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Applying Lean Startup MVP Methodology to China's High-tech Startups in the Early Stage: Case Study of Company A

TIAN Hu

Doctor of Management

Supervisors:
PhD Pedro Fontes Falcão, Assistant Professor,
ISCTE University Institute of Lisbon
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University of Electronic Science and Technology of China

March, 2023

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TIAN Hu

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I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed: TIAN HU Date: March 6, 2023

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作者申明

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Abstract

Lean startup theory, together with its methodology, provides theoretical guidance for new product development in startups. It effectively reduces the cost of startup failure and increases the success rate of new products. While its application can be found in numerous cases in Europe and the United States with great results, there are only a few studies in China that reflect the application of lean startup theory in high-tech industries to guide their startup process. Very limited literature is available in this regard. This thesis aims to identify whether the Lean Startup MVP approach can be adapted to Chinese high-tech startups and whether specific and scientific methods and tools can be found to validate MVP.

Based on an analysis of the failure of the first-generation product of Company A, a typical representative Chinese high-tech startup, this thesis puts forward a specific model and tool for validating MVP - MVP-Select model. The core idea of the MVP-Select model is that MVP should not only meet the core needs and address the pain points of customers, but also need to verify the company-side business model and competitiveness through the market. Besides, by applying the model to the development of the second-generation product, it is concluded that the Lean Startup MVP approach can be applied to Chinese high-tech startups; the MVP confirmed by the MVP-Select model meets the needs of the company and its customers. This has theoretical and practical contributions and implications for Lean Startup MVP approach.

Keywords: Lean startup; minimum viable product (MVP); high-tech innovative enterprises; MVP-Select model; unmanned aerial vehicle (UAV)
JEL: M11; M13

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Resumo

A teoria Lean Startup, juntamente com a sua metodologia, fornece orientação teórica para o desenvolvimento de novos produtos em startups. Reduz eficazmente o custo do fracasso da startup e aumenta a taxa de sucesso de novos produtos. Embora a sua aplicação possa ser encontrada em numerosos casos na Europa e nos Estados Unidos com grandes resultados, existem poucos estudos na China que refletem a aplicação da teoria lean startup em indústrias de alta tecnologia para orientar o seu processo de desenvolvimento inicial. A literatura disponível a este respeito é muito limitada. Esta tese visa identificar se a abordagem Lean Startup MVP pode ser adaptada às startups chinesas de alta tecnologia e se podem ser encontrados métodos e ferramentas específicas e científicas para validar o MVP.

Com base numa análise do fracasso do produto de primeira geração da Empresa A, uma típica startup chinesa representativa do setor da alta tecnologia, esta tese apresenta um modelo e ferramenta específicos para validar o MVP - modelo MVP-Select. A ideia central do modelo MVP-Select é que o MVP deve não só satisfazer as necessidades centrais e abordar os "pontos de dor" dos clientes, mas também verificar o modelo de negócio do lado da empresa e a competitividade no mercado. Além disso, ao aplicar o modelo ao desenvolvimento do produto de segunda geração, conclui-se que a abordagem Lean Startup MVP pode ser aplicada a startups chinesas de alta tecnologia; o MVP confirmado pelo modelo MVP-Select satisfaz as necessidades da empresa e dos seus clientes. Isto tem contribuições teóricas e práticas e implicações para a abordagem do MVP Lean Startup.

Palavras-chave: Lean Startup; produto mínimo viável (MVP); empresas inovadoras de alta tecnologia; modelo MVP-Select; veículo aéreo não tripulado (UAV)
JEL: M11; M13

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摘要

精益创业理论及其方法论是指导创业企业新产品研发的理论思想，它有效的降低了创业失败的成本并有效提升了新产品的成功率，在欧美等国家有众多的应用案例并取得巨大的成果，但在中国仅有几篇文献体现出了高科技行业应用精益创业理论指导其创业过程，相关资料极少。本文研究的主要问题是精益创业 MVP 理论是否能够适应中国高科技创业企业；是否能够寻找出具体的、科学的方法和工具对 MVP 进行确认。

本文通过具有典型代表的中国高科技创业企业 A 公司第一代产品失败分析，提出了确认 MVP 的具体模型和工具——MVP-Select 模型，它的核心思想是 MVP 不仅要解决客户的核心需求和痛点，同时也需要通过市场来验证公司侧的商业模式和竞争力，并通过将其应用到第二代产品的研发中，得出精益创业 MVP 理论是可以应用到中国高科技创业企业中的；通过 MVP-Select 模型确认的 MVP 符合公司和客户的需求。这对精益创业 MVP 具有理论和实践的贡献和意义。

关键词：精益创业；最小价值产品；高科技创新创业；MVP-Select 模型；无人机

JEL: M11, M13

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Acknowledgements

Over the past twenty years of my career, I have encountered many management problems and solved many of them through consulting and information search. In this process, I have also accumulated some management experience. However, I lacked systematic management thinking, which was my initial motivation for choosing to pursue further study. Although I expected that the DoM journey would not be easy, it turned out even more difficult. Specifically, the DoM commitment used to conflict with my time and work, causing me to suffer confusion and to feel at a loss. In the worst case, I got stuck and could not move forward. Fortunately, there were many people who supported, cared for, guided and encouraged me, enabling me to complete the journey. I feel grateful!

First, I would like to thank my two supervisors whose professional and patient guidance has been the motivation for me to keep moving forward in my study. Prof. Falcão's professionalism and rigorous scholarship have influenced me deeply and enabled me to develop the attitude required for academic research; his meticulous and patient guidance has enabled me to keep solving problems I encountered in my study and research and keep moving forward. Prof. LU Ruoyu's professionalism and rich theoretical and practical experience in Chinese entrepreneurship research gave me confidence in studying Chinese high-tech startups; his patient guidance enabled me to keep solving problems in my research and keep making progress. Once again, I would like to thank both supervisors for being the lighthouse along my DoM journey, showing me the way forward and constantly encouraging me to move forward.

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I am appreciative of the warmth from my classmates, with whom I was able to relive the experience of a campus class. They have also helped me a lot along my journey. My thanks go to them, and to all my friends who have helped me along my journey!

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致谢

在工作的二十多年中，我遇到了很多管理上的问题，通过咨询、查找资料也解决了很多问题，同时也积累了一些管理上的经验，但缺乏系统性管理学思维体系，这是我选择进一步进行学习的初衷。虽然也预计到了这个过程不容易，但实际情况更加艰辛，时间冲突、工作冲突等等导致我一度的迷茫和失落，甚至一度举足不前。幸好有众多支持、关心、指导和鼓励我的人，我才得以坚持下来，感恩感谢！

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List of Acronyms

AMR: Academy of Management Review

CDFD: China Doctoral Dissertations Full-text Database

CMFD: China Master's Theses Full-text Database

CNKI: Chinese National Knowledge Infrastructure

CSTJ: China Science and Technology Journal Database

JIT: Just in Time

JSQC: Japan Society for Quality Control

MSEs: Micro and small enterprises

MSMEs: Medium, small, and micro enterprises

MVP: minimum viable product

NASA: National Aeronautics and Space Administration

RPA: Remotely piloted aircraft

UAS: Unmanned aircraft system

VTOL: Vertical take-off and landing

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Chapter 1: Introduction

1.1 Research background

1.1.1 External environment

China is an important player in the world economy. In general, China's national economy has maintained a stable and favorable development trend. However, it is undeniable that with the changes of market environment at home and abroad, the rapid rise of labor costs and the comprehensive resources constraints, the three drivers of economic growth advocated in the past, namely, consumption, investment and export, can no longer support the sustainable growth of China as a huge economy. The past pattern of economic growth driven by technological imitation is hard to sustain. Seen from the global economic landscape, China's "late-mover advantage" is in danger of becoming a "late-mover disadvantage" Z. P. Zhang and Du (2012). Therefore, it is imperative to change the development mode and restructure the economy, hence the emergence of the supply-side structural reform. In the context of the "mass entrepreneurship and innovation", more and more people are joining the wave of entrepreneurship. At the opening ceremony of the Summer Davos Forum 2014, Premier Li Keqiang delivered a speech in which he put forward the concept of "mass entrepreneurship and innovation" for the first time (K. Q. Li, 2015). Later, China's State Council (2015a) successively introduced such important documents as the Guiding Opinions of the General Office of the State Council on Expanding Makerspace and Promoting Innovation and Business Startups by the General Office of China's State Council and the Opinions on Policies and Measures for Promoting Mass Entrepreneurship and Innovation (China's State Council, 2015a) to encourage and support the establishment of innovation and entrepreneurship ecosystems all over the country.

With the support from central policies, encouragement from local policies and the public's enthusiasm for entrepreneurship, "mass entrepreneurship and innovation" has become one of the engines driving the further high-speed development of China's economy. According to the statistics provided by the professional version of TianYanCha, China's leading business query platform, the number of micro and small enterprises (MSEs) in China had reached 80 million in 2019, accounting for about 70% of the total number of enterprises in the country. In 2019,

the number of new MSEs reached 15 million. From 2016 to 2019, the annual increase in the number of newly registered MSEs all surpassed ten million (Xu, 2020). The specific statistics from 2016 to 2020 are shown in Table 1.1 below.

Table 1.1 The number of newly registered market entities from 2016 to 2020

Year	The number of newly registered market entities (million)
2016	16.513
2017	19.249
2018	21.496
2019	23.774
2020	27.354

Source: Xu (2020)

Many new startups have been springing up like mushrooms, and most of these startups are MSEs, which play a critical role in China's socio-economic development. They have not only contributed to economic growth as well as market economy and competition, but also provided more job opportunities and significantly pushed forward technological innovation, thereby playing an important role in the development of China's national economy. However, the rise of startups has also increased the competition, degree of openness and uncertainty in the market. Enterprises can only survive through continuous innovation and development of new products that meet the needs of consumers and the market.

The rapidly developing new Internet ecosystem has provided more unprecedented technical means, opportunities, and user scenarios for the market. This has, on the one hand, intensified market competition, rendering the complexity of the market environment a new normal, and on the other hand, led to increasing diversification and differentiation of user needs, resulting in greater uncertainty. In this context, the traditional product development method characterized by a long cycle and a relatively stable environment can no longer meet the demand for rapid product changes and updates. Therefore, a new model needs to be adopted to help companies quickly respond to the changes in market and customers, enhance product vitality and reduce product cost. Among the available models, the lean startup theory was used by Silicon Valley entrepreneur Ries (2011) to quickly validate new products in an uncertain market environment based on lean thinking. Specifically, lean startup theory advocates rapidly iterating the minimum viable product (MVP) based on continuous study and customer feedback to meet the needs of customers and quickly respond to changes in the market. It has been widely used for new product development. MVP, a concept from the lean startup theory, is a very important link for entrepreneurs or new products. An MVP is a version of a product developed based on the entrepreneur's idea or an idea for a new product in the simplest way possible. It can be either a product interface or a prototype that allows for interactive operation. Its advantage lies

in that it can be intuitively perceived by customers and thus stimulate customers to give feedback. In general, an MVP has four characteristics, namely, reflection of project idea, availability for testing and demonstration, minimal functionality and minimal or even zero development cost (D. W. Zhao, 2014). Dr Kai-Fu Lee, founder of Sinovation Ventures, argues that the lean startup model will continue to influence, permeate, and change entrepreneurs in the future (Ries, 2011).

Lean startup represents a theory and a methodology based on the application of lean thinking to the field of entrepreneurship to validate whether a new product meets market demand with an MVP or at the minimum cost. Derived from the concept of "lean manufacturing", lean startup advocates "validated learning", where companies first introduce a minimal prototype to the market and then validates whether the product meets user needs in a cost-efficient way through continuous experimentation and learning. If the prototype fails to meet customers' needs, companies will transform in time. This approach can significantly reduce the cost of new product development and effectively increase the success rate of new product development. Ries (2011) described lean startup as a "Build-Measure-Learn" loop, where continuous efforts are made to push forward the entrepreneurial process through the loop of "idea-build-product-measure-data-learning-new idea".

In China, many startups are seeking theories and methodologies to improve their startup success rate. Particularly, high-tech innovation-driven companies are more receptive to new things, more capable of learning, and more capable and grounded to improve their startup success rate. The theoretical sources and successful practice in high-tech fields such as the Internet have made lean startup the choice of high-tech startups' practice in China. However, due to differences in the external environment, the application of the methodology in practice must be adapted and moderately revised to enable high-tech startups to identify core problems and actively explore the corresponding countermeasures amidst the rapidly changing environment in the competitive business society. Only in this way can high-tech startups bring their intrinsic motivation into full play during their own development as well as survive and develop in the forest of large enterprises and the fierce market competition.

1.1.2 Case company background

1.1.2.1 An introduction to Company A

Company A, a leader in independent innovation and an ecological builder of unmanned system technology in China, is committed to providing complete unmanned aircraft system (UAS)

solutions to various industries around the world and creating value for users with superior technology. Its product solutions include key subsystems such as A series UAS, ground stations and flight control systems as well as collaborative design and simulation tool chains of UAVs.

Company A is headquartered in Chengdu, with branches set up in Beijing, Shanghai, Shenzhen and overseas. It boasts a full-fledged UAV development system covering R&D, production, testing, training and flight services, excellent scientific research capabilities, rich industry experience, a sound production system and a complete service system. The A-series UAS, which occupies the high-end market of the industry, has served in such fields as line patrol, environmental monitoring, land surveying and mapping and public security, providing complete and customized system solutions for various industries and enabling users to obtain enhanced value brought by cutting-edge technology. The company has its own R&D base, production base and test flight base.

By the time of this study, the company had around 100 employees, most of whom were R&D staff, and most of them had a master's degree or a doctoral degree in aviation-related disciplines. The overall ratio of master's or doctoral degree holders in the company's R&D staff was over 80%, and their specificalities' covered a wide range of disciplines. By the time of this study, the company had finished developing the first-generation product and had launched it into the market in small batches. While it normally takes at least five years for a large aircraft company to launch a product, Company A significantly shortened the time to launch a product due to the rich experience and strong expertise of its team. Though the company's first-generation product did not receive very positive market feedback, it symbolized an important step taken by the company. Company A's brand awareness has been growing and has been recognized by an increasing number of users, and its reputation for after-sales service has been recognized within the industry. The company is developing with strong momentum and at a very fast pace and is receiving more and more attention from the outside world.

Company A plans to further subdivide its work and optimize its technical division of labor in the next five years to be technically prepared to become a leader of the UAV industry. In the future, when the staffing of various professionals is more adequate, Company A will work towards the development of industry standards and strive to become the industry benchmark and standard setter, to lay the foundation for the unhindered development of its business. In the context of the gradual expansion of the company's business and its increased profitability, the company hopes to be successfully listed in the next five years and to have the capacity to prepare for the establishment of an UAV research institute to provide more companies with advanced

technology for the development, production and manufacturing of UAVs as well as the commercialization of advanced technologies.

1.1.2.2 Background of establishment

There were several factors that led to the establishment of the company, namely:

1. Strong support by national policies

On May 8, 2015, PRC State Council (2015) issued "Made in China 2025", which called for vigorously promoting breakthroughs in core and key areas and provided positive suggestions for the development of the general aviation industry by focusing on supporting regional aviation including manned aircrafts and UAVs. On October 29, 2015, the Central Committee of the Communist Party of China adopted the "13th Five-Year Plan", which called for vigorous innovation and industrialization in high-end equipment, semiconductors, and artificial intelligence to form a number of new growth points. Two years later, China's State Council (2015b) issued the Notice on the Issuance of the New Generation Artificial Intelligence Development Plan, according to which efforts should be made to develop intelligent technologies for autonomous UAS and accelerate the creation of global leaders and brands in artificial intelligence in areas such as UAV, voice recognition and image recognition. China's national policy support for companies lied mainly in two areas. On the one hand, due to China's promotion and encouragement of innovation and entrepreneurship, the Chinese government gave strong support for innovative and entrepreneurial projects and medium, small, and micro enterprises (MSMEs), and China's Central Government and local governments both strongly advocated the development and implementation of innovative and entrepreneurial projects. In the context of national policy support, a new wave of "mass entrepreneurship" and "grassroots entrepreneurship" was formed in China, forming a new trend of "innovation for all" and "widespread innovation". China's Central Government and various local governments successively introduced relevant policies to support the public to carry out entrepreneurial and innovative activities. They also introduced a lot of substantial preferential policies in these aspects, such as innovation and entrepreneurship funds and tax concessions, shifting the core of support from model innovation to technological innovation. On the other hand, China's Central Government included high-end equipment manufacturing in its key support plans, introduced UAV-related management measures to regulate the market for UAVs, and gradually liberalized the restrictions in the low-altitude field to promote the development of UAVs in a fast and stable manner. In the "13th Five-Year Plan", the Chinese government explicitly proposed to vigorously develop industrial-grade UAVs to meet market demand. The UAV

industry is exactly the representative of high-end equipment in the innovation and entrepreneurship projects supported by China's Central Government, and the R&D of UAVs is also a high-tech project strongly supported by China's Central Government. UAVs, which enjoyed a broad market prospect, had been naturally included in the key support plans of the central and local governments. Therefore, Company A was established in the context of strong support from the national policy and entered a blue ocean market.

2. The advantage of having a full-fledged team

The core team members who founded Company A are all professionals in aviation-related industries, with backgrounds in the R&D and production of large UAVs. The core members had been working together for at least three years, or even five years. They boasted solid professional skills, experience in the R&D of medium and large UAVs, and an in-depth understanding of the R&D process and system of UAVs. They were also good at teamwork and complemented each other in technical expertise. The team members were very professional and obsessed with technology, and they all wished to make a difference. But there were many restrictions in large enterprises, making it difficult to translate ideas and visions into products quickly. With the support of the national policy of innovation and entrepreneurship as well as the background of high-end equipment manufacturing becoming the core support, the team decided to start their own business. Therefore, upon establishment of the core team, the professionals for the development and manufacture of UAVs were already available. After more than two months of discussion and revision, the core team and the direction of the product to be made were basically confirmed, and the process from developing the idea to putting it into practice was fast and smooth.

3. Smooth financing

Although the UAV industry is an industry with a high threshold for technological strength and high investment, it had been favored by capital under the strong support of national policies. The capital market was very optimistic about the prospects of this industry and was striving to find bright teams in this industry to make investment. Financing institutions established based on national innovation and entrepreneurship policies also favored investment funds for high-end equipment manufacturing, which were less competitive and easier to get investment in the financing market.

4. Huge market demand

The promotion by the central government, especially the policy support for high-end equipment manufacturing, facilitated the widespread application of UAVs. As a result, the market demand for UAVs exploded, and the fields of application became more and more

extensive. The original UAVs transformed by aerial models could no longer meet the market demand, and there was an urgent need for truly professional UAVs to cater to the market demand. The industrial structures of traditional manual mapping and inspection industries were also changing from population-intensive to technology-intensive. With the gradual maturation of UAV technology, many jobs that previously required huge human and material resources could be easily completed by UAVs, and the application of small and medium-sized UAVs became more and more widespread. For example, UAVs had been increasingly used in aerial photography and aerial survey, power inspection, agricultural plant protection at an accelerated pace in recent years. Adoption of UAVs in place of the previous approach could help both save a lot of costs and greatly reduce unnecessary risks. From the perspective of the Chinese domestic market, medium and large UAVs were dominated by large enterprises, and the market was relatively saturated. Companies specialized in commercial industrial-grade small and medium-sized UAVs were few, but the market gap was huge. The previous large enterprises did not produce such small operational UAVs. Even if they chose to produce such UAVs, a very long time would be needed. In general, the R&D cycle of a new product in a large enterprise is two years or longer, which is completely unable to meet the urgent market demand. On the other hand, small enterprises were not professional in the development, production and manufacture of UAVs because most of them shifted to producing UAVs from producing model airplanes. They were unable to provide qualified UAVs to meet the needs of users. To conclude, the market was in dire need of a company with expertise in the development, production and manufacture of UAVs to manufacture small operational UAVs. Company A was established in response to this pressing market demand.

1.1.2.3 Product information

A UAV is an unmanned aircraft operated by radio-controlled equipment and programmed control devices. A UAV does not have a cockpit, but is equipped with an autopilot, programmed controls and other equipment. It has the advantages of not requiring the pilot to risk his or her life to carry out the mission, light weight, unlimited size and low cost. UAVs currently have two main application scenarios: military and civilian. By the time of this thesis, Company A had the following UAS solutions.

1. A-1 UAV

It is a high performance pure electric UAV with vertical take-off and landing (VTOL) and horizontal flight. It combines the advantages of multi-rotor UAVs reflected in VTOL as well as the advantages of fixed-wing UAVs reflected in long flight time, long range and fast speed.

It is able to take off quickly in a tight field without a runway. It is a professional grade UAV and adapted to the needs of the operational UAV industry.

2. A-1 UAV platform

The UAV platform is composed of key subsystems such as flight platform, ground control, data link, mission payload and integrated security, allowing for flexible deployment and full autonomous flight capability. It provides users with industry-level total solutions through a modular multi-configuration system.

1.1.2.4 Product status

Company A's first-generation product had been launched into the market for some time. The market feedback was good, but a lot of problems surfaced after a period of market test. So, the first-generation product had been discontinued. The market feedback for the first-generation product consists of the following points.

1. The first-generation product was rather idealistic in its design. As it was the first time the team produced a finished product and launched it into the market, the team had a lot of unrestrained ideas. As a result, the product was very attractive for customers, which was very helpful as a demonstration of the company's technical strength. However, precisely because of this reason, the production was relatively difficult; the product often failed to achieve the desired effects; and consistency was difficult to maintain. In addition to the relatively high cost, the market feedback ended up unsatisfactory.

2. The first-generation product failed to sufficiently grasp the pain points. When the team made the first-generation product, they did not have a sound grasp of customers' needs for small UAVs and simply used customers' needs for large aircrafts or UAVs as references. As a result, they lacked an in-depth understanding of users' pain points, resulting in unsatisfactory feedback from the market and many areas in need of improvement or even complete change. In terms of production, Company A could only repair and replace parts for products sold in the early stages to ensure that the after-sales maintenance of sold products could be followed up in a timely and effective manner.

3. The after-sales service attitude had been well received by the users. There was a lot of room for improvement of the first-generation product. Based on Company A's judgment of the product and market feedback, the first-generation product needed to be redesigned. For the product that had been sold, after-sales service was still being maintained and carried out in an intense and orderly manner. The company had already sorted out and analyzed the problems

based on the feedback from users and its own problems, which laid a solid foundation for the development of the second-generation product.

1.1.2.5 An analysis of main competitors

Company A's main competitors were industrial UAV enterprises specialized in similar business that had direct competition or potential competition with it. Industrial UAV enterprises whose business did not compete with Company A or whose regions did not overlap with Company A were not considered in this study.

1. Chengdu JOUAV Automation Tech Co., Ltd.

Established in 2010, JOUAV is a high-tech enterprise focusing on the R&D, production, sales and services of industrial UAV-related products. It is one of the leading and most competitive industrial UAV enterprises in China, committed to providing customers with intelligent, platform-based and tool-based industrial UAS solutions. In 2015, JOUAV took the lead in the release and mass production of VTOL fixed-wing industrial UAVs in China, which later became one of the mainstream types of industrial UAVs. Through its business layout covering the whole industrial chain of UAVs, JOUAV is able to quickly form suitable solutions for different application scenarios while optimizing the performance of its aircrafts, thus meeting the diversified application needs of industrial customers, continuously improving its customer service capability, and enhancing its market competitiveness. JOUAV's products are similar to Company A' products. Therefore, the two companies have a direct competitive relationship with each other.

2. Shenzhen FEIMA Robotics Co., Ltd.

FEIMA Robotics was established in 2015 by its founding team. The company's main research direction is ultra-small UAV platforms with a focus on VTOL fixed-wing UAVs. It also provides hardware and software integration and enjoys a good brand reputation in this segment. The company's annual output volume is not large, but its products are similar to those of Company A. So, it is a direct competitor of Company A.

3. Shenzhen DJI Sciences and Technologies Ltd.

DJI, which was established in 2006, is one of the first consumer-grade drone companies in China. DJI has been a leading global developer and manufacturer of drone control systems and drone solutions. Before 2015, DJI devoted itself to the R&D and build-up of the usage scenarios of consumer-grade drones. Later, it fully ventured into the industrial drone field. Thanks to its years of accumulation and experience, its industrial drone products and solutions have rapidly occupied and have been leading the market. DJI's products are differentiated from those of

Company A. Specifically, Company A is mainly specialized in VTOL fixed-wing UAVs. However, there is market overlap between DJI's industry-grade drones and Company A's UAVs in the inspection and surveillance field.

4. Shenzhen Micromulticopter Aero Science & Technology Co., Ltd.

With a registered capital of RMB 50.8 million, Micromulticopter is involved in the R&D of multi-rotor UAVs, and its products are differentiated from those of Company A. Company A mainly specializes in VTOL fixed-wing UAVs, whereas Micromulticopter's products are mainly used in the fields of public security, fire-fighting and electric power. Micromulticopter is in competition with Company A in the industry. Micromulticopter's comprehensive R&D strength is strong, and its UAV products have certain market applications.

5. Shanghai Huace Navigation Technology Ltd.

Huace Navigation, established in 2003, is a listed company specialized in high-precision satellite navigation and positioning-related technology and products as well as one of the industry's leading enterprises. Later, relying on its industrial strengths, Huace Navigation established its UAV business unit, mainly producing multi-rotor and compound-wing UAVs used for forest environmental monitoring and industry mapping. As its main products and industrial field overlap with those of Company A, Huace Navigation is a competitor of Company A.

6. Ewatt Technology Co., Ltd.

Ewatt, established in 2010, is a leading civil UAV manufacturer across the globe. Its business covers the design, R&D, production, sales and service of a full range of industrial-grade UAVs. It is headquartered in Wuhan, the hinterland of central China. It has a R&D center in Europe, branches in Beijing and Xi'an, and more than 20 offices in China. Its main products are multi-rotor and compound-wing UAVs mainly applied for power line patrol, environmental protection and land mapping. It overlaps with Company A in terms of products and market.

1.2 Research dilemma and questions

1.2.1 Research dilemma

Despite the remarkable achievements of "mass entrepreneurship and innovation" in recent years, many enterprises failed in the start-up stage. Undoubtedly, MSEs play an important role in China's national economic development because of their large number, wide distribution, small investment, small scale, lean organization, flexible system and strong intrinsic motivation. But

their financing difficulties and poor management are also bottlenecks to their development (Niu, 2016). Given the fierce market competition, most of the small startups in their own development stage lack core competitiveness, are constantly facing survival and development challenges, and are in a high degree of uncertainty. The shortage of funds, lack of systematic startup guidance and restrictions by relevant policies are major external causes of the development challenges to small startups. Besides, the development of small startups is also significantly constrained by their own backward management concepts and sub-standard enterprises systems. A core problem among all the problems facing high-tech startups is that most entrepreneurs have not found the theories and methodologies suitable to their start-up process. They are still using the traditional entrepreneurial approach to start a business in a highly uncertain and rapidly changing market environment, thereby the high startup failure rate (Allen, 2022).

For startups, the initial stage is the stage where it is most likely to fail. The same is true for the U.S., which is known as the most desirable country to start a business. In fact, the situation in the U.S. appears to be even worse. Studies show that in the U.S., approximately 700,000 new businesses are established every year, of which only 3.8% manage to survive and eventually grow into large enterprises (Barringer et al., 2005). Most scholars (Lee, 2019; Singh, 2020; Szerb & Vörös, 2021) believe that the main reasons for startup failure are the overconfidence of entrepreneurs, the lack of entrepreneurial resources, such as poor access to capital, as well as entrepreneurs' lack of entrepreneurial experience. The overconfidence of entrepreneurs leads to blind expansion, greed for large-scale and comprehensive development, as well as risk-taking behaviors without considering the actual conditions. A startup is usually created by a single entrepreneur or a few entrepreneurs, and thus the entrepreneurs have a great deal of decision-making power and can determine the fate of the startup. Existing studies suggest that entrepreneurs are generally optimistic and that their overconfidence usually leads to unrealistic expectations, resulting in over-expansion of the business, which ultimately leads to the failure of the startup. Entrepreneurship does require passion. But passion can turn into impulse if not controlled by reason. The reason why many startups fail is the blind impulse of the entrepreneurs and their eagerness to achieve success, which cause them to amplify market demand without market research and testing. Their loss of objective decision-making rationality and the lack of awareness and ability to control risks ultimately result in the failure of the startup. To a large extent, the success of innovation-driven entrepreneurship requires not only research and development but also application. Therefore, innovation-driven entrepreneurship should be market-oriented and characterized by constant improvement of products according to customers' needs (Holt, 2002).

Startup failure can be attributed to two major types of factors, namely internal factors and external factors. Internal factors include problems in internal management and strategies, an inappropriate organizational structure, as well as problems caused by the overconfidence of entrepreneurs; external factors include fierce market competition and financing difficulties. X. Y. Yu (2011) summarized three causes of startup failure, namely, overconfidence of entrepreneurs, unsmooth fundraising channels and lack of a sound system, as well as entrepreneurs' lack of entrepreneurial experience. In response to the causes of startup failure, studies on measures to avoid startup failure have also been carried out. For example, scholars have made analyses from the perspectives of learning theory, cognitive theory, entrepreneurial team heterogeneity, as well as strong and weak ties theory. Among them, lean startup theory is an integration of the theory of entrepreneurship, learning theory and cognitive theory, and is of great guiding significance to startups, especially innovation-driven startups. Lean startup theory became popular all over the world in just a few years and has been widely recognized in the field of startup research. Lean startup will continue to influence more and more entrepreneurs.

Compared with mature large enterprises, startups generally suffer from "new establishment disadvantages" such as a small size, inadequate resources, experience and capabilities, lack of social connections, difficulty in financing and low legitimacy, which put them at a disadvantage when competing with mature enterprises (B. Yang, 2014). All these disadvantages threaten their survival and long-term development.

Survival and development are the most critical concerns of every enterprise, regardless of their size. In particular, "to survive" has become the core demand of startups. Besides, influenced by the internal environment and external environment, most enterprises have to make adaptations and adjustments in strategy. Therefore, corporate strategy is one of the most important means to coordinate the internal and external environment, and it is also a way to allocate internal resources to adapt to the external environment. Excellent strategic planning enables a company to not only survive but also develop in the long run. Therefore, it is very important to study which strategy to choose in the early stage of entrepreneurship to maximize the core strengths of the enterprise, so that the enterprise can survive the difficulties of the start-up period.

In the current era of mass entrepreneurship and innovation in China, people are jumping on the bandwagon of entrepreneurship with unprecedented enthusiasm. However, entrepreneurship is an activity with high risks. When uncertainty becomes the new stability, innovation and entrepreneurship are bound to face an extremely high risk of failure. According to the Global Entrepreneurship Monitor (GEM) 2015-2016 China Report, China's

entrepreneurial success rate has not been able to exceed 4% in recent years, much lower than that in Europe and the U.S. on a year-on-year basis. The last thing an entrepreneur lacks is passion, but passion alone is not enough. To contribute to such a small probability event as entrepreneurial success, entrepreneurs need to have a sharp mind, a forward-looking perspective, positive thinking, excellent execution ability, the ability to integrate resources, excellent leadership skills and enough luck. Undoubtedly, the most important is the need for a proven theoretical system and methodological support. In other words, there is a universal approach to entrepreneurship, and the right approach to entrepreneurship can increase the success rate (Maurya, 2012).

"Lean startup" is a relatively new theory of entrepreneurship. Nevertheless, after over ten years of practice, development, and improvement, it has been applied in many areas of entrepreneurship and has formed a set of theoretical systems and methodologies. Besides, the lean startup theory and methodology have been applied in foreign countries for many years. There are successful cases of their application in large enterprises' internal startup projects or in entrepreneurial projects or even in government projects.

1.2.2 Research questions

However, since "lean startup theory" was put forward in the U.S., it has been validated and applied mainly by European and American companies, which differ from China in terms of economy and level of development. Currently, the iterative model of lean startup is widely recognized and applied, but the theory is only an abstract theory based on the accumulation of many practices and experience in applying the theory to entrepreneurship. A series of concrete and systematic implementation steps is yet to be formed. Therefore, there is a lack of a clear implementation path and methodological steps to guide the application of lean startup theory and its methodology in the new product development process, and thus to improve the success rate of new products through such application. In particular, the specific implementation path and steps of the MVP theory in lean startup theory are important steps for startups, but there is an extreme lack of specific methods, tools and operational steps to determine the Minimum Value Product (MVP).

Therefore, to better apply lean startup theory and its methodology to high-tech startups in China, this study focuses on the MVP theory of Lean Startup and puts forward the following three research questions:

1. How should we apply the "lean startup" MVP theory and methodology to the entrepreneurial practices of Chinese high-tech startups in light of such factors as economy and development?

2. How can we effectively implement the Lean Startup MVP theory and methodology?

3. Can a model and methodology for validating MVP be found and applied to the practice of high-tech startups in China?

1.3 Research purpose

The present study aims to apply the lean startup MVP approach to the UAV project of the high-tech startup Company A to theoretically guide the company's entrepreneurial process and increase its probability of startup success. Based on this overall purpose, the author has identified two sub-purposes: The first is to review Company A's development history and preliminary management practices and problems of the UAV project and identify the gaps and weaknesses. The second is to explore the feasible solutions for high-tech startups in China to use the lean startup MVP approach and to identify feasible solutions for the MVP through the case of Company A.

1.4 Research framework

Based on lean startup theory and the MVP approach, this thesis systematically builds a path for new product development by applying the lean theory MVP approach to the Chinese UAV startup Company A to analyse and improve its UAV product with MVP analysis and MVP confirmation. On the one hand, this study validates the lean startup MVP approach suitable for innovation-driven enterprises and startups in China from the perspective of practice. On the other hand, through the practice and application of the lean startup MVP model in Company A's new product development process, the success rate of Company A's new products was effectively improved and product cost investment and product development risks were reduced.

Based on the above research framework, this thesis will be arranged in the following structure:

Chapter 1 describes the research background of this thesis by way of introducing the market environment and the background and development of Company A's case chosen for this thesis. It then introduces the dilemmas and problems encountered by MSEs in the entrepreneurial process today. Based on the background and dilemmas, the research purpose and research

framework of this thesis are put forward. After that, the author moves on to analyse the lean startup MVP approach as well as the *status quo* and opportunities of UAV products before highlighting the innovations and research significance of this study.

Chapter 2 is a detailed literature review of existing studies related to this topic. It proceeds from the macro landscape and goes all the way to the micro dynamics, with a review of relevant theories on entrepreneurship, lean startup, minimum viable product (MVP), Kano model and the application of the lean startup theory in China.

Chapter 3 provides a detailed description of the research methods used in this thesis and analyses the research methods required throughout the process from data collection to data analysis in accordance with the research path and logical structure of this thesis.

Chapter 4 analyses the R&D process of the first-generation UAV product of Company A and the reasons for its failure, then proposes a scientific MVP selection model approach, the MVP-Select model, for Company A's UAV product by applying the MVP method of Lean startup theory through comparative analysis for the core failure reasons.

Chapter 5 introduced in detail the process of confirming the MVP of Company A's UAV using the MVP-Select model. Firstly, the list of candidate functional characteristics of the UAV is confirmed; secondly, company-side questionnaires and customer-side questionnaires are designed according to the MVP-Select model MVP confirmation methods; thirdly, questionnaires are distributed and collected from both company-side and customer-side; finally, the MVP of Company A's UAV is analyzed and confirmed by applying the MVP-Select model according to the collected data.

Chapter 6 draws practical insights into the Lean Startup MVP selection method MVP-Select model in guiding new product implementation by comparing the new product implementation effects before and after the implementation of the MVP-Select model, a Lean Startup theory-based MVP selection model, for Company A's UAV project. On this basis, final conclusions are drawn, and limitations pointed out.

The research framework of this thesis is shown in Figure 1.1 below.

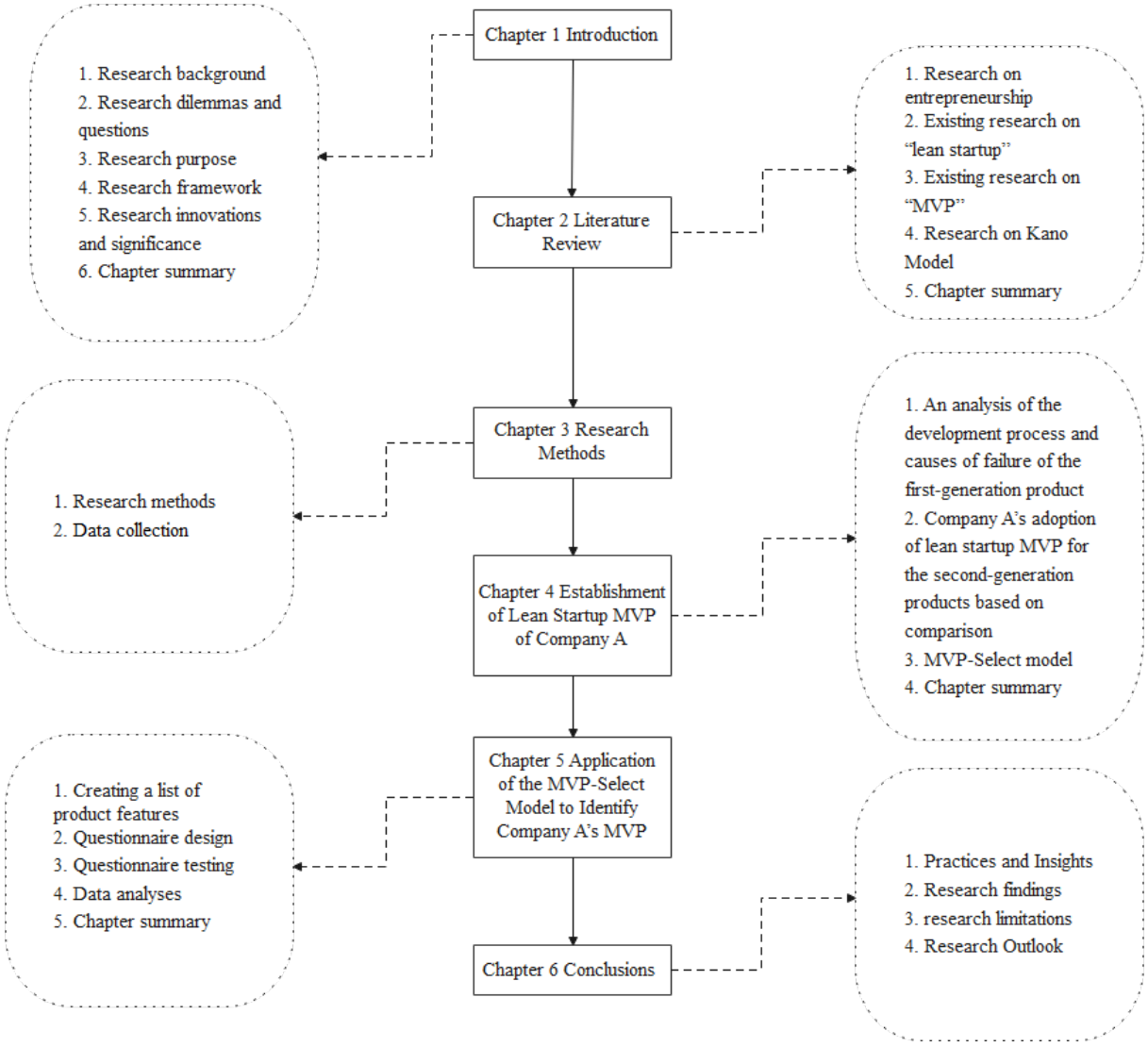


Figure 1.1 Research framework

1.5 Research innovations and significance

1.5.1 Research innovations

The present study has the following innovations:

1. This study applies the lean startup MVP approach to the practice of new product development and puts forward the methods and paths of new product development from the perspective of innovation and entrepreneurship, which provides scientific and theoretical support for enterprises to carry out new product development.

2. This study designs scientific and effective methodological steps for the application of the various steps of lean startup MVP approach to new product development with the aim of improving user satisfaction and rapidly responding to changes in user needs.

3. The MVP-Select-Model is proposed for the identification of MVP, which provides a feasible and practically applied approach for the identification of MVP.

1.5.2 Research value

The value of the present study lies in the following two aspects:

1. This study fills the research gap in China. At present, foreign entrepreneurs and scholars are at the forefront of theoretical research on lean startup compared to their Chinese counterparts. Most of the existing studies on lean startup in China provide only a general introduction to its theory. Only a few studies in China explore how to apply theory to actual projects. In particular, very few studies explore application of the lean startup theory in startup projects in non-Internet industries. This study uses the UAV project of Company A for case analysis and focuses on the lean startup theory's minimum value product (MVP) identification method and the practical application of the method to derive the experience and model of lean startup, which will further increase the applicability of the lean startup theory to specific projects in different national contexts.

2. By analyzing the key problems encountered in Company A's startup, divergent product requirements and too many features but poor market feedback, the study innovatively proposed the MVP-Select-Model and applied it to Company A's new-generation products to enhance their market value and success rate. In response to the initial management problems in Company A's UAV research project, the project team boldly abandoned the established "negotiation – planning – implementation - feedback" project management process and instead systematically carried out dynamic lean startup management optimization. In other words, it carried out a dynamic closed-loop management of "customer demand evolution - lean startup capability renewal - customer value enhancement". This closed-loop approach emphasizes a high degree of alignment between customer demand, lean startup capability and customer value, with customer demand as the pivot, lean startup capability as the effective means, and customer value as the goal. The research findings have practical guidance for startup projects, especially for startup projects in the initial stage to move from high volatility to sustainable development.

1.6 Chapter summary

This chapter first introduces the research background and research significance of this thesis, and then points out the dilemmas and problems of MSE entrepreneurship in today's society in light of the *status quo*. On this basis, it puts forward the research purpose and research

framework. After that, it elaborates on the structure and innovations of this thesis and puts forward the overall research framework, which lays the foundation for subsequent research and analysis.

Chapter 2: Literature Review

2.1 Entrepreneurship

2.1.1 Definition of entrepreneurship

The notion of "starting a business" has been widely referred to in Western countries for a long time, and this notion can be expressed through many different terms in English. From the perspective of time, the earliest endeavors to start businesses were a small group of explorations. Such endeavors, which were full of uncertainties and risks in terms of the products themselves, technical difficulties, marketing and financing, were thus considered high-risk ventures (Block & MacMillan, 1993). Although the term "risk" is mainly used to indicate uncertainty, it denotes a source of danger. Therefore, the English term "venture" was used in the earlier days to indicate the uncertainty involved in starting a business as it can be found in dictionary that "venture" mainly refers to risks associated with enterprises or in other words, commercial risks. Today, starting a business remains a high-venture business activity. Yet the current market situation is complex, and it is more important to successfully start businesses by creating new enterprises or products and optimizing new products, new management or new services. Nowadays, the notion of "starting a business" is more about the industrialization or marketization of new products and services rather than the level of risk. Therefore, "starting a business" is no longer a risk-taking behavior per se, which renders the term "venture" inaccurate. So over time, the term used to refer to "starting a business" gradually shifted from "venture" to "startup" (D. S. Zhang & Liu, 2000).

The notion of starting a business can be seen from different perspectives. Specifically, a business can be established by a venture/a startup or an entrepreneur, and the newly established business can be referred to as a business venture or a new business venture. The person who starts a business is referred to as an entrepreneur. From the perspective of the process, venture may refer to either the behavior of starting a business or investment in starting a business. The former is referred to as venturing or entrepreneurship, whereas the latter is referred to as venture capital, meaning the investment made to seed early-stage, emerging growth companies (Q. Lin et al., 2001).

An enterprise's engagement in innovation can be simply referred to as "business venturing", where "business" is equivalent to "enterprise", and "corporate venturing" is an alternative expression of "entrepreneurship". Besides, the term "entrepreneurship" is also used to symbolize the identity, capabilities and spirit of an entrepreneur. Chinese scholars used to translate the term "entrepreneurship" into an entrepreneurial spirit. However, the meaning of entrepreneurial spirit in Chinese is relatively vague. Therefore, it is generally believed that the most accurate translation is entrepreneurial innovation spirit.

As a specific concept used in scientific research, "starting a business" is commonly referred to as "entrepreneurship" in English, which is already a basic consensus among scholars studying entrepreneurship abroad. Other terms of an adjective nature, such as "entrepreneurial", are often used to indicate meanings related to "starting a business" or "entrepreneurship research". Currently, most business schools outside of China have successfully established or launched an innovative or research-oriented entrepreneurship program or have a dedicated innovative or research-oriented entrepreneurship research and development center, typically known as Entrepreneurship Centre (such as MIT Sloan School of Management), Entrepreneurial Research Centre (such as Wharton School of Business), or Centre for Entrepreneurial Studies (such as Stanford Graduate School of Business).

The term "entrepreneur" has two layers of meaning: the first layer is usually understood as the person who is the principal, manager or business decision maker in a formally formed startup or a business that is ready to be started, and the second layer refers to the founder of a company. When combining these two layers, "entrepreneur" can also mean the chief leader of a new business that is about to be started or a new business that has already been started. An entrepreneur is essentially a person who starts a business (a startup owner), and a founder is essentially a person who starts a business (a startup owner). Only a business leader who has the positive mindset to independently innovate and start a business and who is able to carry out profitable business activities on their own can be called an entrepreneur. Therefore, entrepreneurs are fundamentally not only business managers. Whether they are co-founders of a company or senior entrepreneurs, they are not just ordinary senior managers who are responsible for the day-to-day management of companies. In fact, there is a fundamental difference between the two. A large corporate organization may have many managers, but only a handful of entrepreneurs, or in most cases, only one entrepreneur.

Although most of the best startup owners started from scratch, not all startup owners can be considered as such. Many entrepreneurship experts and leading scholars have clearly stated that entrepreneurial activities can be freely carried out within a firm or an existing

entrepreneurial organization (Amit et al., 1993). It has also been argued that entrepreneurial activity is in itself a process of starting a new business, and that the concept of entrepreneurship in the narrow sense essentially refers to "starting a new business from scratch", while the concept of entrepreneurship in the broad sense can also refer to the creation and development of a rejuvenated new enterprise from scratch in a small enterprise that has long had major development problems (D. S. Zhang & Liu, 2000). In other words, entrepreneurship in the broad sense includes the iterative renewal of enterprises in addition to its meaning in the narrow sense. And for the purpose of this study, entrepreneurship in the broad sense will be used.

There are various academic definitions of entrepreneurship. Y. L. Zhang et al. (2011) are more convinced of the view of Professor Stevenson from Harvard University (Stevenson & Gumpert, 1985) on entrepreneurship. Specifically, Professor Stevenson is more inclined to interpret the term "entrepreneurship" as a process of developing employment opportunities and trying to create business value by breaking away from the limitations by the current social resources and environmental conditions, fully seeking employment opportunities, and integrating the resources in different industries for full utilization and sustainable development. This definition of entrepreneurship can fully highlight the essence of the entrepreneurial development process, the core of opportunity needs, the conditions of resource allocation as well as the values of the company and the goals of the creator.

2.1.2 Development of entrepreneurship

In the mid-1970s, the economic structure of Western societies gradually underwent significant changes, where continuous development in knowledge and technology gradually replaced social capital and professional talents and developed into an important leading and driving force for sustained economic growth in Western developed countries (Romer, 1986); however, entrepreneurial activities and MSEs were still gradually flourishing, making outstanding contributions in various aspects such as employment, innovation and regional economic development. As a result, entrepreneurial activities gradually received adequate attention. After the 1980s, the Third Industrial Revolution in Science and Technology led to profound changes in the way and characteristics of industrial technology development, which further expanded and strengthened the important role of high-tech entrepreneurship and MSEs in forming the industrial structure of China's modern market economy. After that, the field of entrepreneurship research also gradually started to develop; since the late 1990s, entrepreneurship research has

made significant progress and has become part of the mainstream of management research (Y. L. Zhang et al., 2012).

Shane and Venkataraman (2000) published a paper in the *Academy of Management Review* (AMR), one of the most influential and frequently cited management journals, in which they pointed out the essence of entrepreneurial behavior. Specifically, they hold that entrepreneurship requires the combination of entrepreneur and opportunity, that neither can go without the other, and that the combination of the two is the law of the entrepreneurial process. They also presented and elaborated on a research model in their paper, expressing the idea that entrepreneurship should not remain at the level of "old wine in new bottles" or the level of "new wine in old bottles" and that the two ways are not contradictory to each other as they are both central to entrepreneurial activities.

Although entrepreneurship-related ideas were very active during the same period, a mature theoretical framework had not yet formed for the theory of entrepreneurship, and controversies related to it had persisted. Busenitz et al. (2003) suggest that entrepreneurship research has not yet fully developed into a relatively unified analytical theoretical framework, nor has it fully developed a cumulative body of scholarship. Besides, it has not developed into a theory of entrepreneurship research that is independent of other fields of science and technology and has some actual significance. However, with the development in recent years, their paper had accumulated more than 18,100 citations on Google Scholar (as indicated by a search on June 19, 2021), affirming that it had had a tremendous impact on and made a significant contribution to entrepreneurship research and had "led entrepreneurship research through another golden decade" (J. Yang, 2013). In 2009, the writer Shane's academic paper was awarded the "Global Award for Entrepreneurship Research" in Germany and Sweden. Besides, in 2010, Shane and Venkataraman won the "Best Paper Award in the Past Decade" by AMR, the academic presider of entrepreneurship journals. This is not only a significant award for this outstanding academic paper on entrepreneurship but is also widely regarded as a formal and well-deserved recognition of the authenticity and legitimacy as well as an academic achievement of entrepreneurship research by the traditional market economy and business management scholars once again.

Comparing the *status quo* of domestic and international research, Chinese scholars' research on entrepreneurship has not lagged behind Western scholars but has generally followed the pace of Western research on entrepreneurship. However, China's domestic situation has some uniqueness caused by a combination of various factors such as China's institutional transformation, cultural traditions, and emerging economies. Such uniqueness has, to a large extent, caused venture creation and process elements in China as well as the

interrelationship between the two specifics. Therefore, the ideas and perspectives put forward based on Western entrepreneurship practices cannot be fully applied in the Chinese context. The fact that the entrepreneurship research in China has been able to contribute to the construction of a universal theory of entrepreneurship is attributable to not only the uniqueness of entrepreneurial activities carried out in China but also the uniqueness of China's entrepreneurial environment. Specifically, the uniqueness of China's entrepreneurial context is mainly manifested in two aspects, namely, institutional transformation and social organizational restructuring.

First, since the Reform and Opening up, China has embarked on a path of institutional transformation. China has chosen a step-by-step approach to reform by gradually abolishing the centrally planned system and gradually building up a scaled market mechanism through continuous exploration (Xu et al., 2015). Many scholars (Y. Li et al., 2008; Peng, 2003) constructed the development model of the structural reform of national political and economic system as well as rapid transformation in three different periods. The three different periods are respectively the early stage of economic transformation (where planned economy continued to dominate the economy for a long time), the middle stage of transformation (where planned economy and market economy complemented and competed with each other), and the late stage of transformation (where market economy continuously dominated the economy for a long time).

Scholars unanimously agree that China is currently in the middle of a rapid transformation of national political and economic restructuring, and that a market economy based on socialism with Chinese characteristics is being gradually improved. However, the system based on planned economy has not yet been eliminated as the structural reform of the economic system continues. In this context, entrepreneurs in China need to actively respond to additional risks and uncertainties from institutional changes and transformations. Besides, in the process of their behavioral choices, they will encounter the influences and factors produced by various complex scenarios and are likely to encounter some problems that can hardly be explained or predicated by current theories in the process of interacting with emotional factors and analyzing games. This also provides room for us to build, enrich and improve a new theory of entrepreneurship based on the Western context.

For example, studies on innovation in Western enterprises (Barringer & Harrison, 2000; Ensley & Hmieleski, 2005) all suggest that entrepreneurs' previous work experience has a direct impact on their entrepreneurial activities and performance and that previous work experience can equip entrepreneurs with some business knowledge and skills that will help them run and

manage the new generation of businesses. In China, however, the situation may be somewhat complicated, and perhaps not all work experiences can provide entrepreneurs with the experience and knowledge to manipulate the market. Unlike organizations that function properly under a traditional market system, businesses or organizations in which planned institutional power prevails do not strive for quality and efficiency as their primary goals, but rather focus more on maintaining relationships and organizational stability, with more emphasis on how to maintain their *status quo* rather than how to change and innovate (Boisot & Child, 1999). When most individuals who have worked in such firms or organizations switch their career paths to invest or start their own businesses, the impact of their work experience on entrepreneurial activities and performance differs from that in the Western context: on the one hand, they may be unable to navigate the market in the complex and changing entrepreneurial behaviors and activities to a large extent due to their own lack of knowledge in market operations; and on the other hand, they may rely excessively on utilizing their existing social relationships to enhance the efficiency and outcomes of their access to resources. In other words, in the context of China's current institutional and economic transformation, entrepreneurs' previous work experience under China's traditional system of centrally planned economy is not the same as the previous work experience referred to in the relevant Western economic theories in the modern world.

Therefore, given the accelerated transformation of the current institutional and economic reforms in China, an in-depth analysis and study of previous work experience is very likely to promote the further entrepreneurship development in the socialist market economy with Chinese characteristics, thereby better developing entrepreneurial behaviors and making a significant contribution to both the entrepreneurial development and institutional reform for China to develop market economy.

Besides, China's specific socio-economic structure is very likely to lead to specific contexts in which innovative activities take place. While Western societies tend to be characterized by group structures in which individuals manifest their social values by belonging to a group, China's traditional agrarian civilization and Confucianism have created a social structure characterized by ethnic ties, forming a differential pattern based on the phenomenon of ethnic affinity (Y. L. Zhang et al., 2012). In Western societies, business activities are usually based directly on the credit system and other related legal systems of the capitalist market economy, while most Chinese firms and individuals are likely to be based directly on other interpersonal relationships, which to some extent is characterized by "relational capitalism" (Boisot & Child, 1999). More importantly, the institutional gap left in the social context of institutional

transformation further reinforces the important influence of social relationships on business behavior since relationships, as an informal governance mechanism, can effectively reduce the costs and risks of merchandise trade, largely make up for the absence and deficiencies of the formal regulatory system, and replace the formal system to perform the resource allocation function (Xin & Pearce, 1996).

The degree of reliance on personal relationships in entrepreneurial behavior further exacerbates the unevenness in China's social structure caused by individuality, forms of organization and various other factors. Bian et al. (2005) found in their study that while Reform and Opening up has given rise to a class of socialist entrepreneurs in contemporary China and significantly altered China's social class structure based on its politics and power, the allocation of social resources and transmission of information based mainly on personal relationships have led to large differences in the distribution of resources and power among social classes in China, and such differences may be more pronounced than those in Western societies. Besides, there is a certain amount of mutual fragmentation of relational networks among social classes. Under the conditions of an inadequate mechanism for allocating social resources oriented by market entities, it is difficult for members of low-level social groups to effectively acquire accumulated social resources and rights through such impersonal means, and thus enhance their social status.

In general, since the 1950s, the entrepreneurial environment in China and abroad has changed from a risky environment characterized by a low level of uncertainty to a fuzziness environment characterized by a medium level of uncertainty and then to a Knightian uncertainty environment characterized by a high level of uncertainty (J. Qin, 2010; Tang et al., 2007). The evolution of the entrepreneurship theory can be roughly divided into three stages. The first development stage lasted from the 1950s to the 1980s, when China was an emerging industrial society with manufacturing development as its primary product and the domestic and international entrepreneurial environment showed stable and obvious economies of scale (W. Y. Wang & Li, 2007). This period was characterized by clear demand and supply in the market and known entrepreneurial resources and information (Tang et al., 2007). The overall entrepreneurial environment was one with a low level of risk, where entrepreneurs were able to adapt well to the market demand as long as they reconfigured the resources they had. During this period, scholars used trait theory to discuss the question of "who is an entrepreneur", and the study of the traits, resources, natural endowment and competencies of entrepreneurs became topics of high interest in entrepreneurship research during this period.

The second stage lasted from the 1980s to the 1990s, when the entrepreneurial environment in Western countries, led by the United States, began to undergo turbulence due to the rise of

the Internet, resulting in a gradual change from a manufacturing-oriented industrial society to an Internet economy. During this period, supply and demand did not coexist in the market, and entrepreneurial risks were known but the probability of entrepreneurial outcomes was unknown (Courtney et al., 1997; Tang et al., 2007). The overall entrepreneurial environment shifted from a risky entrepreneurial environment to an ambiguous entrepreneurial environment in which only a fraction of people could capture the entrepreneurial opportunities in the entrepreneurial process. In this stage, the academia gradually focused their research on the global development process of firms and innovation, and scholars chose diverse and mature theories from different disciplines, including organizational theory, strategic management theory, resource-based theory, social network theory and cognitive development theory, to try to explore the interactive processes and interactions among various elements in the entrepreneurial process (Wu, 2020).

The third stage of development started from the end of the 20th century and has continued to the present, when the overall socio-economic development of the world has begun to shift further to the new era characterized by the rapid development of such emerging information sciences such as "Internet+", "big data", "artificial intelligence" as well as modern information and electronic technologies, and the entrepreneurial environment has exhibited such characteristics as rapid changes in information and knowledge, high-frequency changes in environment and globalization (W. Y. Wang & Li, 2007). During this period, both supply and demand in the market are not clear; the probabilities of both entrepreneurial risks and entrepreneurial outcomes are unknown; and the overall entrepreneurial environment is changing to Knight uncertainty entrepreneurial environment with a high level of uncertainty. In such an environment, it is necessary to not only clarify the process of relationships of interaction process among the factors influencing entrepreneurship but also make scientific decisions and minimize entrepreneurial risks in the entrepreneurial process. Therefore, the study of entrepreneurial decision-making has become the focus of research during this period, and the representative theories are effectuation theory and lean startup theory. Meanwhile, this is also the period when entrepreneurs started to widely apply lean theory to the field of entrepreneurship.

In this context, individuals or teams that have long functioned as the "structural bridge" between the institutions that create the intellectual property and the people who have the resources are more easily able to identify innovative opportunities and launch their own ventures than others. In other words, entrepreneurs' characteristics in various aspects of the social dimension (such as social class, occupational characteristics and work unit) can have a more important impact on the various aspects of their behavior involved in promoting

entrepreneurial activities, and there are significant differences among various types of entrepreneurs in the social dimension in terms of their innovation potential and their ability to survive in the entrepreneurial activities they engage in or carry out (Haddad & Hornuf, 2019; Honoré, 2022; Y. L. Zhang et al., 2011).

This phase is rich in research on entrepreneurship based on emerging technologies; Welter et al. (2019) conducted a scenario-based study of innovative entrepreneurship; Ferreira et al. (2019) and Hota et al. (2020) examined the structure and organization of entrepreneurship-related research through a bibliometric approach; Kraus et al. (2018) studied the opportunities, challenges and success factors of digital entrepreneurship; McDonald and Eisenhardt (2020) explored the business models of gaming startups; Y. J. Chen et al. (2020) analyzed the problems faced by online platform startups; Guzman and Kacperczyk (2019) studied the gender gap on startup financing; König et al. (2019) examined in detail the evolution of the model of digital startups versus non-digital startup intermediaries; there are studies on the business models of digital startups emerging from the evolving digital-based technologies (Brecht et al., 2021; Gupta & Bose, 2019; Rippa & Secundo, 2019); studies on blockchain technology-based startups (Ahluwalia et al., 2020; Andoni et al., 2019; M. A. Chen et al., 2019); and studies on the impact of startup gas pedals on entrepreneurship (Crișan et al., 2021); Cico et al. (2021) have studied and proposed a framework for integrating entrepreneurship into higher education.

2.1.3 Summary

Entrepreneurial activities are very complex human social activities. In recent years, Chinese scholars have gone through a continuous developmental stage in their research on entrepreneurship. Most of the domestic studies on entrepreneurial activities are now mainly based on a process-based research perspective, different from the earlier research on entrepreneurial activities from a trait-based perspective and an opportunity-based perspective. In this process, entrepreneurship research has gradually developed into a complex combination of entrepreneurship research content and different objects, which can be divided into three different levels: macro, intermediate and micro from entrepreneurship research objects (Yan, 2018). The entrepreneurship research at the macro level is dedicated to the study of innovation-driven activities in general and focuses on issues related to business innovation and economic growth, institutional environment and socioeconomics of entrepreneurial activities. The entrepreneurship research at the intermediate level studies entrepreneurial activities from the general to the local level, mainly targeted at specific segments. The current focus is on specific

types of entrepreneurial behavior or specific consumer groups. The entrepreneurship research at the micro level studies various entrepreneurial activities from the elements and process of innovation, and the scope of the research mainly includes startup owners, entrepreneurs and teams. The research is generally carried out from the perspective of business management, mainly around the entrepreneurs, enterprise elements and their entrepreneurial processes.

Both domestic and international research on such topics as entrepreneurship and entrepreneurial development have a certain theoretical foundation. Overall, entrepreneurship outside of China has a lot in common with entrepreneurship inside China, and this section mainly summarizes the differences between entrepreneurship inside and outside China. Specifically, entrepreneurs outside China create products or services with social value and focus on their innovation and efficiency. In comparison, entrepreneurs in China, given China's unique era and national conditions, do not strive for high quality and efficiency as their main goals, but place more emphasis on the maintenance of such relationships and ensuring organizational security and stability. In general, regardless of the means used to carry out these entrepreneurial activities, the study of corporate entrepreneurship has gradually become one of the mainstays and directions of research in the management discipline, and it is growing rapidly both in China and abroad.

2.2 Lean startup

The theory of "lean startup" was developed by Eric Ries, who, after an in-depth analysis of "lean production" and "lean thinking", drew on the basic theories and concepts of modern lean and finally put forward "lean startup" (Bu, 2015), which is a practical application of "lean thinking" in contemporary innovative business management (Frederiksen & Brem, 2017).

2.2.1 Lean thinking

Lean thinking was first derived from the lean production management model independently invented by Toyota Motor Corporation in Japan in the 1980s, and it refers to the valuable technical achievements made by Toyota in Japan during its continuous innovation and production practice in the application of the lean production management model. In short, lean thinking was, to a large extent, derived from Toyota Japan's lean production management model, matured with the in-depth research and application of Toyota's lean production, and eventually developed into a new lean production philosophy that has been recognized and widely used in the international community (Fan & Hu, 2013). Lean thinking was first put

forward in 1990 by the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology (MIT) in the United States. Specifically, "lean manufacturing" was officially put forward in the "IMVP Research Report" (Q. Z. Wu, 2020). The report elaborated on the concept of "lean thinking" in detail.

In 1985, a few professors at MIT, represented by Prof. James P. Womack, Prof. Daniel T. Jones and Prof. Daniel Roos, made an in-depth analysis of the fundamental nature and causes as to why large U.S.-based automobile manufacturing companies were directly defeated by U.S. auto manufacturers from Japan in the international market competition (Womack et al., 2007). In March 1990, after analyzing more than 90 U.S. auto manufacturing plants, they published the book entitled *The Machine That Changed the World*, where they introduced the basic concept of "lean" of Toyota Motor in the U.S. for the first time and defined Toyota's production model as Toyota Lean Production. As the concept of lean production permeated the business community, Japan's real economy experienced a boom in the 1970s and 1980s when various major Japanese automobile manufacturing companies and joint ventures represented by Toyota Motor Corporation successfully moved towards an era of internationalization and rapid economic development. The theoretical study and research of lean production as well as its application in production practice gradually become a topic of keen interest among modern automobile manufacturing enterprises, production researchers and in the society at large.

The application of lean thinking in entrepreneurship begins with the search for a business model. The primary process is to continually gather customer feedback by testing, revising and discarding hypotheses, and rapidly iterating and redesigning the product, a strategy that greatly reduces the chances of startups spending a lot of time and money launching products that no one actually wants to pay for. S. Blank (2013), consulting associate professor at Stanford University, is one of the architects of the Lean Startup Movement, an approach he believes can help companies get off to a fast and successful start. Besides, if widely adopted, it will reduce the incidence of startup failure.

2.2.2 Lean management and its development

In 2003, Womack and Jones (2010) co-edited and published the first professional sequel entitled *Lean Thinking*, which summarizes the various management concepts, tools and methods contained in lean production at a high level and put forward the concept of "lean thinking". According to the book, the management connotation of "lean" is no longer simply limited to every field of lean industry and lean production. Instead, it was extended to every link and every

aspect of enterprise operation and management to effectively promote enterprise senior management to rethink in depth how to effectively change the entire business process, eliminate waste of resources and create enterprise value.

In this book, Prof. Womack and Prof. Jones put forward five principles of lean management: identify the value, which is about defining the entire process within a company from product design and development to production, sales and delivery from the customer's point of view to achieve effectiveness and maximization of the value of customer service; value stream mapping, which is about identifying the true value-added activities in the value stream and eliminating the non-value-added activities; value flow, which is about using such means as sustainable improvements, just in time (JIT) and one-piece flow to meet the continuous flow of high value for enterprises under mass manufacturing conditions; pulling, which is about making inputs and outputs based on the needs of customers and enabling other customers to get exactly what they need in a necessary period of time; and perfection, which is about arranging inputs and outputs according to the needs of customers to ensure that each user gets the exact product they want in a short period of time (Womack & Jones, 2010).

After Prof. Womack and Prof. Jones published the book *Lean Thinking* in 1996, lean thinking officially started to develop and became an effective methodology for reducing waste of human resources, creating value, shortening life cycles and increasing chance of success (Womack & Jones, 2010; F. Yu, 2015). Alternatively, lean thinking can be considered an effective methodology to perform process management optimization (Samuel et al., 2015). Since the 1990s, it has been applied successively in industries such as integrated manufacturing, aerospace aircraft and electronics manufacturing, as well as apparel, food and other areas of consumer lifestyle engineering. Lean thinking has been rapidly developing and widely used in many professional fields. For example, Koskela (1992) applied lean thinking to the construction industry and developed the concept of "lean construction" in practice. In this process, relevant emerging concepts were also put forward, including "lean management" (Kammel, 2013), "lean supply" (Rand, 1994), "lean logistics" (Fynes & Ennis, 1994), "lean manufacturing" (Shah & Ward, 2003), "lean marketing" (Glomb, 1995), "lean enterprise" (Womack & Jones, 1994) and "lean government" (Kühnlein & Wohlfahrt, 1994). Dennis (2010) put forward a management system that applies lean thinking broadly to the "whole organization" process. Lean thinking has been an important technological enabler and driver for the development of several new industries around the world, mainly in advanced manufacturing technologies, by enhancing their core value, creating new capabilities, and reducing waste of resources.

2.2.3 Lean startup and its development

As mentioned in Section 2.1.2, there are three stages of entrepreneurship, of which the third stage is characterized by increased entrepreneurial risk due to rapid changes in information and knowledge, high frequency of environmental changes and globalization. In this stage, entrepreneurship is no longer an easy task, thus giving rise to lean entrepreneurship in the context of such times. For the introduction and launch of products in emerging companies, traditional entrepreneurial models comply with the following schematic illustration of the product development process (Blank, 2020). As shown in Figure 2.1, such product research and development process clearly demonstrates the traditional product research and development process. This new product research and development process is well suited for the introduction and launch of new products in mature and regulated markets. In this market, both the number of customers and the needs of consumers are clear and precise. But in the current context of global innovative product development, the market is full of uncertainty. Therefore, the traditional emerging product research and development model is not suitable for all startups.

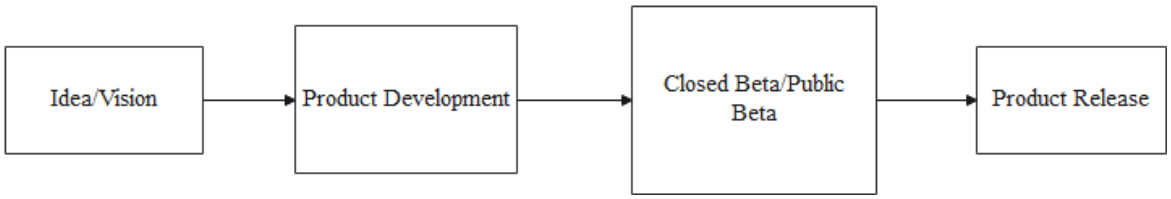


Figure 2.1: Product development method diagram

Source: S. G. Blank (2013)

For some newly established enterprises, the products just produced in the early stage of their enterprise development are experimental and significantly unstable. Despite the instability of the products, once the products are tried to be put into the market, the experimental results generated can be verified in the market to come up with a sustainable business model, and the idea of updating and iterating the products can also be derived based on the feedback from customers. Lean startup mainly applies three important management tools: "minimum viable product", "customer feedback" and "rapid iteration". The iterative cycle of lean startup is shown in Figure 2.2 below.

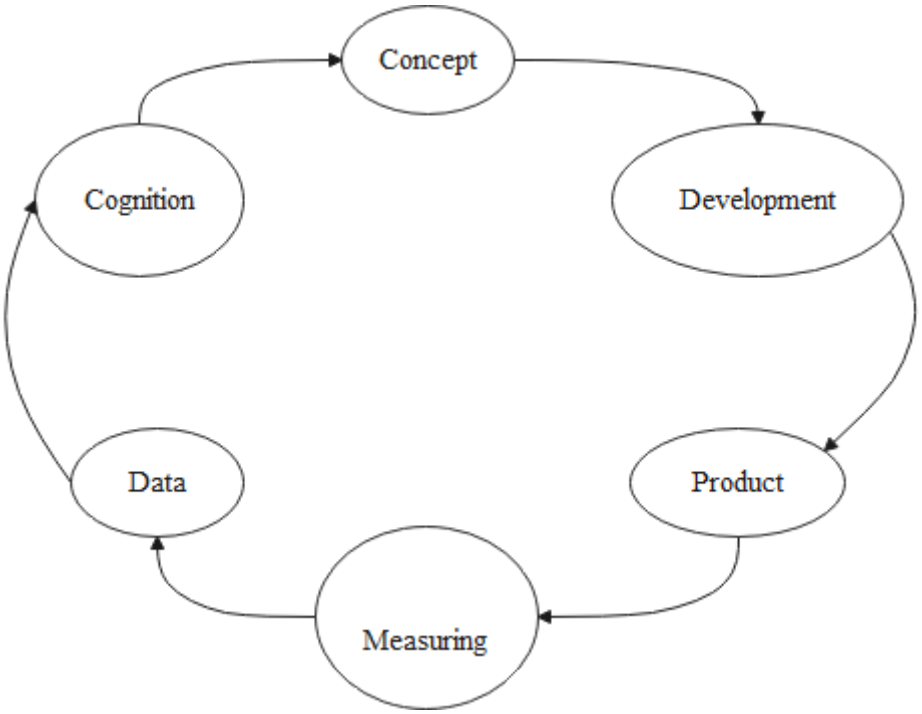


Figure 2.2: The cognitive iteration cycle of lean startup

Source: Ries (2011)

In his preface to the Chinese edition of the *Lean Startup*, Kai-fu Lee of Innovation Works writes, "a company will only win the future if it adapts quickly to the times, and the way products are produced must change for the times" (Ries, 2011). Ries (2011), a Silicon Valley entrepreneur, first introduced lean thinking into the startup world, defining the concept of lean startup as an entrepreneurial path that exists through a process of practice and learning, and that leads to continuous innovation. Ries, who started his career as an engineer, used to live in Silicon Valley. Ries had already accumulated in-depth knowledge and experience about the rules of sustainable deployment, customer development, agile development and extreme programming from conducting Internet research in the past. He started collecting and organizing information and content closely related to his own entrepreneurial practices in August 2008 to find and summarize some principles based on these practices to explain their success in creating emerging Internet businesses and companies. He concluded a rule: when the project research and development of startups is developed in an uncertain environment, the prediction and strategy models under traditional management rarely work when faced with such uncertainty. It was at this stage that Ries learned how to use customer development and its flexibility and agile practice in product development by attending his investor Steve Blank's entrepreneurship workshop (S. Blank, 2013). By learning "lean production" in depth, he found that the concept and terminology of lean production also make sense for entrepreneurial effectiveness. So, he tried to integrate the "lean thinking" embedded in "lean production" with

his Internet startup experience and published the book entitled *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Business* in 2011. In this book, he put forward a logical approach: "Build—Measure—Learn" feedback loop. The core of this approach lies in the integration of lean thinking in entrepreneurial activities. In this approach, "Build" is about rapidly introducing minimum viable products (MVPs) to potential customers based on value and growth assumptions; "Measure" refers to the establishment of an evaluation system to track and measure the MVPs qualitatively and quantitatively in time as they are validated in the market; and "Learn" refers to the validated understanding, or in other words, the adjustment and implementation of MVPs based on the measurement indicators. The method mainly provides a viable solution to effectively and efficiently avoid the various possibilities of failure of new products and services to secure their rapid development and expansion (S. Blank, 2013). In other words, MVPs can significantly accelerate the development of innovation and the productivity.

The lean startup model assumes that startups are not smaller versions of large corporations. In fact, they are distinctly different. While one of the main tasks of well-developed companies is to implement the traditional business model by building and developing it, the main task of some startups and new companies is to find a new business model by building and implementing it. Specifically, the latter look for a repeatable and scalable business model to turn it into their own fixed model. Lean startups do not completely follow traditional business operating strategies, nor do they operate according to hidden business models or release fully functional lean products or samples. They usually start with a "business model canvas" to quickly map out their business model assumptions and quickly design and produce the easiest, simplest and most widely implementable business model products possible. After that, they take the initiative to launch such products in the market and test their business model assumptions on a case-by-case basis through in-depth conversations with consumers. Subsequently, they will continuously improve, test, and further adjust the design assumptions based on the timely feedback on design from the preliminary users, buyers and merchants or later partners. Throughout such a long-term cycle, they will constantly adjust, replace and improve their original design ideas to find a viable solution before they can start planning to produce the products in large scale or make new transitions regarding some infeasible business ideas (Ries, 2011).

In today's business world, innovation and entrepreneurship have become a major trend. Currently, the increased application and rapid development of modern business information Internet technology, especially mobile Internet, has significantly facilitated people's rapid

understanding of business information and the global dissemination of such information. After being put forward by Eric Ries in the earlier days, lean startup quickly developed into a popular entrepreneurial management methodology in various global entrepreneurial management scenarios in today's world. It has been reported in *The New York Times*, *Wall Street Journal*, *Harvard Business Review*, *Huffington Post* and many other business media, starting a Lean Startup Movement featuring people-oriented learning, research, pioneering and continuous development of innovative lean startup. Ries set up a website on lean startup (http://theleanstartup.com) to study in depth and expand the application of his successful lean startup cases. On this website, visitors can access free readings (images and texts), videos, slides and audio of his presentations, as well as images and texts of his blog "Startup Lessons Learned" through publicly available links. Besides, he has hosted many entrepreneur parties themed on lean startup in important places such as San Francisco, Boston, New York and Chicago in the United States as well as Beijing. There is also an official website about lean startup parties and their organization (http://lean-starup.meetup.com); on the Wikipedia Startup Network (http://leanstartup.pbworks.com), an autonomous lean startup project co-founded and maintained by volunteers, there is a list of detailed startup events and other project information and resources; Rich Collins has created a circle of friends to share emerging lean startup technology practices. Every day, thousands of technology entrepreneurs learn from each other and share their startup skills, resources and experiences, and tell their stories here; and currently in China, many of the business schools set up by large enterprises provide courses on lean startups in their MBA entrepreneurship programs, and various outstanding entrepreneurs offer training workshops on lean startups in this community. There are also a lot of paid courses on lean startup and trainings on professional knowledge and business skills.

Although lean startup theory has attracted widespread attention in the field of entrepreneurial practice in recent years, there has been relatively little research on the application technology and practical applications of lean startup. The research on relevant technologies is mainly focused on three areas: lean startup methodology, regional application of lean startup and other segments of lean startup.

1. Research on lean startup methodology

The research and analysis methods of lean startup were first published in the paper entitled "Research-Technology Management" by the American scholar Ries (2011). These methods quickly became widely accepted and applied in practice along with such concepts as MVP and pivoting put forward by the author. Eisenmann et al. (2012), after careful research and analysis, argue that lean startup is essentially an "assumption-driven" entrepreneurship model (Monds,

2015); Dr Steve Blank, a well-known Silicon Valley serial startup innovation founder and investor, argues that enterprises that adopt an efficient lean startup approach are likely to have lower costs and failure rates in the future than their counterparts that use traditional management methods, and that this management method has important value for the enterprise innovation and economic development in various regions and countries (S. Blank, 2013). Mansoori (2017) explored the mechanism by which lean startup guidelines impact entrepreneurs based on the semi-structured in-depth interview design. He believes that entrepreneurs learn, internalize, and apply lean startup methods through alternative learning and learning in practice.

Besides, Ladd (2016) also clearly identifies the limitations of lean startup. Specifically, there is little linear relationship between the number of assumptions a startup has validated and the success of other businesses. In other words, more often, the validation of assumptions does not make any difference. It is not sure the teams that adopt which method will end up performing worse compared with teams that engage in open dialogues and actual practice at the same time. The lean startup method may produce "false negatives", where entrepreneurs and intrapreneurs keep testing their ideas repeatedly before they finally move on to mass production because the method does not have a clear rule for when they should stop testing, which results in their mistaken belief that their ideas are not good enough (Kaminskaite, 2017). Hwang and Shin (2019) studied the case of the Korean company Samsung's enterprise transformation and summarized the limitations of lean startup methodology and the management characteristics of the enterprise itself and that adaptation and tailoring are required when applying lean startup methodology. C. J. Yang et al. (2019) studied the impact of the search and execution process in lean startup on the outcomes and effect perceptions of lean startup. The study by Bocken and Snihur (2020) suggests that startups using lean startup have great potential for business model innovation and are more influential and novel. Lean startup is essentially an experiment and the toolset for experimentation. It emphasizes more on experimentation than on informal planning (Contigiani & Levinthal, 2019; Harms & Schwery, 2020). Shepherd and Gruber (2021) provide a detailed explanation of the five main constructs of Lean Startup to avoid misunderstandings during application. Moralles et al. (2020) examined the maturity model of Lean Startup. There are also studies on performance landscapes in relation to Lean Startup (Baumann et al., 2019), studies on a review of the literature related to Lean Startup (Silva et al., 2020), and a revision and upgrade of Lean Startup (C. B. Wang et al., 2022). Leatherbee and Katila (2020) argue that business education is a key factor for lean startup teams. Tkalich et al. (2021) examined and put forward important recommendations for the successful application of lean startup for

intrapreneurial innovation. C. B. Wang et al. (2022) examined the limitations of the lean startup approach and suggested solutions.

2. Research on the regional application of lean startup

Martin (2016) explored in detail the wide application of Lean Startup in Brazil, mainly through some new micro-typical cases and research findings. Lalic et al. (2012) found through a study of a structured market questionnaire survey of technology-based companies and their structured business development and management models in Croatia that the internal logics of operation, development and management models of some technology-based startups in Croatia are very similar to the principles of lean startup methodology and that it can be considered that Croatian startups are successfully implementing lean startup methodology in business. Ardyanti et al. (2019) studied the application of lean startup to a digital platform startup in Indonesia. C. Y. Kim and Park (2021) studied the case of a Korean food online platform that applied lean startup to achieve success. Iturbide Galindo et al. (2020) conducted a study of lean startups in Mexico and concluded that there was no strict linear relationship between entrepreneurial competencies and training. de la Torre et al. (2019) studied the case of applying the lean startup approach to a Spanish tourism product. Q. Qin et al. (2020) conducted a study and practice of applying the lean startup approach to entrepreneurship education in Chinese universities.

3. Research on the application of lean startup in segments

Furr and Dyer (2014) introduced the lean startup approach to product innovation, development and application in order to make it more actionable, and further divided into detailed steps; Silva et al. (2013) applied lean startup to the health sector in the U. S. and found through research that lean startup has a significant effect on new products and services in the health sector; Nientied (2015) applied lean startup to the education sector and validated its effectiveness in the education sector based on a new case study at Polis University; similarly, Hegedić (2016) also applied lean startup to the field of education from different perspectives and validated that lean startup is effective in the process of student development projects; Galluzzi et al. (2017) discussed in depth in their paper the lean startup education approach in IoT technology and its application in the development and implementation of IoT curriculum, and the method yielded good practical and pedagogical results. Cico (2020) explored the application of lean startup to the teaching of software engineering.

Ghezzi (2019) as well as Ghezzi and Cavallo (2020) conducted a quantitative study of digital startups to identify how they use lean startup methodology and to draw advantages and disadvantages of applying lean startup methodology. Razdan and Kambalimath (2019) studied and proposed an engineering model specifically for startups applying lean startup for software

development. Mansoori et al. (2019) studied the change in the relationship between startup mentors and entrepreneurs after applying the lean startup approach. Carroll and Casselman (2019) studied the case of applying lean startup to digital business model startups. Kaylan et al. (2022) applied the lean startup approach in the improvement of medical curriculum. Raneri et al. (2022) showed that lean startup can be applied to artificial intelligence startups with appropriate modifications.

Annisya and Rochman (2020) studied the case of applying lean startup to an online sales platform startup for medical devices. Space X, founded by Elon Musk, is a company that helps the National Aeronautics and Space Administration (NASA) launch carrier rockets and deliver air cargo to the space station. Space X is able to perform these tasks for NASA mainly because its costs are much lower than those of NASA, and the main driver behind this is the constant lean startup iterations. Specifically, Space X iterates at a rate of one month as a unit of measurement, while NASA's iteration rate is generally measured in years or even a decade, and each of its iteration needs to go through approvals by numerous departments. In fact, all of Space X's earliest basic technologies are believed to have originated directly from NASA, so it has not formed any advantage in its technological barriers. However, it underwent constant and rapid updates and iterations to the point that it eventually surpassed NASA in technology. Moreover, its fees and costs are much lower than those of NASA, even by an order of magnitude (Gong, 2015).

"Lean startup" helps foster more capital-efficient, innovative and creative companies. It takes advantage of validation-based learning, rapid technology iteration and scientific practice, as well as the continuous collection of customer feedback to shorten the product development cycle to a certain extent and understand the real needs of customers and the "to-do lists", thus enabling companies to flexibly adjust to changing market conditions and customer requirements to avoid excessive waste. It also provides companies of all sizes and company management with the ability to constantly test their vision as well as adapt and adjust their direction in a timely manner. Today's era is one where innovation is needed more than ever before, and lean startups offer a relatively scientific way for us to create and manage our own startups (Zou et al., 2017).

2.2.4 Summary

After Ries (2011) first explicitly introduced the basic concept of lean startup in 2011 based on his in-depth research on enterprise customer development and agile management methods, the

concept quickly took the world by storm. Later, scholars studied it in depth and initiated the Lean Startup Movement. However, in terms of its basic theoretical research, lean startup has been classified as a new industry phenomenon that is still far from being fully studied in depth (Mansoori, 2017). There are still some obvious deficiencies in both the initial establishment of the concept as an industry methodology and the nature and testing of its exploration in different industry areas and segments. Although the early theoretical ideas presented in lean startup and some of the initial cases of the practical application of lean technology startup were mainly about its application in high-tech or Internet startup scenarios, as Ries wrote in the preface to the book entitled *The Lean Entrepreneur* co-written by B. Cooper and Vlaskovits (2013), it is only by chance that lean startup is interconnected with a particular startup industry (such as high-tech startups or other Internet startup environments) (Gong, 2019). The lean startup approach is not only a method that can be widely applied to high-tech or Internet startups, but also one that can be applied to a broader range of areas. For startups, it is crucial to apply "lean startup theory" as an important guiding theory for the implementation of company strategies and to analyse how to achieve the company's strategic goals with minimal costs. Yordanova (2021) summarized the trends in the development of lean startup through a literature review and suggested methods for digital transformation of enterprises.

In the studies conducted by scholars in China, the only direct application of lean startup theory to guide startup projects is described by Feng (2019), who describes the application of lean startup theory to startup marketing, marketing initiatives and strategic positioning and roughly described the use of lean startup thinking to guide the development of startups. Xue (2018) briefly described the design of a startup's services using lean startup's principle of MVP from the perspective of startups' CEOs, the validation of the growth engine, and the difficulties and risks in applying lean startup thinking to guide the venture creation process. These cases ignore the application of lean startup principles in the product development decision-making process and fail to discuss the value-oriented, action-oriented, scientific trial-and-error and loss-bearing principles of lean startup thinking and methodology, nor do they further analyse and summarize the steps and methods adapted to the implementation of lean startup theory in high-tech startups in China.

2.3 Minimum viable product (MVP)

2.3.1 Development process

Product development process is a standardized system for enterprises to manage the process of product development, which is an important link for the development and growth of enterprises. Unlike general business processes, product development process focuses more on the impact of process management on efficiency and product development cycle. It can be said that the purpose of establishing product development process is to improve development efficiency and shorten product development cycle. The existing mainstream product development processes include the waterfall model, iterative model, rapid prototyping model and agile model.

1. Product and cycle optimization method

The most familiar approach to effective management of product technology development workflows is the product and cycle-time excellence (PACE) program proposed by Michael E. McGrath, founder of PRTM, an American consulting and management firm, together with his team in 1986 (Henderson et al., 1998). PACE refers to a product process and technology reference model specifically for enterprise product development. Chinese scholar Hao (2014) described in his paper entitled "Product and Cycle-time Excellence Method" that PACE mainly integrates some key factors in the enterprise product development process and improves and makes up for the deficiencies in many existing enterprise product development processes at home and abroad on this basis. These key factors are all calculation methods that are validated, based on extensive practice experience and an in-depth understanding of the best design practices.

The general theoretical idea behind PACE is seven-fold. First, the product development process is an organized and systematic activity as well as a process that can manage and improve products internally driven by the decision-making process. Second, the product development process requires a clear definition and implementation plan to ensure that all relevant people have a common understanding of how to coordinate and work with each other. Third, product development is guided by clear rules for hierarchical management and schedule management, and there are logical interrelations between each level. Therefore, problem solving must be considered in an integrated manner, and the improvement of a single link can hardly make a difference. Fourth, product development needs to follow the rules and proceed in a step-by-step manner, and premature intervention of production materials and resources in the next stage cannot enhance development efficiency. Fifth, the product development process

must be adapted to other processes for unified management to comply with the common decision-making process, and the focus of managers is the key point in the process of product development for the conduct of product positioning and decision-making. Sixth, the new product research and development process requires a new organizational system model to be built jointly by the product research and development project team and the management. The product R&D team is composed of authorized product managers and several cross-industry functional team members, with management as the basis for approval and review. Seventh, product development enhancement also relies on advanced manufacturing tools and adequate infrastructure guarantees.

2. Waterfall model

The earliest model widely used internationally is the "waterfall model", which was put forward by Winston Royce in 1920 (Bai & Li, 2012). The model divides the entire waterfall design product development process into six basic work steps, including product development, requirements analysis, design, implementation, testing, and product operation and maintenance, reflecting a top-down, strict and non-linear process with a fixed model of product development work sequence. With the development of industrial technology, products become more and more complex, and design links more and more numerous. In the process of continuous progress of product development technology, some enterprises and scholars noticed in the process of product development process optimization that tasks and links are not always sequential, and some mutually independent tasks and links can be advanced by changing the position in the process. So, the theory of parallel engineering came into being along with the development of product development process optimization theory.

Parallel engineering is a new concept first clearly introduced by The Institute for Defense Analyses (IDA) in its first report in 1986. The report explained it as a system and method that takes its own product as the technical core and integrates its closely related design processes, manufacturing processes and technical support processes. It includes how to set up a cross-departmental integrated development project team, reorganize and optimize the entire product development process, stream rationalization and optimization of the development process. Besides, it focuses on the digital definition and information integration of the entire product lifecycle, so that the product can be developed with all parties' needs in mind. It ensures the operation accuracy of product design and reduces the unnecessary process of iteration and design to significantly shorten the product development and production cycle and reduce the time and costs invested in relevant products.

Wognum and Trienekens (2015) described parallel engineering as a design system for the entire design and manufacturing system, covering marketing, sales and maintenance functions in their book entitled *The System of Concurrent Engineering*. Its main goal is to reduce time-to-market, improve quality and reduce costs by taking into account downstream requirements and constraints that are already in the design phase. Beginning with design-build integration, parallel engineering tends to integrate more lifecycle features with a greater emphasis on customer and supplier attention and involvement. Parallel engineering provides an opportunity to integrate more resources and development opportunities for product development, which greatly reduces the product development cycle time. The introduction of parallel engineering theory allows for the possibility of further transformation of the product development process. It means that when some design iterations in the product development process are bound to exist, a smaller scale of rework can replace the large scale of rework in the serial mode, thus saving various resources in the development process. The adoption of parallel engineering for the optimal planning of the parallel development process is also one of the goals of process optimization.

The waterfall management model divides the entire life cycle of enterprise software development into six management phases, including: project planning and management phase, requirements design and analysis and goal determination management phase, software design phase, coding and software implementation phase, testing phase and software maintenance process management phase. As shown in Figure 2.3, the waterfall model is like a flow line of a waterfall, descending from top to bottom and passing from one level to another.

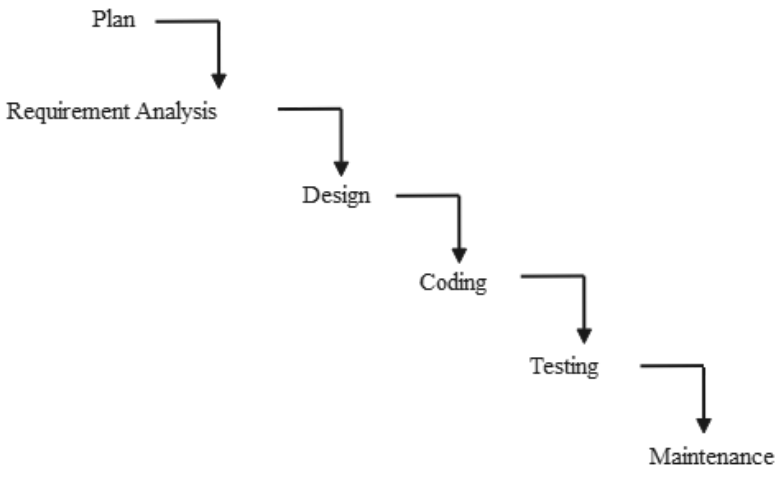


Figure 2.3: Waterfall model

Source: Bai and Li (2012)

The main advantage of this design model is that the process is simple, clear and hierarchical, which is suitable for the organization and deployment of personnel in the research and development of large software systems, thus ensuring the accuracy and quality of research and development of large software projects. However, its drawbacks are also particularly obvious. The biggest one is that the project process it makes is very linear, and users usually only wait until the later stages of the project to observe and experience the effects of the software. Besides, due to the specificity of the waterfall model, we need to track and trace the last development process in the process of identifying the problem, and the orderly development may be disrupted due to changes in customer needs or market reasons, thus increasing the risk faced in the development process.

3. Iterative model

Research on the iterative model can be traced back to the 1960s. Before the 1960s, enterprise software was of a relatively small scale, and the range of areas in which software was applied was limited. Therefore, the use of systematic production did not attract a high degree of attention. In the mid-1960s, high-speed and high-capacity tablet computers gradually came into use, and such areas as high-level programming languages, operating systems and database software began to experience rapid development, which all resulted in the rapid expansion of the scope of application of computers. In the meantime, the software system was no longer a small workshop. Instead, the scale became increasingly large and complex, rendering the previous individualized software production method unable to support. The demand for changing and improving the way software was produced grew stronger, which was what was known as the industry's "software crisis". Signs of the software crisis included such risks and problems as inefficient software development, poor quality of and difficulty of improving the developed software products, software project delay and budget overruns.

Although the iterative model became widely applied late, it does not mean that it came into being late. In fact, it came into being in the 1960s, as early as the well-known waterfall model. The waterfall model has been widely used by the industry for a long time since its birth, while the iterative model has been much less studied and applied in comparison. With the advent of the Internet and the information age in the 21st century, it has become increasingly difficult for the waterfall model to meet project management requirements. The iterative model has gradually gained attention and become popular as a result. The waterfall model does not support making changes to completed phases, and if it is found in subsequent phases that errors exist in previous phases, or if project requirements change midway, a formal change process needs to be followed. The fundamental reason for the rise of the iterative model is that the waterfall

model cannot be adapted to projects with uncertain requirements. The iterative model was originally created to address quality issues. In practice, it was discovered that applying iterative methods allowed for incremental implementations in scope. Small incremental implementations coupled with interaction with users allowed for the elimination of uncertainty in requirements, thereby increasing the success rate of the project.

4. Rapid prototyping model

The rapid prototyping model is an improved version of the waterfall model (Y. S. Zhang & Li, 2006), which focuses on the rapid discovery of requirements. The general idea is to first design and develop an initial system prototype that can run normally to explore and discover deeper user requirements through the initial prototype and user interaction before finally designing and developing a satisfactory software product for customers based on further optimization and improvement of the system prototype. The development steps are shown in Figure 2.4 below.

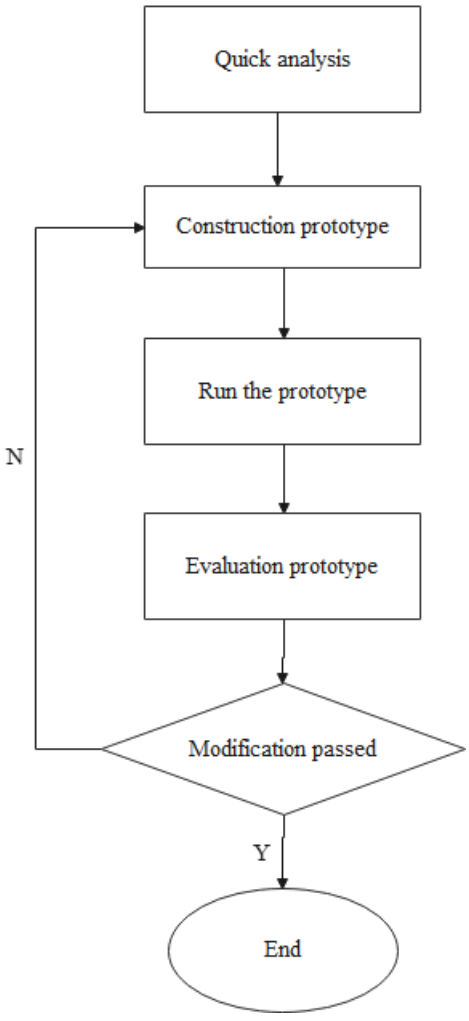


Figure 2.4: Rapid prototype development process

Source: Zhang and Li (2006)

The advantages of rapid prototyping are threefold: the first has to do with the continuous incremental replacement and iteration of new features in the software, high development efficiency and shortened project cycle; the second is about the communication between developers and users, where an intuitive user group can help clarify the details of their requirements and developers can actively engage these users; the third is customers' participation in the whole process from system prototype development to the final delivery of all products, which can help more users know and accept all products and further improve customer satisfaction. The prototype system can be considered as a training environment, and the development process is also a learning process. The main drawback is that the rapid implementation of the prototype model is not sufficient for the overall quality and maintainability of the software, and once the prototype fails to meet the quality standards, it is likely that the traditional prototype will need to be abandoned and a new simulation model will be used for the design, which on the other hand limits the innovation of the product. Therefore, the prototype-based model is not very suitable for the research and development of large software systems.

5. Agile model

The emerging agile project management method is also based on the iterative model. The agile method is a development method based on the iterative model, and the origin of agile development can be traced back to 2001. Back then, people were struggling with the bulkiness, complexity and high failure rate in the process of lightweight software development and were desperate to find a new software development model. In this context, a total of 17 volunteers went to Snowbird Resort in the State of Utah, U.S. to organize research and discussion on the process of developing a new and lightweight software that aimed to free software development from unimportant and process-oriented distractions and enable it to focus on what really matters. Agile development aims to respond quickly to changing times, and its ethos is to focus on specific goals and highlight teamwork.

Agile development proposes and advocates a core value based on satisfying user needs. It is based on a replacement development model that breaks down large projects into smaller projects in steps and finalizes project delivery through short and fast submissions and multiple rounds of communication with users, with a process that advocates light planning and evolutionary development. As of 2010, more than half of the enterprises in Europe and the U.S. had already been using the agile method for project development, including well-known companies such as Microsoft, Amazon, Google and Facebook. Books such as *Agile Project Management* written by Jim Highsmith and *The Elements of Scrum* co-written by Chris Sims

and Hillary Louise Johnson have all scientifically explained in detail the related ideas, practical principles and specific implementation steps of the iterative model and agile development. In the product management system of Scrum, the role of supervisor is similar to that of project manager, who is responsible for supporting the maintenance of the development and work processes of the iterative and upgraded products, and product profits are taken care of by product manager. Nowadays, Scrum has had a profound impact on the industry. Practical research on agile methods covers software development rhymes, agile database techniques, agile modelling and exploratory testing.

A correct understanding of the Agile Manifesto and establishment of the right agile values are key to successful agile research and development efforts. The agile values reinforce the belief in consistently delivering one's value through effective collaboration between individuals and other people in society; and in better embracing change and improving user satisfaction through active participation and rapid response from a wide range of users. It fully embodies the agile culture of results-oriented, value-conscious and collaborative innovation centered on the customer experience of consultants and services. The selection of a model in a software project depends on the specific environment in which its actual work project is located, including the background and nature of the project team, the application area it is in, the product and the organizational culture. Making analysis and comparison based on the actual situation, selecting the right software model, and applying the right calculation method are crucial to ensure the success of a software project. Companies should choose the right development model based on the project's time requirements, availability of talents, budget, the degree of clarity of requirements and risks.

2.3.2 Rapid iteration

Rapid iteration is one of the three main application tools of lean startup. Domestic research on the iterative model also covers a wide range of aspects. Particularly, with the prevalence of agile development in recent years, some domestic companies have started to investigate, study and try to apply the iterative model. Well-known large Internet companies are using development methods based on the iterative model, such as Alibaba, JD.com, Baidu and Xiaomi. Research on the iterative model has also led to many theoretical achievements. For example, the *Software Engineering Practice Guide* co-written by Tan et al. (2009) provides a relatively all-round study of the iterative model process. As project management theory continues to evolve, the iterative model is becoming more sophisticated and popular.

1. Research on iterative thinking and its application

The concept of iterative thinking originates from the solution to mathematics, which refers to finding a series of approximate solutions from an initial estimate to discover the range and interval of solutions to a certain problem to achieve the goal of solving the problem. This iterative thinking is mainly manifested in the fact that the result produced in each iteration of the cycle becomes the initial value for the next iteration, and the goal or result can be finally approached after continuous repetitions and iterations. With the progress and development of the human society, iterative thinking has been widely used in all aspects. For example, genetic algorithm is a typical iterative thinking, which works by generating approximate solutions based on the characteristics and adaptations of individuals in the process of problem processing, continuously optimizing them, and finally extracting and deriving the optimal solution from various approximate solutions (L. Sun & Yang, 2014).

2. Research on the iterative innovation model

The business model of iterative innovation is similar to the business philosophy of lean startup, which is to first directly invest in a very simple system prototype to develop a product and then, after continuous data learning and extensive customer experience feedback, to rapidly iterate change and optimize the functionality of each system of the product to meet the different needs of each customer (Y. Huang & Tao, 2015). Fitzgerald et al. (2010) point out that iterative innovation is a process of using a replacement model cycle to achieve the marketability goals of a company's ideas. Researchers represented by Furr and Dyer (2014) argue that iterative innovation is a technological process that realizes that integration of technology, scientific inventions and market insights through rapid and repeated trials and errors. Dong et al. (2015) posit that iterative innovation is a stage of continuous improvement in the development process that seeks to achieve the transformation of product functionality through multiple iterative cycles in an efficient manner. Huang and Tao (2015) defined the basic concept of iterative innovation and its connotation, analyzed its basic characteristics, summarized some key factors for the success of iterative innovation, and analyzed the problem in detail through specific cases. X. H. Zhu and Chen (2016) provide an in-depth analysis of how two types of equally highly market-oriented startups can rapidly innovate and achieve their own performance evolutionary paths through changes in the iterative innovation business model in an uncertain market context.

3. Research on the iterative development model

In the theoretical study of the iterative development model, the incremental development model expressed by Mills et al. in 1980 was widely used in the earliest days. The model is an iterative development process model that is the most primitive as opposed to the various

traditional waterfall iterative product development workflows in the market. Its basic feature is that it directly decomposes the entire iterative development workflow of an enterprise into a series of short development periods and long development cycles and requires continuous incremental development projects, where each development phase requires repeated execution of the iterative development process starting from customer requirements analysis until the completion of the product delivery to payment (Larman & Basili, 2003). The incremental development model can be considered as one of the basic models of iterative development. Based on such models, a series of classical models such as the Rational Unified Process (RUP), the agile development model, the spiral iterative development model, have been derived, of which the agile development model, the most recognized and most widely used iterative development method in the industry, includes a variety of development method models such as extreme programming and Scrum.

The research and refinement of the iterative development model by many scholars has contributed to the evolution of the iterative model and is an indispensable driving force for the development of the software industry. For example, Mumtaz et al. (2022) provided a clear understanding of iteration through literature and proposed a framework for iterative management; Sharma and Bala (2021) provided a failure rate analysis model for the iterative model; Alam et al. (2022) applied the six-point star framework for a applicability study on various software development models. Paolone et al. (2021) studied the framework in iterative and incremental models and explored the threshold values for the corresponding metrics; Oni and Letier (2021) studied and proposed a methodology on how to plan in iterations; Trivedi and Sharma (2013) provided simulation methods to predict the resources needed in each phase of iterative and incremental development; Nguyen-Cong and Tran-Cao (2013) investigated and proposed directions for further research through the literature on the evaluation of workload in agile, iterative, and incremental models; Sarkar et al. (2017) provided a framework for incremental models with Unified Process Model (UPM) and presented the workflow of each phase; Chang et al. (2019) provide tools for automatic generation of software process models through research for iterative, incremental and other models. The iterative model and its evolutionary model have also been studied, and ideas for further research have been proposed by literature analysis method (Brhel et al., 2015).

Gonzalez-Palacios and Luck (2007) studied in depth the whole process of adopting and continuously improving the iterative development model solutions in cross-field teamwork in enterprises. Gaudl et al. (2013) further investigated how to design and develop models for emerging game products through the iterative model.

In the process of software development practice, the agile model has been comprehensively studied and analyzed in depth together with the waterfall model, incremental model and spiral iteration model. It was concluded that the agile development model is an important feature of the new generation of enterprise mobile Internet App application product development that is more in line with the current enterprise market demand and environmental changes. D. F. Zhang (2006) innovatively applied the iterative R&D model to the specific design and development and implementation process of case teaching, and students practiced through this iterative and progressive process to spirally improve and sublimate the knowledge points of the case and teaching. Mi Jie's company (Mi, 2009) recently made a systematic optimization design for complex intelligent product development and iterative workflow problems with major uncertainties. Sjödin et al. (2020) applied agile methods to microservice innovation management in digital manufacturing firms and provided important recommendations for innovation in manufacturing firms. Cojocaru et al. (2022) applied agile management methods to physical and sports education and produced a positive impact. Chan et al. (2019) applied agile methods to SMEs to cope with an extremely changing innovation environment and proposed a framework for agility. Khalil and Khalil (2020) provided a framework for agile knowledge management through their research. Agile models and methods can also be applied to large software development (Edison et al., 2021; Faisal Abrar et al., 2020). Besides, there is also some review literature on agile models and methods (Gandomani et al., 2020; Heeager & Nielsen, 2018; Perkusich et al., 2020; Rodríguez et al., 2021).

Lean startup is very close to the business model and design concept of iterative innovation, where the customer first puts a minimalist product prototype directly into the whole market, and then rapidly iterates and continuously optimizes the features of the whole product through continuous research and learning and collection of customer feedback to meet customers' needs.

2.3.3 Customer feedback

Customer feedback refers to the suggestions and opinions that a company extracts from its end users through direct or indirect means conducive to improving this product. Through customer feedback, companies can grasp key information, including customers' overall perception of the product, features with which customers are not satisfied, features that are needed by customers but missing in the product, new features that customers deem it necessary to add and the features that should be modified as deemed by customers. The main ways to obtain customer feedback are application and observation in real-life scenarios. Hossain et al. (2019) studied and proposed

techniques for ranking customer feedback. For example, H. F. Zhu (2013) used the "Hotel Tonight" app as a case for study and found that in the lean startup implementation process, products that are improved through customer feedback are highly valued. For every lean entrepreneur, all startup activities must be focused on customers, and all strategic decisions in product design and business development must be directly transferred to customers. Therefore, a company might not be called a lean startup if it fails to get enough feedback from our users in a timely manner. Such a strategic goal and meaning are both derived from the core content of lean business thinking: avoiding waste of human and financial resources while allowing for accurate identification of the core values of customers.

2.3.4 Minimum viable product

MVP is the abbreviated form of Minimum Viable Product. An MVP is a version of a product developed based on the entrepreneur's idea or an idea for a new product in the simplest way possible. It can be either a product interface or a prototype that allows for interactive operation (Ries, 2011). Its main advantage lies in that it can be intuitively perceived by customers and thus stimulate customers to give feedback. In general, an MVP has four characteristics, namely, reflection of project idea, availability for testing and demonstration by all people, minimal functionality and minimal or even zero development cost.

Using Dianping app as a case, T. Zhang (2013) analyzed the connotation of the MVP approach and argues that an MVP is a streamlined product that meets the most basic needs of users. Besides, he also pointed out that the MVP approach is one of the main methods of lean startup theory. Startups can produce MVPs with the minimal cost to rapidly validate products' value assumptions and growth assumptions. *The Lean Startup*, written by Ries, provides a good summary of cases: startups analyse the potential target customer base and select "user validation" for feedback correction. "Product iteration" allows for the core feeling and perception, which leads to rapid success. World-class enterprises like Facebook acquired tens of millions and even hundreds of millions of users in a short span of two years by applying this model only to the single product of its social media platform. Ries (2011) introduced the concept of MVP in his paper and proposed that the main goal of MVP is to achieve quantitative validation and testing of product characteristics and to answer unconfirmed or unproven illegal commercialization assumptions from real customers. The advantage of MVP lies in its ability to validate the desirability of products through the "Build-Measure-Lean" feedback loop rather than through entrepreneurs' subjective judgments.

Ries (2011) redefined the basic concept of lean startup as a process of creating and managing one's own entrepreneurial activities in an environment of high uncertainty as well as testing one's assumptions through proactive trial and error and scientific experimentation and examination to create more customer value as quickly as possible and eliminate the waste that occurs in the entrepreneurial process (S. Blank, 2013; Ries, 2011); the concept proposed by Ries (2011) emphasizes that all activities other than providing customer value are defined as waste and that lean startup is a closed-loop feedback process of scientific experimentation and assumption validation through active trial and error. Lean startup clearly defines users' entrepreneurial pain points and the underlying assumptions of users' solution to the problem, followed by further in-depth validation of users' startup pain points and the underlying assumptions of users' solution to the problem. From the perspective of the design of business attributes in this theory of thinking assumptions, the user startup time thinking assumptions in the traditional sense are propositions. All variables involving time in the venture creation process must be accurately measurable, and the future can be accurately predicted. Therefore, all measures, whether business models or users' startup pain points or other solutions used to solve startup problems, must have a high extent of exact stability. In contrast, the lean startup assumption is that it is very difficult to accurately measure the variables involved in the venture creation process and that the future cannot be accurately predicted. Therefore, there is often a great deal of logical uncertainty in understanding the potential pain points of users and the ultimate solution. Thus, it is necessary to keep iterating and continuously explore and accumulate new insights to gradually approach users' actual pain points and find effective solutions.

This thesis argues that in the venture creation process, startups have to solve two core problems: whether the business they engage in can bring value to customers and whether the business they engage in can grow sustainably (de Faria et al., 2021; Ranta et al., 2018; Saura et al., 2019). For example, the customer value a restaurant owner brings refers to delicious food, low prices and attentive services, while sustained growth refers to a steady and increasing stream of customers coming to eat day by day so that there will be sustained revenue. However, this is easier said than done because the ideas entrepreneurs get from epiphany may not turn out what customers want, and it is even harder to sustain growth. As a result, entrepreneurs generally work on assumptions, and both business plans and product solutions are expressing an assumption that this will work, that people will like the product, and that users will flock to buy the product. But assumptions are often untested, and their results are unknowable. A

rational entrepreneur should not act blindly based on assumptions, let alone use their startup capital to start a business based on assumptions.

The venture creation process is an experimental process of multiple times of eliminating the false and retaining the true (H. Lin et al., 2005), and the whole process needs to continuously test two assumptions: the assumption of value and the assumption of growth (Euchner, 2019; Ries, 2011). The reverse thinking method can be used to solve these two core questions, namely, whether there is value and whether it is possible to continue converting value. If you cannot directly answer the two core questions, then use the exclusion method to remove the opposite option, namely, which methods cannot bring value and which methods cannot sustain. After you have an assumption, you need to test the assumption. In the process of testing the assumption, it is not necessary to go through a complete venture creation process. You just need to design an experiment that can prove (or disprove) the assumption at the minimal cost (Euchner, 2019). For example, a young man in a small town who wants to open a Sichuan restaurant thinks his cooking skills are good. So, he thinks he can make money by opening a restaurant. However, from an objective point of view, whether one's cooking skills are good or bad is largely a matter of person opinions, which obviously cannot be the criterion for customers to judge whether they will pay for it. In this case, the man needs to put his idea into practice to get customer feedback. Since an individual's startup capital is limited and the risk associated is high, it is not necessary for the man to invest a large sum of money to open a restaurant immediately. Instead, he needs to test his idea on a small scale by cooking a few dishes for a small number of potential customers to test whether his assumption is feasible. As to testing the assumption of whether opening a Sichuan restaurant is sustainable, he needs to find a few Sichuan restaurants in the town for on-site study before reaching a conclusion.

It can be concluded from the above cases that what matters most is not to make a perfect product but to test all the assumptions quickly and continuously with minimum cost. After getting these test results, the rest depends on the case. If venture creation with the minimal cost turns out successful, then you may start to continuously adjust and optimize your products; if the venture fails, then you need to stop in time and change your business model. Different attempts have been made to apply MVP in different scenarios such as: application in established companies (Dennehy et al., 2019; Edison et al., 2018), industry-academia collaboration (Kalinowski et al., 2020) application in universities (de Waal & Maritz, 2022; Mardhia & Anggraini, 2019). Isoherranen and Ratnayake (2019) investigated how the features of MVPs are identified. Melegati et al. (2020) concluded through a study that MVP is more related to how customers think of value. Matturro et al. (2021) studied and documented the entire process

of identifying the MVP of a software startup. Tristão et al. (2021) provided decision recommendations for nursing by applying the lean startup MVP approach. Teixeira et al. (2021) applied lean startup to the oil industry and defined the MVP. Tripathi et al. (2019) proposed in their study that the identification of MVP is directly related to empirical skill sets as well as advanced technologies. Baba et al. (2019) applied MVP to the development process of plasma power supply. Mao et al. (2020) applied MVP to a renewable framework for ecological agriculture. Nagy et al. (2018) studied a case study of MVP applied to the IoT industry. Hyrynsalmi et al. (2018) applied MVP to games and studied minimum viable games. Alonso et al. (2021) analyzed and studied the literature related to lean startup MVP and suggested that for MVP feasibility assessment is very limited.

Since venture creation has evolved into an activity of repeatedly testing and making assumptions, now people are bound to also resort to a scientific means to study and solve the entrepreneurial problems they face. This scientific means is called the engineering method, which is a set of methods and ideas used to solve problems. The process involved therein probably includes the following steps: first, put forward the problem and make an assumption; second, establish a model for validation and look for a feasible solution; third, implement the plan on a small scale, collect feedback, and adjust the plan, accordingly; fourth, implement the plan on a large scale to eventually solve the problem or identify new problems; and fifth, repeat the first step (Eisenmann et al., 2012).

The mathematics word problems we do in junior high school math exams (such as how to adjust the angle to make the cannon hit the farthest) are the embodiment of the engineering method, except that these math word problems only stop at the first two steps of the engineering method and end after calculating the results, and are not really applied in practice; for companies and products, when opening new features in the online environment, they also introduce very little traffic each time to do feature validation (this small-scale validation is known as grayscale in technical terms) and ensure that the validation results meet expectations before opening the feature to all users.

In summary, the first thing to do for a start-up is to validate two assumptions: the value assumption and the growth assumption. Specifically, in engineering terms, the first step is to model and then validate, namely, to quickly build an MVP and then quickly put it into the hands of the target customers and collect responses in a timely manner. In this step, only enough resources need to be invested, and there is no need to put a lot of effort into building a complex automated system, because the goal is just to test the assumption - to confirm whether the startup idea is really liked by anyone. But in most cases the startup idea will prove to be biased.

Putting an MVP into the validation market first will ensure a manageable capital investment, and if it fails, we can draw lessons from it and fix the startup idea (Eisenmann et al., 2012; Ghezzi, 2020).

In addition to putting the MVP into the market, it should be clear that this is a process of multiple rounds of trials and errors as well as repeated iterations. So, you must have patience and not be discouraged or even give up because of one failure. Throughout the process, the idea and the MVP are modified repeatedly by validating some assumptions and invalidating some assumptions, and feedback is collected repeatedly via repeated validations. Finally, we find a feasible way to validate the assumptions about value and growth, and after proving value and growth, we can enter the next stage - implementing the solution on a large scale, which is called systematization, scaling and industrialization. Alternatively, we can sell this prototype product to large enterprises for idea realization. The above process is also reflected in the review of some literature (Bortolini et al., 2021; Melegati et al., 2021).

1. New products and the concept of new product development

The research, development and production of new products is a specific activity for an enterprise to manage the whole process of modern products from design conception, selection, trial production to official production, product launch and start of mass production to adapt to the different needs of consumers in the modern market economy and to the changing conditions of the development of the market economy and social environment. It is also a management process that is required to combine the core elements of a product in a rational way to obtain greater economic benefits. And the main objective of new product development is to create new products (Blindheim et al., 2020; Ying et al., 2018).

According to Schumpeter (2017), who studied the basic concept of new products, a new product is a new technical product that has never officially appeared in the market before or a completely new technical product. However, this theoretical statement still has some limitations, because "new" can be understood in two ways: one is that the product is new for companies; the other is that the product is new or innovative for the whole market. When analyzed from the influence of products on the market or enterprises and their degree of novelty and argues, new products can be broadly classified into six categories, namely new-to-the-world products (really new products), new-to-the-firm products (new product lines), additions to existing products lines, improvements and revisions to existing products, repositioning and cost reduction (Kanwar & Vanier, 2015). L. P. Cooper (2003) argues that product development is a development process in which a company relies on its existing human resources and capabilities to develop or improve on other people to create new products or improve on existing products.

2. The importance of new product development

N. Kim et al. (2013) argue that in the context of shortened product life cycles and accelerating pace of technology renewal, rapid development and application of new generation products have become essential for companies to gain a foothold in the international technology and market competition. Islam et al. (2009) hold that for many industries, the innovative development of new generation technologies and emerging products is often an important competitive factor that directly affects a firm's core competencies and business outcome. Sheng et al. (2013) posit that a rapid approach to new product development can help firms respond more effectively to changes in technology and market demand, more accurately grasp the development opportunities in the new generation market, and establish the first mover advantage as leaders in the industry to improve enterprise performance. Song and Parry (1997) suggest that new product development not only directly determines a company's current competitiveness and market position, but also has a profound impact on the future survival and growth of the company. It has a profound impact on the future survival and development of the company. H. G. Li and Lu (2016) believe that in today's competitive international market environment, new product development is particularly important as it is the basis and key to promote the sustainable and healthy development of a company and its profitability growth, which is of vital importance for the company to enhance their competitive advantage. X. M. Zhu et al. (2011) hold that many companies regard successful new technology and product research and development as their ultimate way to achieve their profitability goals and organizational survival capability and try to maintain their sustainable competitive advantage in the market by continuously introducing new technologies or new products.

3. Research on new product development process or model

Among the studies conducted outside China, the first widely used management model is the "waterfall model" proposed by Winston Royce in 1970. The model divides the entire product development process into six major parts, including the development of product strategic planning, requirements feedback analysis, design, implementation, testing and product operation and maintenance, reflecting a top-down, rigorous and linear management process (Bai & Li, 2012). Based on the research of such process models, a series of development process models have gradually emerged overseas, such as PACE (product and cycle time excellence), Stage-Gate System (SGS) (R. G. Cooper, 1990), Integrated Product Development (IPD) first promoted and put into practice by IBM, the product innovation, research and development mechanism and innovation process concept of concurrent engineering, as well as the product innovation, research and development mechanism and innovation process concept based on

enterprise lean thinking. In addition, Ulrich et al. (2020) delved into the development of equipment manufacturing industry and proposed a new next-generation industrial product design research and technology development work model composed of five major technical activities, namely industrial planning, concept and technology development, system and multi-level structure design, system structure design, testing and performance correction as well as mass production and full process restart. Badri et al. (1997) identified five major research phases that comprise the majority of new product design research: identification of the main problem, practical research activities, research proposal for problem analysis and solution implementation, prototype design research as well as research, development, organization and implementation of the specific problem analysis and solution implementation plan. Pompermaier et al. (2019) studied how MVP can be implemented in software startups using a minimal development process. Zimmermann et al. (2021) applied MVP to the development process of electromechanical systems engineering.

Among the research projects carried out in China, S. Wang (2014) introduced the traditional lean management concept into the new product development workflow, solved the practical problems in the new product development workflow, and effectively realized the reconstruction and reengineering of the new product development workflow. Guo et al. (2004), based on a thorough summary of previous experience, divided the new product development process into five stages: new product strategic planning, new product conception, new product development, testing and technological improvement as well as commercialization. He then conducted an in-depth discussion and analysis of the knowledge and management work process in each new product development stage. From the perspective of resource allocation and sharing, S. R. Wu (2010) analyzed how companies choose new product development models in different contexts, including in-house, outsourced and crowdsourced development models. L. H. Sun (2004) proposed a set of new product development model with customer satisfaction as the guiding requirement based on the goal of achieving customer satisfaction. C. J. Yang et al. (2010) introduced a series of models for the research, development and improvement of new products, from the gradual development of traditional product concepts to the commercialization of current products, and then to the gradual development of current product concepts. They also analyzed and described the problems of each development stage with the case of Microsoft. Xue (2018) briefly described the design of a startup's service from the perspective of a startup CEO using the "MVP" principle of the lean startup concept, briefly introduced the validation of the growth engine, and finally briefly touched upon the difficulties and risks in applying lean startup thinking to guide a startup. But they did not fully document how the MVP approach is

applied and how MVP came into being, nor did they summarize or conclude the steps and methods for implementing the MVP approach in Chinese high-tech startups.

The core concept of MVP has been studied by many scholars, and the determination of MVP should follow certain rules. Melegati et al. (2019) found in an exploratory study that misunderstanding of the MVP concept is one of the important reasons for MVP application failure. So, in the product development stage of a company, it is necessary to hold fast to the essence of its products and the development core, fulfil the responsibilities in every key link along the company's key development path, and deal with every key branch of ever important detail carefully. However, many people still tend to hold on to the sense of dependence on the sense of completeness. They worry about the consequence of only having this or the consequence of missing that. However, now we are actually completely unable to do so. For example, in the early days of product development, when we had already developed the two features of user login and password registration, we had to add the feature of "forget user password" to the product when in fact that was completely unnecessary. As a matter of fact, nothing serious would happen if the feature of "user password forgotten" was missing in the first product version. This is because, in the first version, users just finished the user registration through the official website and saw the product directly after logging in. At that time, they were just in the initial experience of using the product. So, the chance that they forget their passwords is very low. Under the premise of being in line with the basic human memory curve, the feature of "user password forgotten" was added in due course, such as when the second product version was to be officially released soon. In this way, we were able to free up a lot of the resources that we had spent on the first version to deal with such features as "forgot user password" and put these resources into more important features. When we weigh and consider each product, we should ask ourselves which features are not needed at the present stage and remove the features that users will not use for a while, so what remains is the MVP.

In short, when making a new product, do not wish to make a "perfect" product at one stretch. Instead, make a "viable" product and prototype at the lowest technical cost and financial costs to check and constantly test whether the new product now has value and whether it is viable before recreating and continuously improving every detail of the product through iterations and upgrades. For example, Figure 2.5 is a widely circulated image that is often used to describe and demonstrate the MVP creation process.

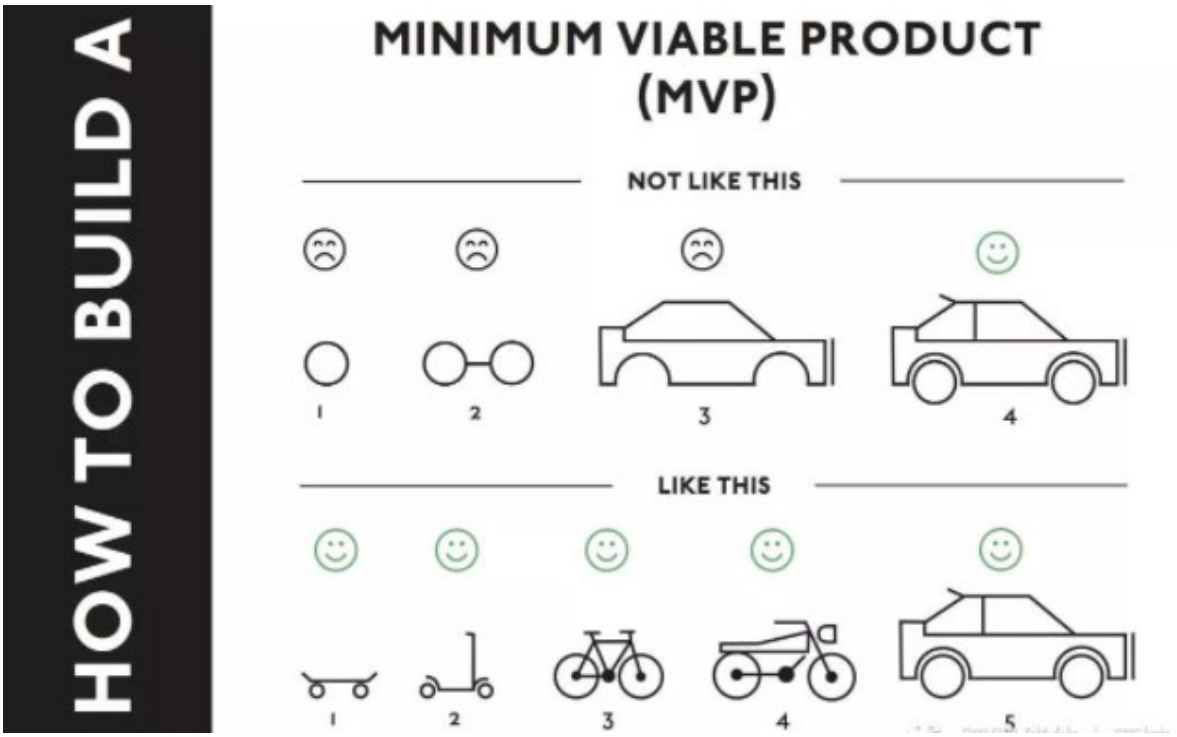


Figure 2.5: MVP creation process

Source: Pillai (2023)

Suppose the vision of the product is like an advanced means of transport, such as a small car. The traditional product design concept and thinking are step by step, from the process of a link, such as wheels, cylinders, shell, power safety device and internal safety decoration to finally delivering a brand-new product to the customer. The idea of the MVP, on the other hand, will first open a small skateboard car or bicycle to see how the target users recognize the travel tool at this stage. If the user has approved the product concept, the next step is to produce a more advanced and complete motorcycle, or even a small car.

The traditional product iteration model is costly, slow and risky to invest in due to the high cost of producing a product that makes users likely to disagree; the main advantage of the MVP strategy is that it has lower trial and error costs and production cost, relatively fast production, and relatively low risks, and is well suited to the rapid and iterative nature of the entire product.

2.3.5 Summary

It can be clearly seen from the above study that the process of new product development is an effective way to help firms build their competitive advantage in the marketplace, gain possibilities and sustain growth in the long run. Nevertheless, the following problems still exist in the current research on the iteration of new product development technology.

Although many experts and scholars have proposed theoretical research on new product development processes or models from different perspectives, laying the foundation for the

implementation of new product development processes, most of the existing theories only put forward some conceptual processes or models from two aspects, namely new product development process management or product optimization. The descriptive suggestions made on how to implement the specific work process of the new generation product development lack scientific implementation methods and steps.

On the point of iteration, first, the existing iterative product development theory is still only an abstract iterative model, and most of the existing research is focused on applying the iterative idea to the whole process of product development, such as design and optimization, product design and management. In the actual operation of product iteration, it is only a simple description of the specific implementation and operation process of each aspect of iteration. Besides, there is a lack of specific technical means, methods and steps to help us guide the promotion of each link. Second, the existing iterative idea is mainly expressed as a way to improve the whole process of new products by continuously repeating and developing new products, but there is not much in-depth research on how to explore the drawbacks and deficiencies of new products and provide further ways and steps to improve the new products.

There is even a lack of complete case studies on the application of the lean startup MVP approach in China. There is no description of the specific methods and steps used by the MVP approach in startup projects, let alone a generalized summary of the methods and steps used by the MVP approach in high-tech startups in China.

2.4 The Kano Model

2.4.1 Origin of the Kano Model

The research on quality has a long history and has strongly contributed to the development of quality management in practice. Aristotle (384-322 B.C.) was the first person who studied the concept of quality in detail. Locke (1632-1704) was one of the giants who studied the concept of quality. Walter A. Shewhart was one of the pioneers who introduced quality management into the development of industrial societies. He looked at quality from two related aspects: the objective and subjective aspects of quality (Löfgren & Witell, 2005). The objective aspect of quality regards quality as an objective reality independent of human existence; in contrast, the subjective aspect of quality regards human thoughts, feelings and sensations as the result of objective reality (Shewhart, 1931). There are various definitions of quality. In the traditional view, quality is seen as a process of assurance, i.e. ensuring that a product meets certain

standards. Products under this concept are primarily material products, with an emphasis on the product itself and its quality attributes; the better the quality attributes are met, the more satisfied customers will be, and vice versa. In this sense, quality as a process of assurance is a typical one-dimensional view of quality (J. Q. Chen, 2016).

At the end of the 19th century, the principle of separation of planning and execution functions was put forward in the book entitled *Principles of Scientific Management*. This principle drove a significant increase in productivity, and one of the key components of the scientific management system is to establish a dedicated and independent quality department whose main responsibility is testing and inspection (Taylor, 1919). In the modern society, people are often concerned about the quality and qualification rates of sampling inspection and are able to know whether a product meets national or international quality standards through media reports. This shows that quality is already a product-specific attribute crucial to enterprises and is a fundamental objective for all enterprises. Although companies that produce high-quality products may not necessarily achieve success in the market, the companies that are successful must be the ones that produce high-quality products. Of course, the idea of high-quality product orientation does not explain why many high-quality products fail to gain recognition from and popularity among customers, while certain products of average quality are recognized by customers and are sold in huge volumes.

In the modern era, the intrinsic nature of quality has mostly been explored from two or even more dimensions. Although no two-dimensional definition has yet been proposed, the two research perspectives, i.e. the product perspective and the customer perspective, are indeed interconnected. Joseph M. Juran is a recognized leader in the field of quality management. Over the past 70 years or so, he has published numerous books that have guided the development of quality management. His extensive work experiences, as an engineer, a government official, a corporate executive and a university professor, enabled him to accumulate a wealth of management experience. His most famous book, *Juran's Quality Handbook*, triggered a global revolution (Jiao et al., 2003; Juran et al., 1962). According to the definition of quality in *Juran's Quality Handbook*, the concept of quality has the following two meanings (Juran et al., 1962):

1. Quality refers to how well certain attributes of a product satisfy customer needs. It is a benefits-oriented concept. Higher quality is aimed at achieving a higher level of customer satisfaction and thus an increase in benefits. Certainly, this process also requires additional inputs, which can lead to an increase in the cost of the product. In this sense, higher quality incurs "a higher cost". Quality in this sense corresponds to the "forward-looking quality" proposed by Ishikawa (1990).

2. Quality is the absence of defects, such as repetitive work or defects leading to field failures, customer dissatisfaction or customer complaints. In this sense, higher quality means "a lower cost". Quality in this sense corresponds to the "backward-looking quality" proposed by Ishikawa (1990).

With increased market competition and customer needs, as well as other non-market-related aspects such as government regulation, companies need to produce higher-quality products to meet the requirements in all aspects, including but not limited to organizational development, industry positioning, cost reduction, technological innovation, production line automation and marketing of products. Therefore, it is more necessary to improve the quality of products or services than to improve other aspects.

The top priority for quality in Japan is customer-oriented quality assurance activities. Although customer orientation is widely recognized and accepted in Japan, in practice many companies assess and measure the adequacy of quality assurance in terms of the amount of customer compensation, which ultimately assesses the cost to the company rather than to the customer.

Kano (1984) defined retrospective quality as quality that must be had, or "must-be quality", and prospective quality as "attractive quality". Must-be quality, as a generic attribute that applies to different kinds of products, can be measured by the data of such indicators as rework, defect rates and the number of customer complaints. Unlike must-be quality, attractive quality is highly personalized and product-specific. Whereas must-be quality can be effectively controlled through statistical tools such as control charts, attractive quality can only be captured through analyzing cases of failure and success. The two types of quality have a subtle relationship: some products are very attractive to customers and sell well, but customers have many complaints, while other products have little or no sales because they are not attractive to customers, and precisely because there are few sales, customers have few or no complaints about such products. Therefore, to achieve customer satisfaction, not only must defects and complaints be eliminated to ensure product quality, but the product must also possess attractive quality (Baek et al., 2009; Berger et al., 1993; Rejeb et al., 2008).

Customer satisfaction is the highest standard for judging product quality (C. L. Yu, 2003). In 1984, the Japanese quality expert Kano (1984) presented his research at a conference held by the Japan Society for Quality Control (JSQC) under the title "Attractive Quality and Must-Be Quality", in which he analyzed the relationship between the objective and subjective aspects of quality. Specifically, objective quality concerns the quality of product attributes, while subjective quality represents customer satisfaction. Kano (1984) developed the Kano Model of

Quality Attributes, which has important implications for product quality evaluation and the design of product attributes and sets higher goals for quality management (Green & DeSarbo, 1978; Hazelrigg, 1998; Jiao & Chen, 2006). Compared to the product-centered quality orientation, the customer-centered quality orientation encompasses more multifaceted considerations that integrate the customer's needs and the product in a holistic and systematic way. It emphasizes the quality attributes of the product itself and takes into account the needs of the customer in a more objective way, resulting in higher and better customer satisfaction and returns.

The Kano Model (Kano, 1984) is shown in Figure 2.6 and is based on the two-factor theory proposed by Herzberg et al. (1993) (Y. L. Li et al., 2009; H. Lin et al., 2010).

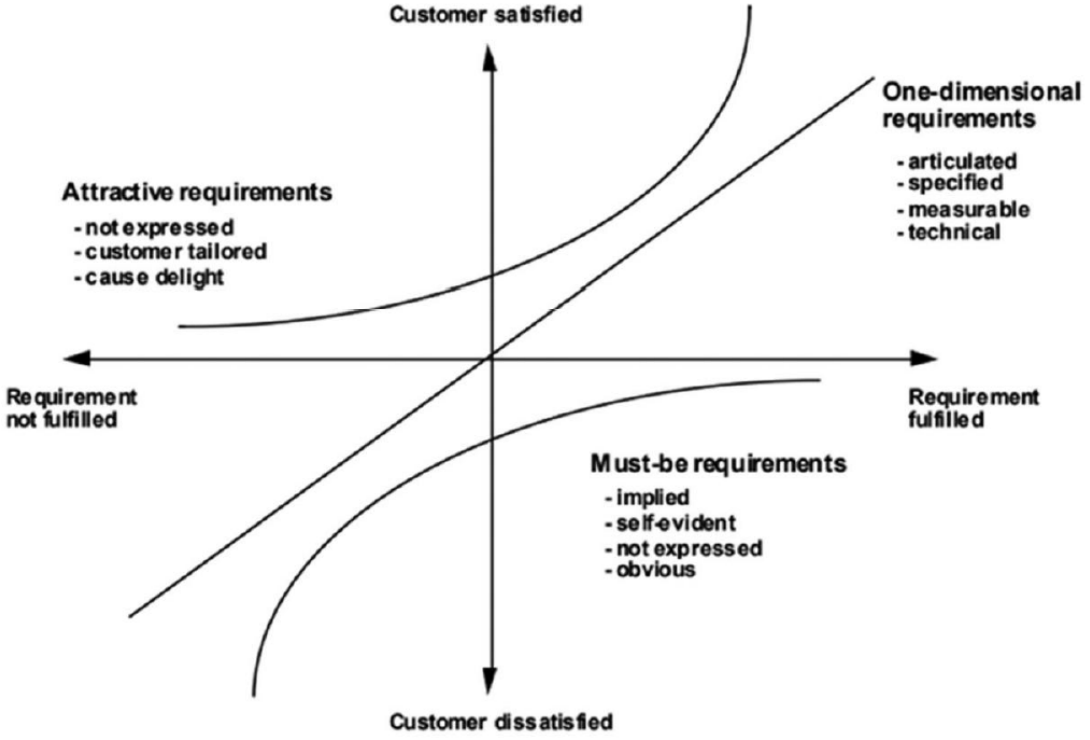


Figure 2.6 The Kano Model

Source: Berger et al. (1993)

The Kano Model reveals a non-linear relationship between quality attributes and customer satisfaction, allowing for classification of product quality attributes by the customer satisfaction already obtained and grouping them into five categories of perceived quality, including attractive quality (A), one-dimensional quality (O), must-be quality (M), indifferent quality (I) and reverse quality (R) (Kano, 1984). Attractive attributes generate high levels of satisfaction when they are in the product, but no customer dissatisfaction when they are not; one-dimensional attributes are customer needs, and their level of fulfilment is linearly related to customer satisfaction; must-be attributes are the most basic needs and generate very high levels

of customer dissatisfaction when the product does not have them, and no customer dissatisfaction but no increase in satisfaction when they are present; indifferent attributes refer to the requirements that have no effect on customer satisfaction or dissatisfaction; and reverse attributes generate serious customer dissatisfaction when present in the product and customer satisfaction when not present (J. Q. Chen, 2016; Kano, 1984).

2.4.2 Development of the Kano Model

Since its introduction in 1984 by Kano (1984), the Kano Model has become one of the most popular quality models, also known as the Kano Model of Customer Satisfaction because it is based on customer satisfaction. Since then, there has been a steady stream of research on the Kano Model. Over the last 40 years, Dr. Kano's theory has been widely discussed and developed through articles on quality management, operations management or marketing management (Kazemi et al., 2000; Sugiura et al., 2000), and the Kano Model has been used in a wide range of industries and fields. The concept of attractive quality has been widely used in strategic planning, business planning and product development. In the meantime, innovation, competitiveness and product flexibility have been highlighted as sources of business ideas (Watson, 2003).

Gustafsson (1998) argues that the Kano model provides a practical framework for product design strategy, with the help of which aspects of customer comments on a product or service can be better understood. Matzler and Hinterhuber (1998) proposed a method for discovering customer-described needs and undescribed expectations and decomposed the collected customer descriptions into different categories that have different impacts on customer satisfaction. They also pointed out that the categories analyzed in this method can be used as a basis for product development, especially for the deployment of quality functions. Tan and Shen (2000) proposed a method for integrating the Kano Model into a planning matrix for the deployment of quality functions to assist in the accurate and in-depth understanding of customer voice.

P. Zhang and von Dran (2001) conducted two studies on user perceptions of websites. They used the Kano Model to exploratorily investigate customer quality expectations for the website of CNN.com. The results showed that (1) customers' quality expectations change over time, and thus the quality checklist needs to be updated accordingly; (2) the Kano Model is an effective method or framework for identifying quality expectations and the time transition of quality factors; (3) different customers judge the importance of the same quality factors

differently; and (4) despite difference in the rankings of important quality factors across different Web domains, the high importance of certain factors is unanimously recognized across all the domains studied (P. Zhang & von Dran, 2001). Kim (2016) applied the Kano model to the analysis of exhibition quality and concluded from a multi-case study that only indifferent, attractive and one-dimensional quality classifications emerged from the exhibition quality analysis results, while reverse and must-be quality classifications did not emerge. Besides, the results of the Kano model quality classification analysis and the Timo customer satisfaction coefficient analysis were largely consistent. Kim (2021) applied the Kano model to the transformation of ancient towns and sustainable tourism research and clearly explained the results of applying the Kano model to the analysis of classification through the Timo customer satisfaction coefficient.

The Kano Model has also been applied, improved and validated in numerous regional studies. Qi et al. (2016) applied the Kano Model to customer reviews of JD.com, China's leading one-stop e-commerce platform, classified customers reviews based on the combination of the Kano Model and big data analysis and applied the results to website improvement. Song (2018) proposed a better-worse (B-W) approach in comparison with the Kano Model and applied the B-W approach to a case of Korean smartphones. Materla et al. (2019) reviewed the extensive use of the Kano Model in the development of healthcare apps and concluded that customer needs and preferences vary with the type of care and services provided by healthcare facilities. Joung and Kim (2021) integrated the explainable neural network-based approach with the Kano Model, classified product features from online reviews into Kano categories, and used the Kano categorization by the proposed approach to real-world cases in the United States. Malinka et al. (2022) applied the Kano Model to the development of a mobile internet health app in Germany. Lizarelli et al. (2021) proposed a new approach based on an integration of SERVQUAL, A-Kano and QFD and applied the new approach to a Brazilian education start-up specialized in experiential services. Barrios-Ipenza et al. (2021) applied the Kano Model to the quality of healthcare services in two public-private partnership (PPP) hospitals in Peru. Zoghi et al. (2022) implemented the Kano Model in the deconstruction design of traditional building demolition in Italy to select the best plan.

There are also many studies and cases where the Kano model is used as a base model to combine with other modeling methods and enhance scientific methods and practices. For example, Avikal et al. (2020) integrated the Kano model into quality function deployment and applied it to the aesthetic study of customers' cars; Xi et al. (2020) proposed a mechanism for evaluating the grid method by combining the fuzzy Kano model and performance analysis

methods; J. Q. Chen and Chang (2018) improved the Kano model and applied it to customer requirements identification in vehicle design and called it the V-Kano model; W. C. Huang et al. (2022) improved the Kano model and applied it to passenger requirements identification in rail transportation; M. C. Chen et al. (2020) improved the Kano model and applied it to the satisfaction evaluation of pharmaceutical companies by healthcare organizations; H. Sun et al. (2022) proposed the customer-manufacturer-Kano (CM-Kano) model based on the Kano model to address the ever-changing customer changes; S. Y. Zhao et al. (2020) applied the improved Kano model to product requirement identification; Baier and Rese (2020) proposed a method to solve the problems of online retail enterprises based on the Kano model. Azizi and Aikhuele (2015) integrated the Kano Model with quality function deployment to develop and evaluate a decision model for how to select lean production tools.

2.4.3 Summary

It can be seen from the above studies that the Kano Model is a very popular analytical tool that is commonly used to identify the importance and concern of products and services through the classification and ranking of quality factors (Shokouhyar et al., 2020). The significant advantage of the Kano Model is that the model is based on feedback, analysis and classification of the actual needs of actual customers, and the results are reflected in product improvements.

The advantages and implications of applying the Kano Model are as follows.

1. The Kano Model can effectively classify customer needs and feedback and better understand the actual needs of customers while discarding some disoriented and meaningless needs. The Kano Model can significantly reduce subjective judgement in the organization and analysis of customer feedback and requirements, which helps companies accurately and efficiently grasp customer and market demand at the product design stage and reduces the probability of product failure after market due to the completely subjective definition of product requirements. In this sense, the Kano Model is consistent with the concept of MVP based on Lean Startup.

2. The Kano Model is used to classify and categorize customer requirements. Only the most critical requirements are selected for implementation, while other non-essential requirements are excluded to ensure that energy and money are spent where it counts the most (Bilgili et al., 2011). This idea coincides with the MVP concept based on Lean Startup.

3. By applying the Kano Model, differentiated spatial features can be formed (Liu et al., 2016); the questionnaire of the Kano Model is simple, easy to understand and not ambiguous

for customers. By analyzing the results of the questionnaire, companies and designers can identify the necessary and attractive needs of their products in a more direct and intuitive way. In turn, through the analysis of competing products, companies will be able to correctly and effectively identify their target markets and the advantages of competing products, so as to position the competitiveness and business model of their own products to innovate or create excellent products that meet market demand.

2.5 Summary

This chapter focuses on the research areas related to the emergence and development of lean startup theory as well as the emergence, development and application of lean startup methodology. The research progress and developments in the above areas are organized, summarized and reviewed through critical discussion order identify issues and perspectives that need further research.

The application and practice of theories and methodologies as well as case studies are necessary means to improve the theories and methodologies. This chapter presents a literature summary and review of a series of concepts, methodologies and the main research results on innovative enterprises and lean startup with the aim of laying a solid scientific and theoretical foundation for the various research efforts that follow. Section 2.1 is devoted to the study of entrepreneurship, where the existing research on Chinese firms' innovation activities is divided into macro, intermediate and micro stages through a holistic analysis. Section 2.2 reviews the research on lean startup, including the definition and development history of lean thinking and lean startup in the Chinese economy and society. Section 2.3 elaborates on MVP and the concepts and cases related to MVP. Section 2.4 details the generation, development and application of the Kano Model.

To summarize the status of lean startup research in China from the literature, most of the literature is based on how to integrate lean startup thinking into the education field to develop and cultivate entrepreneurial talents due to the active startup environment in China. Compared to the high-tech startup field, although many Chinese mobile Internet startups claim to be using lean startup theory and its methodology to guide their startup process, case studies based on lean startup are very few and very inadequate in China. Besides, there are still gaps in research on whether lean startup theory and its methodology are truly adapted to the Chinese startup environment and entrepreneurs. Particularly, there is no clear research or review of the use,

methods, steps and effectiveness of MVP. Currently, there is no complete case study on the application and effectiveness of the lean startup MVP approach in high-tech startups in China.

Through an analysis of the existing literature, the Kano Model is innovatively modified for lean startup MVPs and applied to the identification of MVPs. The MVP-Select model is proposed, and its theoretical basis and application steps and methods are elaborated on.

Chapter 3: Research Methods

3.1 Research methods

3.1.1 Literature analysis method

In this thesis, the existing research results in the field of lean startup at home and abroad are collected, analyzed and cited through research materials, books as well as literature sources such as Chinese National Knowledge Infrastructure (CNKI), Wanfang Data, China Science and Technology Journal Database (CSTJ), Xinhua News Agency Multimedia Database, China Master's Theses Full-text Database (CMFD), China Doctoral Dissertations Full-text Database (CDFD), foreign language databases and campus libraries. By drawing on the main findings and research methods in the above research literature and reading the literature on the sources, concepts, core contents and characteristics of lean startup, the development history of UAVs and the operation of UAV companies at home and abroad, the author summarized the relevant methods and proposed the MVP-Select model, then apply MVP-Select model to the R&D processes of UAV project. These efforts provide a solid theoretical foundation for the thesis research.

First, the differences in entrepreneurship between China and other countries are summarized based on an analysis of startup development processes at home and abroad. It is concluded that regardless of the means used to implement entrepreneurial activities, entrepreneurship research has gradually become a mainstream and one of the directions of management research and is developing rapidly at home and abroad. Second, the concept and connotation of lean startup MVP are described based on relevant literature, and the methods of applying lean startup MVP are summarized. "Lean startup MVP", as an important guiding theoretical approach to the implementation of corporate strategy, is applied to the entrepreneurial process to analyse how to achieve company strategic goals through MVP. Thirdly, the development of MVP and its practical application will be studied to provide theoretical support and implementation basis for this paper to propose the use of MVP-Select model to develop drone products and implement lean startup MVP for company A.

3.1.2 Case study method

Case study method is one of the methods used to conduct social science research. Other approaches include experiments, surveys as well as analysis of historical records and archival information. Galliers (1991) defined 14 research methods, of which case study is the most widely used. This is indicated by the frequency with which the term "case study" appears in publications. Google Ngram Viewer compared the citation frequency of "case study" with three other similar terms, namely "survey research", "experimental design" and "random sampling". Figure 3.1 shows the appearance frequency of the four terms from 1980 to 2019. Although the frequency with which the term "case study" appeared was still lower in absolute terms than the others, it was clearly on the rise. As the preferred "gold standard" for all social science research, the frequency with which "case study" appeared in publications increased more significantly than "random sample design" in the last decade. It can be clearly seen from the frequency trend analysis that case study will grow in prominence among all kinds of research.

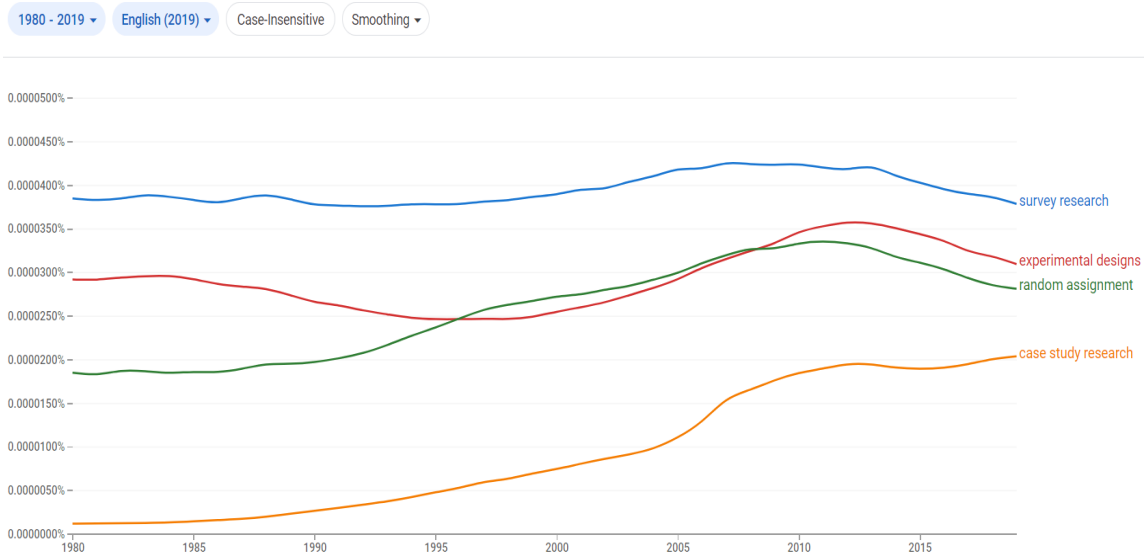


Figure 3.1 The appearance frequency of four methodological terms in publications from 1980 to 2019

Source: Google Books Ngram Viewer (2021)

The most common definition of case study focuses only on the type of topic to which the case study is applied. To quote the words of one observer: the essence of a case study and the main trend in all types of case studies is that case study attempts to elucidate a decision or series of decisions, specifically, why these decisions were taken, how they were implemented, and what the results were (Schramm, 1971).

The use of case study for research purposes remains one of the most challenging of all social science endeavors. A case study can be defined as an empirical study of a contemporary real-life situation using multiple sources of evidence. In a case study, individual objects, events

or organizations are usually studied in detail. The goal is to design a good case study and to collect, present and analyse data fairly. Another goal is to bring the case study to an end by writing a thesis. Yin (2018) advocates three ideal conditions for conducting a case study: experiments, surveys, as well as archival analyses and histories. First, the research question is put forward in the form of why or how. The two remaining conditions are that there is no need to control for the behavioral event being studied and that the research focuses on contemporary events. Thus, the case study should be applied to contemporary events instead of historical events. Ideally, a multi-case design involving multiple sites should be adopted, and multiple methods employed to analyse the data collected. The rationale for choosing multi-case design rather than single-case design is that observed practices of the topic under study can be compared to gain a more comprehensive understanding of those practices.

Case study, as a research strategy, is conducive to the study of individuals, organizations, societies and related phenomena. It can be used in many fields such as psychology, sociology, political science, social work (Gilgun, 1994), business (Ghauri et al., 2020) and community planning (Yin, 2018). Case study method can even be used in economics. For example, it can be used to study the structure of a given industry or the economy of a city or region. It can be seen from these cases that the desire to understand complex social phenomena brings about a unique need for case studies. In short, case study allows researchers to understand the dynamics of real-life events.

This thesis analyses the reasons why startups cannot validate their business models at minimal cost and the reasons why startup products fail through Company A as a practical case and proposes the MVP-Select model for the core problem that startups do not have specific scientific tools and methodological steps to confirm MVP and applies it to Company A's UAV product development process by fully collecting Company A's UAV case. The practice of adopting the MVP-Select model so as to integrate the solution and final results of this case, practically proves the feasibility of the MVP-Select model proposed in this thesis to confirm the MVP of the startup company's product.

3.1.3 Index construction method

The MVP-Select model is proposed through a multi-dimensional approach of constructing indicators by constructing a system of minimum feasible degree indicators for the initial product in new product development research, which provides a scientific basis for discerning MVP. The MVP-Select model firstly constructs the company-side MVP by modifying the Kano

evaluation table from the dimension of the startup company and the perspective of its most concerned business model and competitive advantage; secondly, it provides an important support for investigating the product customer satisfaction by constructing customer experience indicators in the customer satisfaction segment from the customer dimension; finally, after analyzing the above steps, the analysis results based on the company side and the customer side lay an important foundation to help screen the product iteration improvement points.

3.1.4 Data analysis method

EXCEL 2019 and SPSS 22.0 data statistical software are used to process the data and then validate the MVP-Select model proposed in this thesis. Among them, EXCEL2019 is used for questionnaire design, layout and preliminary screening and sorting of collected data; SPSS26.0 is the main data statistical analysis software, which is the most widely used statistical analysis software for research data, and can analyze data reliability, validity and other information simply and quickly, and show the relationship between research variables and other functions for researchers. It provides a scientific and efficient way and method to verify hypotheses and actual data.

3.2 Data collection

3.2.1 Direct observation

First-hand data are obtained by directly observing such activities as business operations, decisions and discussions. The direct observation method is about obtaining information by directly observing the research objects using one's own senses and auxiliary means according to a certain research purpose, research outline or observation form (X. P. Chen & Shen, 2018; Yin, 2018). Scientific observation is purposeful and planned, systematic and repeatable. In scientific experiments and research, the observation method has the following roles: (1) to expand people's perceptual understanding; (2) to inspire people's thinking; (3) to lead to new discoveries.

In order to better understand the cultural background of Company A as well as the problems and possible improvements in the management process of UAV products, the author followed the teams of Company A to conduct an accompanying study on the development, production and marketing of its main products. Subsequently, after adopting the MVP-Select model, the author participated in the processes of product design, product development and resource

integration in the early stage, project implementation and management, problem identification and problem solving in the middle stage, as well as the project summary and review in the later stage.

3.2.2 Questionnaire survey

This thesis is based on two rounds of questionnaire surveys based on the proposed MVP-Select model needs. First, based on the functional characteristics of UAV design, manufacturing and industry conventions, the list of functional characteristics of the MVP to be selected was compiled for the field and industry characteristics to which Company A's UAV flight platform belongs; secondly, construct a revised Kano questionnaire based on the business model and competitive advantage that the startup team focused on for the MVP to get confirmation of the company-side MVP. Finally, the customer-side Kano questionnaire was constructed based on the list of features to be included in the MVP selection and the Kano model traditional questionnaire, and the customer-side satisfaction was investigated and the customer-side approved MVPs were identified by the Kano attributes (Tehranineshat et al., 2022). The questionnaire design is based on the MVP-Select model, the Kano model and the modified Kano evaluation form. Besides, the questionnaires were distributed to the employees as well as the customers and potential customers of Company A to obtain relevant data. Internally, the founders or members of the founding team of the startup were identified as survey participants. Externally, the customers closely connected with Company A and high-quality potential customers of Company A were identified as survey participants to improve the reliability and validity of the questionnaire.

3.3.3 Interview

The interview method in the present study is used to obtain first-hand information and data in the form of interviews and research with key people in charge of the relevant departments of the startup (X. P. Chen & Shen, 2018; Yin, 2018). The role of interviews is to obtain information that cannot be obtained from direct observation and to verify such information. An interview, though not as well structured as a questionnaire, has a role that questionnaires cannot replace. The interview method is suitable for understanding complex and abstract issues and allows for an in-depth exploration of the research topic through relatively free conversations.

In this thesis, five executives and employees from different positions in Company A were selected as the main interviewees for the author to understand the background of the company,

the R&D path of the company's products and the reasons for the failure of the first-generation product. Project manager, R&D manager, sales manager and sales team members were involved. A semi-structured interview outline was designed beforehand to address the research questions, and a one-on-one question and answer session was conducted during the interviews. In order to ensure that the interview questions could be answered objectively and correctly by the interviewees, and to eliminate ambiguities and get effective feedback, one of the interviewees was interviewed before the formal interview, and the results were analyzed to confirm the reasonableness of the interview outline. And after each interview, the relevant materials were organized to form documentary materials that could be used for subsequent analysis.

The interviews not only examined whether Company A's product and service strategy is reasonable or not, but also studied and explored in depth its current customer experience and the specific working conditions of its sales staff. Through the interviews on each issue, the author developed an in-depth understanding of the company's UAV development, production, operation and sales, which laid a foundation for him to dig out and analyse the reasons for the failure of the first-generation product and provide corresponding improvement suggestions. In this way, the author managed to dig out the deep-seated problems that the questionnaire survey may not directly reflect.

3.3 Summary

The correct research methods are the fundamental basis for correct research direction, and the correct data collection and analysis methods are the premise for reliable and valid research results. This chapter introduces the selected scientific research methods that are applicable to this thesis after analyzing the research direction, the case, and the data collection methods.

Section 3.1 identifies the single-case study method as the main method of this thesis and the index construction method and data analysis method as the supporting methods through a comprehensive analysis of the literature review and the case. Section 3.2 introduces the data collection methods that can effectively guarantee the reliability and validity of the research results, including direct observation method, questionnaire survey method and interview method, based on the guidance of the case study method and the characteristics of the case.

Chapter 4: Establishment of Lean Startup MVP of Company A

4.1 An analysis of the development process and causes of failure of the first-generation product

Interviews with five senior managers of Company A revealed that the company's first-generation product had been discontinued due to unsatisfactory market feedback. After-sales work was still in progress. The main problem was that the product was expected to meet too many requirements, leading to an increase in product complexity and a lack of product highlights. Consequently, the product failed to fully meet the needs of users. After internal self-examination and analysis of the causes, Company A concluded that the failure of its first-generation product was inevitable.

Structured interviews were conducted with five executives from Company A: Product Manager, CEO, CTO, Marketing Director and Production Director. The interview transcripts were then organized and analyzed to produce five interview documents, which provided an understanding of the company's background, its product development path and the reasons for the failure of its first-generation product. NVivo was used to assist in the analysis of the interview transcripts, and Figure 4.1 shows the cloud chart of the words for interview analysis. On this basis, the main reasons for the failure of the first-generation product are presented in Figure 4.2 below.

1. The product was expected to meet too many requirements, with neither distinction of core functions nor identification of priorities, and the analysis of product requirements was inadequate. As a result, the products ended up with no highlights and required high market validation cost. Figure 4.2 shows that 71% of the cause was composed of two sub-causes: too many requirements expected to be met by the products (39%) and insufficient requirements analysis (32%).

2. The R&D process adopted was not in line with startup products, and the product validation time was too long, resulting in the inability to give quick response and high product trial and error cost (29%). The 29% of the cause can be attributed to two sub-causes: the R&D process adopted was not in line with startup products (21%); and the product validation time was too long (8%).



Figure 4.1 Cloud chart of the words for interview analysis

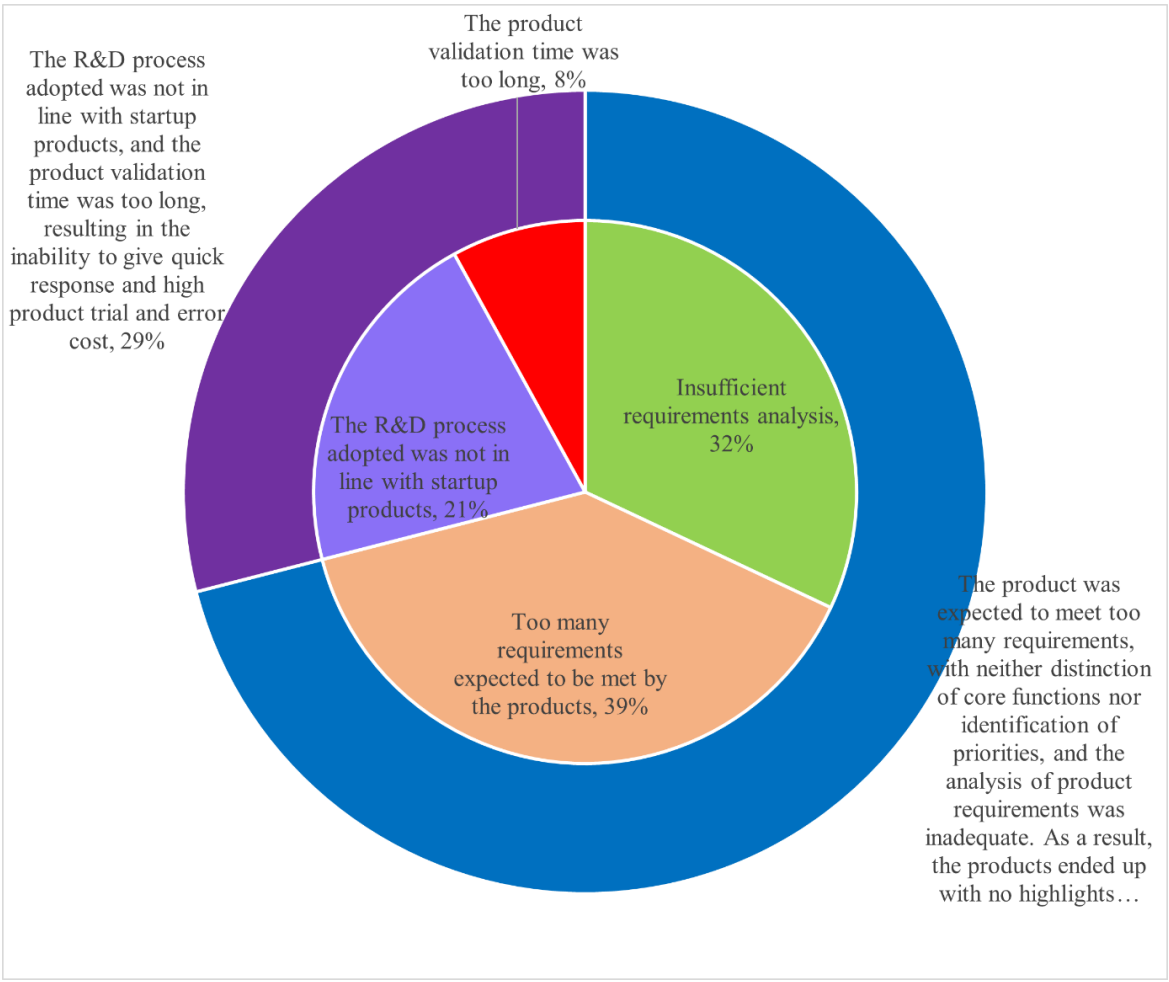


Figure 4.2 Reasons for the failure of the first-generation product

4.1.1 Products were meant to meet too many needs with a lack of focus.

Among the reasons for the failure of the first-generation product, the main reason was that the product was expected to meet too many requirements, with neither distinction of core functions nor identification of priorities, and the analysis of product requirements was inadequate. This

reason contributed to 71% of its failure. In the development and design of the first-generation product, no detailed analysis of market demand was conducted in advance, and the design was based solely on the subjective ideas of the designers, while the actual needs of customers and users' pain points got completely ignored. Besides, there was a lack of accurate positioning of the product. The team wanted to make a product that would meet the needs of all industries and customers, which caused the product to have no highlights after being launched into the market. Furthermore, civil UAVs need to carry different application loads in different application scenarios, and different application scenarios will have different requirements for the UAVs themselves. The first-generation product did not catch or solve these application pain points and failed to meet the core needs of customers. So, it was a matter of course that the product could not excel in market competition.

First, the product was expected to meet too many requirements, with neither distinction of core functions nor identification of priorities. The team did not analyse or position the industry segments in the UAV market to be adapted to by the developed product, leading to the excessively redundant functions of the first-generation product. Without detailed research into the market demand, Company A blindly thought that the product could meet the needs of all users of small operational UAVs. It wished to meet the needs of the entire UAV market with one model, and the R&D took it for granted that all the needs that could be thought of should be met by the first-generation product. As the market sector was not very clear about market requirements, the R&D team supplemented the requirements with their own experience of large aircrafts, resulting in the addition of many highly complex features and performances that are only necessary for large aircrafts. On the one hand, such complex design led to a significant increase in the time needed for the overall product development cycle as well as the time and cost for production, testing and maintenance. On the other hand, the complex requirements rendered product development and design extremely difficult. As there was no targeted input of requirements, the R&D personnel added many ideal requirements and indicators as a matter of course, which led to difficulties in product design, implementation and production. Finally, these difficulties directly led to high product cost and market validation cost.

Second, Company A failed to sufficiently identify product requirements and to capture core pain points and needs from users' perspective. There was no targeted collection and analysis of users' needs. As a result, Company A ignored the actual needs of the market, the industry and target customers, which led to the production of products that failed to meet the needs of the relevant parties. As the marketing department did not analyse the market demand in detail, it was taken for granted that the product requirements proposed would be liked by customers, and

all the requirements thought to be liked by customers were added to the product, resulting in multiple and comprehensive product requirements that did not meet the core needs of customers. Due to the explosive growth of product requirements in both number and complexity, the team failed to grasp the core market demand and users' pain points. As a result, the product developed could only meet some users' partial demand. It could not fully adapt to the application scenario. Besides, UAVs can be used in a wide variety of fields, including aerial photography and aerial survey, power inspection and monitoring. Each of these fields has a lot of application needs. It is impossible to offer one solution to meet the needs of all markets. Should the team wish to cater to the needs of every market, the increased investments in such resources as manpower and material resources would be significant. If the team wished to do everything, it would not only fail to make the right product, but the whole team would be exhausted and weighed down by all kinds of requirements.

The lack of analysis of product requirements was mainly reflected in two aspects: (1) the team neither adequately analyzed the market nor thoroughly understood the needs and pain points of users; and (2) the team neither adequately analyzed competing products nor understood in depth the main functions of existing UAVs in the market and the industry.

1. Insufficient analysis of market demand

In the early stage, due to the relatively small number of customers and market fragmentation, Company A did not conduct sufficient market research and analysis. Instead, it determined product requirements based on previous experience and started to define the functions and performance indicators of the product, taking it for granted that what it defined was what the customers needed. Consequently, the product definitions ended up too idealistic; technical indicators turned out hard to realize; and the designed product was not industry specific. All these led to the lack of consistency in the later production stage. Testing, manufacturing and factory acceptance were basically all completed manually. The product ended up impractical; the price was high; and the after-sales cost was also high. Ultimately, as the product was not industry-specific, it failed to fully meet the needs of industry customers.

2. Inadequate analysis of competitive products

Company A did not pay attention to competitors and their products and did not bother to conduct detailed research or make thorough analysis, which caused its product to deviate seriously from the needs of the civil market. Without in-depth and careful research and analyses of competitive products, it completely designed small commercial UAVs in the same way as large aircrafts. In addition, its designers pursued perfectionism and were overly confident. Consequently, the product turned out cool but was not practical.

To address the first reason for the failure of Company A's first-generation product, it is necessary to find a method and model that (1) can accurately identify core requirements and avoid divergent and unfocused requirements; (2) can get early feedback from customers to involve them in identifying core requirements as early as possible; and (3) can make a product with core functionality at minimal cost and achieve market validation at minimal cost.

4.1.2 The R&D process adopted failed to meet the needs of startup products.

As the core team's past background and experience were predominantly in large aircrafts, they were limited by a fixed mindset to some extent. Based on previous experience, they directly adopted the R&D process and model of large aircrafts in the development of civil products, ignoring the differences between startups and large enterprises as well as the differences between small UAVs and large aircrafts. Consequently, the R&D process failed to adapt to the status of startups and products, leading to long product validation time, poor rapid response capabilities and high product trial and error cost.

1. The R&D process failed to adapt to startups and the product status.

Company A mainly adopted the traditional waterfall R&D process used by large aircraft companies. As a supplement, the V-model was used for a small part of software R&D process. Though there was no unification, Company A was mainly using the waterfall model in R&D process.

The waterfall model is a traditional development model with a clear process. This model is used especially in traditional 2B enterprises, in such systems as ERP, MES, WMS, CRM, OA and IBMS. This model is still popular in large scale projects or maintenance projects.

Waterfall development has the following main advantages and is therefore common in large companies or large projects.

First, clear phases. The three phases from planning to development and finally to implementation are very clear.

Second, time sequence. Each phase must be sequenced from top to bottom, in strict chronological order.

Third, interlocking. Each phase must be completed before the next phase can begin.

Fourth, the black box model. Each phase has its own role and division of labor, and each is concerned only with its own tasks. For example, the requirements phase is not of concern to developers.

As there are many people in a large enterprise or project and the roles of each department are clearly defined, it is easier to follow the process step by step to achieve product development, and it is easier and clearer to find the appropriate department head for accountability when problems arise. Company A adopted the waterfall development process mainly because the majority of the company's team were from large aviation-related industries, and this R&D process was unanimously used in the previous large aircraft development.

In the early days of the team, there was a discussion about whether to adopt the traditional waterfall model or the more recent agile development process regarding the compatibility between the R&D process and the company's product. However, because all team members were motivated and confident and they regarded the product as the focus while ignoring the significance of the R&D process, they neither seriously thought about nor analyzed this matter before engaging in product development.

2. However, the waterfall development process clearly has its own disadvantages despite the above advantage. The main disadvantages are as follows.

First, isolated requirements. Because people in each phase only have access to what is within their scope of work, their understanding of customer requirements varies, and developers are regarded more like workers on an assembly line.

Second, costly changes. As its name suggests, waterfall means that there is no going back. Otherwise, rework would entail high cost. Coders can be very resistant to changes in requirements.

Third, restraints to creativity. Managers tend to prefer the waterfall model because of its emphasis on document management. Yet this emphasis restricts the creativity of developers.

Fourth, a long cycle. The whole development lifecycle is long, and the time spent on requirements and design can be particularly long, sometimes taking up a third or more of the total time. As a result, the whole cycle becomes rather long, mostly in the range of six months to a year. Therefore, it is more suitable for large projects with relatively stable requirements.

In summary, the waterfall development process has both advantages and disadvantages, which are determined by each company's own characteristics and the characteristics of the product being developed. A major reason for the failure of Company A's first-generation product was that the R&D process and model were not in line with the external environment as well as Company A's status of development and its products. Although the core staff of the team were familiar with each other, they still needed to learn to effectively cooperate and coordinate with each other from the perspectives of product development and production. This

was because the roles of the team members had changed from their previous roles, but their mindset had not changed accordingly.

3. The focus of an aircraft is on safety. In this sense, the waterfall development model is relatively rigorous with each step proven, so the relative risk is rather small. However, seen from the R&D process and result analysis of Company A's first-generation product, the waterfall development model was not applicable to its status and product. The following reasons can be identified through analyses of the interviews.

Firstly, Company A is a small start-up with high external competitive pressure, high requirements for the timeliness of product development and the need to control costs. The waterfall model is a step-by-step process where the product is not available until the last step is completed. Besides, under the waterfall model, the team members work serially, which is inefficient and does not meet the needs of micro and small-sized start-ups. Furthermore, micro and small-sized start-ups need to strictly control costs, while the waterfall model entails high communication cost between each step and cannot quickly produce a finished product. So, product validation cannot be completed quickly. Besides, a lot of resources are invested at once, which takes a long time and leads to high internal and external communication cost. Ultimately, the product cost is high; the time needed for product validation is long; and the market competitiveness of the product is significantly undermined.

Secondly, the nature of the civil market determines that the products offered must be responsive and iterative; Company A was faced with a purely civil, open and competitive market, and all its customers were desperate for products to capture the market. Besides, it needed to respond quickly to changes in the requirements from end users, which were completely different from the previous large aircraft customers. Any changes that are made are expected to be addressed immediately and updated to the product for their use. However, the waterfall development model is characterized by serial work from start to finish, and development of an aircraft is in itself a complex task. It basically takes a cycle of two to more than six months of development and testing to meet each requirement before delivering the product to the customer. In some cases, the requirement is only met in new or improved products. If some requirements are not considered in the first-generation product, using the waterfall R&D model after evaluation to meet these requirements is basically a major upgrade of the product, which would take at least one year and is completely unable to meet the rapidly changing market and user needs. Considering that Company A is a new start-up focusing on small operational UAVs for the civil market, the waterfall development process is not applicable to Company A's internal and external environments as well as product development.

Thirdly, the company is small with no clear division of labor. The main R&D staff of Company A were previously employed in traditional large domestic aviation companies. Because of this, Company A adopted the waterfall model used by traditional aviation companies for its R&D and production processes. However, Company A was still very small and had few staff. Thus, adoption of the waterfall development model isolated the requirements team from the development team as well as the production and test teams, reducing the communication efficiency of the whole team. The waterfall development process is suitable for large aviation companies to carry out R&D of large aircrafts as it can better cope with the relatively slow upgrading and iteration of large aircrafts as well as the higher safety and reliability requirements. Company A is a micro and small-sized startup with a small scale and few staff. Its products are mainly aimed at the civil UAV market, which is an open and competitive market. Its products need to respond positively and quickly to market demand so that it can stand firm and excel in market competition. Besides, the market is diverse in its needs due to different application scenarios. In this context, it is difficult for the company to meet customers' need for rapid response with a waterfall development process, and the company will be left behind as a result. Therefore, the company should choose a flexible and responsive R&D process that is able to respond to market feedback in the shortest possible time and validate the market value of the product quickly.

Fourthly, the aircraft industry has special characteristics. The development of aircrafts is different from that of other types of civilian products. Ordinary civilian products rarely have fatal injuries after problems or failures, while UAVs fly in the sky and are met with too many uncertainties. So, the safety of UAVs must be ensured by a set of standardized processes, and the cycle will not be too short. Certainly, the premise of these is to have an accurate grasp of the demand analysis of UAVs. Any deviation would directly undermine the market performance of the product. Yet nowadays companies are faced with a very competitive market, and a long R&D cycle will have a huge impact on the promotion of products. Therefore, there is a need for a system of R&D processes that can quickly respond to the needs of the market and quickly validate whether the product meets the market demand. So, in response to this market environment, the waterfall R&D model is no longer applicable. After internal discussions and analysis of the first failure by the team, it was confirmed that Company A needed an R&D model in line with the market, the industry and itself to enhance the competitiveness of its products to meet the market demand.

Based on the above analysis of the pros and cons of the waterfall development process, it is easy to find that the waterfall model is more suitable for mature products and large enterprises.

Large enterprises have few requirements for product iteration, and the focus is on the interlocking production process. So, standardized production process is conducive to consolidating product quality and enhancing the company's image; while for small companies, the waterfall development process is less applicable because small companies have a pressing need for time and rapid market feedback. Therefore, it is particularly important to quickly validate the market value of the product at minimal cost.

In summary, to address the second reason for the failure of Company A's first-generation product, it is necessary to find a method and model in line with the size of Company A as a micro and small start-up, its products and its target market. The ideal method and model should be able to (1) effectively improve the communication and efficiency of the team; (2) develop and improve the ability to respond quickly to the rapidly changing market demand; and (3) produce a product that meets customer needs at minimal cost and quickly validate the usability of the product, the extent to which it meets customer needs and the market value of the product.

4.2 Company A's adoption of lean startup MVP for the second-generation products based on comparison

Based on the analyses of the interviews with Company A's core team members regarding the reasons for the failure of its first-generation product, it is clear that to address these reasons and to respond to the perfectly competitive market in which Company A operates, its internal and external environments and its own characteristics, Company A needs to identify a method and model that integrate the following characteristics: (1) able to accurately identify the core requirements, avoid divergence and concentration of requirements, and get feedback from customers as soon as possible to involve customers in the confirmation of core requirements as soon as possible; (2) able to produce products with core functions and achieve market validation at minimal cost; (3) able to develop and improve the ability to quickly respond to the rapidly changing market demand; and (4) in line with the internal and external environments of Company A as a micro and small start-up, with widely recognized and applied methods and models.

Based on the methods and models in line with Company A's requirements, this study selects the incremental model, rapid prototyping model, agile development model and lean startup MVP for comparison to select and derive the most suitable method and model for Company A's products.

4.2.1 Incremental model

Incremental model is a process of modularizing the software system to be developed by treating each module as an incremental component and thus analyzing, designing, coding, and testing these incremental components in batches. The software development process using the incremental model is an incremental process. Alternatively known as the successive version model, or the planned product improvement model, the incremental model starts with a given set of requirements and implements development activities by constructing a series of executable intermediate versions. The first version incorporates some of the requirements; the next version incorporates more requirements; and this process goes on until the system is complete. Each intermediate version performs the required processes, activities and tasks (Lv, 2017; Tan et al., 2009; Zeng et al., 2018).

In contrast to the waterfall model, the incremental model of development does not require developers to submit the entire software product to the user at once. Instead, they can submit it in batches. The incremental model is a combination of the waterfall model and the prototype evolution model. It considers the software process in such a way that the overall project development follows the flow of the waterfall model to facilitate project management; but in the actual creation of the software, the software system is broken down into many incremental components by function and is created and delivered one by one until all the incremental components have been created and integrated into the system and delivered to the user.

The most important feature of the incremental model is the modularity and componentization of the software system to be developed. Based on this feature, the incremental model has the following advantages.

1. The modularization of the software system to be developed allows for the submission of software products in batches, so that users can be kept informed of the progress of their software projects.

2. Development in components reduces the risk of software development. Errors in one development cycle do not affect the entire software system.

3. Flexible development order. Developers can prioritize the order of implementation of components and complete core components with stable requirements first. The implementation order can also be adjusted in a timely manner when the priority of a component changes.

The disadvantage of the incremental model is that it requires that the software system to be developed can be modularized. Difficulty to modularize the software system to be developed

will make it impossible to implement the incremental model effectively and quickly enough to exploit its benefits.

Combining the above advantages, the incremental model is suitable for software development projects with the following characteristics: the software products can be delivered in batches; the software system to be developed can be modularized; the software developer is not familiar with the application area, and it is difficult to develop the system in one go; and the project manager has a high level of grasp of the whole project.

Compared to the waterfall model, the incremental model has very significant advantages. However, the incremental model has higher technical requirements for the software design. Particularly, it requires the software architecture to have good openness and stability to enable smooth integration of the components. When integrating each new component into the structure of an existing software system, it is generally required that the new component should change the original software structure as little as possible. Incremental components therefore require a good degree of functional independence and a simple interface to facilitate the connection to the system during integration.

In summary, the incremental model has many advantages but also has special requirements. Compared to Company A's four requirements for the method and model, the incremental model can only partially meet Requirements 2 and 3 (see Table 4.1 for a detailed comparison). So, the incremental model does not meet Company A's requirements.

4.2.2 Rapid prototyping model

Rapid prototyping model is another form of incremental model that requires the rapid construction of a working software prototype in order to understand and clarify issues, enable developers to reach consensus with users, and ultimately develop a satisfactory software product based on defined customer requirements (Tan et al., 2009). The rapid prototyping model allows for an initial, but not complete, analysis and definition of software requirements during the requirements analysis phase, and the rapid design and development of a prototype software system that demonstrates all or part of the functionality and performance of the software to be developed to the user; the user tests and evaluates the prototype and gives specific suggestions for improvement to enrich the software requirements; the developer modifies and improves the software accordingly until the user is satisfied. After approval, the software is fully implemented, tested and maintained (Lv, 2017). It is the construction of a prototype prior to the development of a real system, based on which the development of the whole system is

gradually completed. The first step in the rapid prototyping model is to build a rapid prototype that enables the customer or future user to interact with the system, followed by the user or customer's evaluation of the prototype to further detail the requirements of the software to be developed. By gradually adapting the prototype to meet the customer's requirements, the developer can determine what the customer's real needs are; the second step builds on the first step to develop a software product that the customer is satisfied with (Zeng et al., 2018).

Advantages: Rapid prototyping model overcomes the disadvantages of the waterfall model and reduces the development risks associated with unclear software requirements. This model is suitable for the development of software systems where requirements cannot be precisely defined in advance.

Disadvantages: Due to the need to build prototypes quickly, the development techniques and tools chosen may not always be in line with mainstream developments; a rapidly built-up system architecture coupled with continuous modifications may lead to low product quality.

In practical scenarios, it is difficult to rely only on analyses to identify a complete, accurate, consistent and valid set of user requirements before the system is built. This approach of defining requirements in advance is even less adaptable to changing user requirements. The proposed rapid prototyping model can better address the limitations of the waterfall model by building prototypes that can better communicate with customers, clarify some ambiguous requirements, and better adapt to changes in requirements. The prototype model can reduce technical and application risks, shorten development time, reduce costs and increase productivity. Running the prototype provides a way for users to evaluate the system directly, prompting them to take the initiative to participate in development activities, strengthening the feedback of information, facilitating the coordination and communication among all kinds of people, reducing misunderstandings, being able to adapt to changes in requirements, and ultimately effectively improving the quality of the software system.

Considering the advantages and disadvantages of the rapid prototyping model and comparing them with Company A's four requirements for methods and models, the rapid prototyping model partially meets Requirements 1, 2 and 3 (see Table 4.1 for a detailed comparison). Overall, the rapid prototyping model does not meet Company A's requirements.

4.2.3 Agile development model

Agile development is characterized by the use of an iterative and step-by-step approach to software development with the evolution of users' requirements at its core. In agile

development, software projects are initially cut into subprojects at the beginning of the development, and the results of each subproject are tested and have the characteristics of being visible as well as availability for integration and operation (Zeng et al., 2018). In other words, a large project is divided into multiple smaller projects that are interconnected but can also run independently, and these smaller projects are completed separately. In this process, the software remains in a usable state. Agile modelling (AM) defines a set of core and supporting principles that form the cornerstone of modelling practice in software development projects. Some of these principles are borrowed from XP and are described in detail in Extreme Programming Explained. Some of the principles in XP are in turn derived from the well-known software engineering, where the idea of reuse is everywhere.

The core principle of the agile development model is that it advocates simplicity and embraces change. It is featured by the following development principles (Balaji & Murugaiyan, 2012; Lv, 2017; Tan et al., 2009; Zeng et al., 2018)

1. Rapid iteration. Smaller releases are easier and faster to require, develop and test than the kind of big releases that come out once every six months. Some companies, with only two to three releases a year and a slow-release process, still use the waterfall development model or, more seriously, have a misunderstanding of the agile development model.

2. Involvement of testers and developers in requirements discussions. Requirements' discussions are most effective when they are conducted in a workshop group consisting of the testers and developers. This makes it easier to define, group and prioritize the requirements that can be tested. This approach also makes it possible to take advantage of the complementary nature of the team members. Requirements identified in this way are often more efficient, more active and more participatory than in a requirements discussion meeting.

3. Compilation of testable requirements documents. Start by writing requirements documents using a "user story" approach. This approach allows us to focus on the requirements rather than on the solutions and implementation technology. Premature references to technical implementation solutions can reduce the focus on requirements.

4. More communication and minimum documentation. Communication is a common problem in any project. Good communication is a prerequisite for agile development. The longer you are inside the circle, the more you will stress the importance of good and efficient communication. Teams need to make sure they communicate on a daily basis, and face-to-face communication is much better than emails.

5. Production of a good product prototype. It is recommended to use sketches and models to clarify the user interface. Not everyone can understand a complex document, but everyone can read a picture.

6. Early consideration of testing. Thinking about testing early is important in agile development. With traditional software development, test cases are written late, which leads to problems in requirements being identified too late, making improvements too costly. By starting to write test cases earlier, the acceptable test cases are largely completed when the requirements are fulfilled.

In summary of the advantages and disadvantages of the agile development model described above and compared to Company A's four requirements for the method and model, the agile development model can mostly satisfy Requirement 1 and satisfy Requirements 2 and 3 (see Table 4.1 for a detailed comparison). Overall, the agile development model does not meet the requirements of Company A.

4.2.4 Lean startup MVP

Lean startup is derived from lean thinking and lean manufacturing and is highly similar to agile development (Womack et al., 2007). It is specifically tailored to the characteristics of entrepreneurial projects. Lean manufacturing refers to a set of guiding principles to ensure quality, speed and customer relations. Originally a term used by manufacturing companies, Poppendieck and Poppendieck (2007) introduced the principles of lean manufacturing into software development, resulting in lean development. Compared to agile development, lean startup encompasses both software-level and production-level methods and models. More importantly, lean startup is specifically designed for the application of entrepreneurial projects and has been applied to a wide range of scenarios successfully.

In the lean startup model, the MVP approach is used to develop the first prototype. This is done by first designing a prototype, a complete model from design to market application. An MVP is now the most respected concept for product development in Silicon Valley. The idea of MVP comes from "lean startup", and it was put forward by Ries (2011) in his book entitled *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. The lean startup method represents a new approach to continuous innovation derived from the concept of "lean manufacturing". It advocates "validated learning" by introducing a minimalist prototype to the market followed by validating whether the product meets the user's needs in the least costly and most effective way through continuous

experimentation and learning before adjusting the direction flexibly. If the product does not meet market needs, it is better to "fail quickly and cheaply" than to "fail expensively"; if the product is accepted by users, it is better to keep learning, explore user needs, and iterate to optimize the product. It costs too much to make a product perfect and then bring it to market, and it can take years to make a product that fails to meet users' actual needs, resulting in a lot of wasted time and money.

Google, in 1997, had only a simple text search feature, and this was when its domain name was still under Stanford. Back then, users needed to enter the keywords they wanted to search for. Then they needed to select how many results they wanted to be displayed. After that, they could click "search" to see the specific number of most relevant results. Originally, Yahoo still added website links to the directory through manual screening by operations staff, but it was inefficient. Yet Google's Page Rank algorithm was scaled up and automated to better meet the needs of users who needed to access information quickly and efficiently. Because of this, Google achieved a great success. In 1994, Amazon was no more than a book list, where users placed an order for a book they liked, and Amazon found the book and sent it to the customer. Back then, it did not even have its own logistics management system. The webpage showed that Amazon had one million books and provided a catalogue where users could view information such as the author, synopsis, title and keywords of a book. Although the website was very rudimentary, it was very popular as it could help customers find books they could not find in bookstores. What these products have in common is that the functionality is very simple in the initial stage, but they all satisfy an unmet need of users in the best possible way. Because of this, users would continue to use them and develop stickiness.

Accelerating speed to market does not mean that a product can enter the market without addressing any problems; an MVP also needs to be feasible. If the MVP does not solve even the most basic and only need, it is time to first improve the experience of this product and see if the need can be solved in a better way, rather than rushing to add new functions/features. When Instagram was first created, it only allowed users to post pictures, and the user experience was not good. At one point, CEO Kevin Systrom introduced the app to his girlfriend. She saw the pictures and asked: "Can we make these pictures look better?" He was so inspired by this question that he and his fellow entrepreneurs developed a few filters, and that was how the rest of the story came about. In this case, Instagram without filters is not an MVP, because users do not just want to share photos but want to be able to easily share presentable photos. So, although the improved Instagram did not yet have features such as Messaging and Explore Page at the time, the user growth rate still skyrocketed.

An MVP needs to satisfy two basic elements (Ries, 2011). Firstly, it needs to satisfy at least one need, and to satisfy it relatively well, otherwise its existence would be meaningless; secondly, an MVP has to have both "minimality" and "viability". The purpose of minimality is to reduce the cost of trial and error and to quickly validate that the product meets the user's needs. Viability, on the other hand, is about making sure that the product meets user needs well, rather than releasing a poor product that only addresses 50% of the needs for the sake of speed (S. Blank, 2013).

In summary, the lean startup MVP model meets all the four requirements (see Table 4.1 for a detailed comparison). In other words, the lean startup MVP meets the requirements of Company A. Therefore, Company A used the lean startup MVP to develop the second-generation product.

Table 4.1 A comparison of the four methods and models

Model Requirement	Incremental model	Rapid prototyping	Agile development	Lean startup MVP
R1: Able to accurately identify the core requirements, avoid divergence and concentration of requirements, and get feedback from customers as soon as possible, to involve customers in the confirmation of core requirements as soon as possible	Unfulfilled	Partially fulfilled	Mostly fulfilled	Fulfilled
R2: Able to produce products with core functions and achieve market validation at minimal cost	Partially fulfilled	Partially fulfilled	Fulfilled	Fulfilled
R3: Able to develop and improve the ability to quickly respond to the rapidly changing market demand	Partially fulfilled	Partially fulfilled	Fulfilled	Fulfilled
R4: In line with the internal and external environments of Company A as a micro and small start-up, with widely recognized and applied methods and models	Unfulfilled	Unfulfilled	Partially fulfilled	Fulfilled

4.3 MVP-Select Model

As economic globalization deepens, companies are faced with increasingly fierce competition. In this context, how to enhance product competitiveness is a major challenge that must be addressed (J. Q. Chen, 2016). Companies or entrepreneurial teams test the effectiveness of their business models and examine the market value of their products by launching MVPs (Lee & Geum, 2021). Therefore, entrepreneurial teams are more concerned about whether the business models of their products are viable and whether their products are competitive.

An analysis of the reasons for the failure of Company A's first-generation product revealed that its functional features did not take into account user feedback but was solely determined according to the team's ideas. As a result, the said product failed to meet the market demand (see Chapter 4 for details). This reflects entrepreneurial teams' tendency to be only focused on the business models and competitiveness of products while neglecting realization of the actual needs of customers in products.

Customers' needs are the comprehensive requirements for a company's products and the company itself, regardless of whether the company provides tangible products or services. Customer feedback is the most realistic "voice" from the market. It is the driving force behind the improvement of existing products and the starting point for innovation. It is also a key consideration for product development at the very beginning. The process of product development and innovation relies heavily on feedback from the market to identify and analyse product requirements. However, customer feedback or complaints are often disoriented. Therefore, the most critical input to product design is to accurately categorize customer needs and feedback on product performance and services into different levels and types, and then communicate the most user-aware propositions to companies and developers (J. Q. Chen, 2016).

Based on the above analysis, the confirmed MVP must include both the functional features confirmed by the company and those confirmed by users. So, the MVP should be analyzed from both company and customer perspectives. The final MVP should be based on both company and customer analyses. The specific model is presented in Figure 4.3 below.

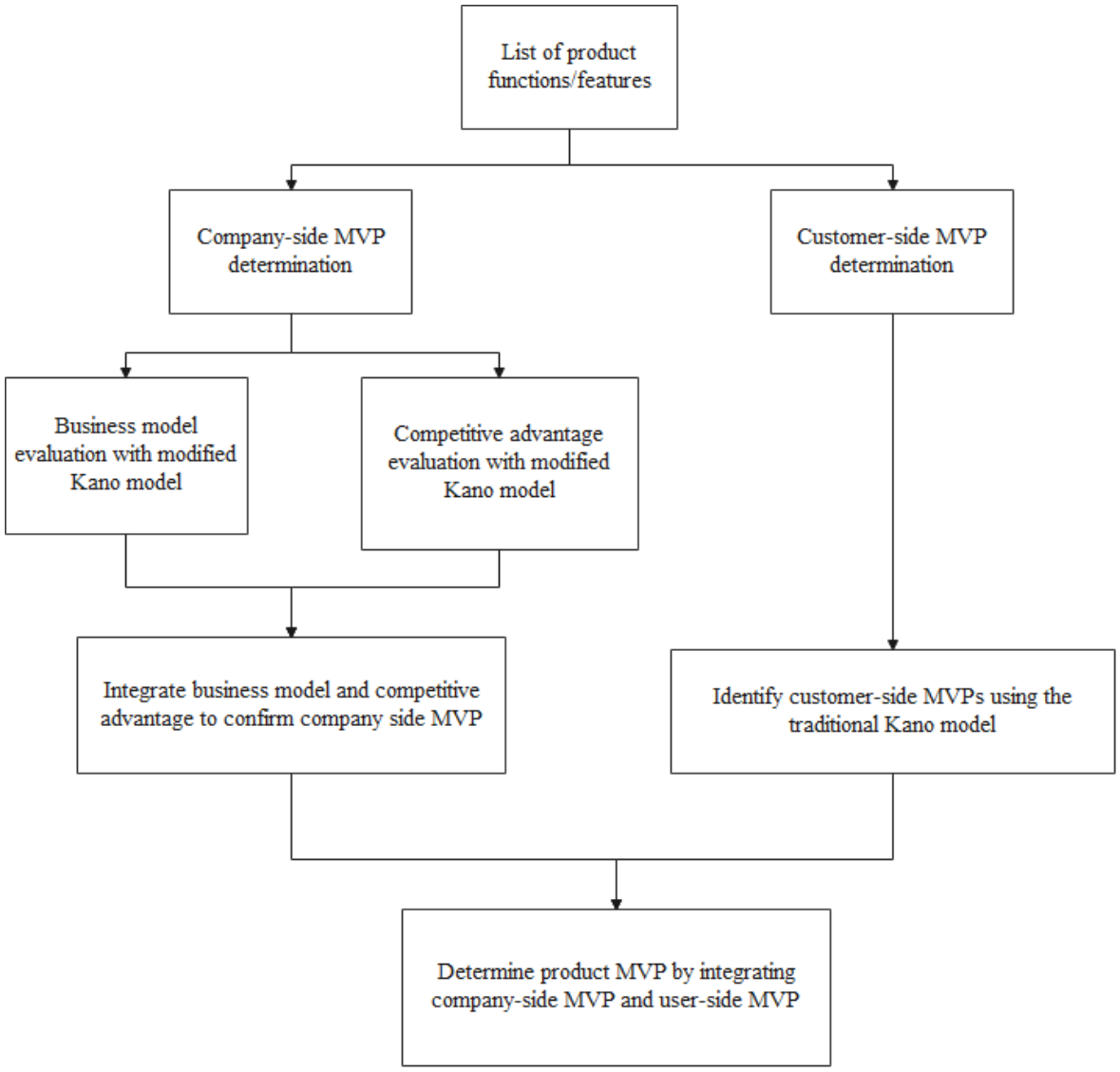


Figure 4.3 MVP-Select Model

The steps of the MVP-Select Model are as follows:

1. Confirm the list of functional features of the UAV product to be included into the MVP.

Identify which functional features are to be included in the MVP based on literature analysis, industry experience as well as market and competitor analyses.

2. Conduct company-side MVP confirmation.

Apply the Kano Model innovatively to the analysis of the company's business model and competitive advantages. Revise the Kano Model evaluation sheet to suit the analysis of the company's business model and competitive advantages.

The Kano Model Evaluation Sheet for Business Model Revision is shown in Table 4.2 below.

Table 4.2 Kano model evaluation sheet for company-side business model revision

		Dysfunctional (feature absent)				
		Like it	Expect it	Don't care	Live with	Dislike
Functional (feature present)	Like it	Q	A	A	Optional business model	Core business model
	Expect it	R	I	I		
	Don't care	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

The Kano Model Evaluation Sheet for Competitive Advantages Revision is presented in Table 4.3 below.

Table 4.3 Kano model evaluation sheet for company-side competitive advantages revision

		Dysfunctional (feature absent)				
		Like it	Expect it	Don't care	Live with	Dislike
Functional (feature present)	Like it	Q	A	A	A	Core competitive advantage
	Expect it	R	I	I	I	Optional competitive advantage
	Don't care	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

Table 4.4 below is a template of the Kano questionnaire on company-side business model and competitive advantages.

Table 4.4 Kano questionnaire on company-side business model and competitive advantages

Type	Functional feature	Like it	Expect it	Don't care	Live with	Dislike
From the perspective of the company's business model	The company's business model can only be realized if the flight time is two hours or more.					
	The company's business model can only be realized if the flight time cannot reach two hours.					
From the perspective of the company's competitive advantages	The company's product is only competitive against competitors if the flight time is two hours or more.					
	The company's product is only competitive against competitors if the flight time cannot reach two hours.					

3. Confirm the company-side MVP based on an integration of the Kano analyses of company-side business model and competitive advantages (see Table 4.5 below).

(1) Include the functional features of the core business model in the core functional features at the company level and give it the top priority regardless of which category of business advantages they belong to.

(2) Include the remaining functional features belonging to other categories in the alternative functional features and give them the second priority.

Table 4.5 Confirmation of company-side MVP based on integration

		Company-side competitive advantages	
		Core	Optional
Company-side business model	Core	Core functional feature	
	Optional	Recommended functional feature	

4. Carry out customer-side Kano analysis.

Only the must-be functional features and one-dimensional functional features on the customer side have a significant impact on customer satisfaction. Attractive functional features, while beneficial to enhancing customer satisfaction when satisfied, do not reduce customer satisfaction when not satisfied and can therefore be included as alternative functional features.

Below is a template of the customer-side Kano questionnaire. See Table 4.6 below.

Table 4.6 Customer-side Kano questionnaire

Type	Functional feature	Like it	Expect it	Don't care	Live with	Dislike
Customer's evaluation of the functional feature	What do you feel if the flight time reaches two hours? What do you feel when the flight time cannot reach two hours?					

5. Integrate the company-side and customer-side Kano analyses, as shown in Table 4.7.

Table 4.7 Company-side and customer-side functional features

		Customer-side functional features		
		Must-be	One-dimensional	Attractive
Company-side functional features	Core	Core MVP		
	Optional		Second priority MVP	Third priority MVP

(1) Because the MVP is designed to validate the business model as well as the competitive advantages of a startup's product at minimal cost, the core functional features identified on the company side represent the company's business model and competitive advantages and are directly identified as MVP functional features.

(2) The must-be functional features identified on the customer side must be added to the MVP functional features because failure to meet them will result in extreme user dissatisfaction.

(3) One-dimensional functional features on the customer side that are identified as optional on the company side are identified as second priority MVPs and may be added for implementation in subsequent iterations.

(4) Other functional features identified as third priority MVPs may be added to the list for implementation in subsequent iterations.

4.4 Summary

This chapter introduced Company A, the background of its establishment as well as its main products and development status. Its competitors' product manufacturing and marketing status were analyzed. On this basis, an analysis of the reasons for the failure of Company A's first-generation product was made. Such an analysis led to a summary of Company A's four needs for a method and model. According to a comparative analysis based on the needs of each of the four popular methods and models, the most suitable product development model for Company A - Lean Startup MVP – was identified. Lean Startup MVP could solve the market dilemma faced by Company A, achieve market validation with fast speed and minimal cost, and iterate out competitive UAV products that meet market and customer needs, and proposes an innovative MVP-Select model characterized by the application of the Kano Model to the identification of lean startup MVPs, modifies the Kano Model to fit the characteristics of lean startup MVPs, and describes the operational steps and methods in detail.

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Chapter 5: Application of the MVP-Select Model to Identify Company A's MVP

5.1 Creating a list of product features

An unmanned aerial vehicle (UAV) is known by a variety of names, such as remotely piloted aircraft (RPA) or simple aircraft (Jha, 2017). It is a remotely controlled or self-piloted aircraft that can carry payloads such as cameras, sensors and communication equipment, and all flight operations (including take-off and landing) are performed without an on-board human pilot. In some professional literature or books, the term "unmanned aircraft system" (UAS) is used, while in media reports, the term "UAV" is mostly used (Mohammad, 2017). The mission of UAVs is to perform critical flight operations without endangering personnel and are more cost-effective and cost-efficient than comparable manned systems. In general, civilian UAVs are designed to perform specific tasks such as information collection, image acquisition, survey, reconnaissance and surveillance (Jha, 2017; Mohammad, 2017).

The Wright brothers invented the airplane in 1903 in the U.S., and the first UAV known as Hewitt Sperry Automatic Airplane, was invented just 13 years later (in 1916). Over the 100 years that followed, along with the development of technology, manned and unmanned aircrafts gained tremendous development and wide application (Dalamagkidis et al., 2012; Grant et al., 2017). Aircraft design is a complex and systematic project that encompasses numerous subject areas. UAVs are one type of aircraft. According to works on aircraft design and UAV design (Jha, 2017; Mohammad, 2017; Sadraey, 2013, 2017; Sforza, 2014), there are ten categories of indicators to focus on in UAV design, and some of these categories or sub-categories under these categories can be ignored depending on the use of the UAV. According to the background and product analysis of Company A in Chapter 4, Company A's UAVs are mainly positioned as civilian UAVs classified as industrial-grade UAVs, and Company A focuses on purely electric UAVs with lithium batteries as the power source. Therefore, the following indicators are included in the list of functional features for Company A's UAV products.

1. Performance (Jha, 2017; Mohammad, 2017; Sadraey, 2017; Sforza, 2014)

(1) Flight time

Compared to fuel-powered UAVs, purely electric UAVs have shorter flight time. One reason is that fuel provides more power per unit than electric power per unit. The other reason is that battery discharge does not bring about a reduction in its own weight. Based on a competitive product analysis, the maximum flight time was determined to be 300 minutes unloaded, 25% higher than the highest indicator of competing products.

(2) Maximum take-off altitude

Due to China's complex landform, the altitude varies significantly, with the average altitude in the plateau area being around 3,500-4,000 meters. To adapt to the mission operations in high altitude areas and based on a competitive product analysis, the highest take-off altitude was determined to be 4,500 meters, 12% higher than the highest take-off altitude of competing products.

(3) Ceiling

UAVs need to operate in the air at a distance higher than the take-off and landing altitude. So, there is a need to increase the operating altitude at the highest take-off altitude. According to the application analysis and competitive product analysis, the general operating altitude is within 1,000 meters, and the ceiling (maximum allowable altitude) is set at 6,000 meters above sea level, which was the same as the highest indicator of competing products.

(4) Control radius

The control radius represents the maximum distance that a data link can communicate with unobstructed radio signals and is closely related to the transmitting power and performance of the receiving equipment. A UAV generally operates within the control radius, beyond which it will continue the mission in accordance with the mission planning or return directly to the communication range to wait for instructions. Based on the competitive product analysis and operational mission analysis, the control radius was determined to be 100 kilometers, an indicator consistent with that of the best competing model.

(5) Wind resistance

In the course of flight, UAVs may encounter sudden high winds. In general, downwind and headwind have little impact on the safety of UAVs, but crosswind has a significant impact on the safety of UAVs as it can directly cause UAVs to side turn and subsequently fall out of control. So, wind resistance directly reflects the safety of UAVs. Based on the competitive product analysis and operational tasks analysis, the wind resistance was determined to be Level 7, which was consistent with that of the best competing model.

(6) Rain resistance

The rain resistance of a UAV is mainly aimed at protecting the motor, electronic speed control (ESC) and other power systems, so as not to cause the power system to stop working because of the excessive amount of water that might cause the UAV to stall and crash. Based on the competitive product analysis, the rain resistance was determined as light rain, i.e., low precipitation intensity. Specifically, the amount of rain within 24 hours should be less than ten millimeters, which can drench clothes and make the earth and ground fully wet without accumulating impounded surface water. This indicator was consistent with that of the best competing model.

(7) Cruising speed

Cruising speed generally refers to the most economical flight speed of a UAV. Flying at such a speed can maintain a longer flight time and ensure minimal wear and tear on the components. Based on the competitive product analysis, the cruising speed was determined to be 72 km/h, in line with that of the best competing model.

(8) Maximum flight speed

Maximum flight speed is the maximum speed of a UAV, which can generally only be maintained for a short time for special tasks or to deal with special situations such as entering a no-fly zone due to the loss of positioning information and needing to rapidly evacuate. Based on the analysis and comparison of competing products, the maximum flight speed was determined to be 125 km/h, slightly higher than that of the best competing model.

(9) Minimum hover radius

Minimum hover radius refers to the minimum circle radius when a UAV is hovering. It is generally only for special operational tasks, such as surveillance of a fixed target. Based on operational task analysis and competitive product analysis, the minimum hover radius was determined to be less than 100 meters, better than that of the best competing model.

2. Weight (Jha, 2017; Mohammad, 2017; Sadraey, 2017; Sforza, 2014)

(1) Maximum take-off weight

Maximum take-off weight represents the weight of a UAV itself plus the weight of the load carried, and the weight of the UAV itself is in turn closely related to the load capacity. For the sake of portable design and the needs of operational scenarios, the maximum take-off weight was determined to be 25 kilograms in line with the best competing model based on the analysis of and comparison with competing products.

(2) Payload

Payload, which is related to the type of load that can be carried on a UAV, is closely related to the flight time. To make flexible use of the balance between payload and flight time, the payload capacity was designed to be six kilograms, in line with that of the best competing model.

3. Maintainability (Jha, 2017; Mohammad, 2017; Sadraey, 2017; Sforza, 2014)

(1) Portability and quick disassembly

As industrial grade UAVs basically have a wingspan and fuselage of over one meter or even more than four meters, simplicity and convenience to transport and carry are very important indicators. It is essential that an UAV is designed in a detachable manner and can be placed in a drop-proof case. The design should be portable and allows for quick assembly by one to two persons for quick operations. Compared to the competing products, the new product was designed in a way more suitable for two-person operation and was thus better than the best competing model.

(2) Quick replacement of parts

Quick replacement of parts play a vital role in improving the field maintenance efficiency of UAVs. In general, the parts of a UAV that can be quickly repaired after damage are basically structural parts, such as wings, tail, VTOL gear and propellers. The increase in the speed of rapid disassembly and replacement of structural parts largely improves the robustness of the UAV. Based on a competitive product analysis, the new product's quick replacement of parts were better than those of the best competing model.

(3) Flight data recorder

The flight data recorder, also referred to as the black box, is used to record all the system operation data and operation instructions of UAVs. It is highly valuable for the stability, accident investigation and analysis, and accident restoration of UAVs. However, it is a burden for small UAVs because of the huge and complex recorded data. In comparison, the competing products did not have this function.

4. Autonomy (Jha, 2017; Mohammad, 2017; Sadraey, 2017; Sforza, 2014)

(1) Autonomous return

When a UAV with the autonomous return function completes its mission, encounters a no-fly zone, loses data link communications or encounters unexpected situations (e.g. high winds, heavy rain), it can return to the take-off location autonomously. This function was consistent with competing products.

(2) Autonomous path planning

A UAV with the autonomous path planning function is able to adjust its flight height and route in time based on GPS positioning information to avoid collision with objects, such as tall buildings or mountain peaks. This function was consistent with competing products.

(3) Parachute landing fall

A UAV with the parachute landing fall (PLF) function can automatically activate the PLF technique upon the occurrence of unexpected situations such as stall, high winds, power failure and collision, to maximize the protection of the UAV safety. In comparison, the competing products did not have this function.

5. Scarcity (Jha, 2017; Mohammad, 2017; Sadraey, 2017; Sforza, 2014)

(1) Rapid load replacement

As UAVs need to use different types of mission load equipment according to different mission operations, the installation and fixed steps of general UAV load equipment are tedious. Besides, there is also the complex workload of wiring and circuit rearrangement, personnel must be professionally trained, and the replacement time is generally more than two hours. The innovative multi-mission payload plug-in replacement method has basically made it possible to replace the payload within ten minutes, which greatly improves the efficiency of mission operations.

(2) Battery swapping

UAVs can carry a variety of loads, and with the rapid load replacement, it is possible to maximize the use of UAVs to complete a variety of operational requirements. Due to the different weights of the individual payload, UAVs with a fixed payload cannot carry more than the fixed payload, creating a limitation on operational requirements. By reducing the weight of the battery and increasing the payload at the same time, the limitation of the payload exceeding the designed fixed payload can be perfectly addressed, maximizing the use of UAVs for a variety of operations. The maximum payload can be increased by up to three kilograms, bringing the maximum payload to six kilograms.

(3) Vertical take-off and landing (VTOL)

In general, a fixed-wing aircraft needs to use a runway to help it reach the take-off speed in order to take off and fly. As the UAV operating site is complex and the operating environment is uncontrollable, the runway that meets the take-off run requirement severely restricts and limits the application and operation of UAVs. The innovative combination of multi-rotor and fixed-wing aircrafts and the use of VTOL to solve the runway problem greatly improve the adaptability of UAVs to different operating environments and increase the UAV application scenarios. This VTOL function is in line with competing products.

(4) Beautiful appearance

Market research and analysis of competing products revealed that the existing purely electric VTOL UAVs are basically similar in appearance, with relatively rough workmanship, giving people an intuitive feeling of not beautiful and high-tech enough. Therefore, the new product was expected to improve its appearance and the high-tech sense.

Based on the above analysis, a total of 21 functional features in five categories were to be selected for the MVP of Company A's UAV. The detailed list is presented in Table 5.1 below. This list was also the core basis for the design of the Kano questionnaires on both the company and the customer sides.

Table 5.1 List of functional features to be selected for the MVP of UAV

Category	No.	Functional feature	Source of reference
Performance	F1	Flight time	Jha (2017); Mohammad (2017); Sadraey (2017); Sforza (2014)
	F2	Maximum take-off altitude	
	F3	Ceiling	
	F4	Control radius	
	F5	Wind resistance	
	F6	Rain resistance	
	F7	Cruising speed	
	F8	Maximum flight speed	
	F9	Minimum hover radius	
Weight	F10	Maximum take-off weight	
	F11	Payload	
Maintainability	F12	Portability and quick disassembly	
	F13	Quick replacement of parts	
	F14	Flight data reporter	
Autonomy	F15	Autonomous return	
	F16	Autonomous path planning	
	F17	Parachute landing fall	
Scarcity	F18	Rapid load replacement	
	F19	Battery and payload swapping	
	F20	VTOL	
	F21	Beautiful appearance	

5.2 Questionnaire design

The questionnaire was designed according to the requirements of the Kano Model, which has one positive question and one negative question for each functional feature. Take the functional feature of the flight time exceeding 300 minutes for example.

The positive question is: What do you feel if the flight time reaches 300 minutes?

The negative question is: What do you feel if the flight time cannot reach 300 minutes?

Each question of the Kano questionnaire is scored on a five-point Likert scale, and the scores will be categorized into different levels for statistical analysis.

In the Company-Side Kano Questionnaire for Improvement, the questions regarding each functional feature were designed from two perspectives: business model and competitiveness and phrased in both a forward manner and a reverse manner. So, there were four questions concerning each functional feature in the list scored on a five-point Likert scale. See Annex A: - Company-Side Kano Questionnaire for Improvement. To get more realistic feedback from Company-Side Kano Questionnaire for Improvement, copies of the company-side questionnaire were distributed anonymously and recovered in a unified manner. To ensure the validity of the questionnaire survey, Kano's traditional evaluation sheet was used to classify the questionnaires, and all the questionnaires classified into the "Q" Category were excluded as invalid questionnaires.

The Customer-Side Kano Questionnaire was designed according to the traditional Kano questionnaire, with a forward question and a reverse question for each functional feature in the list. All the questions were scored on a five-point Likert scale, and the scores were classified into different categories. As the questionnaires were distributed on the internet (see Annex B for details), two questions were added as entry criteria for survey respondents: (1) the user's company was in the field of UAV application (Petrova & Zhivo, 2020); and (2) the user must have worked in the UAV application field for more than one year. Only questionnaires that met both these criteria were regarded as valid questionnaires for subsequent data analysis. After that, Kano's traditional evaluation sheet was used to classify the questionnaires, and all the questionnaires classified into the "Q" Category were excluded as invalid questionnaires.

5.3 Data collection

According to the 5.2 Questionnaire Design, for the customer-side Kano questionnaire, since the questionnaire was distributed in the Internet and we cannot confirm the professionalism of the people who filled out the questionnaire, so the questionnaire was first tested for the customer-side Kano questionnaire to ensure that 1) the content of the questionnaire was complete, clear and easily understood by the customers; 2) the questionnaire had the required reliability; 3) the questionnaire had the required validity.

The questionnaire was released on June 30, 2022, using Questionnaire Star online professional questionnaire platform (www.wjx.com). And as of July 4, 2022, a total of 17 responses were received, of which 17 were valid, with a validity rate of 100%. From the validity of the answers, we could see that the content of the questionnaire itself was complete and clear, and customers could understand the content of the questions and make choices.

The questionnaire reliability analysis, after exporting the data from Questionnaire Star and processing them through SPSS 26.0 analysis, yielded a Cronbach alpha coefficient of 0.912 > 0.700 for the positive questions of the questionnaire; 0.880 > 0.700 for the negative questions of the questionnaire; and 0.820 > 0.700 for the overall questionnaire, and since the Cronbach alpha coefficients for all items is greater than 0.700, so the questionnaire can be considered to have reliability, the data can be found in Table 5.2 below.

Table 5.2 Reliability analysis of the questionnaire

No.	Item	Cronbach α	Number of questions
1	Positive Questions	0.912	21
2	Negative Questions	0.880	21
3	Overall Questions	0.820	42

Regarding questionnaire validity analysis, firstly, from the questionnaire design, there are 21 questions extracted from professional books on UAV design, which are all essential and important functional features of UAVs and are applicable to the current market demand of the industry that Company A is dealing with (Grant et al., 2017; Jha, 2017; Mohammad, 2017; Sadraey, 2013, 2017; Sforza, 2014). Secondly, the questionnaire questions were ordered according to the most easily understood and basic performance questions, so that customers could understand them very easily and the performance questions were the most important concerns of customers, so that they could have patience and interest to complete the questionnaire afterwards. At the end of the questionnaire are the scarcity questions, which have a high attraction to customers and allow them to concentrate and focus on completing the whole questionnaire. Finally, the 21 functional features involved in the whole questionnaire were confirmed by comparing with competitors' products in the market, and the functional features were also designed and reviewed by the professional practitioners of Company A so they have high credibility, and the questionnaire was also confirmed by both two Supervisors. In summary, the questionnaire is valid.

5.4 Data analyses

5.4.1 Descriptive statistics

Printed copies of the Company-Side Kano Questionnaire were distributed among the selected core technical and marketing staff in Company A on July 8, 2022, and the distributed questionnaires were recovered on July 12, 2022. In total, 23 questionnaires were distributed, and 23 questionnaires were recovered, representing a 100% recovery rate. After data organization, one of the questionnaires was judged as invalid because it was not fully answered.

Except that, the remaining 22 questionnaires were valid. Therefore, the valid recovery rate was 95.65%.

The Customer-Side Kano Questionnaire survey was carried out on June 30, 2022, and completed on July 4, 2022. Then the reliability and validity of the survey data were analyzed (see Section 5.3 for details). After the reliability and validity of the questionnaire were confirmed to be up to standard, the official questionnaire survey was carried out and completed on August 19, 2022. A total of 465 questionnaires were recovered, among which 64 questionnaires were filled in by respondents with less than one year of work experience in the UAV industry, accounting for 13.76% of the total number. This indicated that the restrictive items designed in the questionnaire effectively circumvented the low-quality questionnaire responses and effectively improved the quality of the questionnaire responses. Among the recovered questionnaires filled in by respondents with effective work experience, 259 (55.70%) were filled in by respondents with more than three years of experience. This indicated that a large percentage of the respondents had several years of experience in the recent UAV industry, and their responses were more credible and valid. In terms of sample distribution in the industry, 59.60% of the sample were from the monitoring field, reflecting the general direction of market demand in the monitoring field (see descriptive statistics of the Customer-Side Kano Questionnaire in Figure 5.1). Kano analysis was performed on the data of the 401 questionnaires filled in by respondents with the required length of work experience. 22 questionnaires turned out to fall into the "Q" Category, accounting for 5.49%. According to the questionnaire design and data analysis requirements, these 22 questionnaires were judged as invalid questionnaires and eliminated as a result. The remaining 379 questionnaires (94.51%) were used for further analysis.

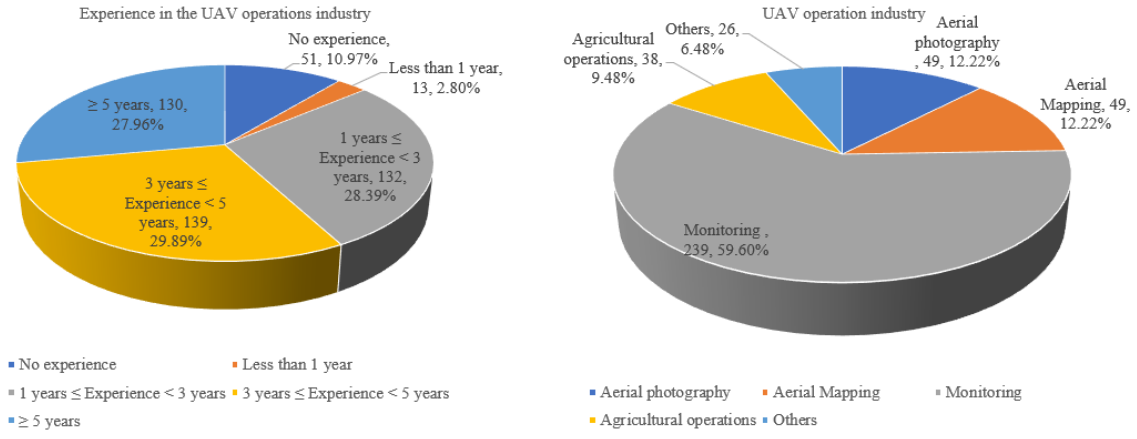


Figure 5.1 Descriptive statistics of the Customer-Side Kano Questionnaire

5.4.2 Use of the MVP-Select model to confirm MVP

5.4.2.1 Analysis of the revised company-side Kano questionnaire

According to the MVP-Select model, the company-side business model analysis was conducted on the list of functions/features. The data of the valid questionnaires were compiled and analyzed in terms of business model based on the modified Kano evaluation table. The results showed that four items, such as payload, quick replacement of parts and rapid load replacement, were reflective of core business models; 12 items, such as flight time, control radius and wind resistance, were reflective of optional business models; and five items, such as maximum take-off altitude, ceiling and cruising speed, were not reflective of business models. See Table 5.3 (Company-Side MVP Analysis Results) for details.

According to the MVP-Select model, the company-side competitiveness analysis was conducted on the list of functions. The data of the valid questionnaires were compiled and analyzed in terms of competitiveness based on the modified Kano evaluation table. The results showed that seven items, including control radius, wind resistance and payload, were reflective of the company's competitiveness; nine items, such as flight time, rain resistance and maximum flight speed, were reflective of the company's optional competitiveness; and five items, such as maximum take-off altitude, ceiling and cruising speed, were not reflective of the company's competitiveness. See Table 5.3 (company-side revised Kano analysis results) for details.

A consolidated company-side MVP analysis of the above-mentioned list of business model functions/features and list of competitiveness functions/features was made according to the MVP-Select model. The results indicated that four items, such as payload, quick replacement of parts and rapid load replacement, were core features/functions of the company-side MVP; 12 items such as flight time, control radius and wind resistance, were optional features/functions of the company-side MVP; and five items, such as maximum take-off altitude, ceiling and cruising speed, were not features/functions of the company-side MVP. The results effectively pinpointed the range of features/functions of the company-side MVP and concentrated the core strength of the entrepreneurial team on the embodiment of the company's business model and competitiveness. Meanwhile, although the three items, namely control radius, wind resistance as well as portability and quick disassembly, were features/functions of the company-side's core competitiveness, were listed as optional features/functions for MVP according to the MVP-Select model because they were not the core embodiment of the company-side's business model. See Table 5.3 for the company-side revised Kano analysis results.

Table 5.3 Company-side revised Kano analysis results

No.	Function/feature	Question	Revised Kano category	Company-side category
1	Flight time	Is UAV's flight time reaching 300 minutes a reflection of the company's business model?	Optional	Optional
2		Is UAV's flight time reaching 300 minutes a reflection of the company's competitiveness?	Optional	
3	Maximum take-off altitude	Is UAV's maximum take-off altitude reaching 4500 meters a reflection of the company's business model?	Exclusion	Exclusion
4		Is UAV's maximum take-off altitude reaching 4500 meters a reflection of the company's competitiveness?	Exclusion	
5	Ceiling	Is UAV's ceiling reaching 6000 meters a reflection of the company's business model?	Exclusion	Exclusion
6		Is UAV's ceiling reaching 6000 meters a reflection of the company's competitiveness?	Exclusion	
7	Control radius	Is UAV's control radius reaching 100 km a reflection of the company's business model?	Optional	Optional
8		Is UAV's control radius reaching 100 km a reflection of the company's competitiveness?	Core	
9	Wind resistance	Is UAV's wind resistance reaching Force 7 wind a reflection of the company's business model?	Optional	Optional
10		Is UAV's wind resistance reaching Force 7 wind a reflection of the company's competitiveness?	Core	
11	Rain resistance	Is UAV's rain resistance reaching resistance to light rain a reflection of the company's business model?	Optional	Optional
12		Is UAV's rain resistance reaching resistance to light rain a reflection of the company's competitiveness?	Optional	
13	Cruising speed	Is UAV's cruising speed reaching 72 km/h a reflection of the company's business model?	Exclusion	Exclusion
14		Is UAV's cruising speed reaching 72 km/h a reflection of the company's competitiveness?	Exclusion	
15	Maximum flight speed	Is UAV's maximum flight speed reaching 125 km/h a reflection of the company's business model?	Optional	Optional
16		Is UAV's maximum flight speed reaching 125 km/h a reflection of the company's competitiveness?	Optional	

No.	Function/feature	Question	Revised Kano category	Company-side category
17	Minimum hovering radius	Is UAV's minimum hovering radius reaching 100 meters a reflection of the company's business model?	Exclusion	Exclusion
18		Is UAV's minimum hovering radius reaching 100 meters a reflection of the company's competitiveness?	Exclusion	
19	Maximum take-off weight	Is UAV's maximum take-off weight reaching 25kg a reflection of the company's business model?	Optional	Optional
20		Is UAV's maximum take-off weight reaching 25kg a reflection of the company's competitiveness?	Optional	
21	Payload	Is UAV's payload reaching 6kg a reflection of the company's business model?	Core	Core
22		Is UAV's payload reaching 6kg a reflection of the company's competitiveness?	Core	
23	Portability and quick disassembly	Is UAV having portability and quick disassembly a reflection of the company's business model?	Optional	Optional
24		Is UAV having portability and quick disassembly a reflection of the company's competitiveness?	Core	
25	Rapid replacement parts	Is quick replacement of parts of a UAV reflective of the company's business model?	Core	Core
26		Is quick replacement of parts of a UAV reflective of the company's competitiveness?	Core	
27	Flight Data Recorder	Is UAV having a flight data recorder a reflection of the company's business model?	Exclusion	Exclusion
28		Is UAV having a flight data recorder a reflection of the company's competitiveness?	Exclusion	
29	Autonomous return	Is UAV having autonomous return option a reflection of the company's business model?	Optional	Optional
30		Is UAV having autonomous return option a reflection of the company's competitiveness?	Optional	
31	Autonomous Path Planning	Is UAV having autonomous path planning feature a reflection of the company's business model?	Optional	Optional
32		Is UAV having autonomous path planning feature a reflection of the company's competitiveness?	Optional	
33	Parachute landing fall (PLF)	Is UAV having the PLF function a reflection of the company's business model?	Optional	Optional

No.	Function/feature	Question	Revised Kano category	Company-side category
34	Rapid load replacement	Is UAV having the PLF function a reflection of the company's competitiveness?	Optional	Core
35		Is UAV having rapid load replacement feature a reflection of the company's business model?	Core	
36		Is UAV having rapid load replacement feature a reflection of the company's competitiveness?	Core	
37	Battery swapping	Is UAV having the battery swapping option a reflection of the company's business model?	Core	Core
38		Is UAV having the battery swapping option a reflection of the company's competitiveness?	Core	
39	Vertical take-off and landing (VTOL)	Is UAV having the VTOL function a reflection of the company's business model?	Optional	Optional
40		Is UAV having the VTOL function a reflection of the company's competitiveness?	Optional	
41	Beautiful appearance	Is UAV having a beautiful appearance a reflection of the company's business model?	Optional	Optional
42		Is UAV having a beautiful appearance a reflection of the company's competitiveness?	Optional	

5.4.2.2 Analysis of the customer-side Kano questionnaire

The traditional Kano evaluation table was used to analyze the valid customer-side questionnaires recovered according to the MVP-Select model. The results showed that four items, such as control radius and wind resistance, were attractive qualities; five items, such as rain resistance and VTOL, were must-be qualities; six items, such as flight time and autonomous path planning, were one-dimensional qualities; six items, such as ceiling and cruising speed, were indifferent qualities; and there was no reverse quality. See Table 5.4 for Customer-Side Kano analysis results.

Table 5.4 Customer-side Kano analysis results

No.	Function/feature	Question	A	O	M	I	R	Q	Total	Kano category
1	Flight time	How do you feel about the UAV flight time reaching 300 minutes?	59	136	45	104	35	0	379	O

No.	Function/feature	Question	A	O	M	I	R	Q	Total	Kano category
2	Maximum take-off altitude	How do you feel about the maximum take-off altitude of the UAV reaching 4500 meters?	54	35	49	225	16	0	379	I
3	Ceiling altitude	How do you feel about the UAV ceiling reaching 6000 meters?	63	29	40	224	23	0	379	I
4	Control radius	How do you feel about the UAV control radius reaching 100 km?	179	24	50	104	22	0	379	A
5	Wind resistance	How do you feel about the UAV wind resistance reaching Force 7 wind?	180	30	48	102	19	0	379	A
6	Rain resistance	How do you feel about the UAV rain resistance reaching resistance to light rain?	70	37	156	99	17	0	379	M
7	Cruising speed	How do you feel about the UAV cruising speed reaching 72 km/h?	57	29	54	221	18	0	379	I
8	Maximum flight speed	How do you feel about the UAV maximum flight speed reaching 125 km/h?	169	35	48	108	19	0	379	A
9	Minimum hovering radius	How do you feel about the UAV minimum hovering radius reaching 100 meters?	61	32	54	213	19	0	379	I
10	Maximum take-off weight	How do you feel about the UAV maximum take-off weight reaching 25kg?	64	152	44	97	22	0	379	O
11	Payload	How do you feel about the UAV payload reaching 6kg?	161	39	56	100	23	0	379	A
12	Portability and quick disassembly	How do you feel about the UAV having portability and quick disassembly?	67	46	150	94	22	0	379	M

No.	Function/feature	Question	A	O	M	I	R	Q	Total	Kano category
13	Quick replacement of parts	How do you feel about the UAV allowing for quick replacement of parts?	55	52	158	90	24	0	379	M
14	Flight Data Recorder	How do you feel about the UAV having a flight data recorder?	54	43	57	203	22	0	379	I
15	Autonomous return	How do you feel about the UAV having the autonomous return feature?	51	163	55	89	21	0	379	O
16	Autonomous Path Planning	How do you feel about the UAV having the autonomous path planning option?	62	45	162	87	23	0	379	M
17	Parachute landing fall (PLF)	How do you feel about the UAV having the PLF feature?	53	158	50	92	26	0	379	O
18	Rapid load replacement	How do you feel about the UAV allowing for rapid load replacement?	50	156	53	100	20	0	379	O
19	Battery swapping	How do you feel about the UAV having battery swapping option?	56	157	34	108	24	0	379	O
20	Vertical take-off and landing (VTOL)	How do you feel about the UAV allowing for VTOL?	48	50	164	94	23	0	379	M
21	Beautiful appearance	How do you feel about the UAV having a beautiful appearance?	59	43	62	194	21	0	379	I

5.4.2.3 Integrated company-side and customer-side analyses and confirmation of MVPs

The company-side and customer-side features/functions of MVP were integrated according to the MVP-Select model. Company-side core features/functions of MVP were automatically included in the final MVP feature list; customer-side must-be qualities were automatically included in the final MVP feature list; and the rest were included in the second-priority or third-priority MVP feature lists based on their different company-side and customer-side categories. See Section 2.5 for details.

After a consolidated analysis, it was concluded that eight items, such as rain resistance and rapid load replacement, were confirmed as core features of the MVP; three items, such as maximum take-off weight and automatic return, were second-priority features of the MVP; four items, such as wind resistance and PLF, were third-priority features of the MVP; and the remaining six items were not included in the MVP feature list. See Table 5.5 for the consolidated MVP features.

Table 5.5 Consolidated company- and customer- side MVP features

No.	Function/feature	Question	Company-side category	Customer-side category	Combined priority	MVP
1	Flight time	How do you feel about the UAV flight time reaching 300 minutes?	Optional	O	2	No
2	Maximum take-off altitude	How do you feel about the maximum take-off altitude of the UAV reaching 4500 meters?	Exclusion	I	Exclusion	/
3	Ceiling	How do you feel about the UAV ceiling reaching 6000 meters?	Exclusion	I	Exclusion	/
4	Control radius	How do you feel about the UAV control radius reaching 100 km?	Optional	A	3	No
5	Wind resistance	How do you feel about the UAV wind resistance reaching Force 7 wind?	Optional	A	3	No
6	Rain resistance	How do you feel about the UAV rain resistance reaching resistance to light rain?	Optional	M	1	Yes
7	Cruising speed	How do you feel about the UAV cruising speed reaching 72 km/h?	Exclusion	I	Exclusion	/
8	Maximum flight speed	How do you feel about the UAV maximum flight speed reaching 125 km/h?	Optional	A	3	No
9	Minimum hovering radius	How do you feel about the UAV minimum hovering radius reaching 100 meters?	Exclusion	I	Exclusion	/

No.	Function/feature	Question	Company-side category	Customer-side category	Combined priority	MVP
10	Maximum take-off weight	How do you feel about the UAV maximum take-off weight reaching 25kg?	Optional	O	2	No
11	Payload	How do you feel about the UAV payload reaching 6kg?	Core	A	1	Yes
12	Portability and quick disassembly	How do you feel about the UAV having portability and quick disassembly?	Optional	M	1	Yes
13	Quick replacement of parts	How do you feel about the UAV allowing for quick replacement of parts?	Core	M	1	Yes
14	Flight data recorder	How do you feel about the UAV having a flight data recorder?	Exclusion	I	Exclusion	/
15	Autonomous return	How do you feel about the UAV having the autonomous return option?	Optional	O	2	No
16	Autonomous path planning	How do you feel about the UAV having the autonomous path planning option?	Optional	M	1	Yes
17	Parachute landing fall (PLF)	How do you feel about the UAV having the PLF function?	Optional	O	3	No
18	Rapid load replacement	How do you feel about the UAV allowing for rapid load replacement?	Core	O	1	Yes
19	Battery swapping	How do you feel about the UAV having battery swapping function?	Core	O	1	Yes
20	Vertical take-off and landing (VOTL)	How do you feel about the UAV allowing for VOTL?	Optional	M	1	Yes
21	Beautiful appearance	How do you feel about the UAV having a beautiful appearance?	Optional	I	Exclusion	/

It can be concluded from the analysis results that there are indeed differences between the set of MVP features/functions confirmed by the company side and that were confirmed by the customer side. For example, rain resistance, autonomous path planning, portability and quick disassembly and VOTL were not included in the top priority list for realization on the company side, but these four items were must-be qualities on the customer side. If the product was implemented only according to the MVP features of the company-side analysis, the customer-side feedback would definitely not be good, and the market competitiveness would be lost. For another example, beautiful appearance was an optional MVP feature on the company side, meaning that the company side thought that users would pay attention to the appearance of the UAV, and a beautiful appearance could increase customers' probability of choosing and buying the product. Integrating the company-side and customer-side analyses results, this feature was excluded from the MVP feature list. Chapter 4 has summarized the reasons for the failure of the previous generation of products, which indicates that the pursuit of appearance will result in a significant increase in cost and time, and also reduce the product yield. Through the MVP-Select model, pseudo-demands were effectively eliminated, and the focus and practicality of product requirements were enhanced.

Based on the above analysis, it can be concluded that the MVP-Select model fully takes into account the different views of the company side and the customer side on product functions/features and combines both sides to form more scientific as well as company- and market-compatible MVP features. It enables the startup team's products to be more focused and more reflective of the company's business model and competitiveness as well as the core needs of customers. It also enables the startup team to significantly reduce the time and cost of product market validation and provides a method for scientific and effective use of Lean Startup MVP.

5.5 Summary

This chapter introduces how Company A identified the special table of MVP functional features to be selected for the UAV product. Questionnaires were designed based on the MVP-Select model for the company side and the customer side, respectively, with the company side focusing on the business model and competitiveness and the customer side focusing on the categorization of functional requirements by customers. A pilot test of the customer-side questionnaire survey was conducted to check the reliability and validity of the designed questionnaire. After analyzing the reliability and validity using SPSS 26.0, the formal questionnaire survey was carried out on a large scale, and the distributed questionnaires were recovered. Then the data

collected from the company side and the customer side were analyzed in strict accordance with the MVP-Select model. Finally, the MVP features of Company A's next-generation UAV product were confirmed. The MVP-Select model is proven to be a scientific approach for the implementation of lean startup MVPs for startup teams.

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Chapter 6: Conclusions

6.1 Research implications

6.1.1 Practical implications

After determining the MVP of the second-generation UAV, Company A started to carry out system design and R&D implementation according to the functions identified in the MVP. Although Company A's first-generation product failed, there were many functions that could be reused or partially reused or borrowed, which provided a good basis for the second-generation product to shorten the development time. Meanwhile, the team improved its collaboration efficiency and tacit understanding after the first-generation product development, which also provided a good basis for the second-generation product development to ensure time and efficiency. After system analysis and design, the whole project is based on functional logic dependency, assisted by manpower and resource reuse, and each function is transformed into a series of parallel combined system function sub-projects for R&D implementation. For example, after confirming the agreement between ground station system and flight control system, the two teams can independently develop the automatic route planning function, and joint debugging and verification can be carried out within the specified time node. As to the rapid load replacement, after confirming the agreement with the flight control, the structure team and the flight control team can also develop independently, and just perform joint debugging and verification within the specified time nodes.

Meanwhile, in order to improve product quality assurance and reduce the risk and cost of product development and testing, the R&D team decomposed the system functions and introduced ground simulation verification techniques and tools for most of the functions. Take the battery swapping function for example. The simulation software was used to conduct aerodynamic and flight control simulation tests for this function to maximize the stability of ground verification and functional robustness of the function to reduce the risk and cost of loss of control, crash, and other problems brought about by actual flight verification.

Due to the foundation and experience of the first-generation product and the fact that the second-generation product adopted the lean startup MVP model for research and development, the R&D and test of the MVP of the second-generation product only took three months to

complete. Besides, the three prototype systems were provided to three of the closest strategic partners for trial. Specifically, one is an aerial mapping service company, and the other two belong to the monitoring field. All are carefully selected after market analysis. The feedback from the three companies was very good, and the functions met the needs of their industries very well. Besides, some of the functions exceeded the expectations of the customers. Certainly, certain customization requirements were put forward for specific types of services, but these requirements were basically in the software functions. For example, the aerial mapping industry proposed to have synchronized photo storage and transmission functions.

It can be seen from the above actual customer trials and feedback that the MVP confirmed by applying the MVP-Select model to Company A's second-generation product is correct, and the products developed by this MVP are accepted and successful in the market.

6.1.2 Managerial implications

Based on the above practical implications, the following managerial implications can be drawn:

1. The MVP must be confirmed with feedback and participation from the end customer. The basis for a new product to be successful must be that it solves the pain points and needs of the end customer. The end customer knows best what is needed but may not be able to describe it completely. So, communication with the end-customer is very necessary. Besides, it is necessary to get the end customer's participation and feedback continuously to ensure that the understanding of the customer's needs is correct and complete.

2. MVP needs to not only reflect the needs of customers but also reflect the core business model and core competitiveness of the startup. If the MVP only reflects the needs of customers, because the needs of customers are numerous, complicated, and not necessarily clear and complete, then the product formed by the mix of many customer needs is inevitably unfocused, without characteristics, and naturally lacks competitiveness and vitality. If a product only reflects the idea of the startup, it will naturally fail like the first-generation product of Company A. In other words, the product is not recognized by the market and customers. For a startup to survive and grow, it must have its own business model and competitiveness. Therefore, validating the business model and competitiveness is one of the important missions of a startup's product, and these are not what customers are concerned about. Therefore, MVP should reflect both the current customer needs and validate the business model and competitiveness of the startup.

3. The confirmation of MVP must require the adoption of scientific theoretical methods and tools as well as correct implementation steps. The MVP method of Lean Startup Theory is a summary of experience and a spiraling upward iterative model. Precisely because it is a summary of experience, it does not propose a specific methodological model and implementation steps for MVP confirmation. Therefore, it must be necessary to select and explore a set of scientific tools and implementation steps in conjunction with the internal and external environment of the enterprise in order to ensure that the confirmation of MVP is scientific, so as to improve the success rate of MVP, and thus improve the success rate of new products in order to improve the survival and development ability of the start-up enterprise.

6.1.3 Theoretical implications

This thesis innovatively puts forward the MVP-Select model and the case practice of the model through the application of the Lean Startup MVP theory. It bears the following theoretical implications:

1. This thesis validates the MVP-Select model as a scientific tool for MVP selection in the Lean Startup MVP theory and analyzes its application in practical cases with concrete implementation steps. It provides a scientific theoretical basis for the empirical-based Lean Startup MVP theory, contributing to the development of the empirical-based Lean Startup MVP theory to a theory supported by scientific tools.

2. This thesis provides a case study and literature support for the extended application of the Kano model to lean startup MVP theory. The analysis and review of the origin and development of the Kano model in the literature review shows that the Kano model has a wide range of applications and that it can be applied to a wider range of applications, industries and scenarios in combination with other models. The application of the Kano model in this thesis enriches its application scenarios and further extends its scope of application.

3. This thesis provides a case study and enriches the literature on the application of Lean Startup MVP theory to high-tech startups in China. It is a useful attempt to apply lean startup theory to the Chinese context and thus contributes to the application of Lean Startup theory in the Chinese context.

6.2 Conclusions

The following conclusions can be drawn from the case study based on lean startup MVP theory:

First, the Lean Startup MVP theory can be applied to Chinese high-tech innovative startups. Company A is a typical high-tech start-up in China. Based on the analysis of the core reasons for the failure of Company A's first-generation product, the Lean Startup MVP theory was selected as the scientific guiding theory for the second-generation product development through comparative analysis. Then, through practical implementation and verification, it was confirmed that the Lean Startup MVP theory can be applied to Company A and played a good guiding role on new product development. It was further inferred that Lean Startup MVP theory can also be applied to new product development in other high-tech innovative companies.

Second, applying and implementing the Lean Startup MVP theory to the development of new products in high-tech innovative companies requires the use of scientific theories, models, tools and specific implementation steps. The Lean Startup theory itself is a theory formed by drawing on the theories and methods of Lean Manufacturing, Lean Thinking, Iterative Modeling and implementation experience, and is in a continuous spiral and iterative process. So, the specific implementation tools and methods for certain steps are not clearly presented, especially in the confirmation of the core theory and steps of the Lean Startup MVP. Therefore, to properly and scientifically implement the Lean Startup MVP theory requires a scientific tool and method and implementation steps for guidance. Otherwise, the startup will not be able to confirm the correctness of the MVP, which in turn will have a chain reaction leading to an increased probability of failure of the startup's new product development, which in turn will further lead to an increased probability of startup failure.

Third, the MVP-Select model can provide models, tools, and guidance on implementation steps for the identification of MVPs in new product development in Chinese high-tech innovative startups. Through the above-mentioned steps on Company A's background, development, reasons for the failure of the first-generation product, and theoretical research on Lean Startup MVP, this thesis proposed a solution to the core problem of the failure of Company A's first-generation product. Besides, combined with theoretical research and analysis, this study innovatively proposed the MVP-Select model and implementation steps to guide the development of Company A's new-generation products. Besides, through actual trials and feedback from customers, this study concluded that the MVP confirmed by the MVP-Select model is effective. Because Company A is one of the typical representatives of high-tech innovative entrepreneurial enterprises in China, the MVP-Select model can provide effective guidance for the confirmation of MVP for new product development of high-tech innovative entrepreneurial enterprises in China.

6.3 Limitations

This study proposes research questions based on the status of the application of Lean Startup MVP theory in Chinese high-tech startups and introduces the MVP-Select model through theoretical research and the case study of Company A. The model is verified through the actual practice of Company A, and some results and insights are obtained. However, due to time, experience and other internal and external constraints, this study has the following limitations:

1. Limited scope of sample

The questionnaires were distributed through the Internet, which has the advantage of wide accessibility, and the range of questionnaire distribution was expanded through UAV exhibitions. However, there are many large and small enterprises in the field of UAV services in China. Therefore, it is not guaranteed that the questionnaires can cover all Chinese UAV service and application enterprises, which may have some influence on the generalization of the results.

2. Limited objectivity of the survey data

The data of the questionnaires were extracted and analyzed by the respondents after completing the questionnaires, which is a typical retrospective mode. Besides, the questionnaire data reflect the subjective perceptions and opinions of the respondents. So, some discrepancies with the objective situation cannot be avoided. This may lead to some discrepancies and deviations between the collected data and the actual objective situation, which may have some influence on the research results.

3. Intrinsic limitations of single-case study

Although Company A, a typical representative of Chinese high-tech startup, is selected as the case company for this study, a typical representative is not necessarily representative of all. Therefore, the robustness of the single-case study results is limited.

6.4 Suggestions for further research

Outside of China, there are numerous applications of the Lean Startup theory and MVP approach. In China, there is a lot of research on Lean Startup theory, and many cases claiming to have used Lean Startup theory to guide their startups or new product development. However, there is a lack of research and documentation on the application of Lean Startup theory in specific cases, especially on the application and validation of the MVP approach using scientific

modeling tools. Therefore, it is hoped that more studies and case studies will be conducted to enrich the application of Lean Startup theory and MVP approach in the Chinese context, so that the application and implementation plans of Lean Startup theory and MVP approach applicable to the Chinese context can be summarized and generalized.

Future research is expected to apply the MVP-Select model to more high-tech industries in China and accumulate more application scenarios and practical experience and data, so that more quantitative data can be accumulated to make this model more scientific and robust. The MVP Select model can become a universal method and tool to guide Chinese high-tech startups to identify MVP in new product development. In this way, the limitations of the MVP-Select model can be identified through analysis for continuous refinement and improvement so that the MVP-Select model can become a universal method and tool to guide the identification of MVPs in new product development of Chinese high-tech start-ups.

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Annex A: Interview Questions

No.	Question
1	What is the background of the establishment of the company? What is the current development status and future expectations of the company?
2	Why choose the industry of UAV R&D and manufacturing?
3	What is the current status of the company's products?
4	What is the R&D process currently used by the company?
5	Is the current company's process applicable to the current company's status quo and products? If not, what are the reasons?
6	The company's first-generation product did not meet the original expectations and has been discontinued. What are the reasons for the failure of the first-generation product? Reasons at the development, production, operation and sales levels.
7	After analyzing these reasons, what will be changed and what are the plans and expectations that the company has for the next generation of products?

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Annex B: Company-side UAV Flight Platform Functional Features Questionnaire

Instructions for filling out the questionnaire: This questionnaire asks anonymous questionnaire, each functional feature in the questionnaire has a pair of positive and negative questions, each question needs to be answered, and choose one of the five options after the question, a question is not selected or there are more than one choice is considered invalid, just choose one option you think is correct, if the feature you are not understand, you can refer to the description of the features in the last column.

Serial No.	Function / Feature	Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Description of function / feature
1	Flight time	Is UAV's flight time reaching 300 minutes a reflection of the company's business model?						Flight time refers to the time that the UAV flight platform can fly continuously under the common environment conditions.
2		Is UAV's flight time not reaching 300 minutes a reflection of the company's business model?						
3		Is UAV's flight time reaching 300 minutes a reflection of the company's competitiveness?						
4		Is UAV's flight time not reaching 300 minutes a reflection of the company's competitiveness?						

5	Maximum take-off altitude	Is UAV's maximum take-off altitude reaching 4500 meters a reflection of the company's business model?	Maximum takeoff altitude refers to the highest altitude at which the UAV can take off normally.
6		Is UAV's maximum take-off altitude can reaching 4500 meters a reflection of the company's business model?	
7		Is UAV's maximum take-off altitude reaching 4500 meters a reflection of the company's competitiveness?	
8		Is UAV's maximum take-off altitude not reaching 4500 meters a reflection of the company's competitiveness?	
9	Ceiling	Is UAV's ceiling reaching 6000 meters a reflection of the company's business model?	The ceiling altitude refers to the maximum altitude at which the UAV platform can fly normally.
10		Is UAV's ceiling not reaching 6000 meters a reflection of the company's business model?	

11		Is UAV's ceiling reaching 6000 meters a reflection of the company's competitiveness?	
12		Is UAV's ceiling not reaching 6000 meters a reflection of the company's competitiveness?	
13		Is UAV's control radius reaching 100km a reflection of the company's business model?	
14	Control radius	Is UAV's control radius not reaching 100km a reflection of the company's business model?	The UAV control radius refers to the distance that can be communicated to the ground without significant occlusion.
15		Is UAV's control radius reaching 100km a reflection of the company's competitiveness?	
16		Is UAV's control radius not reaching 100km a reflection of the company's competitiveness?	
17	Wind resistance	Is UAV's wind resistance reaching Force 7 wind a reflection of the	Wind resistance refers to the maximum wind speed level that UAV can ensure during the flying.

		company's business model?	
18		Is UAV's wind resistance not reaching Force 7 wind a reflection of the company's business model?	
19		Is UAV's wind resistance reaching Force 7 wind a reflection of the company's competitiveness?	
20		Is UAV's wind resistance not reaching Force 7 wind a reflection of the company's competitiveness?	
21		Is UAV's rain resistance reaching resistance to light rain a reflection of the company's business model?	
22	Rain resistance	Is UAV's rain resistance not reaching resistance to light rain a reflection of the company's business model?	Rain resistance refers to the maximum amount of rain that the UAV can guarantee normal flight during flying.
23		Is UAV's rain resistance reaching resistance to light rain	

		a reflection of the company's competitiveness?	
24		Is UAV's rain resistance not reaching resistance to light rain a reflection of the company's competitiveness?	
25		Is UAV's cruising speed reaching 72 km/h a reflection of the company's business model?	
26		Is UAV's cruising speed not reaching 72 km/h a reflection of the company's business model?	
	Cruising speed	Is UAV's cruising speed reaching 72 km/h a reflection of the company's competitiveness?	Cruising speed refers to the flight speed at which the UAV maintains optimal power and maximum flight time during flying.
27			
28		Is UAV's cruising speed not reaching 72 km/h a reflection of the company's competitiveness?	
29	Maximum flight speed	Is UAV's maximum flight speed reaching 125 km/h a reflection of the company's business model?	The maximum flight speed refers to the maximum flight speed that the UAV can reach while flying.

30		Is UAV's maximum flight speed not reaching 125 km/h a reflection of the company's business model?	
31		Is UAV's maximum flight speed reaching 125 km/h a reflection of the company's competitiveness?	
32		Is UAV's maximum flight speed not reaching 125 km/h a reflection of the company's competitiveness?	
33		Is UAV's minimum hovering radius reaching 100 meters a reflection of the company's business model?	
34	Minimum hovering radius	Is UAV's minimum hovering radius not reaching 100 meters a reflection of the company's business model?	The minimum hover radius refers to the minimum circle drawing radius that the UAV can achieve when doing hovering during flying.
35		Is UAV's minimum hovering radius reaching 100 meters a reflection of the company's competitiveness?	

36		Is UAV's minimum hovering radius not reaching 100 meters a reflection of the company's competitiveness?	
37		Is UAV's maximum take-off weight reaching 25kg a reflection of the company's business model?	
38	Maximum takeoff weight	Is UAV's maximum take-off weight not reaching 25kg a reflection of the company's business model?	Maximum takeoff weight refers to the maximum weight of the UAV included payload that the UAV can take off.
39		Is UAV's maximum take-off weight reaching 25kg a reflection of the company's competitiveness?	
40		Is UAV's maximum take-off weight not reaching 25kg a reflection of the company's competitiveness?	
41	Maximum payload weight	Is UAV's payload reaching 6kg a reflection of the company's business model?	The maximum payload weight refers to the maximum payload weight that the UAV can carry when it is able to take off normally.

42		Is UAV's payload not reaching 6kg a reflection of the company's business model?	
43		Is UAV's payload reaching 6kg a reflection of the company's competitiveness?	
44		Is UAV's payload not reaching 6kg a reflection of the company's competitiveness?	
45		Is UAV having portability and quick disassembly a reflection of the company's business model?	
46	Portability and quick disassembly	Is UAV not having portability and quick disassembly a reflection of the company's business model?	Portable and rapid disassembly means that the UAV can be quickly disassembled, easily stowed and can be quickly assembled to achieve easy transport and rapid deployment capabilities.
47		Is UAV having portability and quick disassembly a reflection of the company's competitiveness?	
48		Is UAV not having portability and quick	

		disassembly a reflection of the company's competitiveness?	
49		Is UAV having quick replacement of parts of a UAV reflective of the company's business model?	
50		Is UAV not having quick replacement of parts of a UAV reflective of the company's business model?	
	Rapid replacement parts		Fast change parts means that UAV components can be replaced quickly for efficient repair and maintenance.
51		Is UAV having quick replacement of parts of a UAV reflective of the company's competitiveness?	
52		Is UAV not having quick replacement of parts of a UAV reflective of the company's competitiveness?	
53	Flight Data Recorder	Is UAV having a flight data recorder a reflection of the company's business model?	Flight data recorder means that the UAV has the ability to record flight data including sensing data, operational data, etc. to trace problems, determine responsibility, and improve systems.
54		Is UAV not having a flight data recorder a reflection of the	

		company's business model?	
55		Is UAV having a flight data recorder a reflection of the company's competitiveness?	
56		Is UAV not having a flight data recorder a reflection of the company's competitiveness?	
57		Is UAV having autonomous return option a reflection of the company's business model?	
58		Is UAV not having autonomous return option a reflection of the company's business model?	Autonomous return refers to the ability of the UAV to return to the takeoff location independently when it encounters a forbidden zone, loses data link communication or unexpected situations (e.g. high winds, heavy rain).
	Autonomous return	Is UAV having autonomous return	
59		option a reflection of the company's competitiveness?	
60		Is UAV not having autonomous return option a reflection of the company's competitiveness?	
61	Autonomous Path Planning	Is UAV having autonomous path planning feature a	Autonomous route planning means that the UAV can adjust its flight altitude and route in

		reflection of the company's business model?	time to avoid collision with actual objects based on GPS positioning information.
62		Is UAV not having autonomous path planning feature a reflection of the company's business model?	
63		Is UAV having autonomous path planning feature a reflection of the company's competitiveness?	
64		Is UAV not having autonomous path planning feature a reflection of the company's competitiveness?	
65		Is UAV having the parachute landing fall function a reflection of the company's business model?	Loss of control parachute landing protection means that the UAV can automatically start the parachute landing protection method after the occurrence of stall, high wind, power failure, collision and other unexpected situations to maximize the protection of the UAV flight platform safety.
66	Parachute landing fall	Is UAV not having the parachute landing fall function a reflection of the company's business model?	
67		Is UAV having the parachute landing fall function a reflection	

		of the company's competitiveness?	
68		Is UAV not having the parachute landing fall function a reflection of the company's competitiveness?	
69		Is UAV having rapid load replacement feature a reflection of the company's business model?	
70		Is UAV not having rapid load replacement feature a reflection of the company's business model?	Fast payload change refers to the ability of the UAV fly to quickly change different mission payloads on the ground to achieve rapid operations and multiple uses.
	Rapid load replacement	Is UAV having rapid load replacement	
71		feature a reflection of the company's competitiveness?	
72		Is UAV not having rapid load replacement feature a reflection of the company's competitiveness?	
73	Battery payload weight swapping	Is UAV having the battery payload weight swapping option a reflection of	Battery payload weight interchange refers to the way to increase the weight of the payload simultaneously by

		the company's business model?	reducing the weight of the battery, in order to perfectly solve the problem of the payload weight exceeding the designed fixed payload weight limit and maximize the use of the UAV flight platform to complete a variety of operational needs.
74		Is UAV not having the battery payload weight swapping option a reflection of the company's business model?	
75		Is UAV having the battery payload weight swapping option a reflection of the company's competitiveness?	
76		Is UAV not having the battery payload weight swapping option a reflection of the company's competitiveness?	
77		Is UAV having the VTOL function a reflection of the company's business model?	Vertical takeoff and landing refers to the innovative combination of multi-rotor and fixed-wing aircraft features, using vertical takeoff and landing to solve the runway problem, using a small space to allow the UAV to take off and operate.
78	Vertical take-off and landing (VTOL)	Is UAV not having the VTOL function a reflection of the company's business model?	
79		Is UAV having the VTOL function a reflection of the company's competitiveness?	

80		Is UAV not having the VTOL function a reflection of the company's competitiveness?	
81		Is UAV having a beautiful appearance a reflection of the company's business model?	
82		Is UAV not having a beautiful appearance a reflection of the company's business model?	
	Beautiful appearance		Attractive and beautiful appearance means that the UAV has a beautiful design and looks more distinctive and aesthetic.
83		Is UAV having a beautiful appearance a reflection of the company's competitiveness?	
84		Is UAV not having a beautiful appearance a reflection of the company's competitiveness?	

Annex C: Customer-side UAV Flight Platform Functional Features Questionnaire

Thank you very much for taking a little time out of your busy schedule to fill out this questionnaire, which will not disclose any of your personal information.

Instructions for filling out the questionnaire: This questionnaire asks anonymous questionnaire, each functional feature in the questionnaire has a pair of positive and negative questions, each question needs to be answered, and choose one of the five options after the question, a question is not selected or there are more than one choice is considered invalid, just choose one option you think is correct, if the feature you are not understand, you can refer to the description of the features in the last column.

Basic Information

Serial No.	Question					
1	Your experience in the UAV operations industry is	No experience	Less than 1 year	1-3 years	3-5 years	More than 5 years
2	Which UAV operation industry your company is engaged	Aerial photography	Aerial Mapping	Monitoring (traffic, fire, environment, forestry, power patrol, tower patrol, etc.)	Agricultural operations (pesticide spraying, seeding, etc.)	Others

UAV flight platform functions / features

Serial No.	Function / Feature	Question	Like	Expect	Neutral	Live with	Dislike	Description of function / feature

1	Flight time	How do you feel about the UAV flight time reaching 300 minutes?	Flight time refers to the time that the UAV flight platform can fly continuously under the common environment conditions.
2		How do you feel about the UAV flight time can not reaching 300 minutes?	
3	Maximum takeoff altitude	How do you feel about the maximum take-off altitude of the UAV reaching 4500 meters?	Maximum takeoff altitude refers to the highest altitude at which the UAV can take off normally.
4		How do you feel about the maximum take-off altitude of the UAV can not reaching 4500 meters?	
5	Ceiling altitude	How do you feel about the UAV ceiling reaching 6000 meters?	The ceiling altitude refers to the maximum altitude at which the UAV platform can fly normally.
6		How do you feel about the UAV ceiling can not reaching 6000 meters?	
7	Control radius	How do you feel about the UAV control radius	The UAV control radius refers to the

		reaching 100 km?	distance that can be communicated to the ground without significant occlusion.
8		How do you feel about the UAV control radius can not reaching 100 km?	
9	Wind resistance	How do you feel about the UAV wind resistance reaching Force 7 wind?	Wind resistance refers to the maximum wind speed level that UAV can ensure during the flying.
10		How do you feel about the UAV wind resistance can not reaching Force 7 wind?	
11	Rain resistance	How do you feel about the UAV rain resistance reaching resistance to light rain?	Rain resistance refers to the maximum amount of rain that the UAV can guarantee normal flight during flying.
12		How do you feel about the UAV rain resistance cannot reaching resistance to light rain?	
13	Cruising speed	How do you feel about the UAV cruising speed reaching 72 km/h?	Cruising speed refers to the flight speed at which the UAV maintains

14		How do you feel about the UAV cruising speed can not reaching 72 km/h?	optimal power and maximum flight time during flying.
15	Maximum flight speed	How do you feel about the UAV maximum flight speed reaching 125 km/h?	The maximum flight speed refers to the maximum flight speed that the UAV can reach while flying.
16		How do you feel about the UAV maximum flight speed can not reaching 125 km/h?	
17	Minimum hovering radius	How do you feel about the UAV minimum hovering radius reaching 100 meters?	The minimum hover radius refers to the minimum circle drawing radius that the UAV can achieve when doing hovering during flying.
18		How do you feel about the UAV minimum hovering radius can not reaching 100 meters?	
19	Maximum takeoff weight	How do you feel about the UAV maximum take-off weight reaching 25kg?	Maximum takeoff weight refers to the maximum weight of the UAV included payload that the
20		How do you feel about the UAV	

		maximum take-off weight can not reaching 25kg?	UAV can take off.
21	Maximum payload weight	How do you feel about the UAV payload reaching 6kg?	The maximum payload weight refers to the maximum payload weight that the UAV can carry when it is able to take off normally.
22		How do you feel about the UAV payload can not reaching 6kg?	
23	Portability and quick disassembly	How do you feel about the UAV having portability and quick disassembly?	Portable and rapid disassembly means that the UAV can be quickly disassembled, easily stowed and can be quickly assembled to achieve easy transport and rapid deployment capabilities.
24		How do you feel about the UAV not having portability and quick disassembly?	
25	Quick replacement of parts	How do you feel about the UAV allowing for quick replacement of parts?	Fast change parts means that UAV components can be replaced quickly for

26		How do you feel about the UAV not allowing for quick replacement of parts?	efficient repair and maintenance.
27	Flight Data Recorder	How do you feel about the UAV having a flight data recorder?	Flight data recorder means that the UAV has the ability to record flight data including sensing data, operational data, etc. to trace problems, determine responsibility, and improve systems.
28		How do you feel about the UAV not having a flight data recorder?	
29	Autonomous return	How do you feel about the UAV having the autonomous return feature?	Autonomous return refers to the ability of the UAV to return to the takeoff location independently when it encounters a forbidden zone, loses data link communication or unexpected situations (e.g.
30		How do you feel about the UAV not having the autonomous return feature?	

			high winds, heavy rain).
31	Autonomous Path Planning	How do you feel about the UAV having the autonomous path planning option?	Autonomous route planning means that the UAV can adjust its flight altitude and route in time to avoid collision with actual objects based on GPS positioning information.
32		How do you feel about the UAV not having the autonomous path planning option?	
33	Parachute landing fall (PLF)	How do you feel about the UAV having the PLF feature?	Loss of control parachute landing protection means that the UAV can automatically start the parachute landing protection method after the occurrence of stall, high wind, power failure, collision and other unexpected situations to maximize the
34		How do you feel about the UAV not having the PLF feature?	

			protection of the UAV flight platform safety.
35	Rapid load replacement	How do you feel about the UAV allowing for rapid load replacement?	Fast payload change refers to the ability of the UAV fly to quickly change different mission payloads on the ground to achieve rapid operations and multiple uses.
36		How do you feel about the UAV not allowing for rapid load replacement?	
37	Battery payload weight swapping	How do you feel about the UAV having battery swapping option?	Battery payload weight interchange refers to the way to increase the weight of the payload simultaneously by reducing the weight of the battery, in order to perfectly solve the problem of the payload weight exceeding the designed fixed payload weight limit and maximize the
38		How do you feel about the UAV not having battery swapping option?	

			use of the UAV flight platform to complete a variety of operational needs.
39		How do you feel about the UAV allowing for VTOL?	
40	Vertical take-off and landing (VTOL)	How do you feel about the UAV not allowing for VTOL?	Vertical takeoff and landing refers to the innovative combination of multi-rotor and fixed-wing aircraft features, using vertical takeoff and landing to solve the runway problem, using a small space to allow the UAV to take off and operate.
41		How do you feel about the UAV having a beautiful appearance?	
	Beautiful appearance		Attractive and beautiful appearance means that the UAV has a beautiful design and looks more distinctive and aesthetic.
42		How do you feel about the UAV not having a beautiful appearance?	