%
不确定	31	38.75%
同意	33	41.25%
非常同意	14	17.5%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

35.先进制造技术(AMT)采用

主要是可编程技术的集合，加上高水平的效率，可以为涉及设计、计划、执行和控制操作的活动提供极大的灵活性。它包括各种各样的技术，如CAD， CAE和CAPP(设计)，CNC和FMS(执行)和ERP系统(计划和控制)。

35.Advanced Manufacturing Technology (AMT) Adoption

- Set of mostly programmable technologies which, together with high levels of efficiency, can provide great flexibility to the activities involved in the design, planning, execution and control of operations. It includes a wide variety of technologies, such as CAD, CAE and CAPP (design), CNC and FMS (execution) and ERP systems (planning and control). [单选题] *

选项	小计	比例
非常不同意	2	2.5%
不同意	1	1.25%
不确定	11	13.75%
同意	45	56.25%
非常同意	21	26.25%
本题有效填写人次	80	

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

36.关于上面提到的灵活性度量，您还有什么想说的吗？(例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。

36.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题]

____

37.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多项，请逐项写，详细描述，用“;”分隔。

37.Do you think there are additional flexibility measures that are relevant to analyze? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题]

____

第三部分 新增衡量供应链弹性的指标：

以下指标是基于第一轮问卷反馈的结果新增的，请给出您的同意程度。

Part III New added indicators to measure supply chain flexibility:

The following indicators are newly added based on the results of the first round of questionnaire feedback. Please indicate your level of agreement.

38.多技能员工

培养员工的多技能能力，使其可以在不同工位工作，支持灵活切换产线，产品。（制造领域）

38. Multi-skilled employees

- Cultivate employees' multi-skill capabilities so that they can work in different workstations and support flexible switching of production lines and products. (manufacturing field) [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

39.产线配置灵活性

有灵活的生产线配置，包括设备和机制来应对定制化、少量多样的需求，才能应对市场个性化、定制化的需求。（制造领域）

39. Production line configuration flexibility

- Only with flexible production line configuration, including equipment and mechanisms to cope with customized, small-volume and diverse needs, can we cope with the market's personalized and customized needs. (manufacturing field) [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

40.物料选型弹性

参与供应商产品演进的技术方向和路线； 关注同行的选材趋势； 分析供应链的特点，找出瓶颈并将其转化为通用解决方案。(产品开发领域)

40. Material selection flexibility

- Participate in the technical direction and route of supplier product evolution; pay attention to the material selection trends of peers; analyze the characteristics of the supply chain, identify bottlenecks and transform them into universal solutions. (Product development field) [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

41.物料归一化

开发产品时不同产品间尽可能使用共用物料。(产品开发领域)

41.Material normalization

- When developing products, use common materials between different products as much as possible. (Product development field) [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

42.产品功能可配置

让产品功能灵活可配置，通过不同配置的组合，满足业务中各种“意想不到”的需求。(产品开发领域）

42. Product functions are configurable

- Make product functions flexible and configurable, and meet various "unexpected" needs in the business through a combination of different configurations. (Product development field) [单选题] *

○非常不同意/Strongly Disagree

○不同意/Not Agree

○不确定/Not Sure

○同意/Agree

○非常同意/Strongly Agree

43.关于上面提到的灵活性度量，您还有什么想说的吗? (例如:措施不明确;这一指标可以用另一种方式更好地定义;其他评论) 如果没有，请填写“没有”。

43.Is there any additional comment you want to give related to flexibility measures presented above? If not, fill in "None"

(*e.g.*, the measure is not clear; this measure could be better defined in a different way; amongst other comments) [填空题]

____

44.你认为是否有额外的灵活性措施与分析相关?如果没有，填写“没有”;如果有多

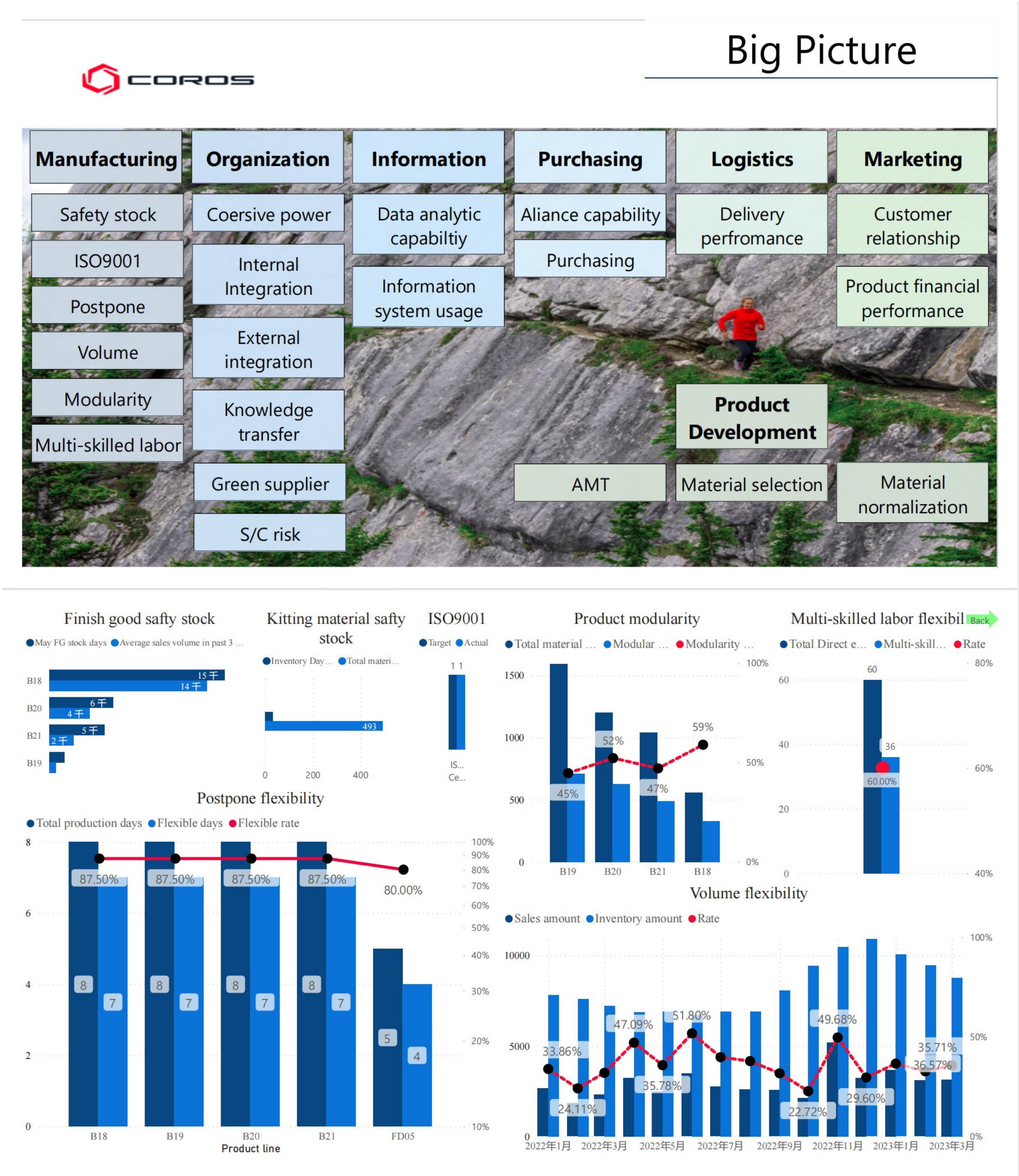
项，请逐项写，详细描述，用“;”分隔。

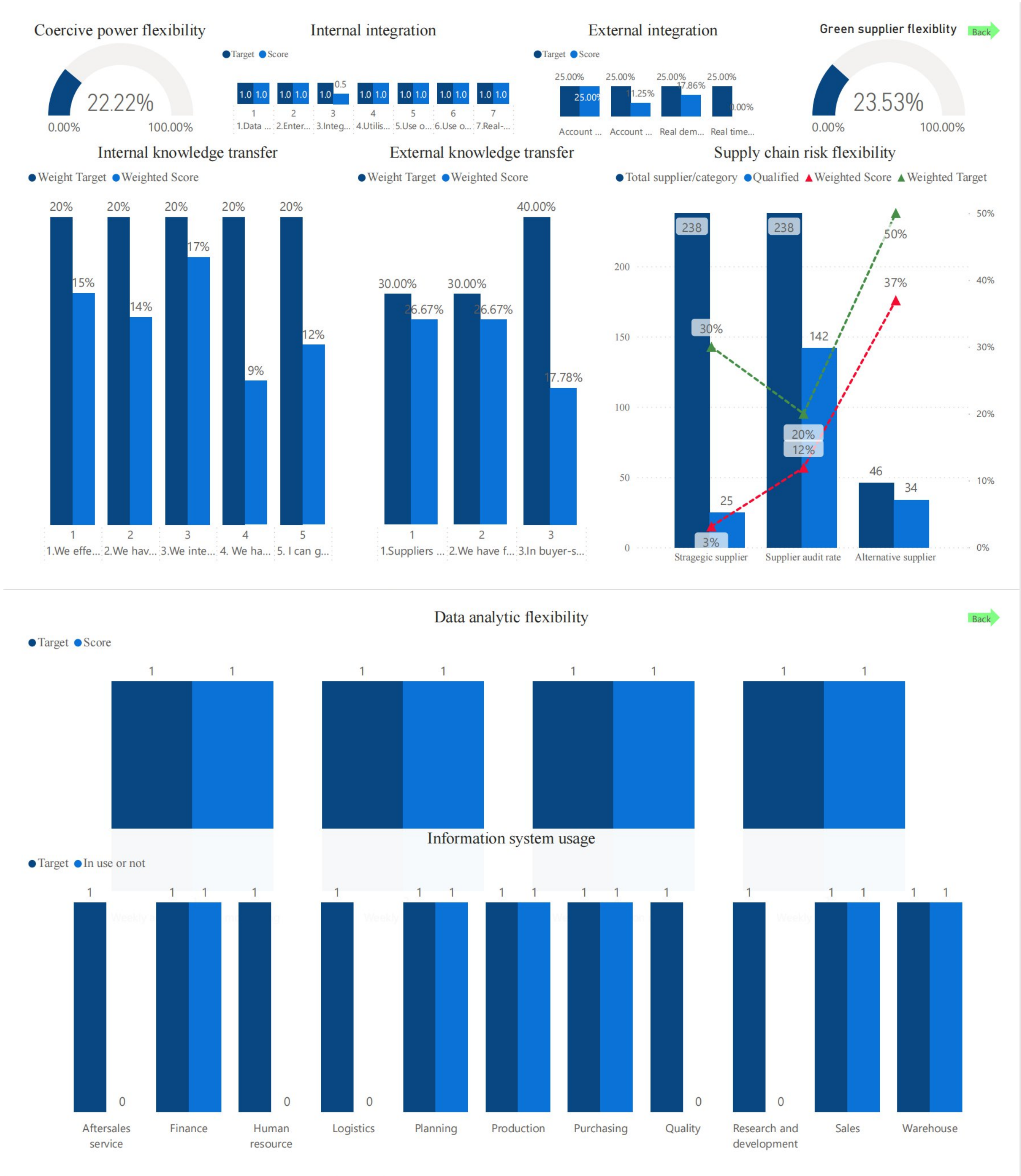
44.Do you think there are additional flexibility measures that are relevant to analyze? If not, fill in "None"; if there are multiple items, write it one by one, describing it in detail, separated by “;”. [填空题]

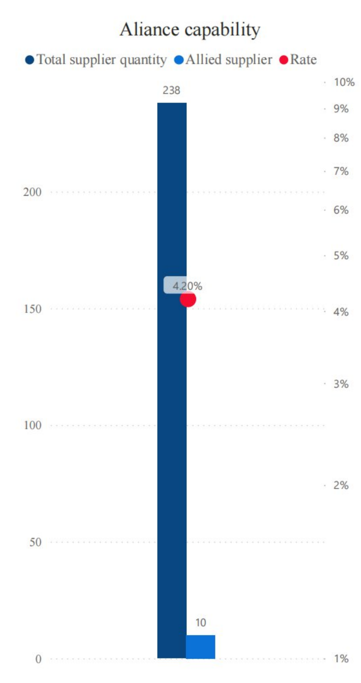
____

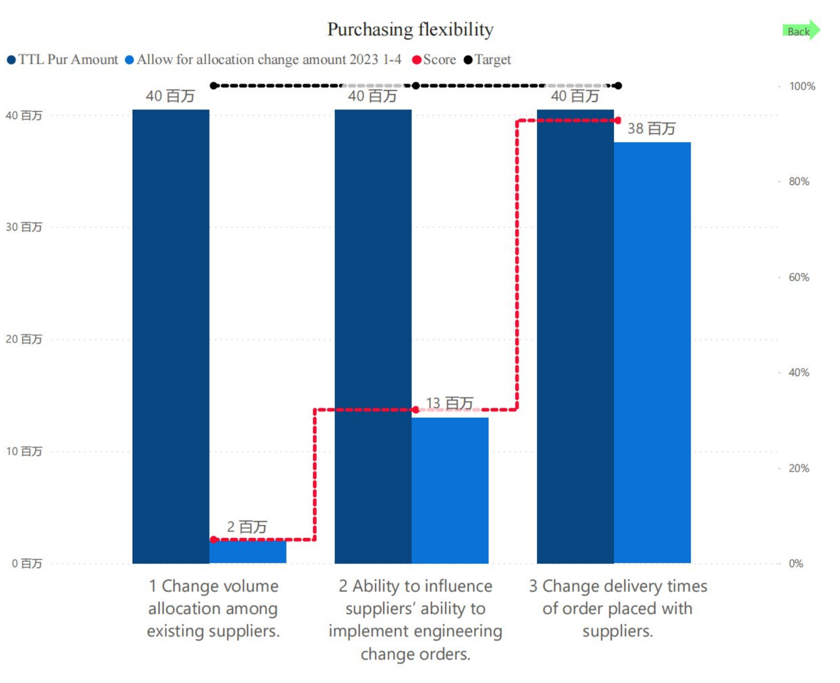
Annex G: COROS SC flexibility dashboard version 1

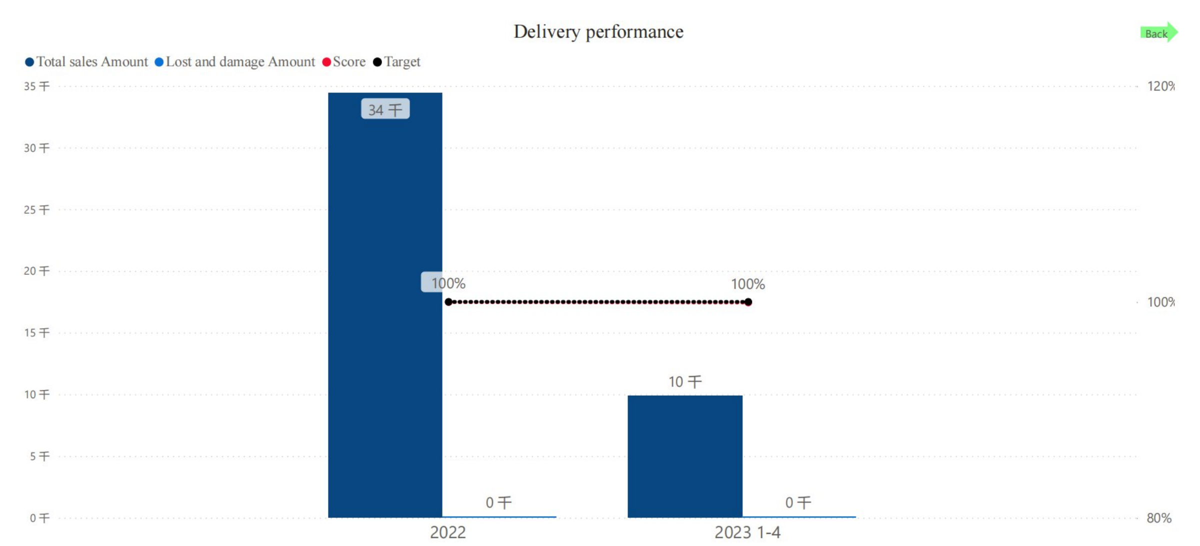
COROS SC Flexibility Dashboard 20230708



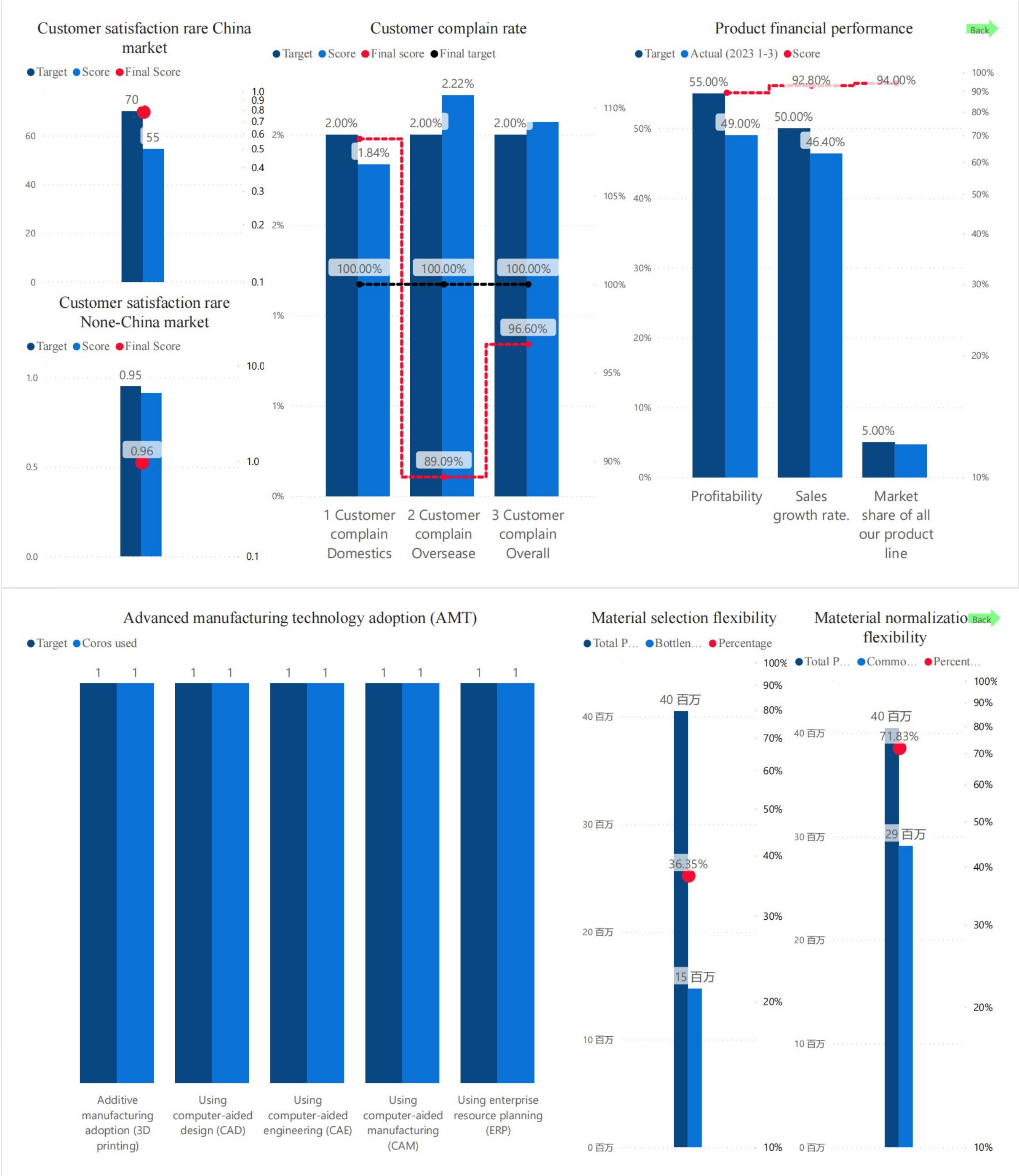

Coercive power flexibility
22.22%
0.00%
100.00%
Internal integration
Target Score
1.Data ...
2.Enter...
3.Integ...
4.Utilis...
5.Use o...
6.Use o...
7.Real-...
External integration
Target Score
Account ...
Account ...
Real dem...
Real time...
Green supplier flexiblity
Back
23.53%
0.00%
100.00%
Internal knowledge transfer
Weight Target Weighted Score
1.We effe...
2.We hav...
3.We inte...
4. We ha...
5. I can g...
External knowledge transfer
Weight Target Weighted Score
1.Suppliers ...
2.We have f...
3.In buyer-s...
Supply chain risk flexibility
Total supplier/category Qualified Weighted Score Weighted Target
Stragegic supplier
Supplier audit rate
Alternative supplier
Data analytic flexibility
Back
Target Score
Information system usage
Target In use or not
Aftersales service
Finance
Human resource
Logistics
Planning
Production
Purchasing
Quality
Research and development
Sales
Warehouse







Year	Total sales Amount	Lost and damage Amount	Score	Target
2022	34440	9.31	99.97%	100.00%
2023 1-4	9895	6.29	99.94%	100.00%
总计	**44335**	**15.61**	**199.91%**	**200.00%**


Customer satisfaction rare China market
Target Score Final Score
70
55
Customer satisfaction rare None-China market
Target Score Final Score
0.95
0.96
Customer complain rate
Target Score Final score Final target
2.22%
2.00%
2.00%
2.00%
1.84%
100.00%
100.00%
100.00%
96.60%
89.09%
1 Customer complain Domestics
2 Customer complain Oversease
3 Customer complain Overall
Product financial performance
Back
Target Actual (2023 1-3) Score
55.00%
92.80%
94.00%
49.00%
50.00%
46.40%
5.00%
Profitability
Sales growth rate.
Market share of all our product line
Advanced manufacturing technology adoption (AMT)
Target Coros used
Additive manufacturing adoption (3D printing)
Using computer-aided design (CAD)
Using computer-aided engineering (CAE)
Using computer-aided manufacturing (CAM)
Using enterprise resource planning (ERP)
Material selection flexibility
Total P... Bottlen... Percentage
40 百万
36.35%
15 百万
Mateterial normalizatio flexibility
Back
Total P... Commo... Percent...
40 百万
71.83%
29 百万

Safety stock - Finish goods :

Finish good stock in factory/past 3 monthly average sales quantity, Target is 100%..

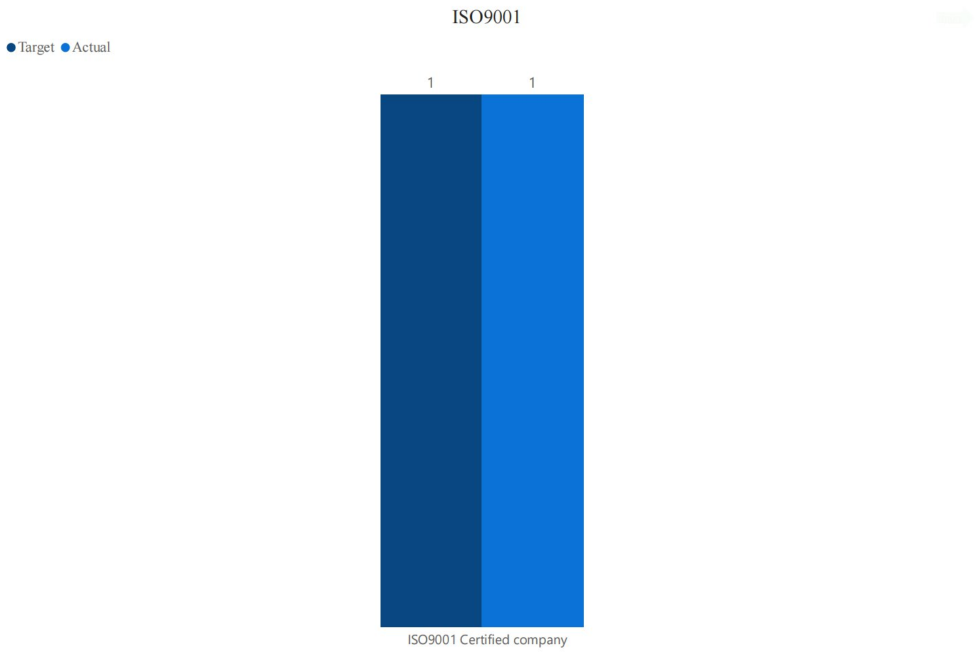
Safety stock - Kitting material:

Actual raw material items which stock days rang from 10-15days/total requested raw material items which stock days from 10-15 days.

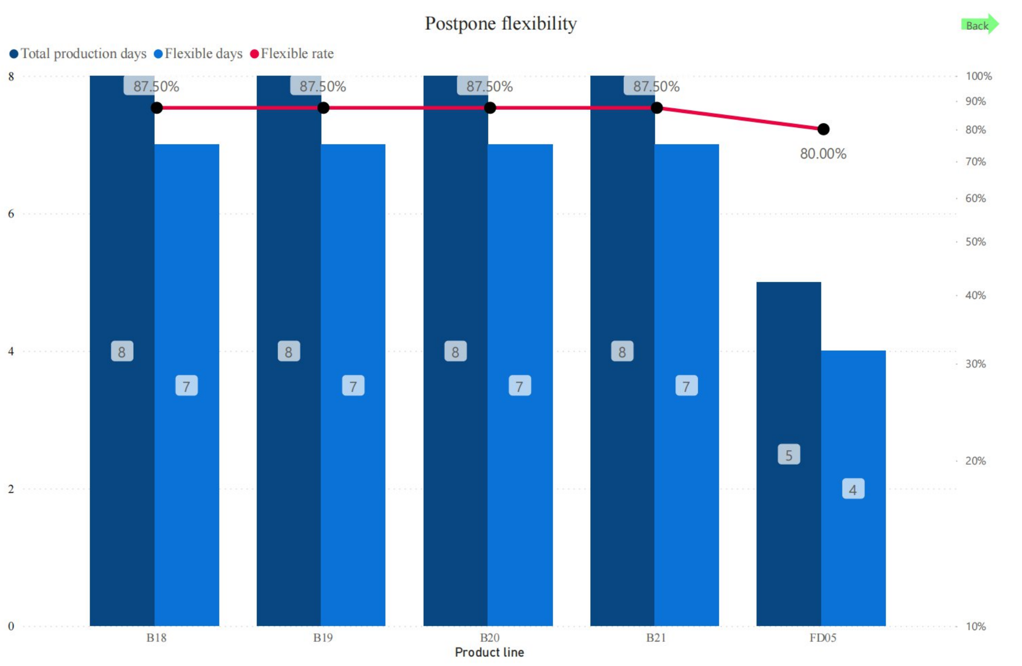
Kitting material rate target is 100%.

ISO9001 :

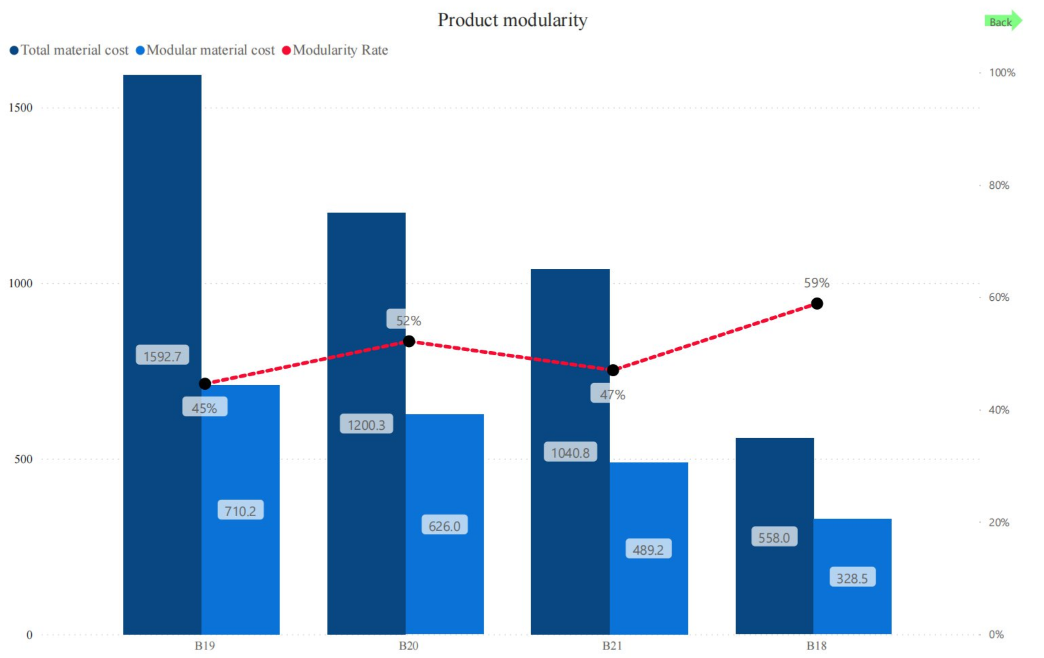
Company had been certified or not.

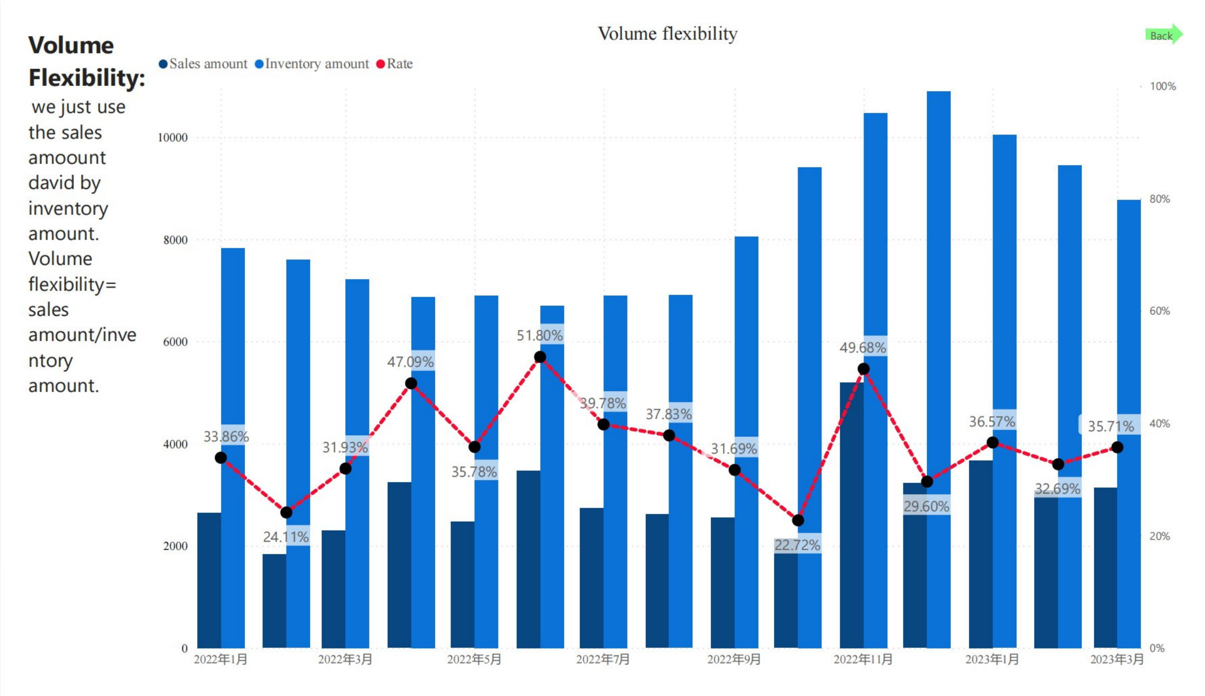


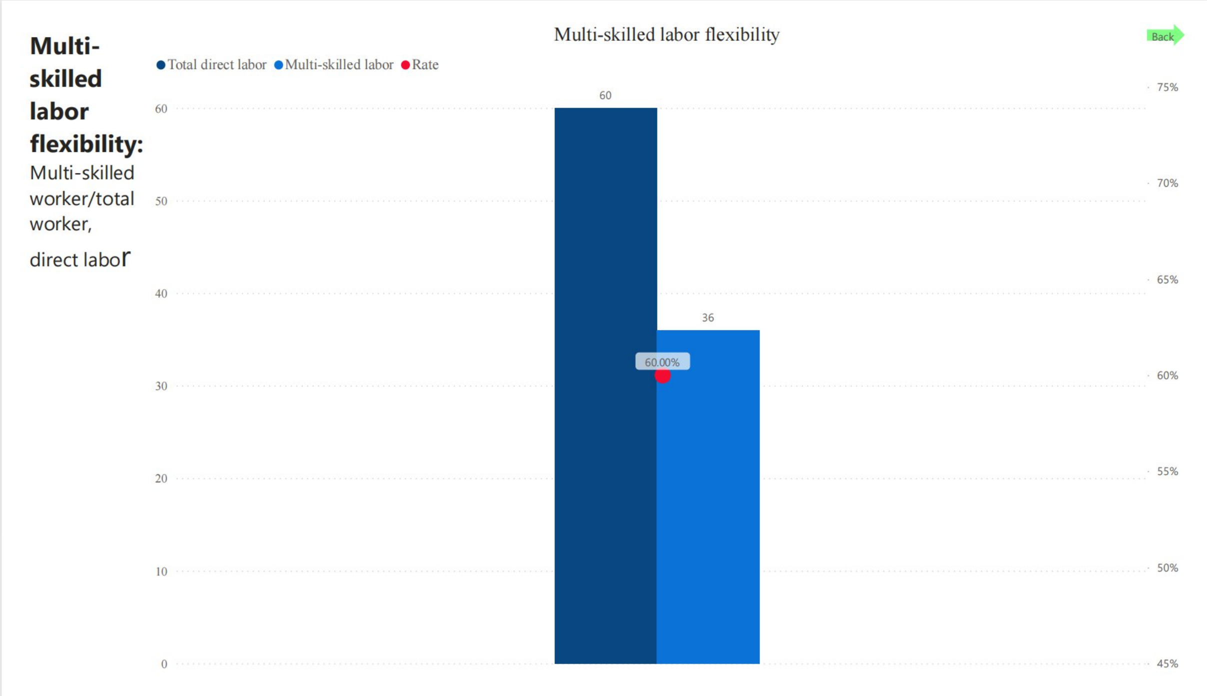
Postpone flexibility: Capability of keeping products in their generic form as long as possible, in order to incorporate the customer's product requirements in later stages.

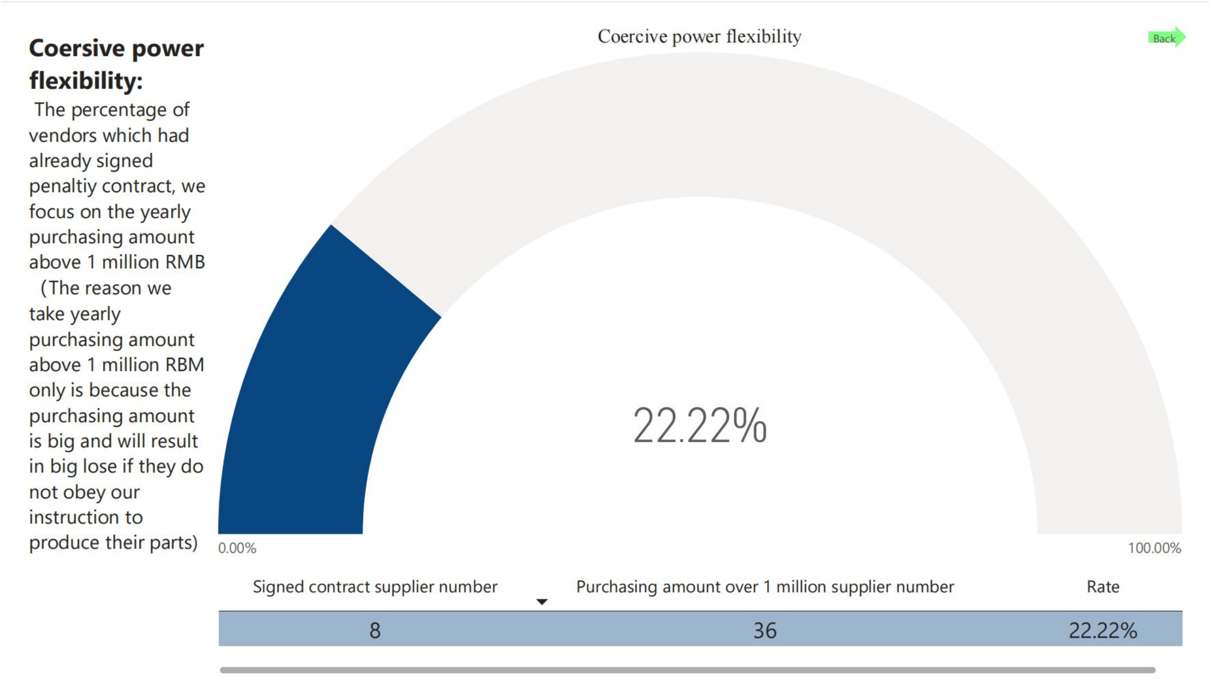


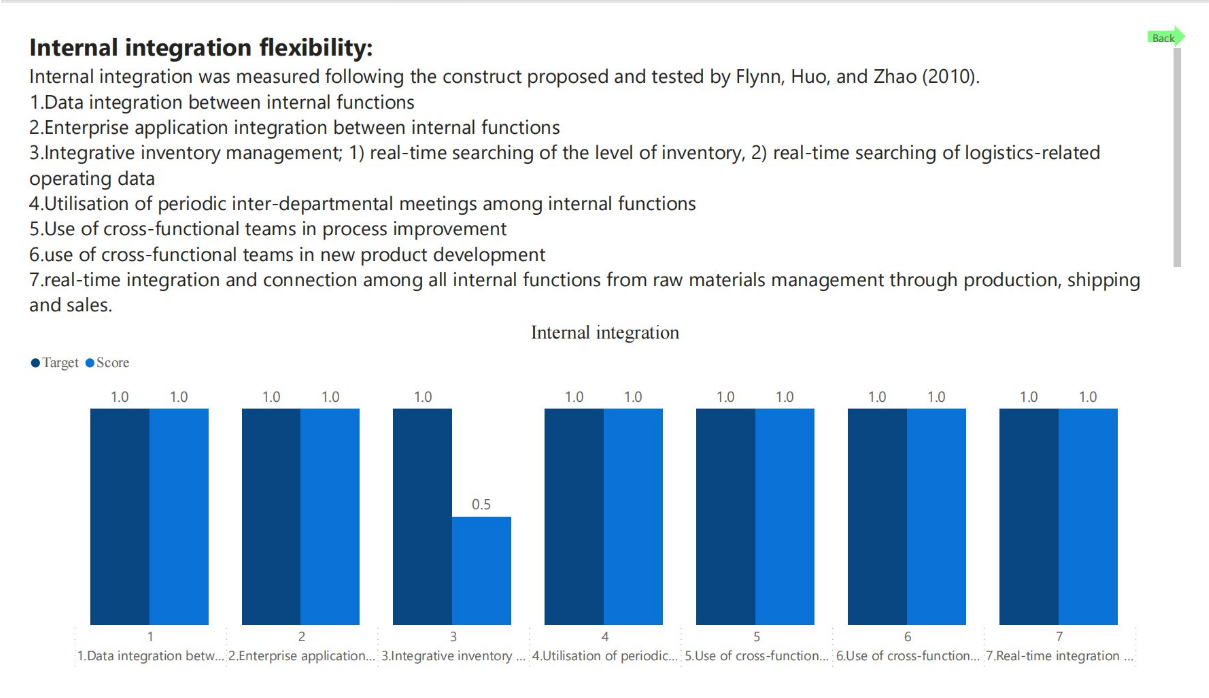
Product modularity: The ratio between total modular components cost and total product bill of material cost.




Volume Flexibility:
we just use the sales amoount david by inventory amount. Volume flexibility= sales amount/inventory amount.
Volume flexibility
Back
Sales amount
Inventory amount
Rate
0
2000
4000
6000
8000
10000
0%
20%
40%
60%
80%
100%
33.86%
24.11%
31.93%
47.09%
35.78%
51.80%
39.78%
37.83%
31.69%
22.72%
49.68%
29.60%
36.57%
32.69%
35.71%
2022年1月
2022年3月
2022年5月
2022年7月
2022年9月
2022年11月
2023年1月
2023年3月

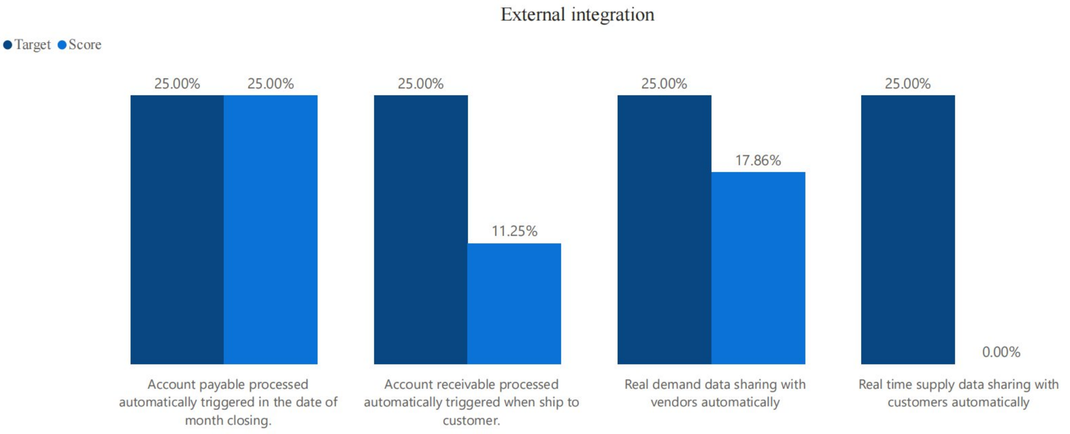

Multi-skilled labor flexibility:
Multi-skilled worker/total worker,
direct labor
Multi-skilled labor flexibility
Back
Total direct labor
Multi-skilled labor
Rate
0
10
20
30
40
50
60
45%
50%
55%
60%
65%
70%
75%
60
36
60.00%


Coersive power flexibility:
The percentage of vendors which had already signed penaltiy contract, we focus on the yearly purchasing amount above 1 million RMB (The reason we take yearly purchasing amount above 1 million RBM only is because the purchasing amount is big and will result in big lose if they do not obey our instruction to produce their parts)
Coercive power flexibility
Back
22.22%
0.00%
100.00%
Signed contract supplier number
Purchasing amount over 1 million supplier number
Rate
8
36
22.22%


Internal integration flexibility:
Internal integration was measured following the construct proposed and tested by Flynn, Huo, and Zhao (2010).
1.Data integration between internal functions
2.Enterprise application integration between internal functions
3.Integrative inventory management; 1) real-time searching of the level of inventory, 2) real-time searching of logistics-related operating data
4.Utilisation of periodic inter-departmental meetings among internal functions
5.Use of cross-functional teams in process improvement
6.use of cross-functional teams in new product development
7.real-time integration and connection among all internal functions from raw materials management through production, shipping and sales.
Back
Internal integration
Target
Score
1.0
0.5
1
2
3
4
5
6
7
1.Data integration betw...
2.Enterprise application...
3.Integrative inventory ...
4.Utilisation of periodic...
5.Use of cross-function...
6.Use of cross-function...
7.Real-time integration ...

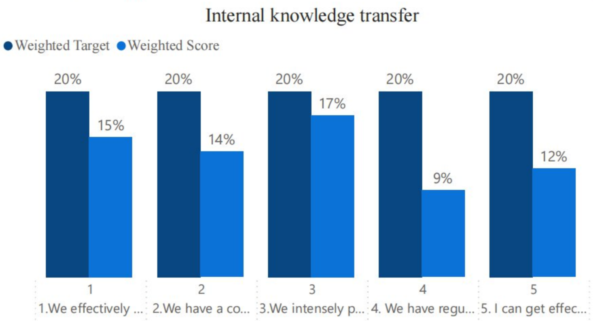
External integration flexibility:

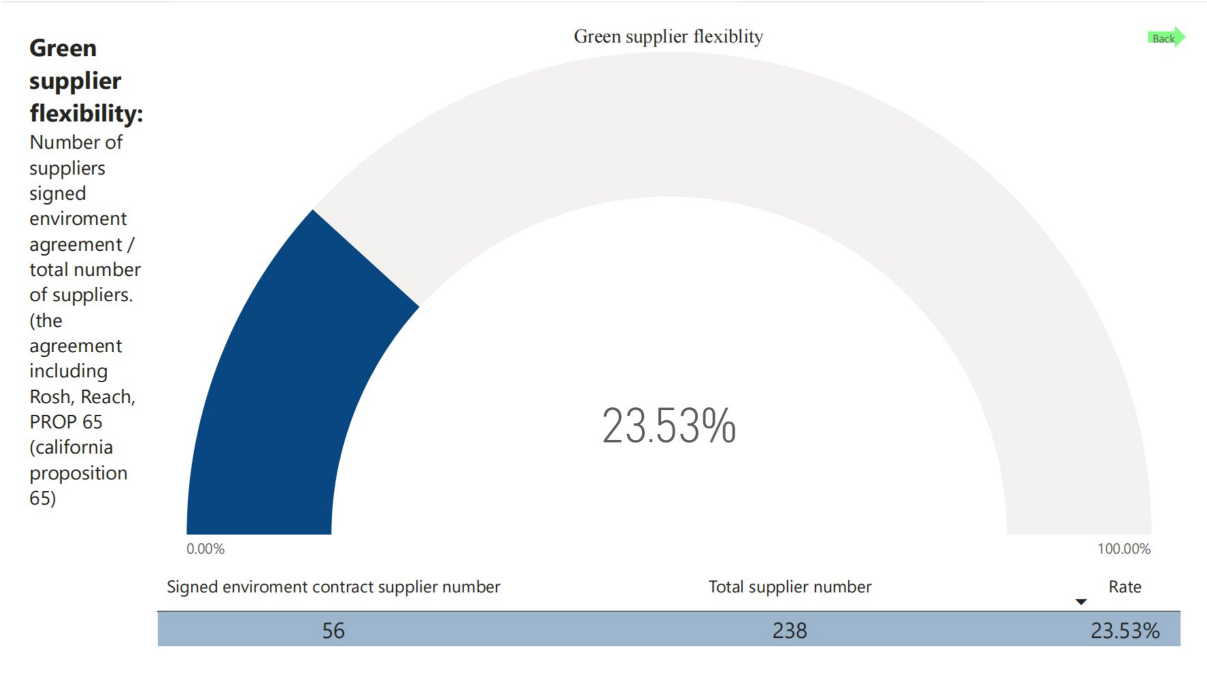
We measure external integration by considering from 2 aspect: Financial flow integration and Information flow integration:
Fiancial flow integration:
A. Account receivable processed automatically triggered when ship to customer.
B. Account payable processed automatically triggered in the date of month closing.
Information flow integration:
A. Real time supply data sharing with customers automatically
B. Real demand data sharing with vendors automatically

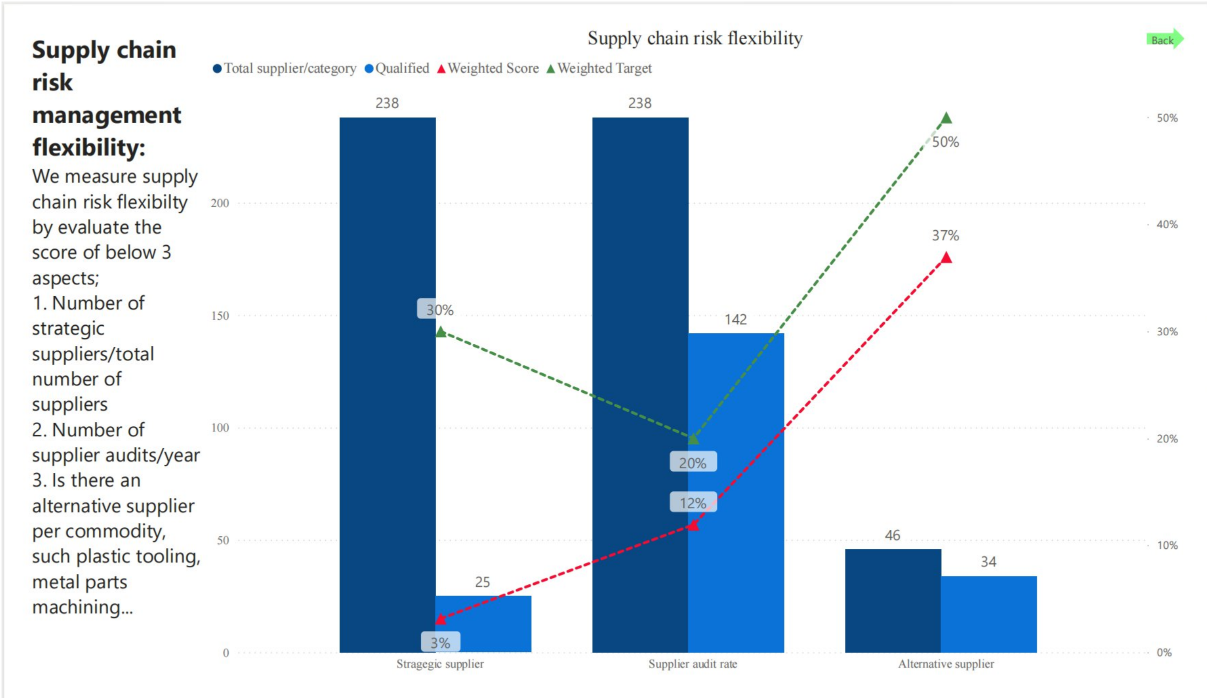


knowledge transfer:

We measure botht internal and external knowledge transfer, while internal knowledge transfer by evaluate the score of below 5 quesitons.
1.We effectively exchange information with relevant departments (I1).
2.We have a common understanding with other departments of the importance of existing information (I2).
3.We intensely pursue cross-functional development of new products (I3).
4. We have regular best case sharing or sharing of relevant professional knowledge (I4).
5. I can get effective training on the content of my work (I5).
We measure external knowledge transfer by evaluate the score of below 3 quesitons;
1.Suppliers are able to share their expertise in new technology with us (I6).
2.We have frequently meetings with suppliers to develop new knowledge (I7).
3.In buyer-supplier relationship we convert technical know-how of suprs into our new products and processes (I8).



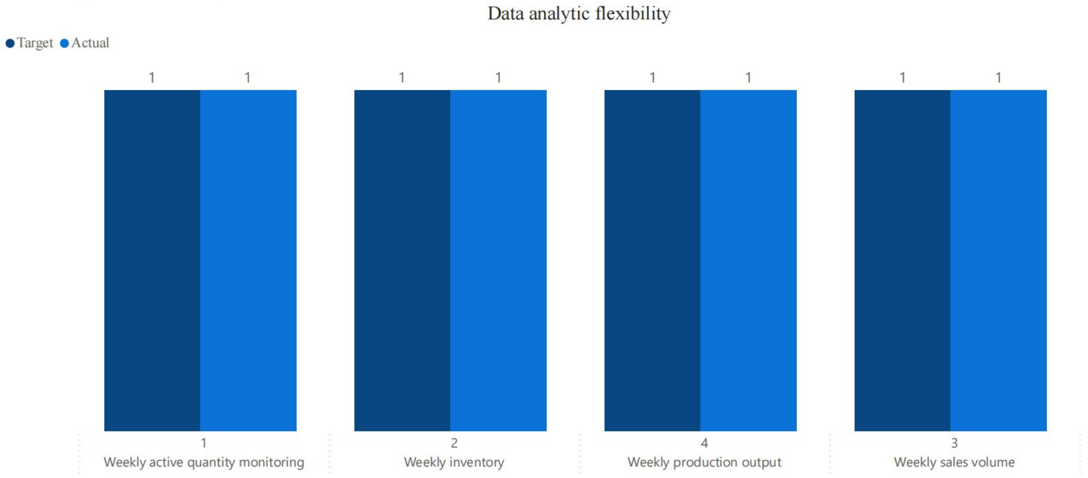

Green supplier flexibility:
Number of suppliers signed enviroment agreement / total number of suppliers. (the agreement including Rosh, Reach, PROP 65 (california proposition 65)
Green supplier flexiblity
Back
23.53%
0.00%
100.00%
Signed enviroment contract supplier number
Total supplier number
Rate
56
238
23.53%


Supply chain risk management flexibility:
We measure supply chain risk flexibilty by evaluate the score of below 3 aspects;
1. Number of strategic suppliers/total number of suppliers
2. Number of supplier audits/year
3. Is there an alternative supplier per commodity, such plastic tooling, metal parts machining...
Supply chain risk flexibility
Back
Total supplier/category
Qualified
Weighted Score
Weighted Target
238
238
142
46
34
25
30%
20%
12%
3%
50%
37%
0
50
100
150
200
0%
10%
20%
30%
40%
50%
Stragegic supplier
Supplier audit rate
Alternative supplier

Data analytics flexibility:

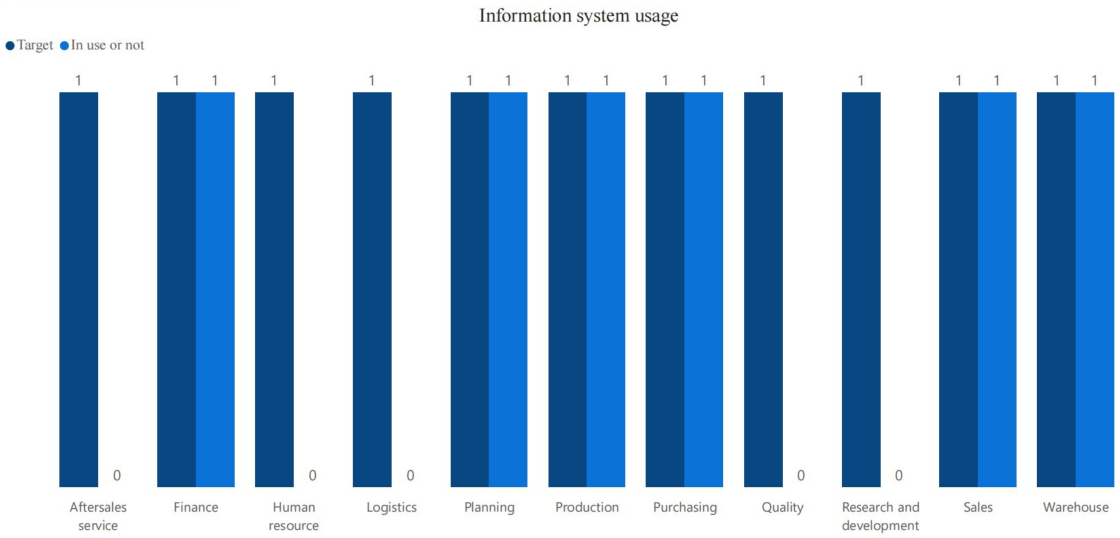
Data analytic flexibiliy was measured by evaluate below 4 aspects;

1. Weekly active quantity monitoring.
2. Weekly inventory
3. Weekly sales volume
4. Weekly production output

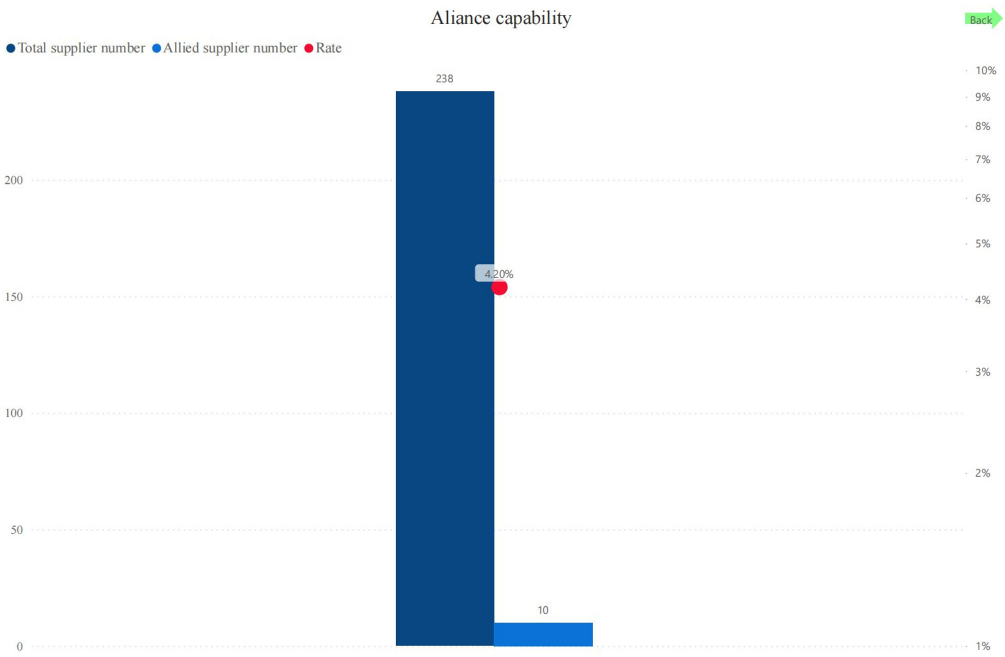


Information system usage flexibility:

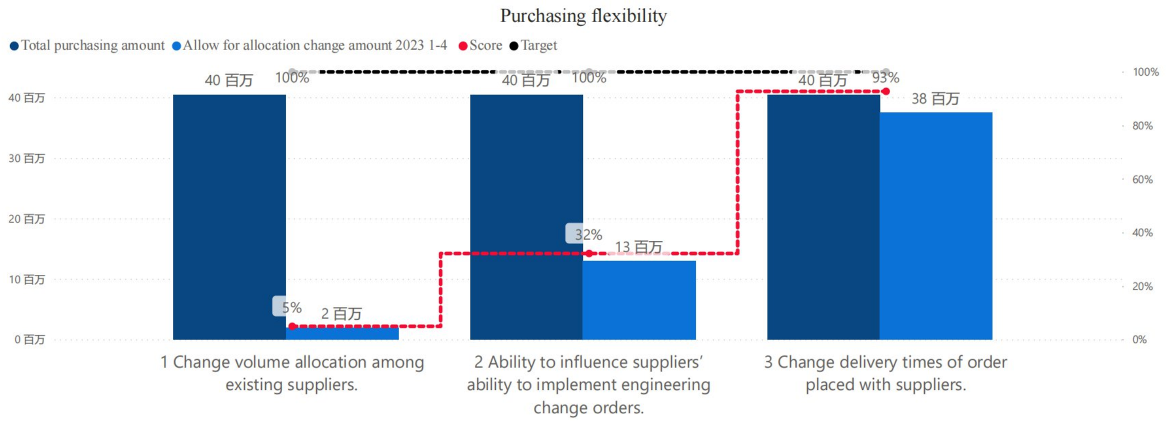
Information system usage flexibility was measured by evaluating the coverage rate of system to below function department; Sales,Planning, Purchasing, Production, Logistics, Warehouse, Quality, Finance, Research and development, After sales service, Human resource, total 11 functions.



Aliance capability flexibility:
We measure the alliance capability by the number of supplier which will prioritize our order production when their capcity is limited, or to do the investment to support our demand increase, joint development for new device / total number of vendors.



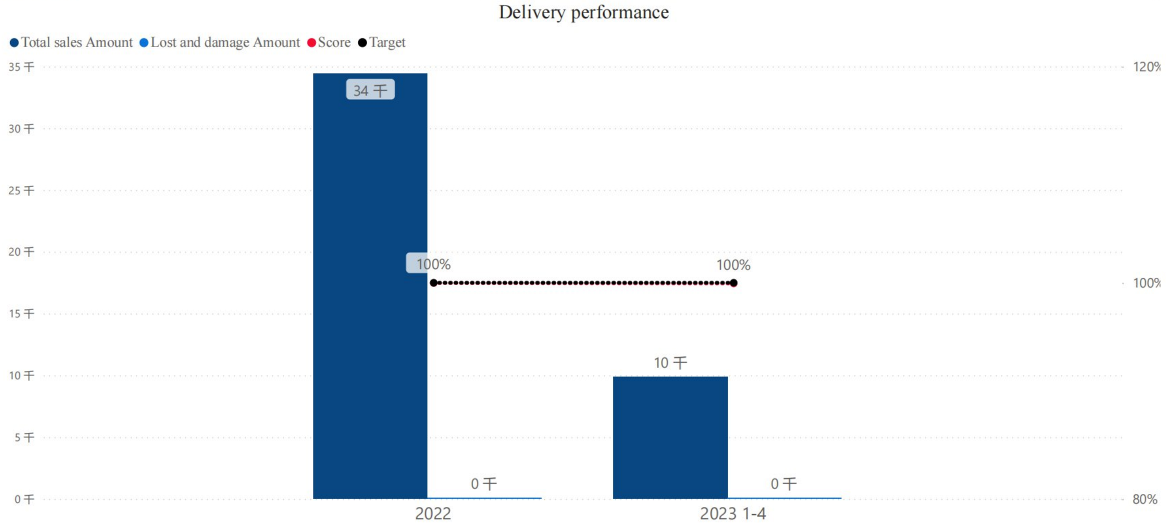
Purchasing flexibility:
We measure external purchasing flexibility by evaluate the score of below 3 quesitons;
Change volume allocation among existing suppliers.
X= purchasing amount of parts which could allow for allocation change/total purchasing amount.
Ability to influence suppliers to implement engineering change orders.
X= Amount of material purchased which could allow to do engineering changes/amount of material purchased in total quarterly.
Change delivery times of order placed with suppliers.
X= X= purchasing amount which could allow schedule change/ total purchasing amount.



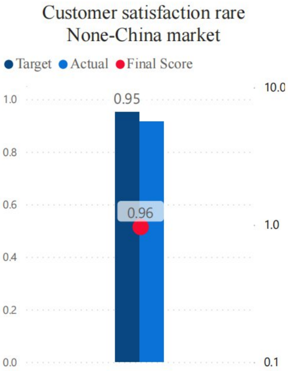
Delivery performance:
We measure delivery performance by measure amount of delivery lost and damage / Total sales amount

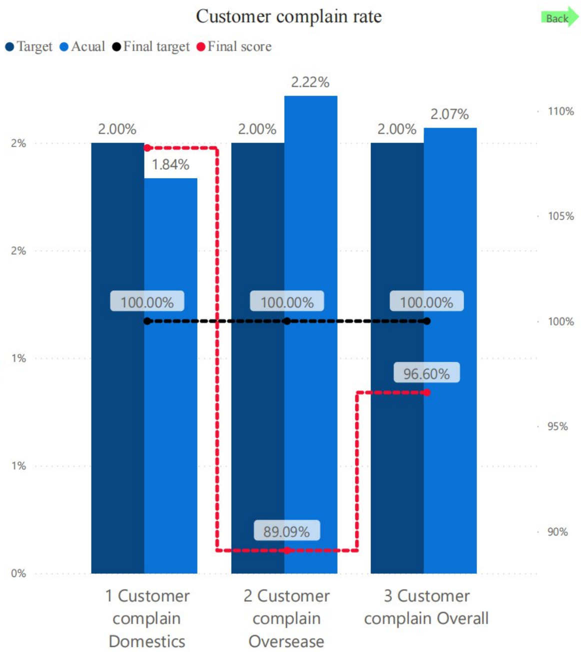
Year	Total sales Amount	Lost and damage Amount	Score	Target
2022	34440	9.31	99.97%	100.00%
2023 1-4	9895	6.29	99.94%	100.00%
总计	**44335**	**15.61**	**199.91%**	**200.00%**

Back



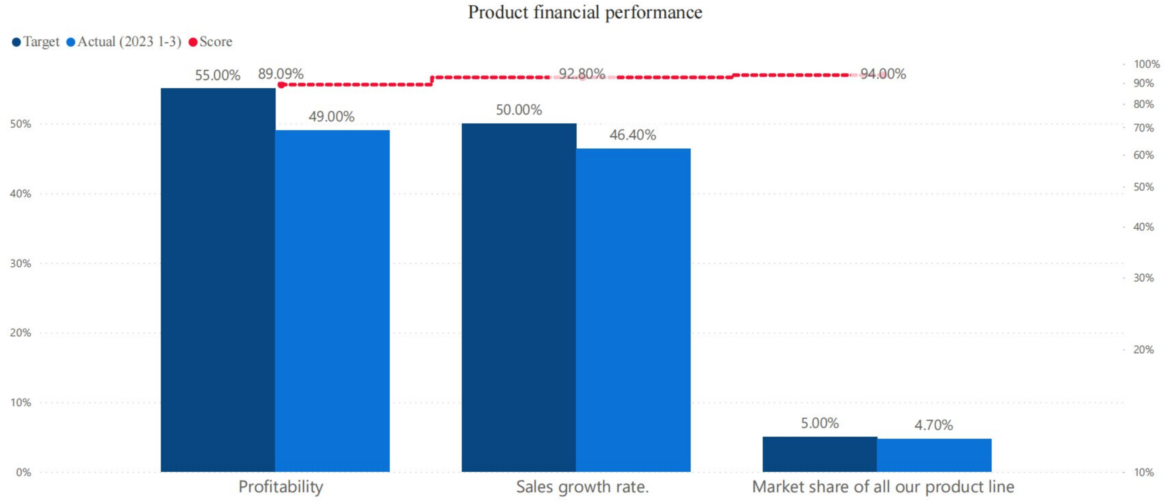
Customer relationship flexibility:
We measure customer relationship flexibilty by evaluate the score of customer complain rate and customer satisfaction rate;
Customer complain rate = total complain number / total sales volume, target is 2%
Customer satifaction rate China market use NPS - net promotion score to measure.
Customer satifaction rate Non-China market use cumtomer satifaction rate to measure = Number of satified customer / total sales quanitty.





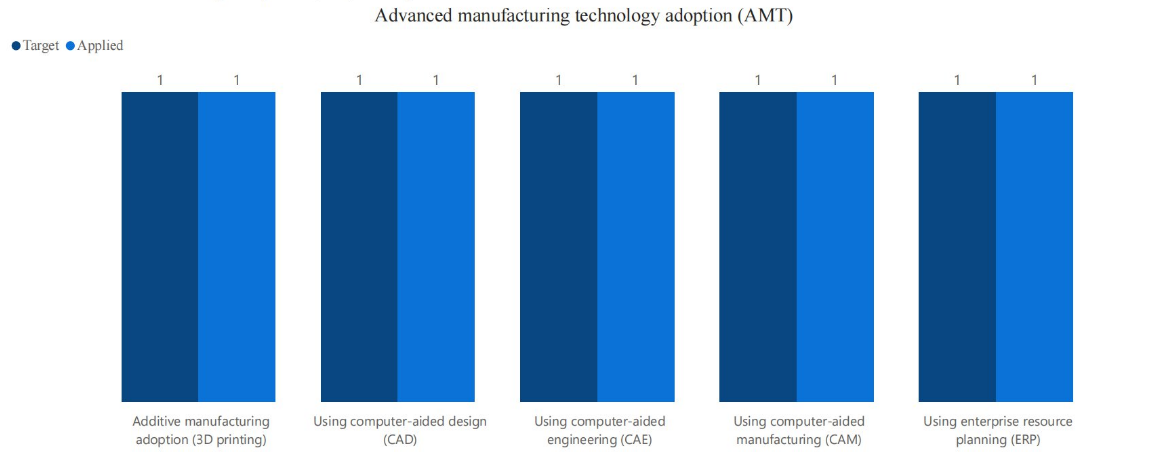
Product financial performance:

We measure customer relationship flexibilty by evaluate the score of customer complain rate and customer satisfaction rate;
Profitability - use gross profit rate to measure.
Sales growth rate = sales volume increase rate year on year.
Market share = Estimated use percentage among big marathone competition.

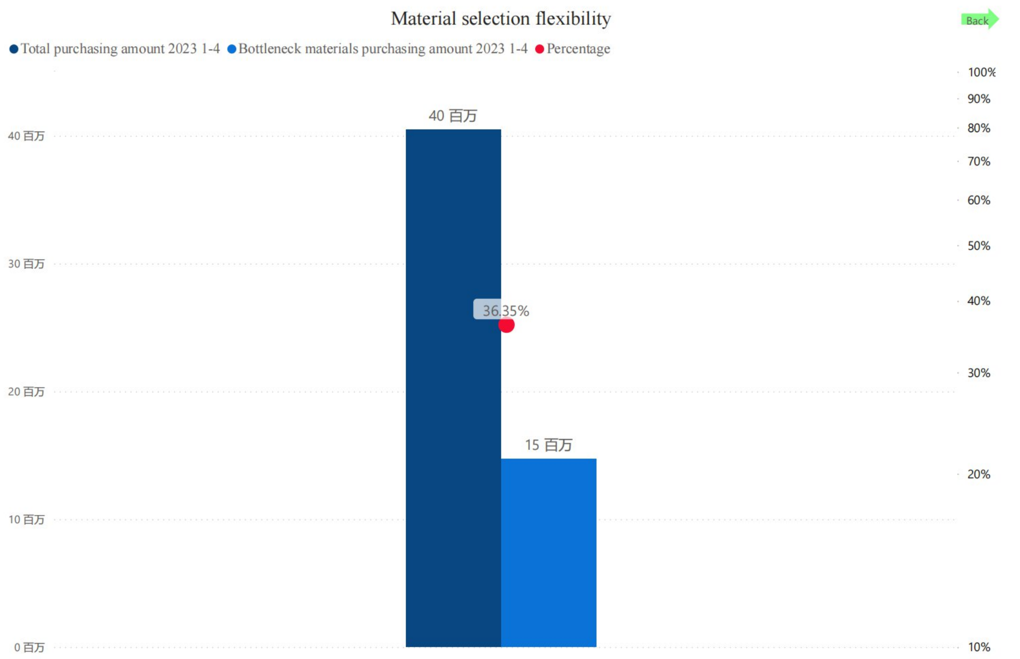


Advanced manufacturing technology adoption:

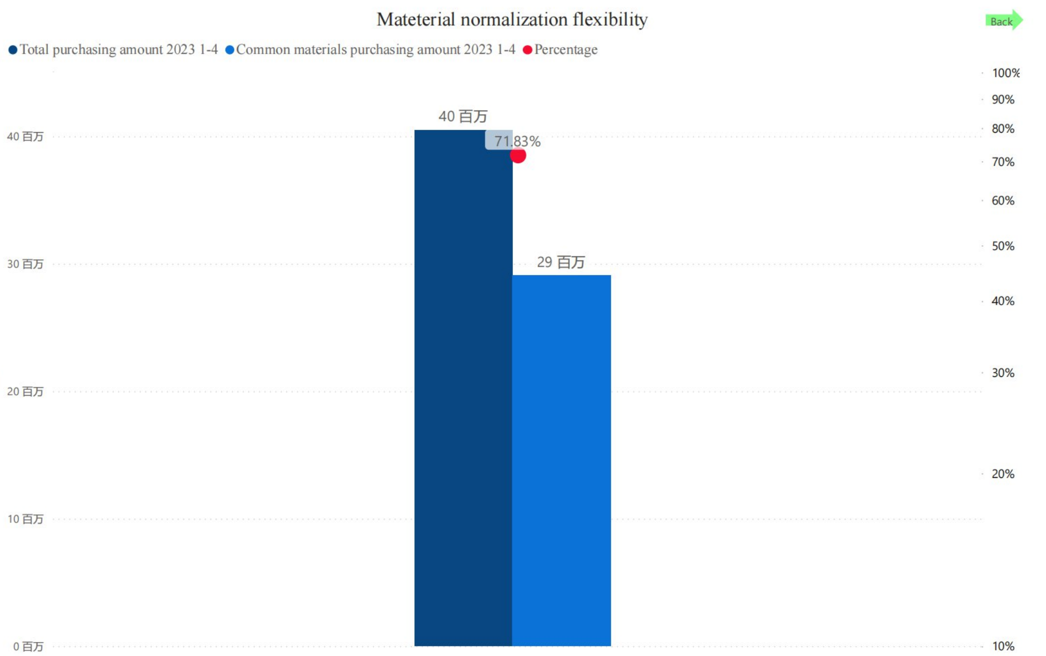
Advanced manufacturing technology adoption was evaluated to see if below technology had adopted or not;
1.Using computer-aided design (CAD)
2.Using computer-aided manufacturing (CAM)
3.Using computer-aided engineering (CAE)
4.Using enterprise resource planning (ERP)
5.Additive manufacturing adoption (3D printing



Material selection flexibility: We measure material selection flexibilty by evaluate the score of customer complain rate and customer satisfaction rate; Bottleneck materials purchasing amount/total material purchasing amount. Bottleneck material is we could replace the material within 6 months.



Material normalization flexibility: We measure material normalization flexibility by evaluation the normalization rate; Rate = common material purchasing amount / total material purchasing amount.



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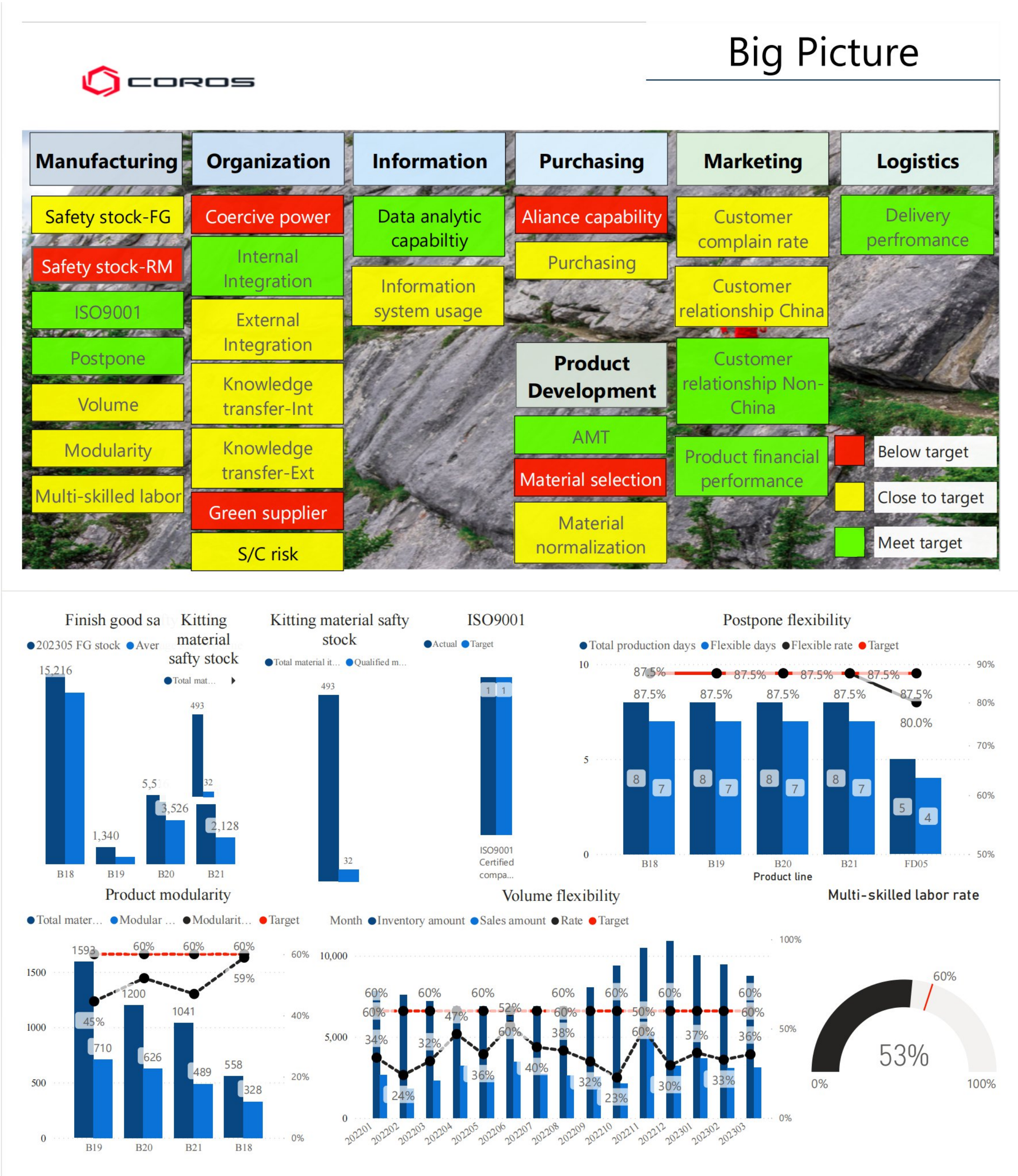
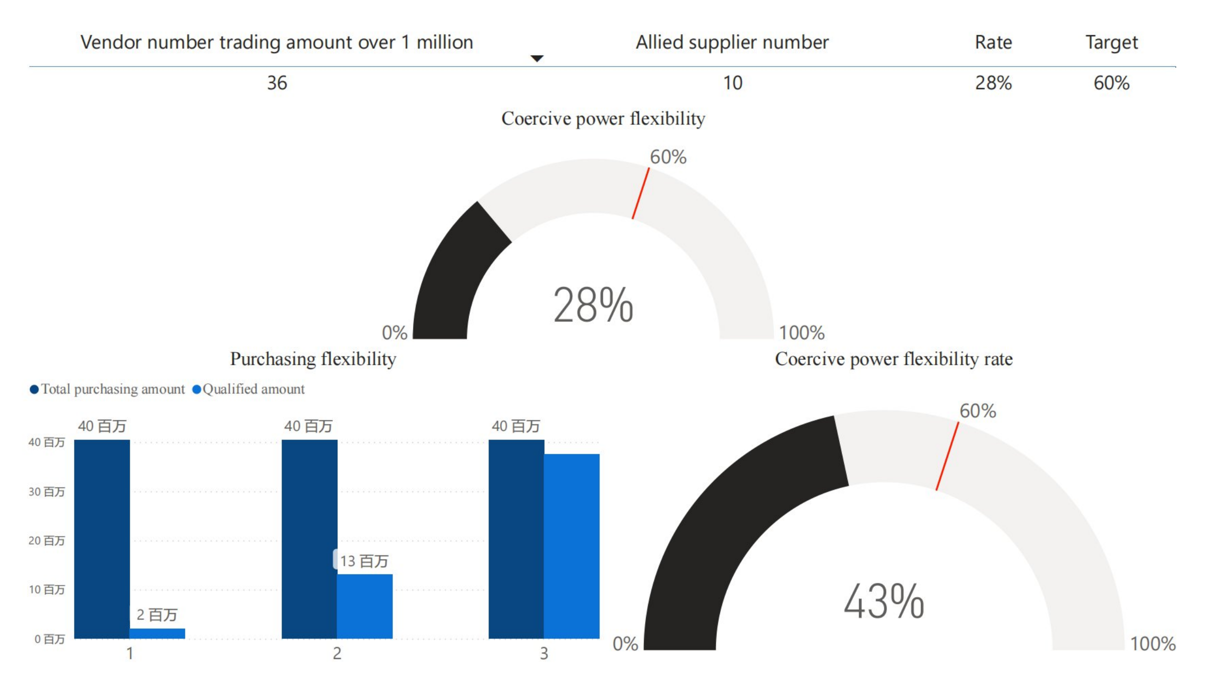
Annex H: COROS SC flexibility dashboard final version

COROS SC Flexibility Dashboard 20231106

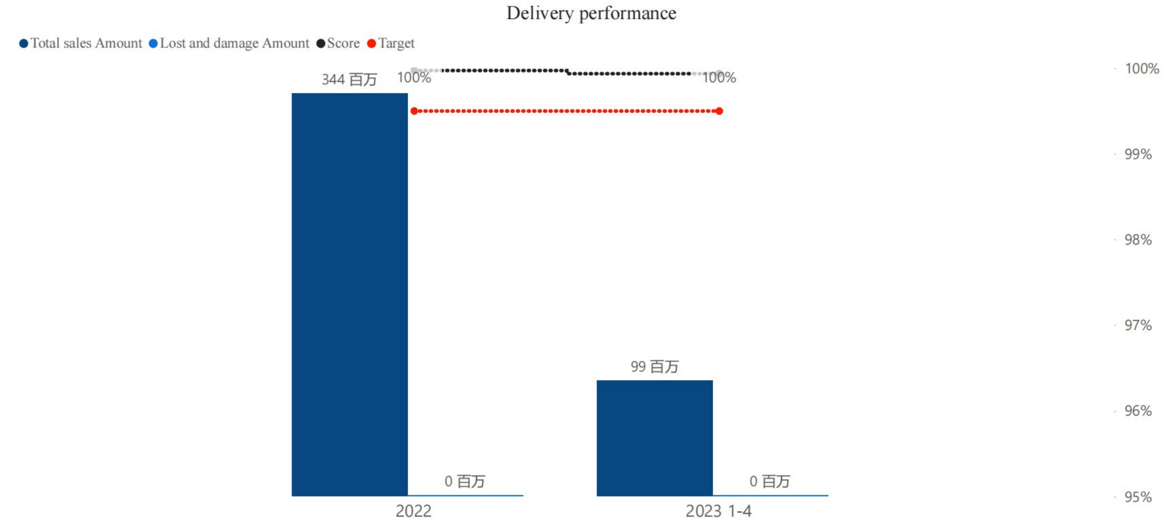


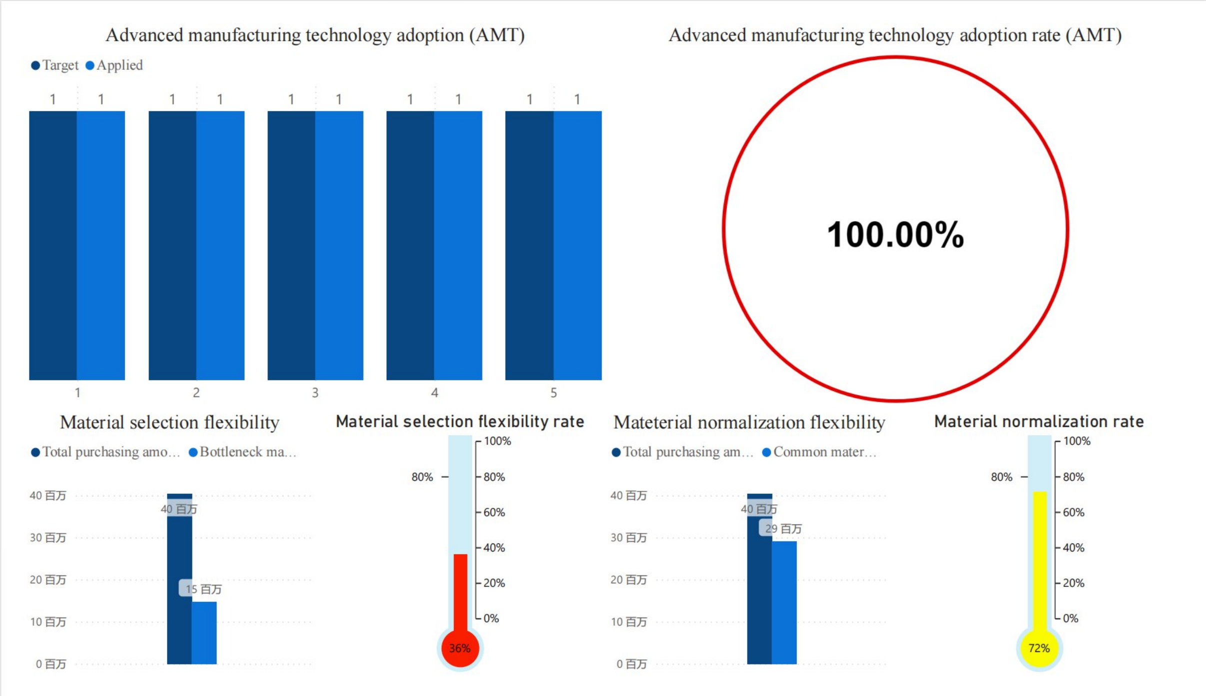

Coercive power flexibility
22%
0%
60%
100%
Internal integration
Target Score
External integration
Target Score
100% 45%
100% 100%
100%
0%
100% 71%
Green supplier flexiblity
24%
0%
60%
100%
Knowledge transfer-Internal
Target Score
100% 75%
100% 68%
100% 87%
100% 47%
100% 58%
Knowledge transfer-external
Target Score
100.00% 88.89%
100.00% 88.89%
100.00% 44.44%
Supply chain risk flexibility
Total supplier/category Qualified Score Target
238
238
142
46
34
25
60%
60%
60%
11%
74%
Strategic supplier
Supplier audit rate
Alternative supplier
Internal integration
Target Score
Rate
100.00%
Information system usage
In use or not
Finance
Human resource
Planning
Production
Purchasing
Sales
Warehouse
Aftersales service
Logistics
Quality
Research and development
Information system usage rate
80%
64%


Vendor number trading amount over 1 million
Allied supplier number
Rate
Target
36
10
28%
60%
Coercive power flexibility
60%
28%
0%
100%
Purchasing flexibility
Total purchasing amount
Qualified amount
40 百万
30 百万
20 百万
10 百万
0 百万
2 百万
13 百万
1
2
3
Coercive power flexibility rate
60%
43%
0%
100%


Customer complain rate
Target
Acual
2%
1%
0%
2.00%
1.84%
2.22%
1 Customer complain Domes...
2 Customer complain Overse...
Customer satisfaction rate None-China market
91.40%
95.00%
0.00%
100.00%
Customer satisfaction rate China market
Target
Actual
70
55
60
40
20
Product financial performance
Actual (2023 1-3)
60%
40%
20%
0%
55.00%
49.00%
50.00%
46.40%
5.00%
4.70%
Profitability
Sales growth rate.
Market share of all our product line

Year	Total sales Amount	Lost and damage Amount	Score	Target
2022	344,400,000	93,120	99.97%	99.50%
2023 1-4	98,950,000	62,940	99.94%	99.50%
总计	**443,350,000**	**156,060**	**99.95%**	**99.50%**

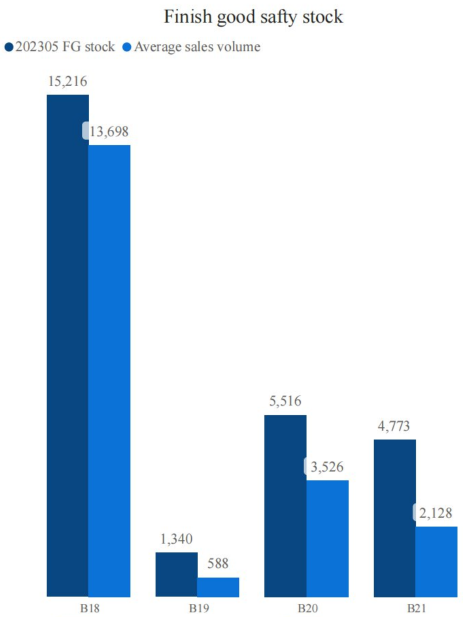


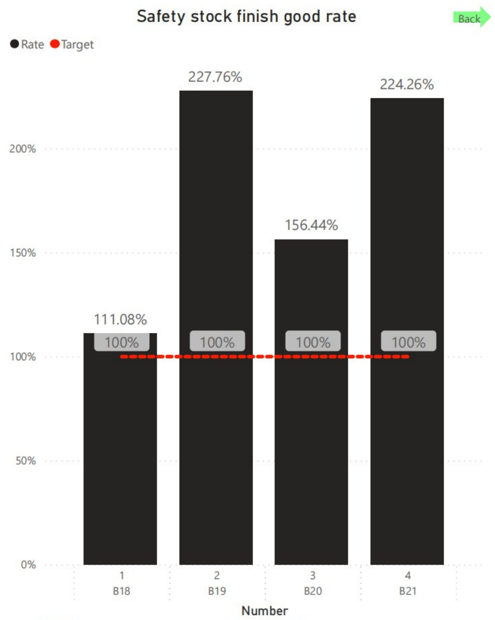


Safety stock -Finish good :

Formula:
Finish good stock in factory/ average sales quantity in past 3 monthes.

Target is 100%
The weighted rate is 134%,



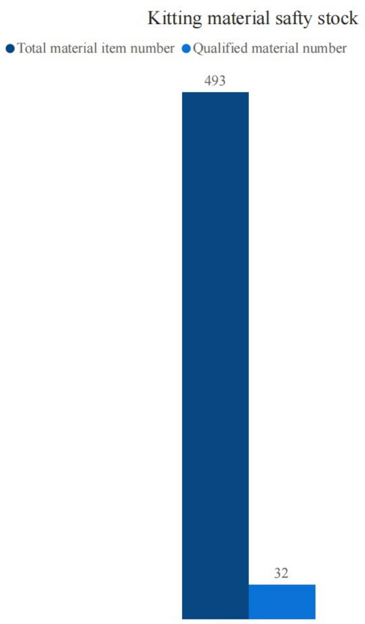


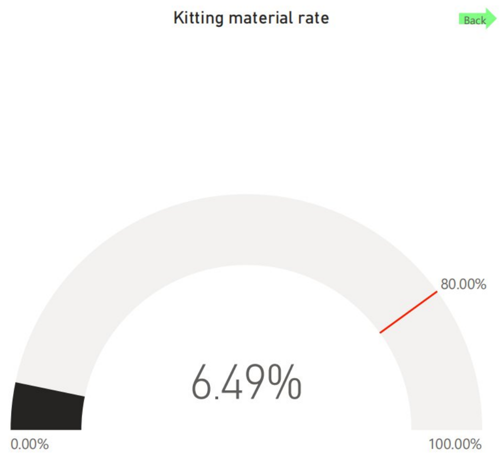
[0%,50%) [50%,80%) [80%,120%) [120%,150%) [150%

Safety stock - Kitting material:

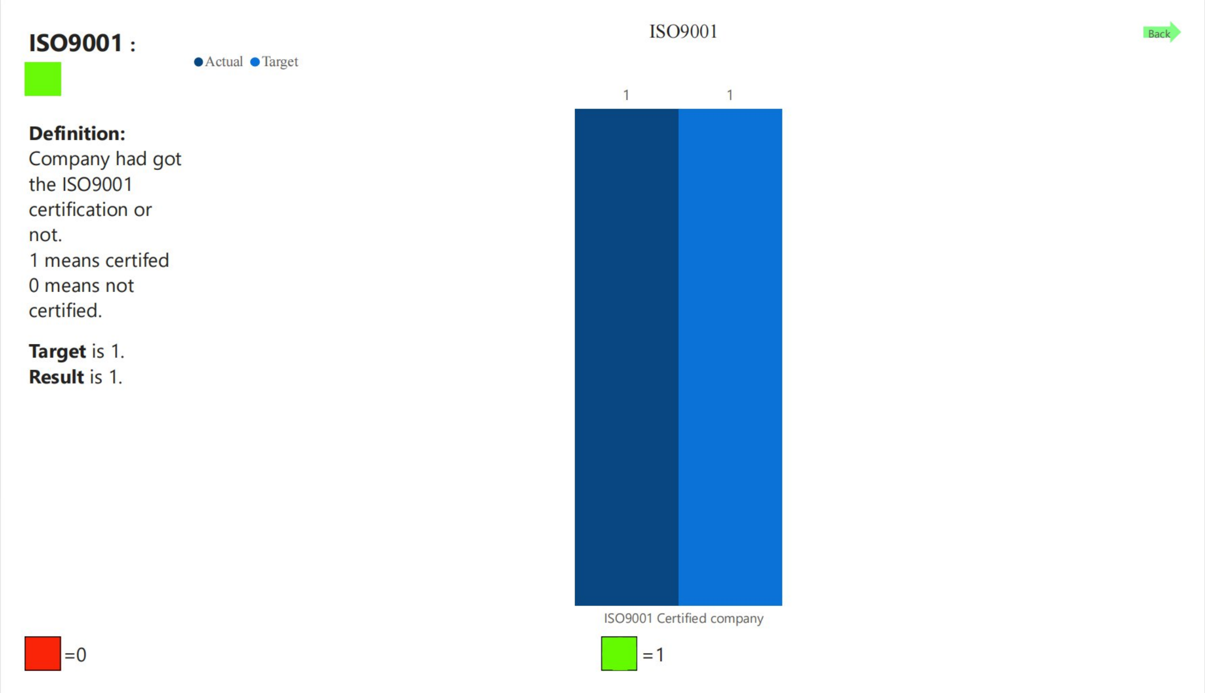
Formula:
Raw material item number which stock days rang from 10-15days/total requested raw material item number which stock days range from 10-15 days.

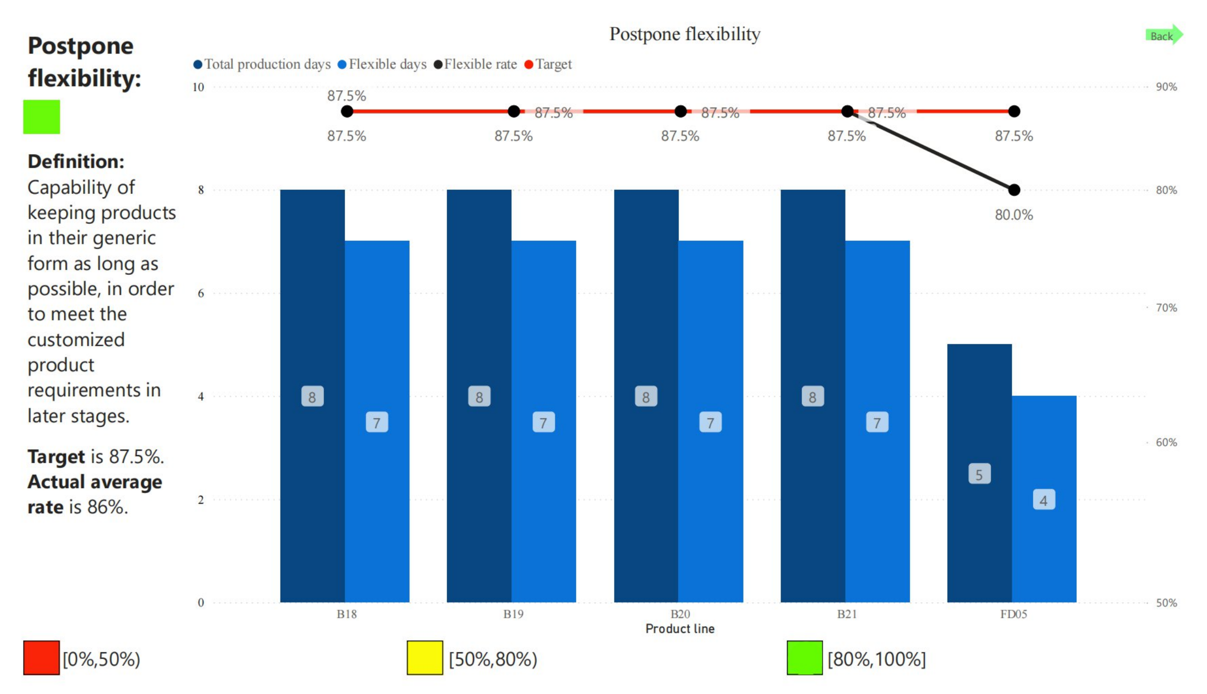
Target is 80%.
The actual kitting rate is 6.49%.

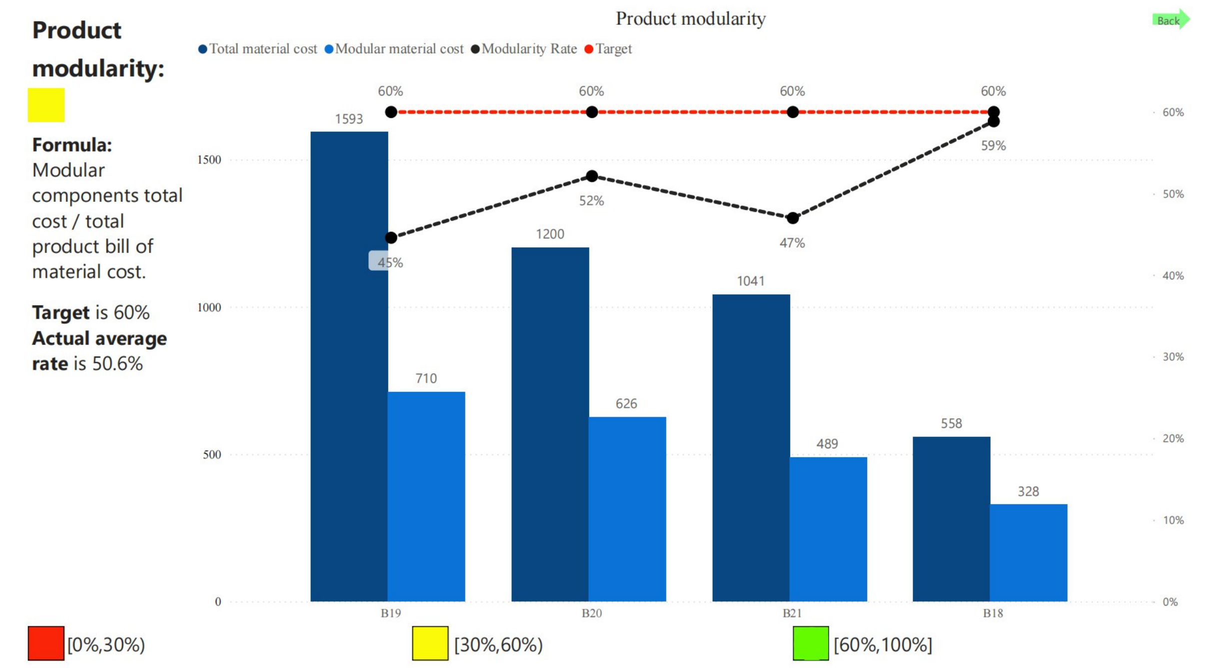


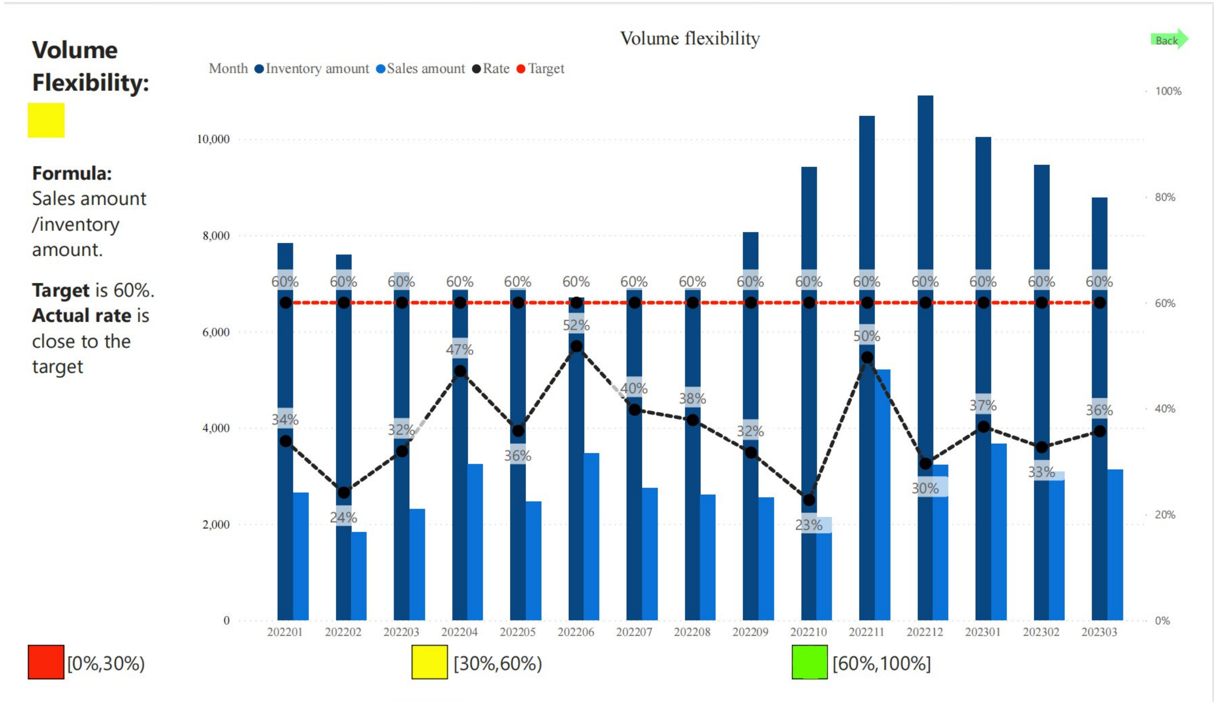


[0%,50%) [50%,80%) [80%,100%]


ISO9001 :
Definition:
Company had got the ISO9001 certification or not.
1 means certifed
0 means not certified.
Target is 1.
Result is 1.
=0
ISO9001
Back
Actual
Target
1
1
ISO9001 Certified company
= 1


Postpone flexibility:
Definition:
Capability of keeping products in their generic form as long as possible, in order to meet the customized product requirements in later stages.
Target is 87.5%.
Actual average rate is 86%.
Postpone flexibility
Back
Total production days
Flexible days
Flexible rate
Target
87.5%
80.0%
B18
B19
B20
B21
FD05
Product line
[0%,50%)
[50%,80%)
[80%,100%]


Product modularity:
Formula: Modular components total cost / total product bill of material cost.
Target is 60%
Actual average rate is 50.6%
[0%,30%)
[30%,60%)
[60%,100%]
Product modularity
Total material cost
Modular material cost
Modularity Rate
Target
Back
1593
710
1200
626
1041
489
558
328
45%
52%
47%
59%
60%
B19
B20
B21
B18
0
500
1000
1500
0%
10%
20%
30%
40%
50%
60%


Volume Flexibility:
Formula: Sales amount /inventory amount.
Target is 60%.
Actual rate is close to the target
[0%,30%)
[30%,60%)
[60%,100%]
Volume flexibility
Month
Inventory amount
Sales amount
Rate
Target
Back
34%
24%
32%
47%
36%
52%
40%
38%
32%
23%
50%
30%
37%
33%
36%
60%
202201
202202
202203
202204
202205
202206
202207
202208
202209
202210
202211
202212
202301
202302
202303
0
2,000
4,000
6,000
8,000
10,000
0%
20%
40%
60%
80%
100%

Multi-skilled labor flexibility:

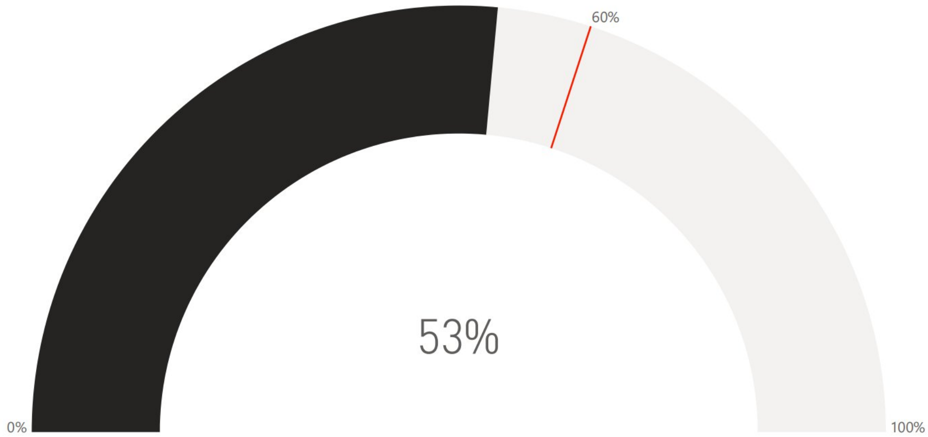
Formula: Multi-skilled worker/total worker, direct labor.

Target is 60%. **Actual average rate** is 53% in past 5 months.

Month	Multi-skilled employee	Total Direct emloyee	Rate	Target
202301	41	82	50%	60%
202302	33	69	48%	60%
202303	35	73	48%	60%
202304	40	68	59%	60%
202305	36	60	60%	60%

Back

Multi-skilled labor rate



[0%,30%) [30%,60%) [60%,100%]

Coercive power flexibility:

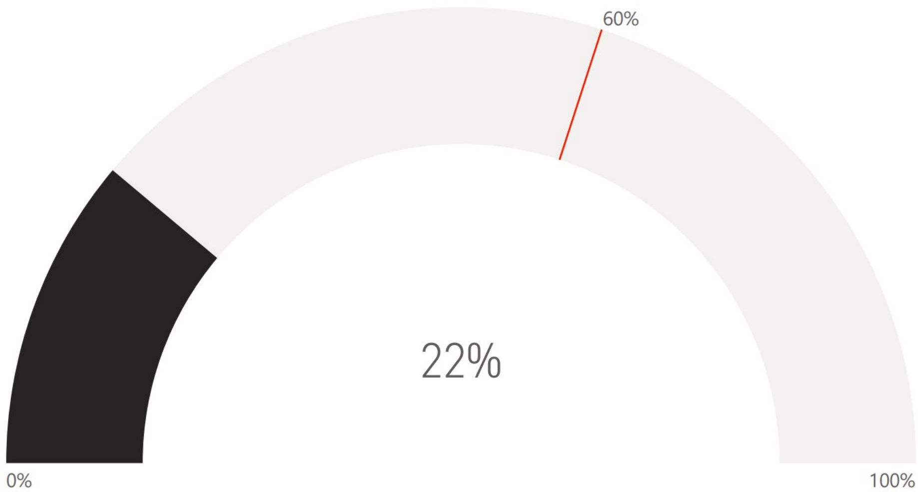
Formula: Number of Vendor signed penaltiy contract /key supplier number (purchasing amount above 1 million RMB in 2022)

Target is 60%. **Actual rate** is 22%.

Signed contract supplier number	Trade amount over 1 million vendor number	Rate	Target
8	36	22%	60%

Back

Coercive power flexibility

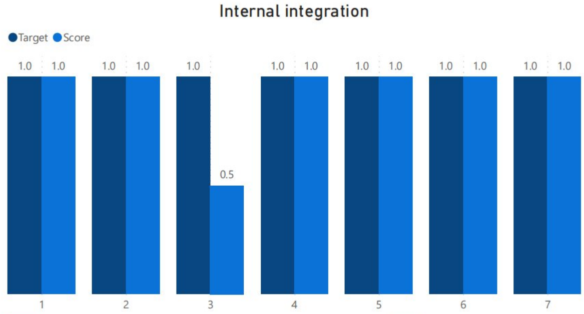


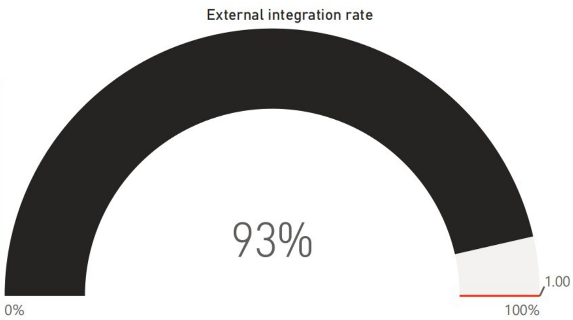
[0%,30%) [30%,60%) [60%,100%]

Internal integration flexibility:

Back

Definition: Measured by evaluating below 7 questions:
1.Data integration between internal functions
2.Enterprise application integration between internal functions
3.Integrative inventory management.
4.Utilisation of periodic inter-departmental meetings among internal functions
5.Use of cross-functional teams in process improvement
6.use of cross-functional teams in new product development
7.real-time integration and connection among all internal functions from raw materials management through production, shipping and sales.
Target is 100%, **Actual Score** is 93%



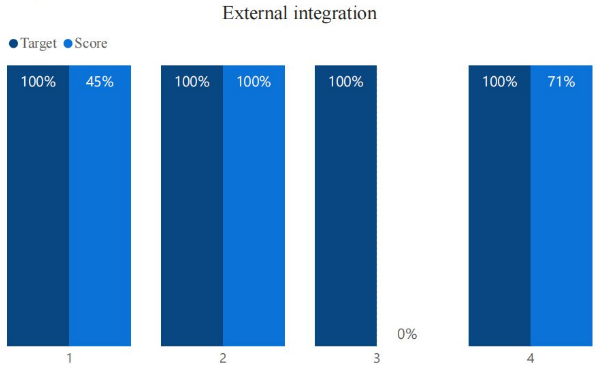


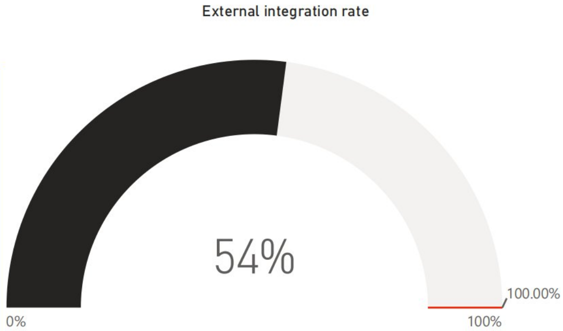
[0%,50%) [50%,80%) [80%,100%]

External integration flexibility:

Back

Definition: Measured from 2 aspects: Financial flow integration and Information flow integration, 4 questions in toal:
Financial flow integration:
1. Account receivable processed automatically triggered when ship to customer.
2. Account payable processed automatically triggered in the date of month closing.
Information flow integration:
3. Real time supply data sharing with customers automatically.
4. Real demand data sharing with vendors automatically.
Target is 100%. **Actual score** is 54%.





[0%,50%) [50%,80%) [80%,100%]

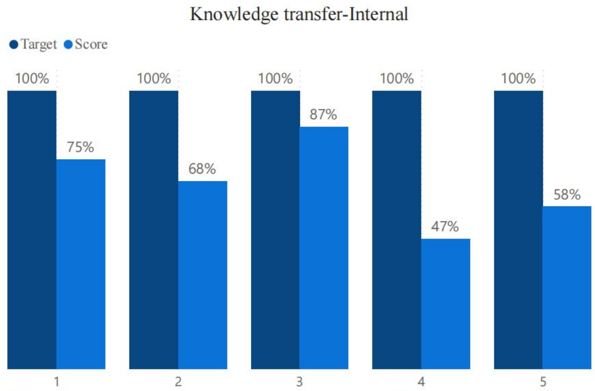
knowledge transfer-internal:

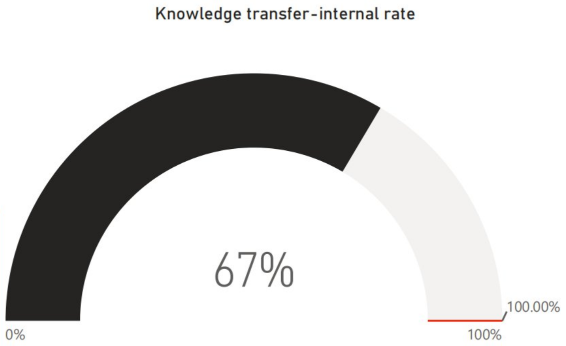
Back

Definition: Measured by evaluating the score of below 5 quesitons;

1.We effectively exchange information with relevant departments.
2.We have a common understanding with other departments of the importance of existing information.
3.We intensely pursue cross-functional development of new products.
4. We have regular best case sharing or sharing of relevant professional knowledge.
5. I can get effective training on the content of my work.

Target is 100%. **Actual score** is 67%.





[0%,50%) [50%,80%) [80%,100%]

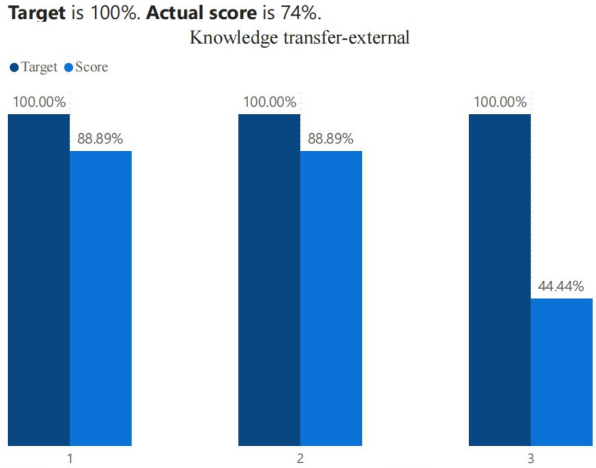
knowledge transfer-external:

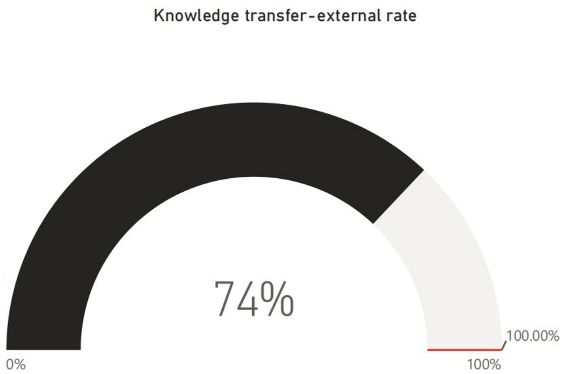
Back

Definition: Measured by evaluating the score of below 3 quesitons;

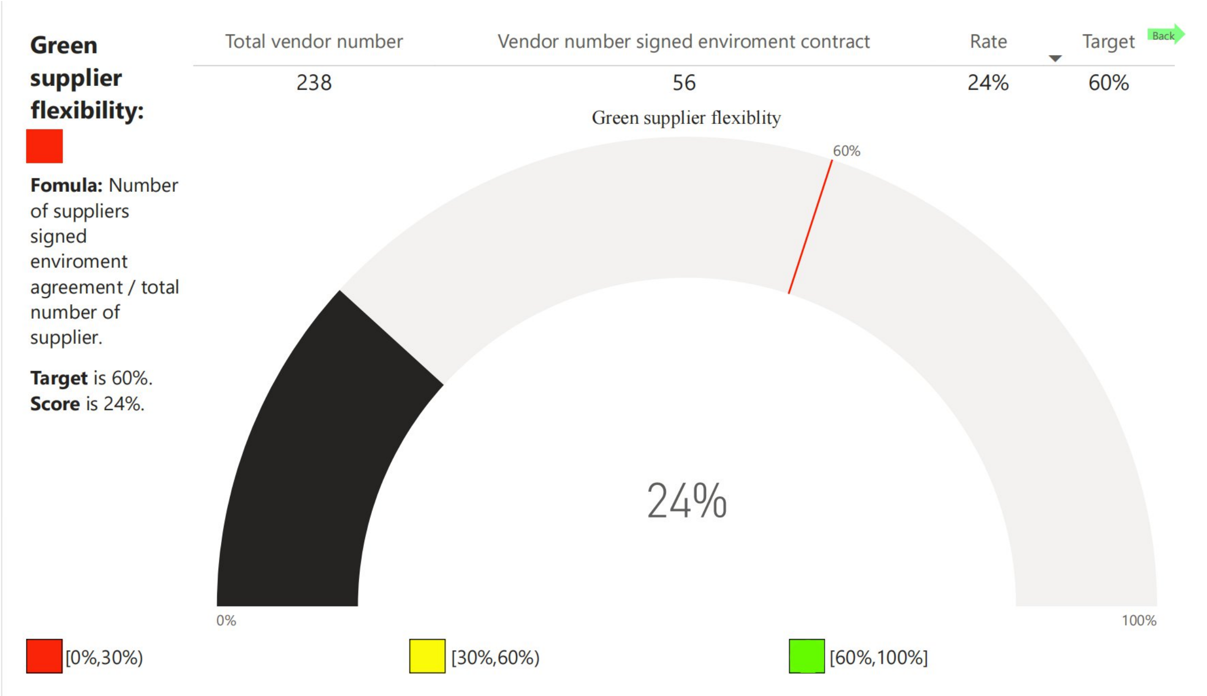
1.Suppliers are able to share their expertise in new technology with us .
2.We have frequently meeting with suppliers to develop new knowledge.
3.In buyer-supplier relationship we convert technical know-how of supplier into our new products and processes.

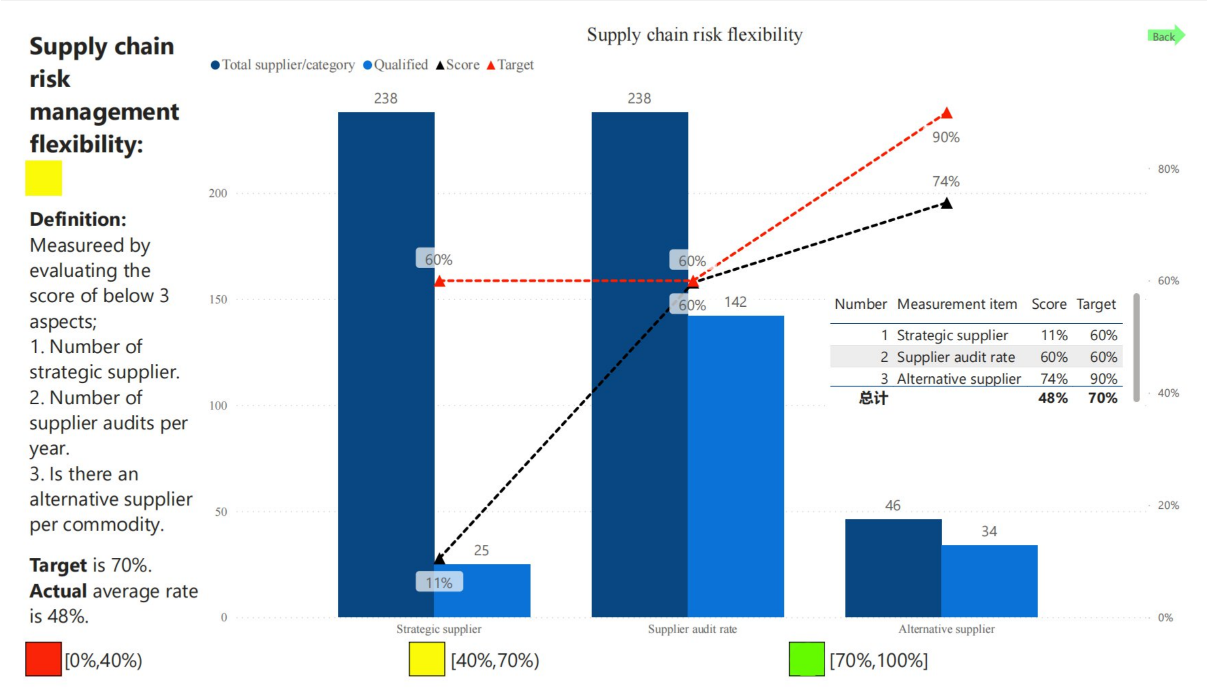
Target is 100%. **Actual score** is 74%.





[0%,50%) [50%,80%) [80%,100%]

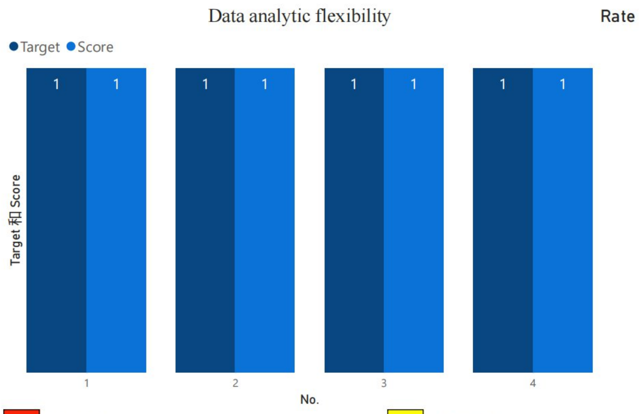

Green supplier flexibility:
Fomula: Number of suppliers signed enviroment agreement / total number of supplier.
Target is 60%.
Score is 24%.
Total vendor number
Vendor number signed enviroment contract
Rate
Target
Back
238
56
24%
60%
Green supplier flexiblity
60%
24%
0%
100%
[0%,30%)
[30%,60%)
[60%,100%]

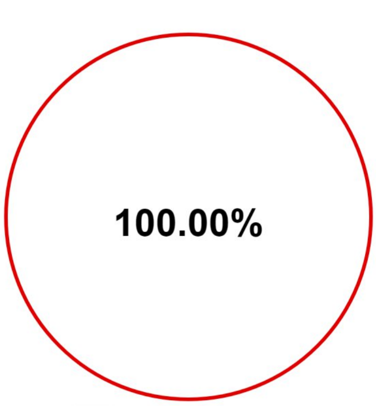

Supply chain risk management flexibility:
Definition: Measureed by evaluating the score of below 3 aspects;
1. Number of strategic supplier.
2. Number of supplier audits per year.
3. Is there an alternative supplier per commodity.
Target is 70%.
Actual average rate is 48%.
Supply chain risk flexibility
Back
Total supplier/category
Qualified
Score
Target
238
238
90%
74%
60%
60%
60%
142
25
11%
46
34
200
150
100
50
0
80%
60%
40%
20%
0%
Strategic supplier
Supplier audit rate
Alternative supplier
Number Measurement item Score Target
1 Strategic supplier 11% 60%
2 Supplier audit rate 60% 60%
3 Alternative supplier 74% 90%
总计 48% 70%
[0%,40%)
[40%,70%)
[70%,100%]

Data analytic flexibility:

Definition: Data analytic flexibiliy was measured by evaluating below 4 activities;
1. Weekly active quantity monitoring.
2. Weekly inventory
3. Weekly sales volume
4. Weekly production output

"1" means activity implemented already, "0" means activity not implemented. **Target** is 100%, **Actual score** is 100%.

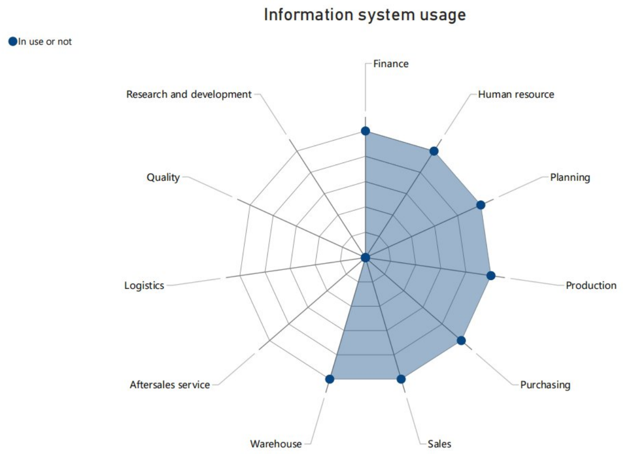


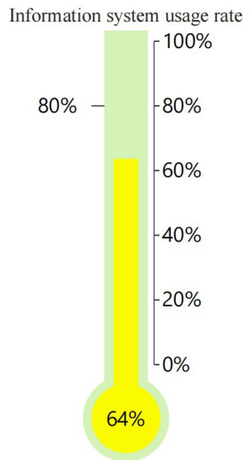


[0%,50%) [50%,80%) [80%,100%]

Information system usage flexibility:

Definition: Information system usage flexibility was measured by evaluating the system adoption rate for 11 function departments; Sales,Planning, Purchasing, Production, Logistics, Warehouse, Quality, Finance, Research and development, After sales service, Human resource, total 11 functions.
Target is 80%, **actual usage rate** is 64%





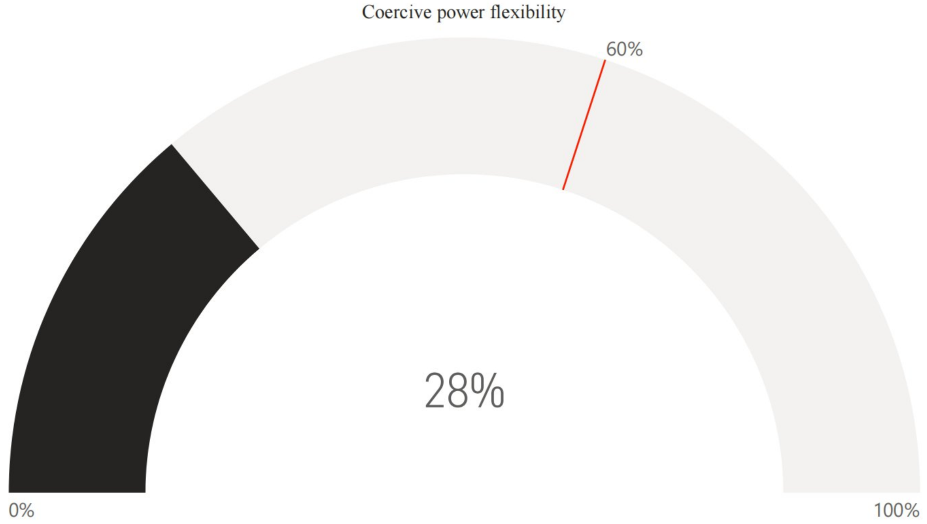
[0%,50%) [50%,80%) [80%,100%]

Alliance capability flexibility:

Formula:
Allied vendor number / key supplier number (purchasing amount over 1 million RMB in 2022)

Target is 80%. **Actual rate** is 28%.

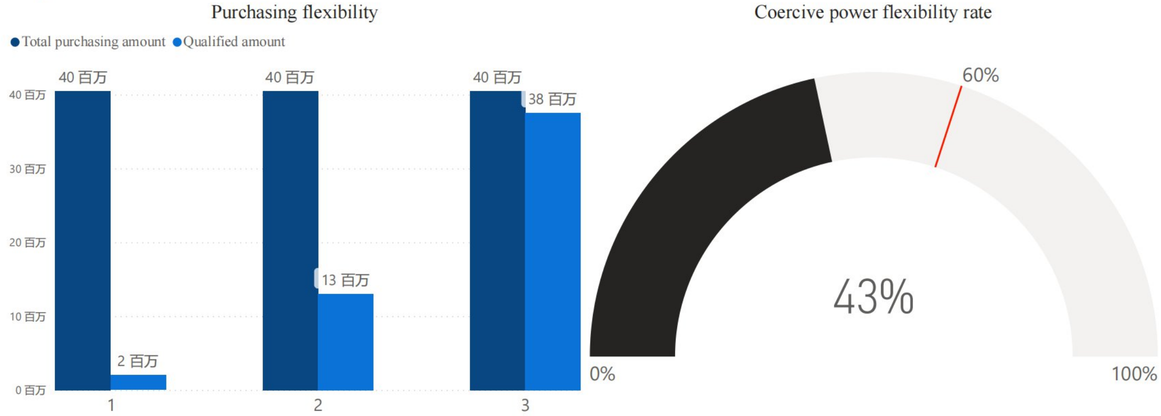
Vendor number trading amount over 1 million	Allied supplier number	Rate	Target
36	10	28%	60%



[0%,30%) [30%,60%) [60%,100%]

Purchasing flexibility:

Definition:
Measuring external purchasing flexibility by evaluate the score of 3 quesitons (using transaction amount for measurement);
1.Change volume allocation among existing suppliers.
2.Ability to influence suppliers to implement engineering change orders.
3.Change delivery times of order placed with suppliers.
Target is 60%. **Actual average score** is 43%



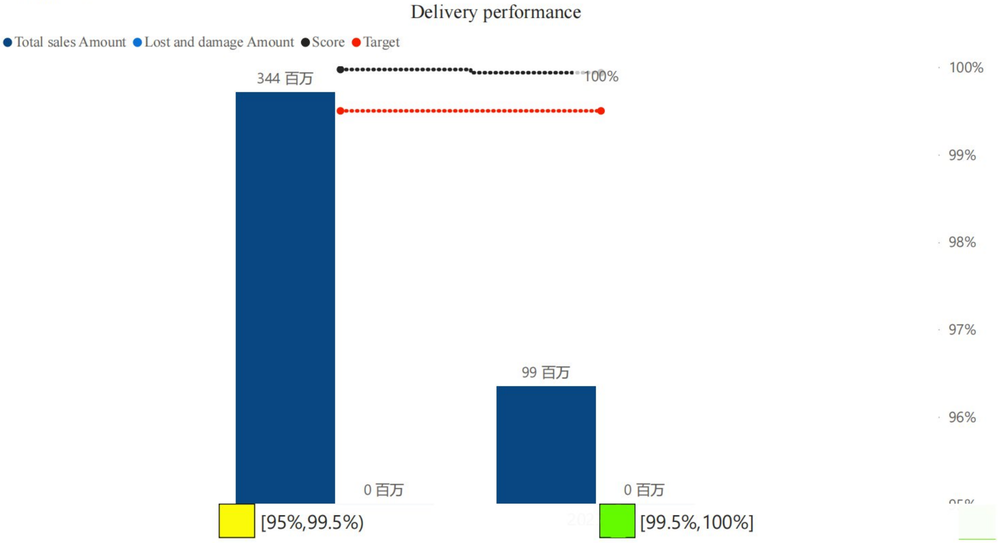
[0%,30%) [30%,60%) [60%,100%]

Delivery performance:

Formula:
The amount of delivery lost and damage / total sales amount.

Target is 99.5%
Actual score is 99.95%

Year	Total sales Amount	Lost and damage Amount	Score	Target
2022	344,400,000	93,120	99.97%	99.50%
2023 1-4	98.950.000	62.940	99.94%	99.50%
总计	**443,350,000**	**156,060**	**99.95%**	**99.50%**



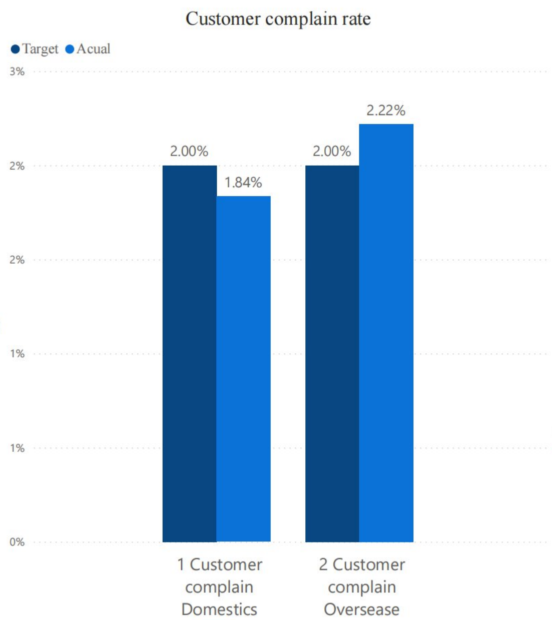
[0%,95%)
[95%,99.5%)
[99.5%,100%]

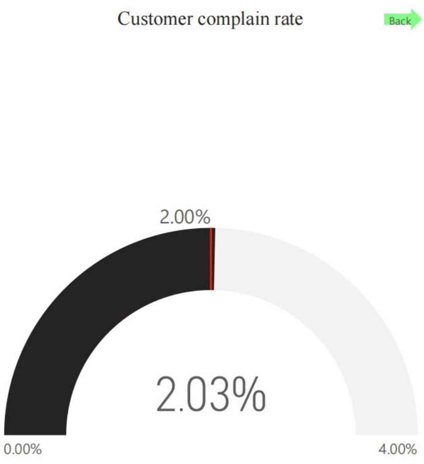
Customer relationship flexibility:

Customer relationship flexibilty measured by evaluating the score of customer complain rate and customer satisfaction rate;

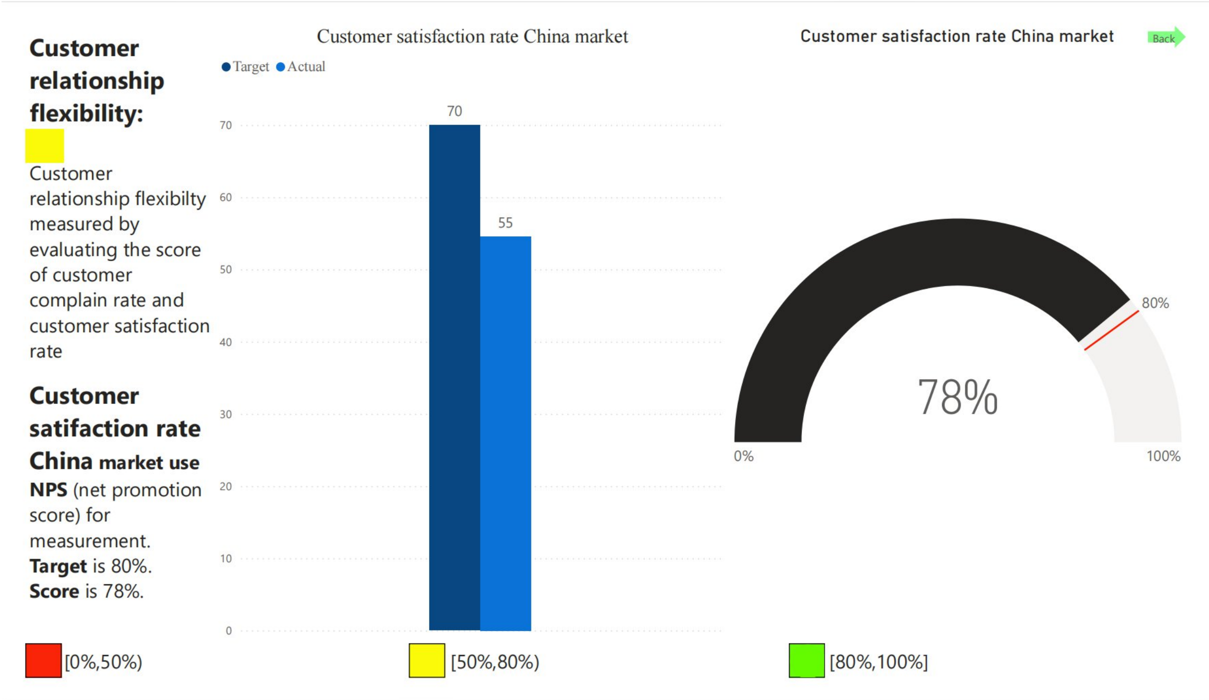
Customer complain rate

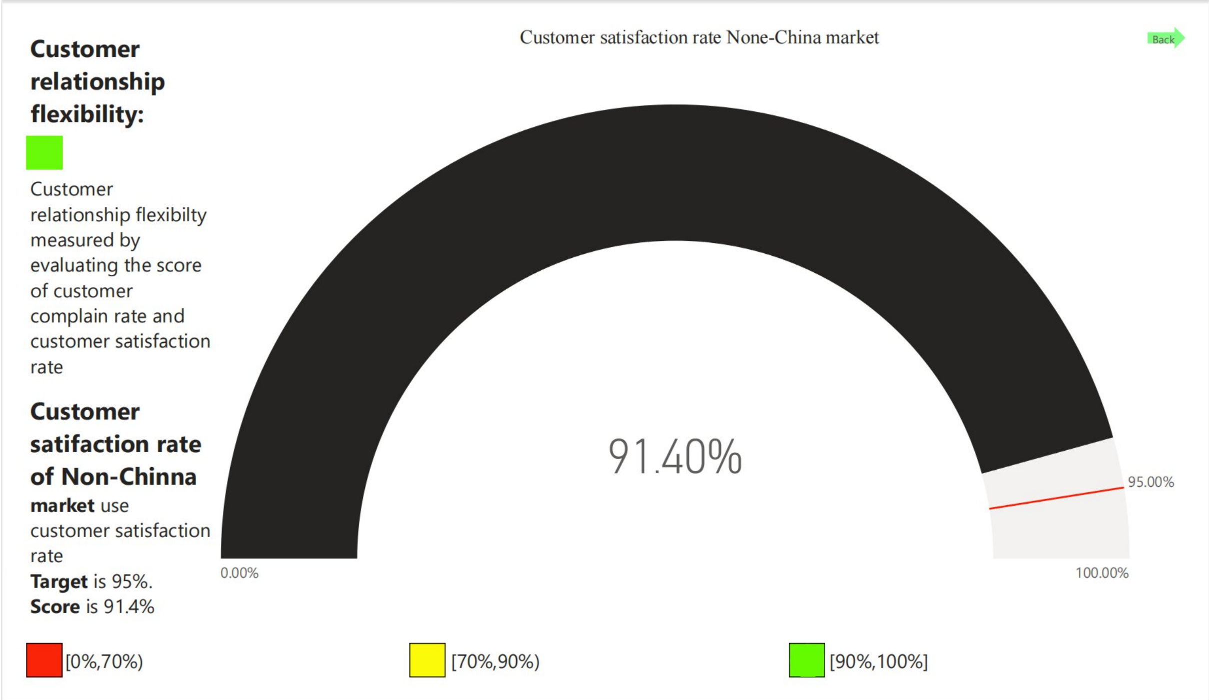
Formula: total complain number / total sales volume.
Target is 2%
Score is 2.03%





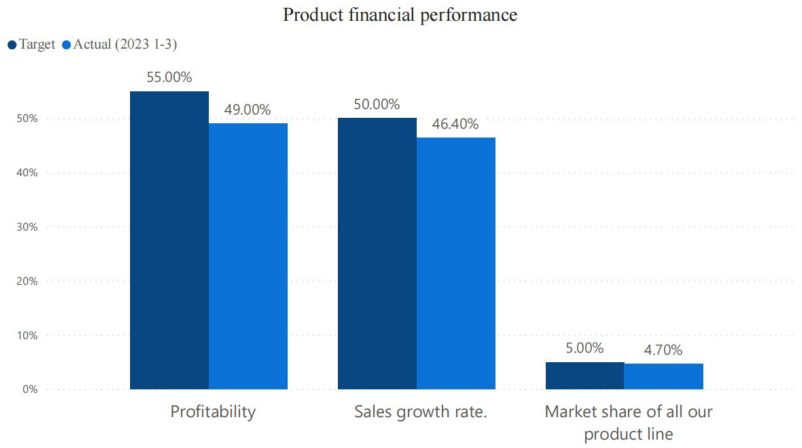
[4%
[2%,4%)
[0%,2%)

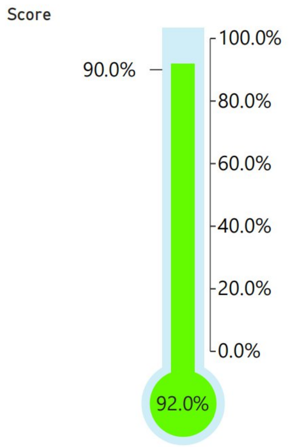

Customer relationship flexibility:
Customer relationship flexibilty measured by evaluating the score of customer complain rate and customer satisfaction rate
Customer satifaction rate China market use NPS (net promotion score) for measurement.
Target is 80%.
Score is 78%.
Customer satisfaction rate China market
Target
Actual
70
55
70
60
50
40
30
20
10
0
Customer satisfaction rate China market
Back
78%
80%
0%
100%
[0%,50%)
[50%,80%)
[80%,100%]


Customer relationship flexibility:
Customer relationship flexibilty measured by evaluating the score of customer complain rate and customer satisfaction rate
Customer satifaction rate of Non-Chinna market use customer satisfaction rate
Target is 95%.
Score is 91.4%
Customer satisfaction rate None-China market
Back
91.40%
95.00%
0.00%
100.00%
[0%,70%)
[70%,90%)
[90%,100%]

Product financial performance:

Definition: Measurement by evaluating the score of 3 aspects, profitablity, sales growth rate and market share;
Profitability - use gross profit rate to measure.
Sales growth rate = sales volume increase rate year on year.
Market share = Estimated use percentage among big marathone competition.
Target is 90%. **Score** is 92%.

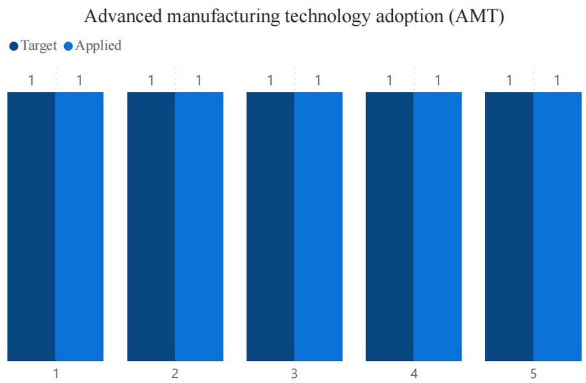


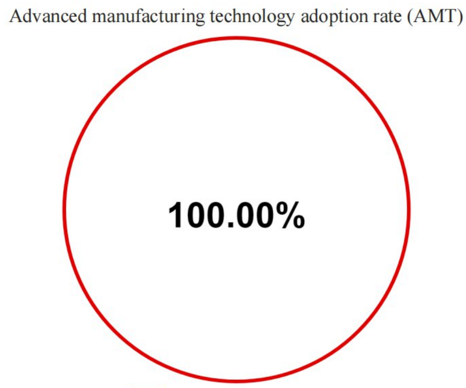


[0%,60%) [60%,90%) [90%,100%]

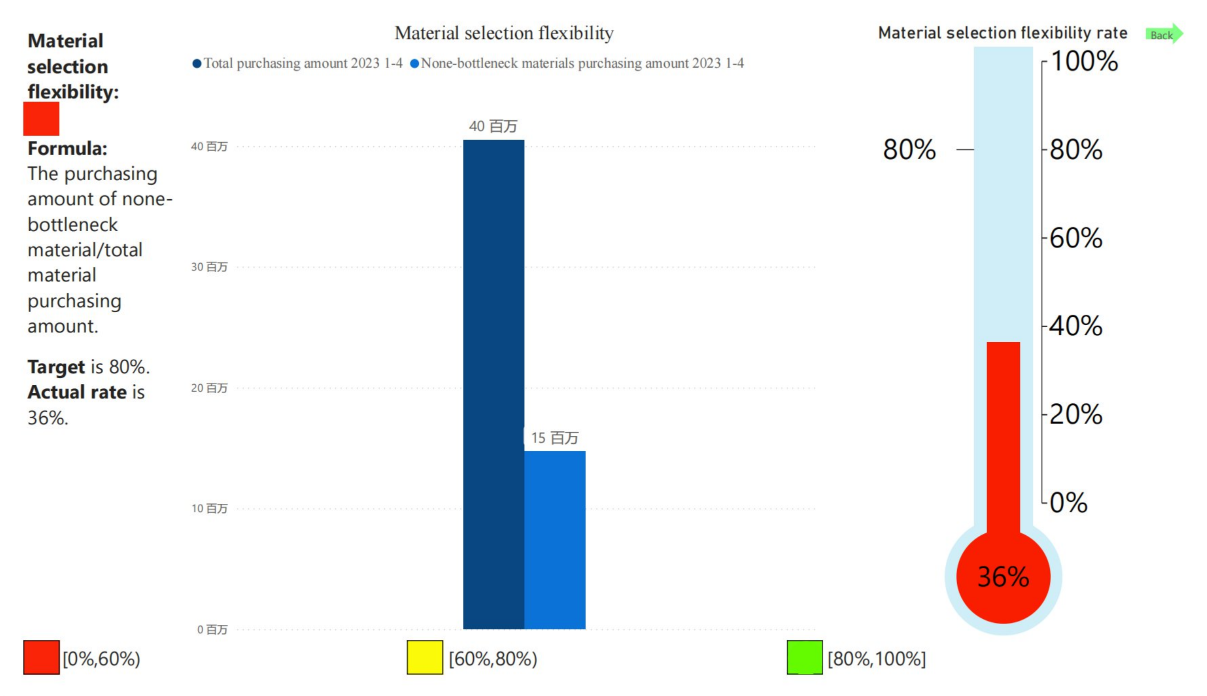
Advanced manufacturing technology adoption:

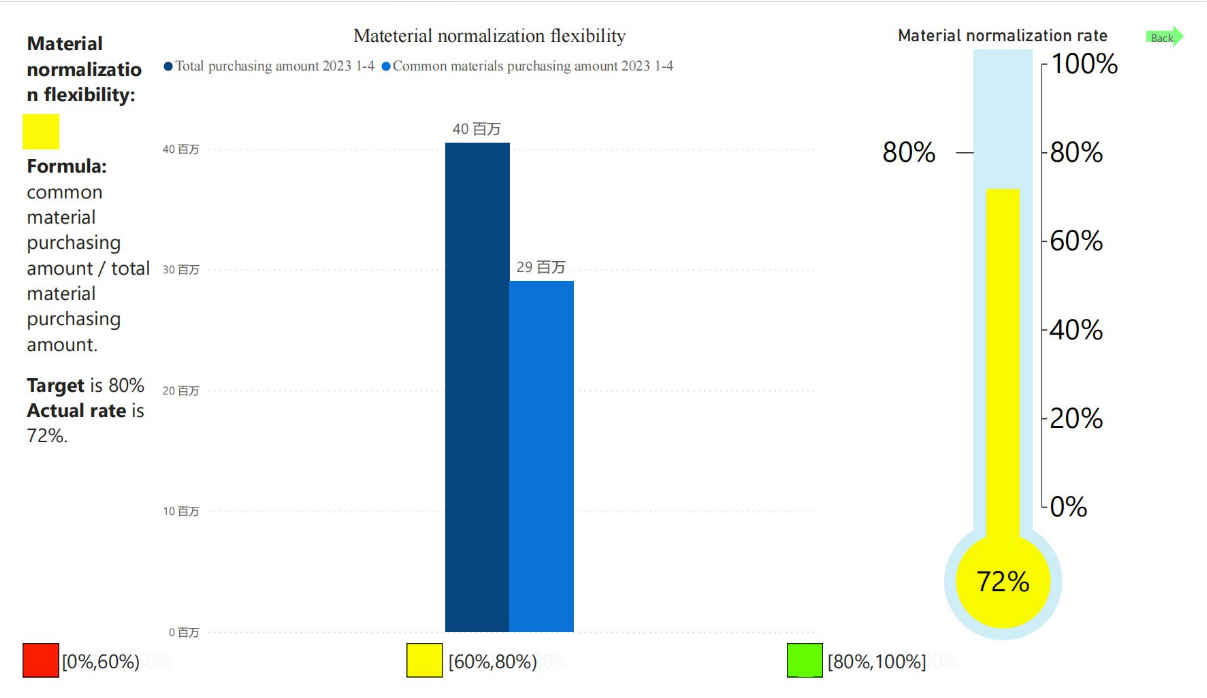
Definition: Measurement by evaluating if below technology have been adopted or not;
1.Using computer-aided design (CAD)
2.Using computer-aided manufacturing (CAM)
3.Using computer-aided engineering (CAE)
4.Using enterprise resource planning (ERP)
5.Additive manufacturing adoption (3D printing
"1" means adopted already, "0" means not adopted yet. **Target:** 100%, **Actual adoption rate:** 100%





[0%,60%) [60%,80%) [80%,100%]


Material selection flexibility:
Formula: The purchasing amount of none-bottleneck material/total material purchasing amount.
Target is 80%. Actual rate is 36%.
Material selection flexibility
Total purchasing amount 2023 1-4
None-bottleneck materials purchasing amount 2023 1-4
40 百万
30 百万
20 百万
10 百万
0 百万
40 百万
15 百万
Material selection flexibility rate
Back
100%
80%
60%
40%
20%
0%
80%
36%
[0%,60%)
[60%,80%)
[80%,100%]


Material normalization flexibility:
Formula: common material purchasing amount / total material purchasing amount.
Target is 80% Actual rate is 72%.
Mateterial normalization flexibility
Total purchasing amount 2023 1-4
Common materials purchasing amount 2023 1-4
40 百万
30 百万
20 百万
10 百万
0 百万
40 百万
29 百万
Material normalization rate
Back
100%
80%
60%
40%
20%
0%
80%
72%
[0%,60%)
[60%,80%)
[80%,100%]