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# Enhancing IoT Technology Acquisition in Emerging Economies: Insights and Recommendations Using Analytical Case Study Review of IoT Startups

**Mohammad Tondro [1,*], Mohammad Jahanbakht [2] and Dervis Ozay [1]**

[1] Industrial, Manufacturing and Systems Engineering (IMSE) Department, University of Texas at Arlington, Arlington, TX 76019, USA; dervis.ozay@mavs.uta.edu
[2] Graduate School of Management and Economics, Sharif University of Technology, Tehran P.O. Box 11365-8639, Iran; mohammad.jahanbakht@sharif.edu
* Correspondence: mohammad.tondro@uta.edu

**Abstract:** The rapid growth of the Internet of Things (IoT) presents emerging economies with an invaluable opportunity to reshape their market standings and reach a competitive advantage. Nonetheless, the acquisition and development of IoT technologies poses significant challenges for businesses in these areas. This study explores the factors affecting IoT technology acquisition and advancement by smart mobility businesses in this market. Through a review of literature and case studies, the research identifies key strategies and their characteristics. We focus on critical factors such as infrastructure constraints, technology acquisition, regulatory frameworks, business structures, and strategic alliances by analyzing related startups engaged in IoT products and services, each with distinct features. Additionally, this research utilizes the Capability Maturity Model to evaluate and enhance technological capabilities and business processes according to their readiness levels. Based on the results obtained, we emphasize the necessity of approaches tailored to specific needs and obstacles. Employing a mixed-methods approach, including conceptual studies, thematic analysis, interviews, questionnaires, and advanced machine learning techniques, the study sheds light on the strategic decisions, technological trends, and achievements of IoT-focused businesses. Therefore, it underscores the importance of recognizing technological trends and the pivotal role of data-driven analytics in strategic decision-making for technology adoption.

**Keywords:** technology acquisition; startup businesses; technology readiness level (TRL); internet of things (IoT); capability maturity model (CMM); emerging economy markets

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## 1. Introduction

In recent years, the adoption of Internet Things (IoT) technology has markedly increased within emerging economies, promising enhanced efficiency, streamlined processes, and innovation in products and services (Peter et al., 2023; Qadri et al., 2020; Mishra et al., 2022). Despite these advancements, emerging economies encounter specific logistical challenges in integrating IoT technology into their business practices (Miller et al., 2023; Ravi & Chelliah, 2023). Moreover, the IoT heralds a new epoch of technological progress, particularly in these economies, with significant implications for business transformation and market competition (Ganichev & Koshovets, 2021). Nonetheless, entrepreneurs and startups in these regions face distinct challenges in assimilating and evolving IoT technologies (Ben-Daya et al., 2019). Within this dynamic IoT landscape, the complexities

involved in technology acquisition and advancement are profound (Aripin et al., 2023; Makhdoom et al., 2023). A critical examination of various data sources reveals the necessity of understanding multiple influential factors for new technology adoption (Hsu & Yeh, 2017). These factors include infrastructure hurdles, talent acquisition, regulatory frameworks, and the importance of strategic alliances. Each component plays a crucial role in shaping a comprehensive perspective on IoT adoption within the unique context of emerging economies (Surbakti et al., 2020; LaGro, 2011; Anabila, 2020).

Robust support networks and collaborative engagements with universities and research institutions play a crucial role in accelerating the technology development process for Internet of Things (IoT) companies in emerging markets. However, IoT firms in these regions that adopt specific, targeted technology development strategies encounter distinct challenges in acquiring and developing technology, unlike their peers, who may not have such focused approaches (Tondro & Jahanbakht, 2023). Although startups in the IoT sector, especially those specializing in mobility and smart transportation, are characterized by their flexible and agile organizational structures, it remains a significant challenge for these firms to adapt to rapid technological and market changes.

The challenges in this sector are notably underexplored, and the dearth of research and responses accentuates the imperative for more comprehensive and targeted scholarly inquiries. The process of adopting and integrating technology into these economies is frequently obstructed by economic barriers, limited access to advanced technologies, and the substantial costs involved in acquiring, adopting, or leveraging inventions and intellectual property rights. These obstacles compel businesses in these regions to explore more frugal, cost-effective, straightforward, or potentially unauthorized methods to cultivate technological partnerships and promote business growth, necessitating deeper understanding and innovative solutions to navigate these complex dynamics effectively (Xin et al., 2024).

A pertinent question emerges regarding how companies in smart and technological industries, particularly those in the mobility sector utilizing Internet of Things (IoT) technologies, can acquire and integrate these technologies within specific economic frameworks (Jahanbakht & Mostafa, 2020). Furthermore, we elaborate on the use of the Capability Maturity Model and its role in assessing technological readiness, ensuring the study's objectives are clearly communicated. This research directly addresses the critical challenges and opportunities faced by emerging economies, specifically Iran, in adopting Internet of Things (IoT) technologies. With IoT driving innovation and economic transformation globally, businesses in these regions encounter significant barriers such as inadequate infrastructure, regulatory hurdles, and underdeveloped business ecosystems. The study focuses on identifying practical strategies and critical success factors to enable IoT startups to overcome these obstacles and effectively integrate IoT solutions into their operations.

By employing a combination of literature reviews, case studies, and advanced analytical methods, the research provides actionable insights into addressing these challenges. Utilizing the Capability Maturity Model, it assesses the technological readiness of IoT startups and proposes tailored solutions that align with the unique needs of emerging markets. The goal is to equip startups businesses and policymakers with strategies to foster IoT adoption, enhance innovation, and unlock economic potential in related startup businesses (Elhusseiny & Crispim, 2022).

The dearth of research and scholarly work in this domain propels our endeavor to augment scientific discourse. We adopt an interdisciplinary methodology to navigate and articulate the intricate interplay between technology adoption, organizational frameworks, and stakeholder engagement. Table 1 summarizes several recent studies that utilize different research methods to examine various aspects of IoT and mobility in emerging economies, providing insights into diverse approaches.

**Table 1.** Recent Scholarly Research on IoT and Technology Integration in Business and Economic Development.

| Title | Authors | Year | Key Findings | Methodology | Journal/Source |
|---|---|---|---|---|---|
| Dynamic Pricing and Service Customization Strategy for IoT-Based Smart Products | (Xin et al., 2024) | 2024 | IoT service customization strategy; Optimal IoT adoption for dynamic pricing; Long-term value of IoT over immediate profits. | Game theory models; case study of ORVIBO and Oppein MALL. | Technological Forecasting and Social Change, Vol. 199, February 2024, 123046 |
| Emerging Technology Opportunities and Challenges Towards Organization and National Development | (Ravi & Chelliah, 2023) | 2023 | Identifies key technological opportunities and challenges affecting organizational and national development in emerging economies. | Conceptual analysis | International Journal of Business and Technology Management, 5(2), 104–113 |
| Smes, Barriers and Opportunities on Adopting Industry 4.0: A Review | (Elhusseiny & Crispim, 2022) | 2022 | Reviews barriers and opportunities for SMEs in adopting Industry 4.0 technologies. | Literature review | Procedia Computer Science, 196, 864–871 |
| Internet of Things (IoT) and Its Challenges for Usability in Developing Countries | (Hopalı & Vayvay, 2018) | 2018 | Discusses usability challenges of IoT in developing countries. | Conceptual analysis | International Journal of Innovation Engineering and Science Research, 2(1), 6–9 |
| Business Model Innovation Through the Application of The Internet-Of-Things: A Comparative Analysis | (Haaker et al., 2021) | 2021 | Analyzes how IoT can drive business model innovation through a comparative study. | Comparative analysis | Journal of Business Research, 126, 126–136 |
| Industrial Internet of Things (Iiot): Opportunities, Challenges, And Requirements in Manufacturing Businesses in Emerging Economies | (Peter et al., 2023) | 2023 | Explores the IoT's potential impacts and requirements in manufacturing sectors of emerging economies. | Review | Procedia Computer Science, 217, 856–865 |

This study considerably emphasizes the complex challenges inherent in the acquisition of technology and its execution within startups operating in the mobility domain, leveraging a variety of Internet of Things (IoT) technologies. The insights derived herein elucidate the obstacles and opportunities, asserting that judicious technological integration and strategic direction in its assimilation, enhancement, and development are critical for entrepreneurial success within the burgeoning IoT landscape.

## 2. Literature Review in Technology Acquisition in IoT-Based Businesses

The emergence of the Internet of Things has generated a technological revolution as part of Industry 4.0 for technologies that transcend geographic boundaries and industries (Schwab & Davis, 2018). Emerging economies are particularly poised to leverage the transformative potential of IoT (Dahlman et al., 2016). This study critically explores the complex

relationship between technology acquisition and development in IoT-based enterprises within these economies, illuminating the challenges, opportunities, and strategies that define this dynamic environment. The adoption of IoT technology is widely recognized as a catalyst for transformative change, offering a significant competitive advantage, especially in regions with emerging technological infrastructures (Pietrewicz, 2019). IoT adoption enables businesses in these economies to bypass traditional barriers, propelling them towards rapid growth and development.

### 2.1. Challenges in Technology Acquisition

The availability and quality of infrastructure, such as reliable power supply, connectivity, and data storage facilities, significantly impact the adoption and deployment of IoT technology in emerging economies (Luthra & Mangla, 2018). Businesses must carefully assess and address these challenges to ensure effective technology acquisition and integration. Infrastructure limitations, identified as major hurdles, require attention for successful IoT implementation (Fishman et al., 2016). Regulatory frameworks also play a crucial role in shaping the IoT landscape by supporting growth while ensuring data security and privacy (Zhan & Santos-Paulino, 2021; Horbach et al., 2012). The need for responsive regulatory frameworks that find a balance between encouraging innovation and managing risks is particularly urgent in rising economies (Kok, 2004; Verma & Bhattacharyya, 2017).

Furthermore, the scarcity of skilled professionals experienced in IoT technology represents a significant challenge (Peter et al., 2023). Effective talent acquisition and skill development strategies, such as partnerships with educational institutions and training programs, are essential to bridge this gap and build a competent workforce capable of leveraging IoT technology (Shan & Wang, 2024; Tamvada et al., 2022). Emerging economies are increasingly establishing innovative ecosystems, comprising accelerators, incubators, and collaborative platforms, that facilitate knowledge exchange, mentorship, and funding opportunities, thereby creating a conducive environment for IoT startups to thrive (Lazarenko et al., 2020; Ek & Vandenberg, 2022). The global connectivity inherent in IoT architecture offers these economies the chance to leapfrog traditional barriers and actively participate in the digital economy (Rose et al., 2015). The intricate challenges of acquiring IoT technology highlight the strategic dilemma of choosing between in-house development and external partnerships. This decision depends on factors such as core competencies, time to market, and resource availability, balancing the benefits of customization against the advantages of outsourcing (Khanna & Palepu, 2010).

### 2.2. Strategies for Technology Acquisition

IoT-based businesses adopt diverse strategies for technology acquisition. Collaborative partnerships have emerged as a compelling approach to leverage external expertise and resources (Paiola & Gebauer, 2020). Research highlights the significance of open innovation models, where businesses co-create solutions with external partners. This strategy accelerates development, reduces risks, and taps into a wider knowledge pool (Chesbrough, 2003). In addition to collaborative partnerships, IoT-based businesses explore various avenues for technology acquisition to stay at the forefront of innovation. Strategic alliances, characterized by formal agreements between two or more entities, serve as a pivotal mechanism for accessing complementary technologies and enhancing overall IoT capabilities (Li et al., 2019). These alliances allow companies to pool resources, share risks, and jointly invest in research and development initiatives, fostering a synergistic environment. Joint ventures also represent a prominent strategy in the IoT sector. In these ventures, companies collaborate to form a new entity dedicated to developing and deploying IoT solutions (Hopalı & Vayvay, 2018). This shared commitment not only spreads the financial burden but also combines

the unique strengths and expertise of each partner, resulting in a more robust approach to technology acquisition (Attah et al., 2024). Consortia, comprising multiple organizations with shared interests and objectives, offer a collaborative framework for technology acquisition in the IoT domain. These consortia unite industry players, research institutions, and sometimes government bodies to collectively address common challenges, set industry standards, and drive innovation. Participation in consortia provides IoT-based businesses access to a vast reservoir of knowledge and resources, creating an ecosystem conducive to rapid technological advancements. Furthermore, the adoption of open innovation models remains integral to the technology acquisition strategies of IoT-based businesses (West & Bogers, 2017). This approach involves collaboration with external partners, including startups, research institutions, and independent developers, to co-create solutions. It facilitates the exchange of ideas, technologies, and expertise, leading to accelerated development cycles, reduced time to market, and increased adaptability to evolving market demands. The landscape of technology acquisition in IoT-based businesses is characterized by a multifaceted approach. By embracing these diverse strategies, IoT-based businesses position themselves to navigate the dynamic and complex IoT ecosystem, ensuring sustained growth and competitiveness in the rapidly evolving technological landscape.

The related literature extensively delves into the multifaceted strategies adopted by IoT-based businesses for technology acquisition, shedding light on the pivotal role of collaborative partnerships in leveraging external expertise and resources (Paiola & Gebauer, 2020). The significance of open innovation models, emphasizing co-creation with external partners, is underscored as a strategy that accelerates development, mitigates risks, and taps into a broader knowledge pool (Chesbrough, 2003). Strategic alliances, joint ventures, and consortia serve as key mechanisms for accessing complementary technologies and enhancing overall IoT capabilities. Formal agreements between entities, characteristic of strategic alliances, play a crucial role in accessing technologies and fostering a synergistic environment by pooling resources and sharing risks (Inkpen, 2005). Joint ventures, as another prominent strategy, involve collaborative efforts to form new entities dedicated to developing and deploying IoT solutions, thereby spreading financial burdens and combining unique strengths for a more comprehensive approach (Slama et al., 2015). Consortia, comprising multiple organizations with shared interests, provide a collaborative framework for technology acquisition in the IoT domain, fostering collective solutions to common challenges and driving innovation. The landscape further emphasizes the adoption of open innovation models as integral to technology acquisition strategies, involving collaboration with external partners like startups, research institutions, and independent developers for co-creating solutions (West & Bogers, 2017). This approach facilitates the exchange of ideas, technologies, and expertise, leading to accelerated development cycles, reduced time to market, and increased adaptability to evolving market demands. The multifaceted approach to technology acquisition in IoT-based businesses, encompassing collaborative partnerships, strategic alliances, joint ventures, consortia, and open innovation models, reflects a commitment to continuous learning and adaptation (Tidd & Bessant, 2018).

### *2.3. Technology Development Strategies in IoT-Based Businesses*

Technology development is pivotal for IoT-based businesses, with a focus on customizing solutions to meet specific industry needs (Datta et al., 2024). Customization is essential for gaining a competitive advantage, enabling businesses to address unique challenges, capture untapped markets, and deliver resonant value propositions to clients (Storbacka, 2011). Recent research emphasizes the iterative nature of technology development, advocating for the adoption of agile methodologies to keep pace with the rapid evolution

of IoT (Johnson et al., 2021). This proactive strategy not only meets immediate industry requirements but also anticipates future trends and challenges.

In sectors like manufacturing and logistics, where precision-driven solutions are crucial for optimal performance and seamless integration, the focus on customization is fundamental for IoT-based businesses. This forward-looking approach establishes these companies as pioneers, enabling them to create transformative solutions that evolve with emerging technological landscapes, thereby fostering sustained client partnerships and achieving market leadership. Moreover, the iterative nature of technology development and the adoption of agile methodologies enhance the adaptability and resilience of these businesses (ElMaraghy et al., 2021). Iterative cycles facilitate rapid adaptation to market feedback, improving the overall quality and reliability of IoT solutions and contributing to customer satisfaction and loyalty. Agile methodologies promote a collaborative and flexible work ethos, empowering cross-functional teams to respond swiftly to changes and fostering a culture of experimentation (Gupta et al., 2020). This cultural shift increases the adaptability of organizations, enabling them to navigate uncertainties in the dynamic IoT ecosystem effectively. In addition, these strategies position IoT-based businesses as dynamic innovators, capable of thriving in the rapidly evolving technological landscape. This approach underscores the commitment to continuous learning and adaptation, ensuring sustained growth and competitiveness in the field.

## 3. Research Framework

Collaboration between businesses, academia, and research institutions fosters innovation and accelerates technology development. Establishing R&D partnerships can help businesses in emerging economies overcome resource limitations and access cutting-edge IoT technologies (Daradkeh, 2023). Strategic accumulation of technological competence underpins an IoT enterprise's drive for innovation and operational excellence, fueling its growth trajectory and competitive edge (Bell & Pavitt, 1993; Elrod & Fortenberry, 2018). The term "technological" extends beyond mere technical dimensions. In the intricate landscape of IoT-driven businesses, technological capabilities include complex synergies of diverse elements. These encompass a reservoir of adept professionals with both formal and tacit knowledge, tangible infrastructures, and foundational organizational structures ranging from well-established engineering frameworks to meticulously curated research and development units, procedural routines, processes, and protocols (Kettunen et al., 2022). These elements merge holistically to form an inseparable, distinctive asset (Intezari & Pauleen, 2018). While a segment of this asset gestates within the organizational confines, other facets diffuse throughout its interconnected partner ecosystem (Anderson et al., 2022).

The former encompasses existing and future technologies in studied businesses that evolve through the application of existing technologies and production systems. The latter includes innovations used in current technologies and production paradigms or the advancement of new technologies. Both technological capabilities and innovation integrate the IoT business components, delineated by their qualitative nuances (Baiyere et al., 2020). In startup businesses, adherence to internationally recognized standards and certifications is non-essential, as technologies play a supporting role in ensuring efficiency, quality, and safety across IoT production processes. The complex interplay between these capabilities due to their symbiotic relationship supports the pursuit of inventive endeavors (Calza et al., 2019).

In the endeavor to operationalize the construct of technological competence accumulation, there is an exclusive reliance on customary proxies, such as research and development structures/expenditures and patents. Viewing R&D activities as the sole metric for gauging innovative aptitude offers a narrow perspective on a firm's technological prowess. There-

fore, understanding the capabilities of technology in IoT-related businesses and examining the innovations within them forms the basis of the research framework in this paper. The capabilities of related business technologies in this research are studied based on the Capability Maturity Model (CMM), which is used to evaluate and improve business process capabilities (Gökalp & Martinez, 2022). Also, based on the capability maturity model, technology is evaluated across six levels. This research review explores the various levels of readiness (ranging from zero to five) and their impact on technology acquisition, utilization, and development. This paradigm includes an evaluation of traditional models of technological readiness, highlighting the important role of human factors in the development of technological proficiency. As we conduct this review, we are guided by the pioneering insights of previous studies to delve into the complex progression that individuals proceed through, from being novices, like aliens encountering a new world, to reaching the pinnacle of professionalism in their familiarity with specific technology.

Table 2 presents the readiness levels of IoT technology based on the capability maturity model at different levels. Levels 0 to 2—Navigating Early Technology Proficiency: This exploration begins with Level 0, where users, like aliens with technology, encounter initial disorientation and hesitancy. There is a need for tailored guidance and comprehensive educational strategies to alleviate this unfamiliarity. By advancing to Level 1, individuals acquire an understanding of technology based on cognitive and psychological principles. Researchers examine how users form basic mental models and construct foundational understanding, with effective training programs and user-friendly interfaces emerging as crucial facilitators. The Intermediate Familiarity with Technology level signifies progress, demonstrating a sense of competence and confidence on the part of the user. Scholars probe the role of experiential learning and hands-on exploration, underscoring the importance of ongoing skill development and adaptable training modules. Levels 3 to 5—Advancing Expertise and Societal Impact: As users advance to Level 3, Experienced in Technology, familiarity, autonomy and integration into daily life or professional practice become prominent. Literature reviews explore socio-technical aspects, emphasizing user communities, mentorship dynamics, and the necessity of support mechanisms. Level 4, Specialist in Technology Familiarity, delves into acquiring advanced knowledge and expertise, often intersecting with professional development studies in specific industries. Themes such as certification programs, domain-specific optimizations, and niche skill cultivation emerge, shaping workforce development and organizational strategy. At Level 5, Professional in Technology Familiarity, users are considered experts who contribute to technology development and serve as mentors. The literature at this level delves into social implications, addressing continual professional development and the constantly evolving nature of understanding in a rapidly changing technological environment.

**Table 2.** Technology Readiness Levels of IoT Based on The Capability Maturity Model.

| The Readiness Levels of IoT Technologies | Levels |
|---|---|
| Level 0 | Alien with technology |
| Level 1 | Beginner in getting to know the technology |
| Level 2 | Intermediate Familiarity with technology |
| Level 3 | Experienced in Technology Familiarity |
| Level 4 | Specialist in Technology Familiarity |
| Level 5 | Professional in Technology Familiarity |

Furthermore, the interplay between the theoretical/conceptual framework and the maturity levels of technology capabilities introduces a dynamic dimension to the research landscape. As businesses navigate the evolving technological landscape, they not only

respond to advancements but also actively shape their innovative strategies in alignment with the theoretical underpinnings (Hanelt et al., 2021). This intricate relationship can lead to novel insights as innovations ripple across different dimensions of the framework, ultimately influencing organizational structures, market approaches, and long-term sustainability strategies (DiBella et al., 2023). By examining the symbiotic interaction between technology acquisition and startup businesses structures within emerging economies, this research aims to elucidate both the immediate impacts and the transformative trajectories that IoT enterprises experience. This investigation extends beyond mere technological implementation to consider the broader conceptual interplay that informs these firms' operational frameworks. The theoretical or conceptual framework proposed for this study is structured as follows in Figure 1.

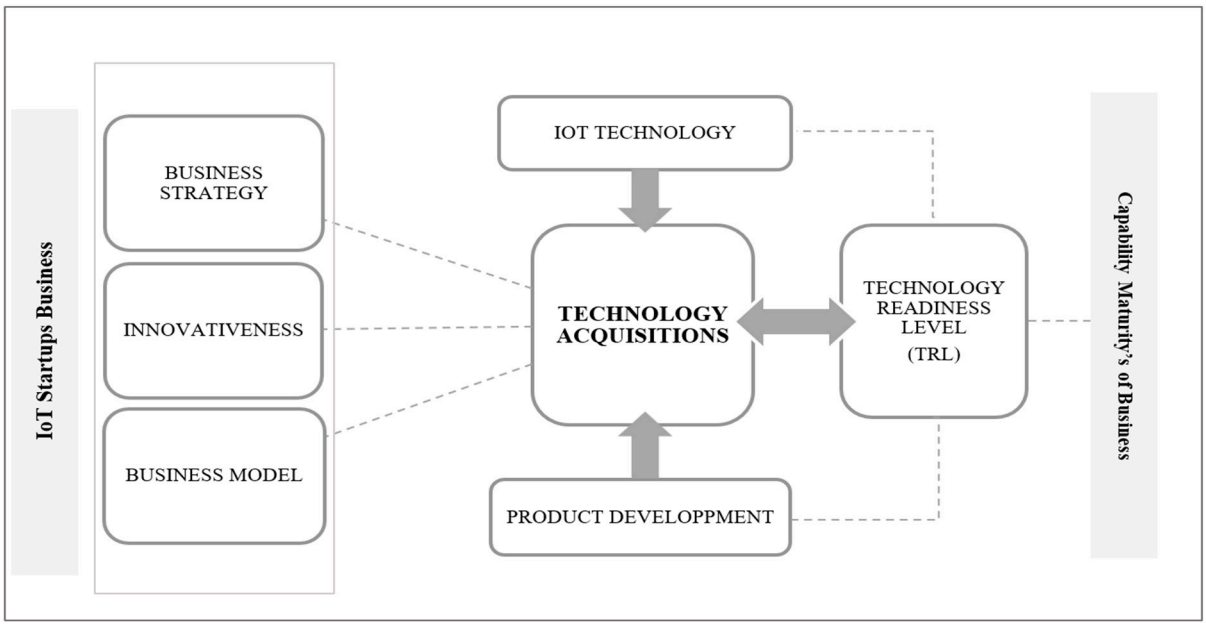


**Figure 1.** Research framework of TRLs of IoT technologies based on the capability maturity level and technology acquisition type.

Within this theoretical framework, the exploration of technology acquisition is structured around three key components: Readiness Levels of IoT Technologies, Technology Acquisition Type, and IoT Technologies themselves. In Readiness Levels of IoT Technologies, the component focuses on assessing the preparedness and maturity of IoT technologies. It encompasses evaluating the developmental stages, from conception to deployment, and gauges the technological robustness at each step (Safitra et al., 2023).

The technology readiness levels serve as a critical metric for understanding the evolution and viability of IoT technologies within the context of organizational absorption. Accordingly, in Technology Acquisition Type, the method by which technology is assimilated is a pivotal aspect, forming a two-way and direct relationship with all types of technology.

This dynamic is not only influenced by the organizational structure but is intricately tied to the levels of familiarity with technology. The choice of technology acquisition type becomes a strategic decision, shaped by organizational needs, market dynamics, and the specific nature of the targeted technologies. Also, the nature and characteristics of IoT technologies themselves play a significant role in shaping the overall landscape. The complexity, adaptability, and innovation potential of these technologies directly impact how organizations approach their absorption. The unique attributes of IoT technologies influence both the technology readiness levels and the preferred types of technology

acquisition. The effectiveness of the chosen technology acquisition type is magnified when viewed in conjunction with the other two components. The arrows depicted within the diagram illustrate the flow or influence direction, suggesting a cyclical interdependence between the elements. This configuration indicates that the readiness level of Internet of Things (IoT) technologies directly impacts IoT startup enterprises, which subsequently focus on product development. This process then perpetuates through the adoption of emerging technologies, further enhancing technology readiness levels.

Furthermore, the diagram underscores a dynamic and continual cycle of enhancement and growth within the IoT business sector. It posits that each phase is essential and builds upon its predecessor, fostering a loop of perpetual development. For example, an aptly chosen type of technology acquisition can expedite the advancement of IoT technology readiness, facilitating seamless integration into the organizational structure.

Concurrently, the organization's familiarity with technology guides the selection of the most appropriate acquisition approach. The nature of technologies targeted for acquisition also influences strategic decisions related to the acquisition process. Ultimately, the efficacy of the technology acquisition type is seamlessly integrated into the organization's technological framework and the distinct characteristics of IoT technologies. Harmonious alignment among these three facets ensures a synergistic and effective approach to technology assimilation within the business context. For instance, a well-matched acquisition type can accelerate the readiness levels of IoT technologies, ensuring a seamless integration into the organizational framework. Simultaneously, the organizational familiarity with technology informs the selection of the most suitable acquisition method. The types of technologies targeted for acquisition also shape the strategic decisions regarding the acquisition process. In essence, the effectiveness of the Technology Acquisition Type is intricately woven into the fabric of the organization's technological readiness and the specific attributes of IoT technologies. A harmonious alignment of these three components ensures a synergistic and efficient approach to technology absorption within the organizational context.

## 4. Research Methodology

This study employs a robust qualitative framework to explore the adoption of IoT technologies among startups in Iran, focusing on the emerging economy's infrastructural challenges. The dataset used in this research was derived from nine startups selected from the Digital University Startups Ecosystem, a prominent hub for IoT innovation in Iran. This ecosystem was chosen as it represents a diverse range of businesses operating under the unique constraints typical of emerging economies, including limited access to advanced technology, regulatory challenges, and resource constraints.

The dataset comprises 1458 discrete data points, which were gathered through semi-structured interviews, document reviews, and direct observations. These data points provide rich qualitative insights into various dimensions of the startups' operations, including their strategies for technology acquisition, organizational structures, and levels of technological readiness. The collected data were systematically coded and categorized into 27 distinct IoT technologies across 6 primary categories for 9 startup businesses. This detailed coding process ensured that the research captured the nuanced interplay between external factors and internal organizational dynamics affecting IoT adoption.

The themes explored in this study include technology acquisition methods, product and service diversity, company complexity, and technological readiness levels. These categories provided a structured framework for analyzing how startups navigate the challenges of IoT adoption in a resource-constrained environment. The study ensured a consistent and rigorous approach to coding and analyzing the qualitative data, enhancing the reliability of the findings.

### 4.1. Machine Learning Insights

This study employs machine learning methodologies to shed light on a specific business in an emerging economy that adeptly acquired and developed IoT technology. Offering an in-depth exploration, the research showcases the strategies and practices utilized to overcome challenges and achieve notable success. The study extends beyond the surface, intricately examining the triumphs and challenges associated with the acquisition and development of cutting-edge IoT technology by a specific business operating in an emerging economy.

The business not only effectively acquired advanced IoT technology but also demonstrated exemplary strategies that were instrumental in overcoming obstacles and achieving noteworthy success. Delving into the contextual intricacies of the emerging economy, the study unveils unique challenges faced and the innovative solutions devised by the business, providing a detailed narrative that enhances understanding of the strategic decisions, risk management approaches, and adaptive practices contributing to overall success in IoT technology integration. Moreover, the study serves as a valuable repository of insights for businesses in similar contexts, utilizing machine learning to offer tangible examples of how strategic foresight, adaptive planning, and effective execution can pave the way for success in the dynamic landscape of IoT technology acquisition. Emphasizing the importance of technological proficiency, the research also highlights the significance of a resilient and forward-thinking approach, particularly in the context of emerging economies, where machine learning methodologies contribute to the nuanced understanding of success factors in the IoT realm.

### 4.2. Methodology: A Dual-Structured Methodological Synthesis Grounded in the Realms of Deep Learning and Machine Learning

The methodology employed in this research is meticulously constructed upon a dual framework, adeptly merging both the conceptual study method and the thematic method, supported by both deep data processing and machine learning (Mao et al., 2024). This synergistic integration facilitates thorough and nuanced exploration, ensuring a comprehensive understanding of the subject matter. The conceptual study method serves as the bedrock, providing a solid theoretical foundation, while the thematic approach steers the intricate organization and analysis of qualitative data, ensuring a holistic understanding of the subject matter. At the heart of this methodological framework lies the utilization of semi-structured interviews (Diefenbach, 2009), strategically positioned as the primary mechanism for eliciting insights from representatives of 9 startup companies.

The application of the conceptual study method is a deliberate and thorough process, involving an exhaustive exploration of existing literature, frameworks, and theoretical concepts pertinent to the domain of technology absorption within startup contexts. This method not only establishes theoretical underpinnings but also plays a pivotal role in shaping research questions, guiding the meticulous collection of data, and informing the overarching theoretical framework that governs this study. Concurrently, the thematic method takes center stage in structuring and analyzing the rich qualitative data garnered from semi-structured interviews. This systematic approach involves the identification and categorization of recurring themes, patterns, and conceptual threads embedded within the interview data. Thematic analysis becomes the linchpin for distilling meaningful insights, facilitating a nuanced comprehension of the fundamental factors influencing technology absorption within startup companies. Semi-structured interviews, strategically positioned as the linchpin of data collection, adeptly align with both the conceptual and thematic dimensions of this research. This approach is thoughtfully designed to strike a delicate balance between predefined questions, ensuring a focused exploration of key areas, and the

flexibility to probe emergent themes during the interviews. The qualitative data emanating from these interviews as shown in Figure 2. offer a firsthand glimpse into the experiences, challenges, and strategic maneuvers of representatives from the 9 startup companies. This wealth of authentic insights enriches the study, providing a dynamic and textured portrayal of the landscape of technology absorption within startup ecosystems.

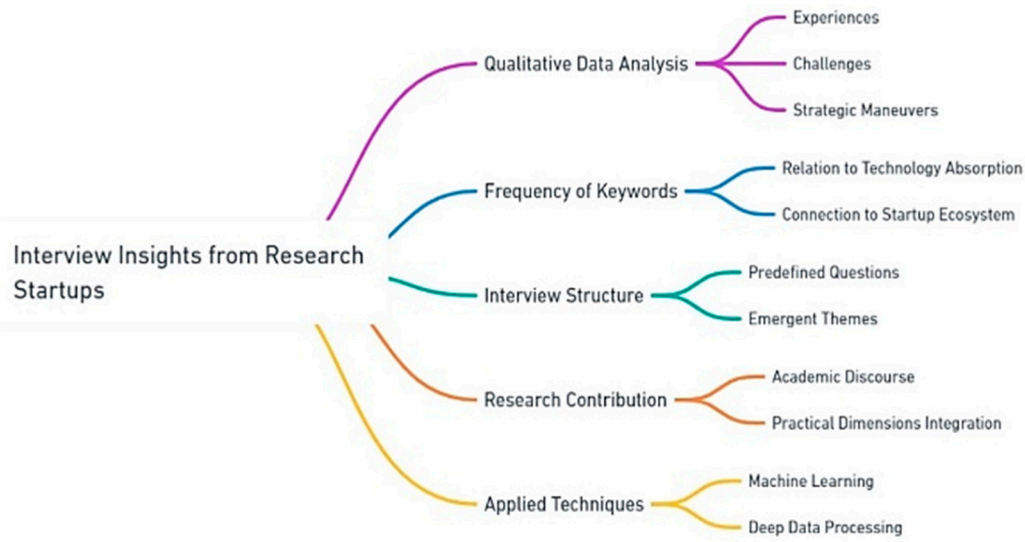


**Figure 2.** Interview insights and keyword frequency used in research.

By synthesizing the conceptual study method, thematic approach, and semi-structured interviews, this research aspires to contribute to the academic discourse by offering a comprehensive exploration that seamlessly integrates theoretical foundations with practical dimensions. Our research endeavors yielded exceptionally positive outcomes, thanks to the synergistic application of machine learning and deep data processing techniques. The development of our own research structure for the paper allowed us to tailor our approach to the unique demands of the study. In particular, the integration of cutting-edge machine learning methods significantly enriched our analytical capabilities. In instances involving survey-based or Voice of the Customer (VOC) datasets, we implemented text-encoding features, expanding the scope of our training sets. However, this approach necessitated a dedicated quality assurance process to thoroughly review the outcomes generated by natural language processing (NLP).

Additionally, sentiment analysis tools proved valuable in classifying open-ended feedback and potentially serving as outcome predictors. Nevertheless, it is crucial to acknowledge that while machine learning models can accommodate qualitative data, the expansive richness of qualitative research remains challenging to fully capture within the confines of current methodologies. To further enrich our dataset, we used a questionnaire in addition to our semi-structured interviews, and we received more than 249 responses. Besides the CEO's and managers of these nine businesses, other activists and experts with significant experience also responded. The totality of these answers, along with the interviews conducted across three layers—managers and business owners, technology sector experts and elites, and marketing and customer service activists—formed the primary data for our study.

## 5. Analysis and Results

Between 2014 and 2023, startups within the Internet of Things (IoT) sector successfully incorporated an extensive range of 27 advanced technologies into their products and services, significantly advancing the mobility industry. These enterprises leveraged the

capabilities of connectivity and automation to drive transformation across multiple sectors. For example, a notable startup business among these startups effectively utilized IoT technology, cloud computing, and data analytics. This integration was instrumental in developing inventory management systems for major retail companies. This transition is increasingly evident when analyzing the technology adoption trends among startup businesses, as illustrated in Table 3.

**Table 3.** Different Types of Technologies Acquisition by The Nine Startups Businesses.

| Business | Technology Acquisition Type |
|---|---|
| B1 | Reverse Engineering /Innovation in Design and Creativity |
| B2 | Technology Acquisition/Chinese Partner/Innovation in Design and Creativity |
| B3 | Non-Consensual Acquisition of Technology (Pirated)/Reverse Engineering |
| B4 | Non-Consensual Acquisition of Technology/Reverse Engineering/Innovation in Design and Creativity/Software Development |
| B5 | Reverse Engineering/Innovation in Design and Creativity/Software Development |
| B6 | Reverse Engineering /Innovation in Design and Creativity |
| B7 | Non-Consensual Acquisition of Technology/Reverse Engineering/Innovation in Design and Creativity/Software Development |
| B8 | Technology Acquisition/Innovation in Design and Creativity |
| B9 | Technology Acquisition/Partner/Innovation in Design and Creativity |

The data highlight distinct patterns of technology acquisition across these enterprises. Beginning in 2019, the initial focus was on establishing a robust technological foundation. Companies prioritized significant investments in fundamental technologies such as 5G networks, which are crucial for device communication. Over the subsequent years, the emphasis shifted towards enhancing data management capabilities.

This transition is underscored by the notable increase in the adoption of data analytics and edge computing from 2018 to 2020. Moreover, in the years that followed 2019, artificial intelligence (AI) and machine learning (ML) technologies were strategically integrated. These advancements facilitated predictive maintenance and the creation of personalized user experiences. During this period, IoT businesses showcased exceptional creativity in integrating these technologies, thereby forging more interconnected and efficient systems within emerging societies.

Furthermore, we examined various dimensions of startup businesses including Line of Business (LOB), Product/Services Diversity, Base of Pyramid (BoP), Users Establishment, Ownership Structure, Founders' Equity Percentage, Product Complexity, Company Size, Customer Segments, Business Type, Stakeholder and Investment Details. Our dataset highlights distinct variations among these startup businesses. The utilized structured approach not only facilitates a detailed analysis of market dynamics but also enhances the understanding of technological acquisition on business development and diversity (Haaker et al., 2021). Developing a template for a dataset comprising 1458 samples, encompassing 27 distinct technologies, and involving 9 companies within 6 different levels of technology readiness necessitates the careful structuring of data with a range of features. Table 4 provides a concise overview of nine IoT-based businesses (B1 to B9), each characterized by distinct attributes. Business 1 (B1), established in 2018, demonstrates a low diversity of products/services, predominantly engaging in Business-to-Business (B2B) and Business-to-Consumer (B2C) operations. With 70% founders' equity and a small-sized company structure, Business 1 operates with relatively low complexity.

**Table 4.** Summary of Key Characteristics for IoT-Based Businesses (B1 to B9).

| Business | Product/Services Diversity | Establishment Year | %Founders Equity | Complexity | Company Size | Type of Business |
|---|---|---|---|---|---|---|
| B1 | Low | 2018 | 70% | Low | Small | B2B mostly & B2C |
| B2 | High | 2013 | 25% | High | Medium | B2B |
| B3 | High | 2015 | 80% | Medium | Medium | B2B mostly & B2C |
| B4 | Average | 2019 | 82% | Medium | Small | B2B mostly & B2C |
| B5 | Low | 2017 | 85% | Low | Medium | B2B |
| B6 | High | 2014 | 55% | Low | Small | B2B mostly & B2C |
| B7 | High | 2020 | 60% | Medium | Small | B2B mostly & B2C |
| B8 | Low | 2019 | 78% | Low | Small | B2B mostly & B2C |
| B9 | Low | 2018 | 40% | High | Medium | B2B/B2C |

In contrast, Business 2 (B2), founded in 2013, exhibits a high diversity of products/services and operates primarily in the B2B domain. Despite its high complexity and medium-sized company structure, Business 2 maintains a lower founders' equity at 25%. Similarly, Business 3 (B3), established in 2015, emphasizes a high diversity of offerings, mainly targeting both B2B and B2C markets. With 80% of the founders' equity, Business 3 operates with a medium level of complexity and a medium-sized company structure. Business 4 (B4), founded in 2019, shows an average diversity of products/services, with operations primarily focused on B2B and B2C markets.

According to Table 4 and Figures 3 and 4, Business 4 (B4), characterized by medium complexity and a small-sized company structure, holds notably high founders' equity at 82%. Business 5 (B5), initiated in 2017, offers a narrow range of products primarily focused on the Business-to-Business (B2B) market. This business maintains an impressive founders' equity of 85%, combined with a medium-sized structure and low operational complexity. Similarly, Business 6 (B6), launched in 2014, reflects the product and service diversity of both Business 1 and Business 5, serving both B2B and Business-to-Consumer (B2C) markets.

Despite its high complexity, Business 6 maintains a low founders' equity of 55% and a small-sized company structure. Business 7 (B7), established in 2020, exhibits characteristics akin to Business 4, with a high diversity of offerings and operations primarily in B2B and B2C markets. Business 7 operates with a medium level of complexity and a small-sized company structure, with a founders' equity of 60%. Finally, Business 8 (B8), established in 2019, aligns with Business 1 and Business 5, featuring a low diversity of products/services and predominantly engaging in B2B and B2C operations. Operating with low complexity and a small-sized company structure, Business 8 maintains a high founders' equity of 78%. Business 9 (B9), established in 2018, shows a low diversity of offerings and a high founders' equity of 40%, operating with a medium-sized company structure and targeting both B2B and B2C markets.

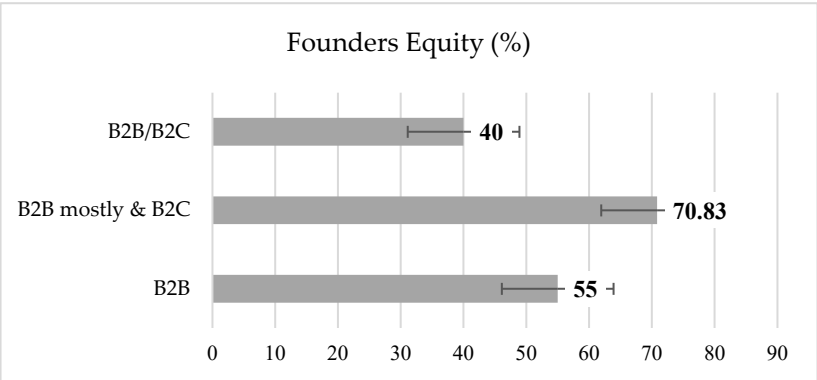


**Figure 3.** Percent founders equity distribution for businesses.

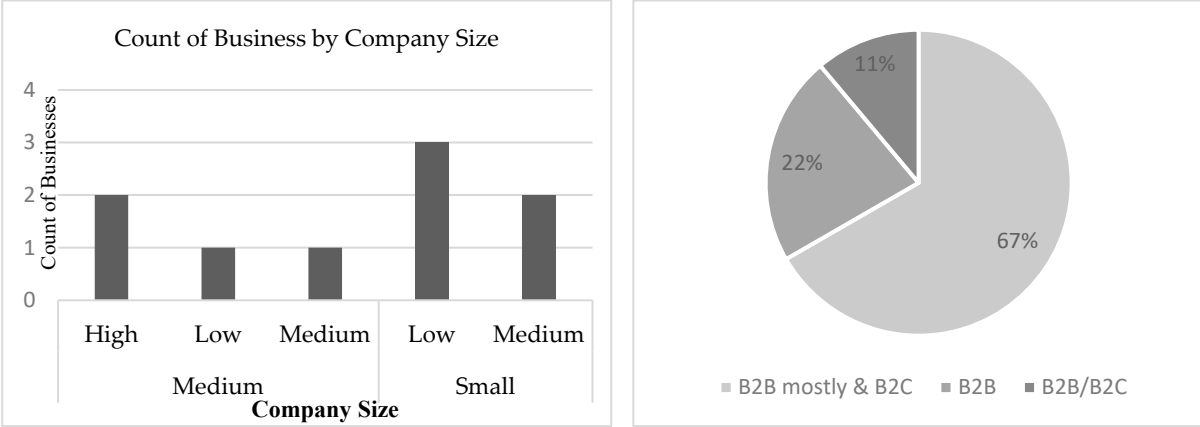


**Figure 4.** Types of business frequency and businesses complexity vs. size.

Through advanced big data analytics, we analyzed 27 distinct technologies across nine startup businesses and found that companies deal with the technologies at different levels. The technologies employed in these startups' products and services are depicted in Figure 5. We achieved classification of these technologies into six leading-edge head categories based on the analysis results.

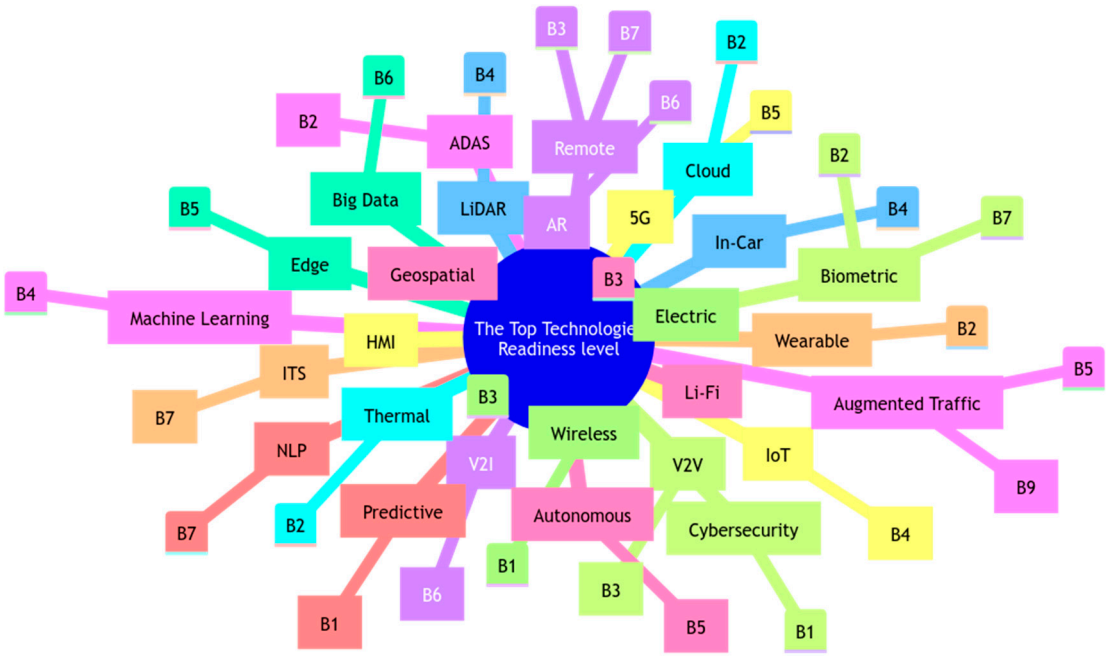


**Figure 5.** The top technology Readiness Level.

We established this classification based on the data presented in Table 5. This categorization facilitates a deeper understanding of the varied technological frameworks utilized by these companies to drive innovation and maintain competitive advantages in their respective markets. The results provide substantial insights into numerous firms' advancements in technology, with results presented in the figures. Business 7 stands out as an expert, demonstrating a strong commitment to Edge Computing for IoT. Business 8 is prominent as well, but with a more focused technological trend. Business 6 is comparable to Business 7 in that it focuses on Edge Computing for IoT, but it stands out for its wide approach, which includes technologies from all six head categories, demonstrating a diverse and well-rounded technological portfolio.

**Table 5.** The Head Categories of Technologies.

| | Head Categories |
|---|---|
| 1 | Edge Computing for IoT |
| 2 | 5G Networks for V2X Communication |
| 3 | Predictive Maintenance with Big Data Analytics |
| 4 | LiDAR for Autonomous Driving |
| 5 | Cybersecurity for Connected Vehicles |
| 6 | Machine Learning for ADAS and Traffic Management |

The study integrates Latent Dirichlet Allocation (LDA) as well as Non-negative Matrix Factorization (NMF) with advanced Natural Language Processing (NLP) analytics in Python 3.12.2 (Albalawi et al., 2020), to enhance the identification of latent topics and patterns in textual data (Natri et al., 2023). We utilize Python's robust libraries like NLTK, SpaCy, and TensorFlow, which use machine learning algorithms such as support vector machines (SVM) and neural networks, among others, to model and predict data patterns. This approach not only improves the accuracy of trend forecasts but also reveals latent variables and connections that impact the dynamics of startup innovation.

Figure 6 presents and comprises detailed technological strategies, highlighting the specific strengths areas of each startup business. Based on these findings, we identify technology trends for IoT mobility startup businesses across different technology levels and six head categories. The different levels of technology in IoT mobility start-up businesses have important implications. Based on these findings, we can identify technology trends for IoT mobility startup businesses across different technology levels and six head categories. For businesses operating at higher levels of readiness, due to their advanced technological capabilities, it is more likely that technology acquisition, upgrading and development are performed with better quality. On the other hand, startups at lower technology readiness levels may face challenges in acquiring and developing technology, financing to compete more with other businesses, scaling, and customer acceptance of products and services, as they strive to develop and refine their technology.

Figure 7 shows the technology readiness for Business 2, reflecting a mix of maturity levels across different technologies, with some, such as 5G Networks for V2X and Big Data Analytics, showing advanced readiness, while others, like Cybersecurity, certain Edge Computing for IoT technologies, being in earlier stages of development. This analysis provides insights into the current state of technology maturity and highlights areas that may require further research and testing. 5G Networks for V2X technology is relatively mature with a readiness level score of five, indicating that it has undergone development in a relevant environment.

The sub-technologies associated with 5G Networks for V2X have made significant progress towards full-scale deployment. In addition, LiDAR technology exhibits a high level of readiness with a readiness level score of five, suggesting that it has advanced to the point of full system integration. This indicates that LiDAR for Autonomous Driving has likely undergone extensive testing and validation. The machine learning technologies, both T6 and T9, are at Readiness Level 4, indicating that they have moved beyond the laboratory environment and have undergone testing in relevant settings. This suggests a moderate level of maturity with room for further development. Additionally, Big Data Analytics technologies (T3 and T22) are at different readiness levels, with T3 at Readiness Level 2 and T22 at Readiness Level 5. Also, Readiness Level 2 suggests that basic research has been conducted, while Readiness Level 4 indicates testing in relevant environments, showing a range of readiness within this domain. Cybersecurity technologies (T5 and T14) are at

Readiness 3 and Readiness 2, respectively. This suggests that while there has been some progress, there is still a need for further development and testing in relevant environments.

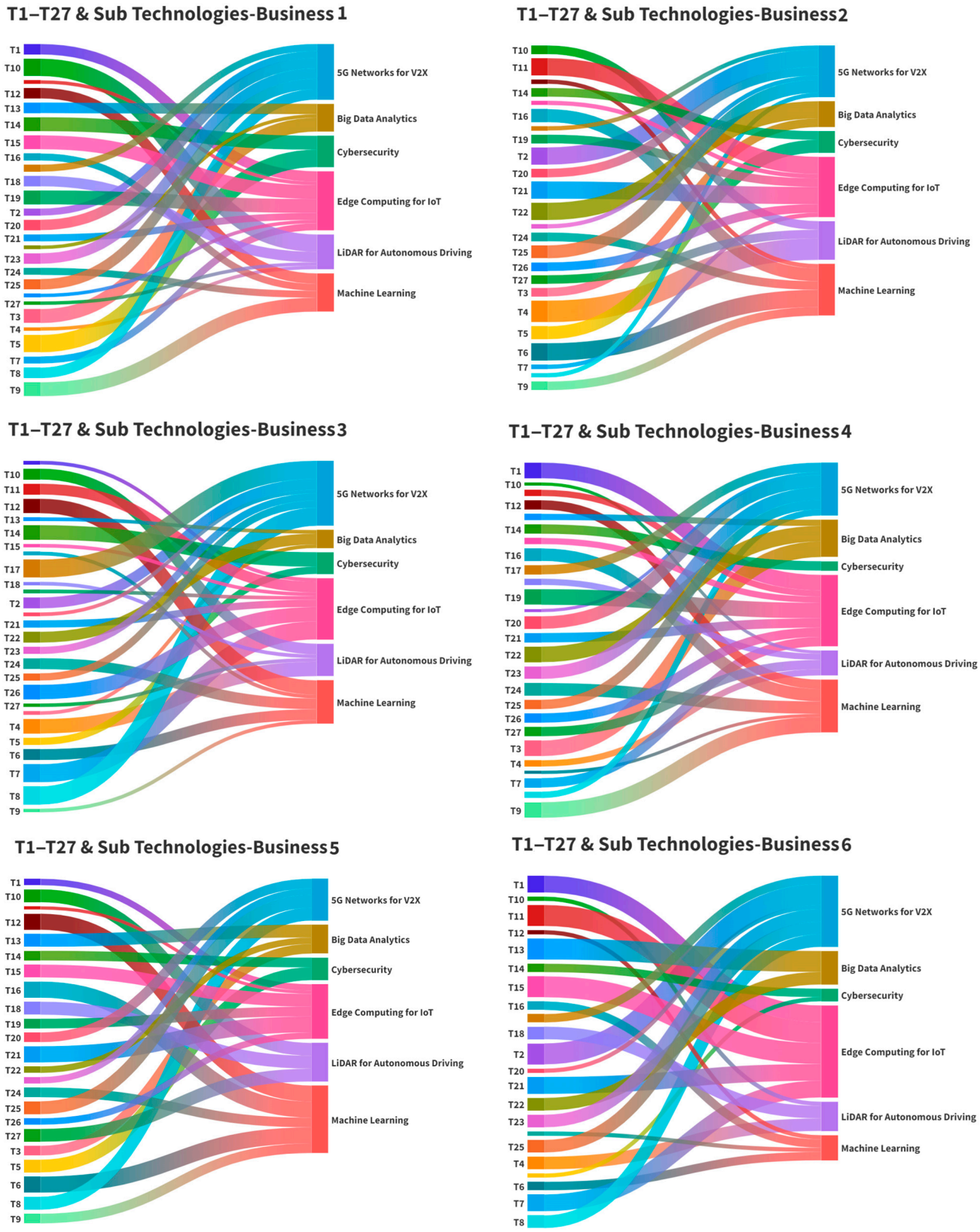


**Figure 6.** *Cont.*

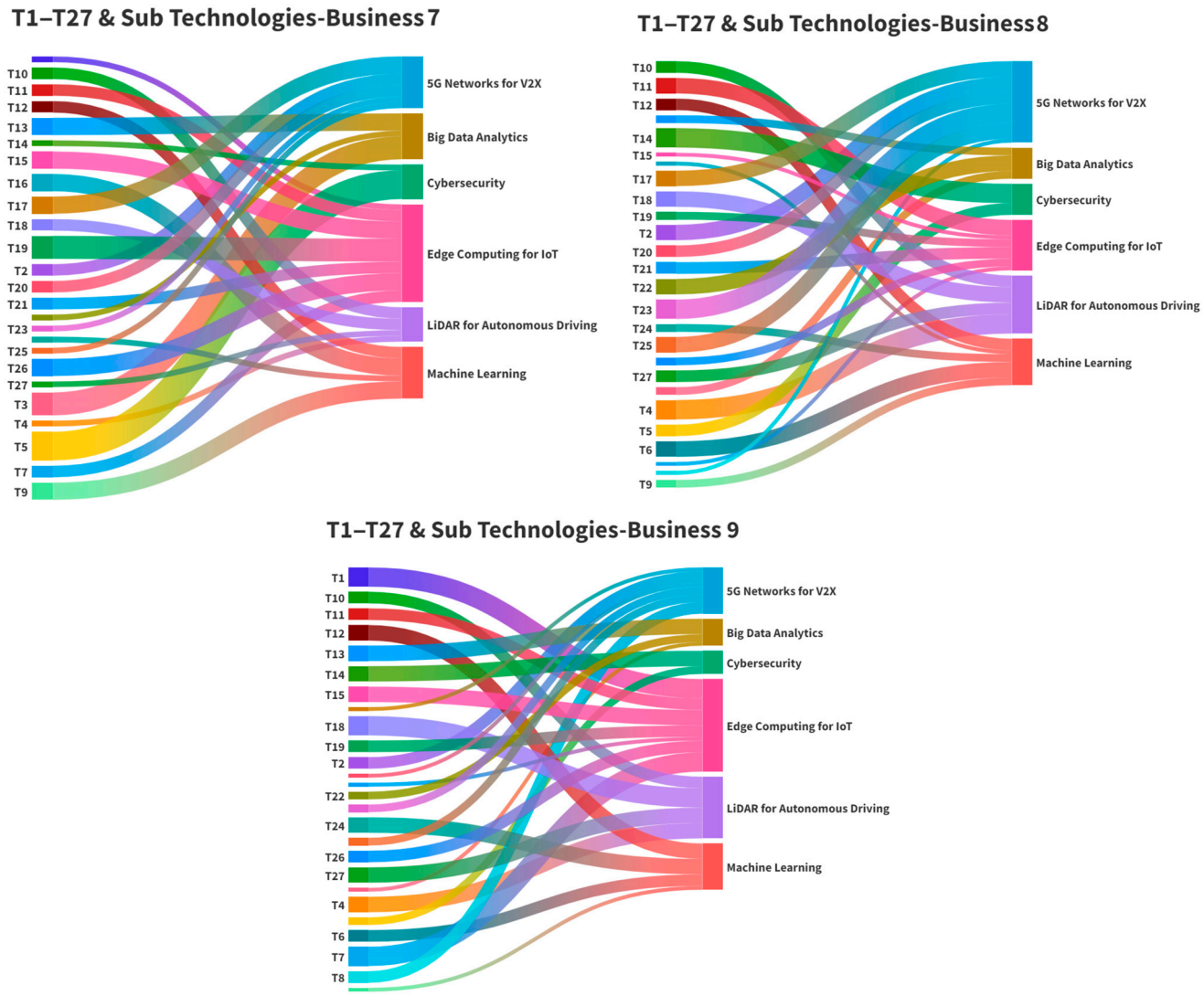


**Figure 6.** Technological trends of TRLs of IoT startup businesses.

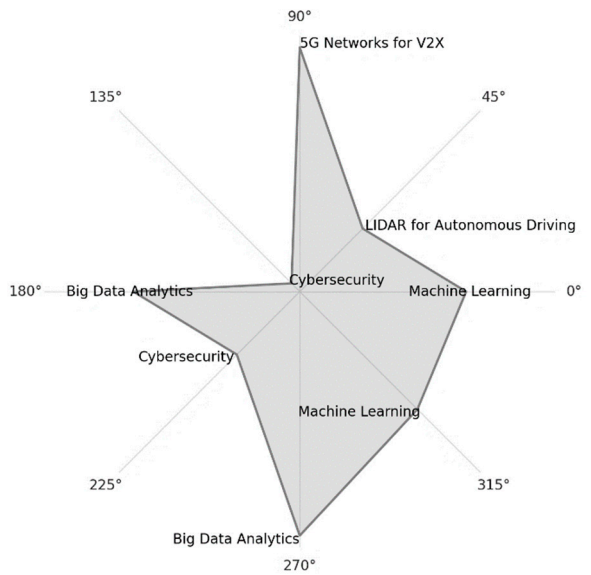


**Figure 7.** Technology and sub-technology acquisition readiness level by Business 2.

According to the findings presented in Figure 6, in the analysis of each of the technology groups, Edge Computing for IoT (T1, T7, T11, T15, T19, T21, T26) technologies vary in readiness from zero to five. This indicates a range of maturity levels within this category, with some technologies still in the conceptualization stage (Readiness 0) and others undergoing testing in relevant environments (Readiness 5). The technology readiness for Business 2 reflects a mix of maturity levels across different technologies, with some, such as 5G Networks for V2X and LiDAR for Autonomous Driving, showing advanced readiness, while others, like Cybersecurity and certain Edge Computing for IoT technologies, are in earlier stages of development.

This analysis provides insights into the current state of technology maturity and highlights areas that may require further research and testing. In our comprehensive study of the readiness levels (0–5) of nine start-ups, we use the Heat-Map model with big data analysis as a guiding framework to assess their technological readiness. The Heat-Map model, which includes technologies, technology groups, and readiness levels of each business, provides a comprehensive lens through which we evaluate the maturity and adaptability of businesses to technology adoption. First, the technology readiness of businesses is examined according to the complexity of their technological infrastructure in each of the companies, along with the integration of advanced solutions and the level of integration with emerging technologies. It shows the different ranges of readiness scores among businesses revealing the distinct technological paths they have embarked on.

Businesses at the higher end of the readiness spectrum exhibit greater depth in technology readiness, indicating a strong foundation for navigating the evolving technology landscape and better absorbing and developing that technology. Moving to the environmental aspect, our analysis shows how businesses are aligned with external factors such as their structures, business models, and the overall technological ecosystem. This dimension clarifies their adaptability to external changes and their activeness in using technological opportunities. Businesses that are more deeply rooted in technology readiness are those that demonstrate a well-tuned alignment with the external environment and position themselves as agile players in the dynamic technology landscape. In addition, the presented model shows how businesses can effectively anticipate and respond to the needs of customers and competitive dynamics with the help of cheap and affordable methods or low-cost strategies according to the structures of emerging economies. Businesses that explain a high level of readiness in this dimension demonstrate a forward-looking approach and use technology as a strategic enabler to stay ahead of market changes and emerging opportunities. This study not only identifies different levels of technological readiness (0–5) in nine businesses but also categorizes them according to the dimensions of the Heat-Map model. As shown in Figure 8, this fine analysis enables us to identify the businesses that are the pioneers of technological readiness in IoT-based mobility businesses, providing us with valuable insights to decide on the methods of acquisition or development strategies.

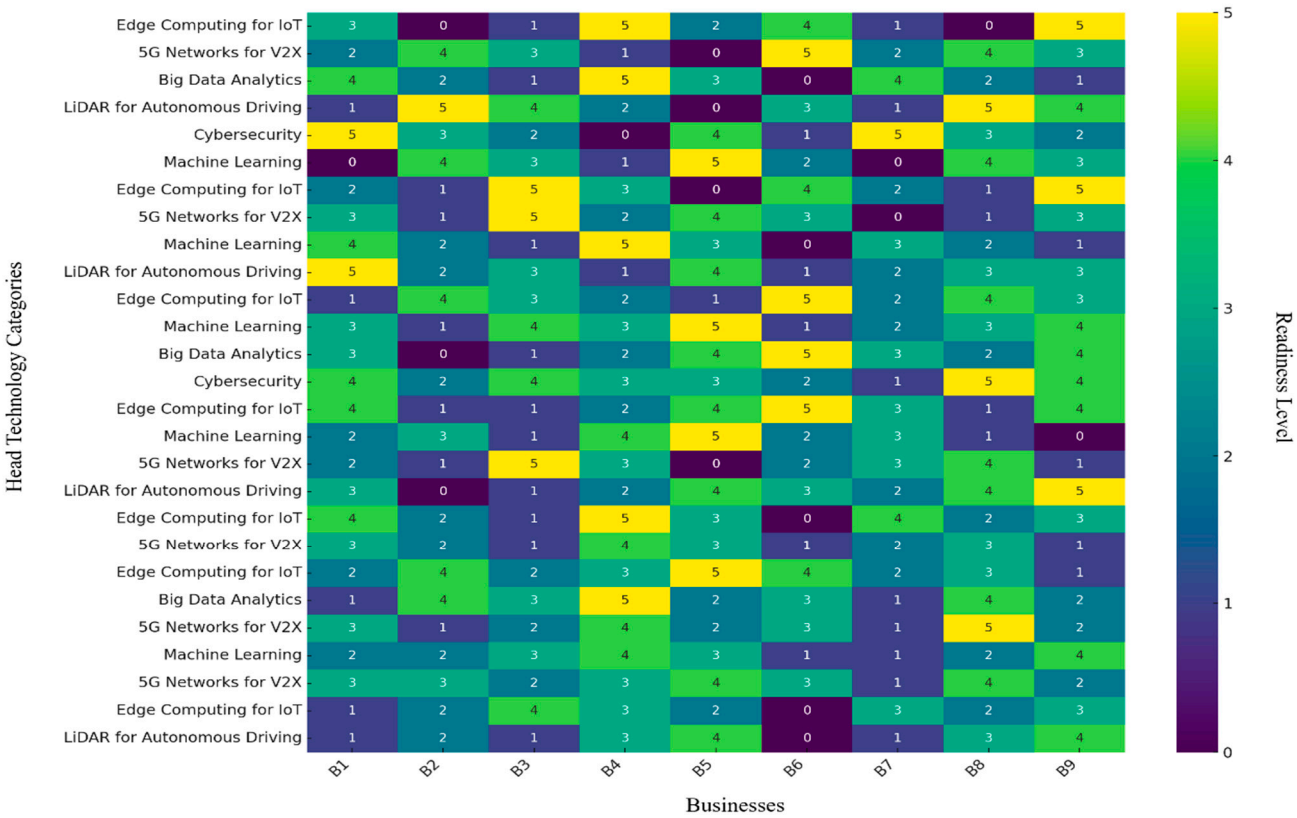


**Figure 8.** Heat-map model for sub-technologies and business Readiness Levels (0–5 scale).

## 6. Discussion

The findings of this study provide a fascinating and profound examination of structural dynamics within startup companies in the technology sector. The analysis underscores a prevailing trend where companies predominantly adopt a cost-effective and frugal approach to technology integration and development. The diligent application of strategies such as investing in talent development, fostering collaboration, and forming strategic partnerships unlocks significant benefits and achieves remarkable outcomes in the dynamic field of Internet of Things (IoT) technology acquisition and development (Subramaniam, 2022). Figures 3 and 4 crucially depict the instrumental role of industry stakeholders in shaping and propelling businesses that engage with IoT technologies. The discussion emphasizes the profound impacts of prioritizing talent development and nurturing collaborative partnerships.

This paper emphasizes talent development as the creation of a workforce equipped with the necessary skills to adeptly manage the complexities of IoT technology. This environment nurtures innovation, facilitating the emergence and progression of cutting-edge solutions. Companies that prioritize talent development thus secure a competitive advantage in the fast-evolving IoT market (Stankosky, 2005). Additionally, enhancing collaboration and knowledge exchange among stakeholders, both within and across organizations, fosters a shared pool of insights and expertise. This collaborative synergy accelerates the product development lifecycle, reduces time to market, and strategically positions companies to outpace competitors in the rapidly changing IoT landscape (Yang, 2015).

The strategic use of these resources enables stakeholders to embark on ambitious IoT projects that may otherwise be daunting if pursued alone (Chen, 2002). This access not only supports a quicker and more extensive adoption of technology, but also spurs industry-wide growth. Given the security and interoperability challenges inherent in the IoT space, collaboration and partnerships are essential for risk mitigation. By pooling

knowledge and resources, stakeholders can collaboratively tackle security issues, ensuring that IoT implementations conform to industry standards and best practices (Pargaonkar, 2023). Moreover, strategic partnerships serve as gateways to new markets and customer segments. Leveraging the customer base and distribution channels of partners significantly expands market reach, thus accelerating the adoption of IoT solutions on a larger scale (Behmann & Wu, 2015).

In the continually evolving IoT industry, sustained growth depends on ongoing innovation and adaptation. Stakeholders that invest in development, encourage collaboration, and establish strategic partnerships are well-placed for enduring success. This proactive stance not only navigates the complexities of IoT but also drives stakeholders to excel in the dynamic environment, leading to technological advancements, business growth, market expansion, and overall resilience against evolving challenges and opportunities (Daraojimba et al., 2023). Entrepreneurs and businesses focusing on technology acquisition and development in the IoT domain can achieve significant success by strictly adhering to the strategies advocated. An essential component of this success is the strategic optimization of infrastructure and resource use, supported by thorough assessments that accurately pinpoint IoT project requirements. This strategic approach enables businesses to allocate resources wisely, minimize unnecessary expenditures, and ensure the technology infrastructure aligns perfectly with project-specific demands. Moreover, prioritizing talent acquisition and development not only secures skilled individuals but also fosters a culture of ongoing learning and innovation, attracting top talent and sustaining a competitive edge in the dynamic IoT landscape. Strategic growth is propelled by actively seeking and nurturing strategic partnerships, which widen the scope of expertise and resources available, thereby speeding up technology development, sharing knowledge, and accessing new markets or customer segments (Xin et al., 2024). Another key strategy is adapting IoT solutions to the local context, demonstrating a commitment to meeting the distinct needs and preferences of the target market. This localization strategy enhances the acceptance and adoption of IoT solutions by aligning them with local cultures, regulations, and infrastructure constraints.

Integrating IoT-based mobility products and services solutions with regional demands not only enhances customer satisfaction but also promotes loyalty and increases referrals. Entrepreneurs and startup businesses that rigorously implement these strategies are better positioned to acquire and expand their products and capabilities and to excel in a competitive environment. Effective utilization of resources, recruitment of top-tier talent, strategic expansion, adaptation of localized solutions, and improved operational efficiency are key factors that collectively drive long-term profitability and success in the IoT industry.

One major contribution of this paper lies in its identification of technology readiness levels (TRLs) across various startups, offering a comprehensive perspective on their technological maturity. The study categorizes startups based on their TRLs and highlights the factors influencing their ability to adopt and integrate advanced technologies, such as 5G networks, edge computing, and machine learning. By employing the Heat-Map model, the research provides a nuanced understanding of the varying levels of readiness among businesses and their alignment with external factors such as market dynamics, regulatory environments, and consumer demands. This detailed framework equips policymakers, entrepreneurs, and stakeholders with a diagnostic tool to assess and enhance the readiness of startups for IoT innovation.

Another significant contribution is the emphasis on talent development and strategic partnerships as key enablers of IoT success. The study underscores how startups that prioritize building a skilled workforce and fostering collaboration—both within and across organizational boundaries—achieve accelerated innovation cycles, improved product de-

velopment, and broader market reach. These strategies not only enhance the internal capabilities of businesses but also create synergies that address common challenges such as security risks and interoperability in the IoT domain.

Finally, this research advances the discourse on localization strategies for IoT adoption in emerging economies. By tailoring IoT solutions to align with local cultural, regulatory, and infrastructural contexts, startups can enhance customer satisfaction and boost adoption rates. The study highlights how such localized approaches, combined with resource optimization and strategic growth initiatives, empower businesses to navigate the complexities of emerging markets and achieve long-term resilience.

We explicitly add a discussion of the research limitations to enhance transparency and contextualize the findings. The study acknowledges the representativeness of the sample, noting that the analysis is limited to nine startups selected from the Digital University Startups Ecosystem. While these startups provide valuable insights into IoT adoption trends and challenges, their specific context may not fully capture the broader diversity of startups globally. Additionally, we highlight the geographic limitation to Iran, acknowledging that unique socio-economic, regulatory, and infrastructural factors in this region may influence the findings and limit their generalizability to other emerging or global markets. These limitations are now explicitly stated to provide clarity and scope for interpretation.

This study revises the conclusion to succinctly highlight key insights derived from the research. Specifically, the study demonstrates how the Capability Maturity Model effectively evaluates and categorizes technology readiness levels (TRLs) among startups, enabling them to prioritize resource allocation and strategic initiatives. The findings emphasize the critical role of talent development, strategic partnerships, and localization strategies in fostering IoT adoption and achieving technological advancement in emerging economies. These revisions ensure that the connection between the analysis, the application of the maturity model, and the study's actionable insights is explicitly clear in conclusion.

We strengthen the connections between the literature review, the analysis of the nine startups, and the application of the maturity model to better align with existing studies and theoretical frameworks. The revised discussion emphasizes how the findings build upon prior research while addressing gaps specific to the context of IoT startups in Iran. This includes clearer linkages between challenges identified in the literature—such as infrastructural constraints, regulatory barriers, and market readiness—and the strategies observed in the analyzed startups, such as their emphasis on cost-effective approaches, collaboration, and technology localization. These improvements ensure a cohesive narrative that ties the theoretical background to the empirical findings and their practical implications.

## 7. Conclusions

This comprehensive exploration emphasizes the complex dynamics of IoT technology adoption within startups operating in a developing economy like Iran. Iranian startups face significant challenges shaped by socio-economic realities, including high inflation, inadequate infrastructure, and restricted access to advanced technologies. These structural barriers are compounded by a lack of skilled professionals and limited institutional support, creating an environment where technology acquisition and development are particularly challenging. Employing nine Iranian startup businesses as a case study, this research investigates the critical factors that shape IoT adoption in such constrained environments and seeks to provide a nuanced understanding of how startups navigate these barriers.

The aim of this study is to evaluate the technological readiness and adoption processes of startups in Iran based on the socio-economic and institutional challenges that hinder their development. This research focuses on key questions, such as the following: What are

the primary barriers to IoT adoption faced by startups in Iran? How do capabilities and infrastructural limitations influence the readiness levels of startups? By exploring these questions, the study aims to uncover insights that are applicable not only to Iran but also to other emerging economies with similar developmental hurdles.

A significant contribution of this study is its identification of technology readiness levels (TRLs) across a sample of nine startups, which serves as a diagnostic tool to assess their technological maturity. By applying the Capability Maturity Model (CMM), the research evaluates how startups progress from initial stages of readiness to more advanced levels of competence. This evaluation highlights how readiness levels are deeply interconnected with external socio-economic conditions. For example, startups in Iran often operate at lower levels of readiness due to insufficient technological infrastructure, limited funding opportunities, and the impact of inflation on resource allocation. These readiness levels are not merely technical indicators; they also reflect broader systemic challenges that define the operational realities for businesses in Iran.

The research finds that IoT adoption in Iran is influenced significantly by external conditions, which restrict startups' ability to invest in technological upgrades or long-term R&D initiatives. Additionally, regulatory inefficiencies create uncertainty, delay innovation, and slow the pace of technology adoption. These findings emphasize that the barriers to IoT readiness in Iran are rooted in systemic issues, including fragmented markets, inconsistent policy support, and the lack of integrated technological ecosystems.

Through the use of advanced Natural Language Processing (NLP) and machine learning techniques, this research provides a deeper understanding of the patterns and themes underlying IoT adoption in Iran. Using methods such as Latent Dirichlet Allocation (LDA) and Non-negative Matrix Factorization (NMF), the study uncovers latent trends in the qualitative data, revealing the structural and operational constraints faced by startups. For example, the results highlight disparities in resource distribution and technology absorption across the ecosystem, with some startups lagging significantly due to resource and infrastructural gaps. These techniques enhance the granularity of the findings, providing valuable insights into the interplay between readiness levels, external constraints, and adoption dynamics.

The study also examines how socio-economic challenges influence the technology absorption process within startups. Startups in Iran are often constrained by underdeveloped infrastructure and inconsistent access to essential tools and equipment. The findings indicate that these limitations force startups to adapt their approaches to resource management, often relying on incremental and experimental approaches to scale their IoT operations. The Heat-Map model employed in the study provides a holistic assessment of technological readiness, considering critical dimensions such as Technology, Environment, Market, People, and Resources. This model helps map the uneven readiness of startups, identifying specific areas requiring targeted interventions, such as skill development and improved access to infrastructure.

By integrating a robust methodological framework—including conceptual studies, thematic analysis, semi-structured interviews, and advanced data analysis—this research provides a comprehensive perspective on IoT adoption in Iran.

**Author Contributions:** Conceptualization, M.T. and M.J.; methodology, M.T.; software, M.T.; validation, M.T., M.J. and D.O.; formal analysis, M.T.; investigation, M.T. and M.J.; resources, M.T., M.J. and D.O.; data curation M.T., M.J. and D.O.; writing—original draft preparation, M.T. and M.J.; writing—review and editing, M.T. and M.J.; visualization, M.T. and D.O.; supervision, M.T. and M.J.; project administration, M.T.; funding acquisition, M.T. and M.J. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** Ethical approval was not required for this type of study. In accordance with Iranian legislation, researchers are responsible for ensuring ethical compliance, including obtaining informed consent and safeguarding participant confidentiality. for these types of studies. In accordance with COPE Guidelines, the authors declare that this study was conducted with rigorous adherence to ethical standards, ensuring full respect for participants' rights and data integrity. The study involved nine IoT startup businesses, and the authors secured their permission to use the data collected via questionnaires and interviews for the purposes of this case study and subsequent journal publication. Additionally, the authors emphasized confidentiality from the outset by agreeing to never disclose the companies' names or any critical data that could benefit competitors.

**Informed Consent Statement:** Informed consent for participation was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author due to being collected from private businesses.

**Conflicts of Interest:** The authors declare no conflicts of interest on this research.

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