# EVALUATING FACTORS AFFECTING CONSTRUCTION TECHNOLOGY START-UP INVESTMENTS AND INVESTOR BEHAVIOR

by

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# ABSTRACT


## EVALUATING FACTORS AFFECTING CONSTRUCTION TECHNOLOGY START-UP INVESTMENTS AND INVESTOR BEHAVIOR

The construction industry has been unsuccessful in adopting innovative technologies compared to other industries. Construction Technology (Contech) start-ups play a vital role in the digital transformation of the sector by providing unique solutions for particular problems. Nevertheless, start-ups are small companies, and they need to be supported by investors to survive and produce their products or services. In this respect, understanding investor behavior is critical for entrepreneurs to get investments. Accordingly, this study aims to evaluate the Contech start-up environment and factors affecting Contech investors' motivation and investment level. A conceptual framework was developed through an extensive literature review and interviews with professionals. An online questionnaire was held to test the relations of factors with investment motivation and investment share. The data was collected from Contech start-up investors in several countries and analyzed by utilizing Structural Equation Modeling (SEM). The results revealed that i) investor familiarity and entrepreneur characteristics have a positive, and environmental factors have a negative influence on investor characteristics; ii) while investor characteristics have a direct and positive influence, market and product characteristics have a direct and negative impact on investment motivation; iii) investment characteristics have a direct and negative influence, and market and product characteristics have a direct and positive influence on Contech share in investor portfolio. This study contributes to the literature by investigating Contech start-ups and proposing a basis for future research. Entrepreneurs and investors in the Contech ecosystem might benefit from the results in their decision-making process.

# ÖZET

## İNŞAAT TEKNOLOJİSİ GİRİŞİM YATIRIMLARINI ETKİLEYEN FAKTÖRLERİN VE YATIRIMCI DAVRANIŞININ DEĞERLENDİRİLMESİ

İnşaat sektörünün diğer sektörlere kıyasla, yenilikçi teknolojileri benimseme konusunda başarısız olduğu gözlenmektedir. Bu hususta endüstrinin spesifik problemlerine eşsiz çözümler sunabilen teknoloji girişimleri inşaat sektörünün teknoloji benimse süreci için hayati önem taşımaktadır. Ancak bu söz konusu girişimler yeni kurulmuş küçük şirketlerdir ve hayatta kalabilmeleri için yatırımcılar tarafından desteklenmeleri gerekir. Bu noktada yatırımcıların karar verme kriterlerinin belirlenmesi, inşaat sektöründe hizmet veren girişim ortamının gelişmesi için kritik bir adımdır. Bu araştırma inşaat teknoloji girişimi yatırımcılarının motivasyonlarını ve yatırım seviyelerini etkileyen faktörleri değerlendirmeyi amaçlamaktadır. Bu bağlamda, kapsamlı bir literatür taraması ve profesyonellerle yapılan görüşmeler sonucunda kavramsal bir çerçeve geliştirilmiştir. Faktörlerin yatırımcı motivasyonu ve yatırım seviyesi ile ilişkisini test etmek için çevrimiçi bir anket düzenlenmiştir. Veriler, çeşitli ülkelerdeki inşaat sektöründeki start-up yatırımcılarından toplandı ve Yapısal Eşitlik Modellemesi (YEM) kullanılarak analiz edildi. Sonuçlar, i) yatırımcı özelliklerinin, yatırımcının inşaat teknolojileri aşinalığı ve girişimci özelliklerinden olumlu, çevresel faktörlerden ise olumsuz bir şekilde etkilendiğini; ii) yatırım motivasyonun yatırımcı özelliklerinden doğrudan ve pozitif yönde etkilenirken, pazar ve ürün özelliklerinden doğrudan ve negatif yönde etkilendiğini; iii) yatırım seviyesinin, yatırım özelliklerinden doğrudan ve olumsuz, pazar ve ürün özelliklerinden ise doğrudan ve olumlu bir şekilde etkilendiğini ortaya koymuştur. Bu çalışma, inşaat teknolojisi girişimlerini inceleyerek ve gelecekteki araştırmalar için bir zemin oluşturarak literatüre katkıda bulunmaktadır. Girişimciler ve yatırımcılar, karar verme süreçlerinde çalışma bulgularından faydalanabilirler.

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# LIST OF ACRONYMS/ABBREVIATIONS

| | |
|---|---|
| AEC | Architecture, Engineering, and Construction |
| AEC-FM | Architecture, Engineering, Construction and Facility Management |
| AR | Augmented Reality |
| AVE | Average Variance Extracted |
| BA | Business Angel |
| BIM | Building Information Modeling |
| CB-SEM | Covariance-Based Structural Equation Modelling |
| CFA | Confirmatory Factor Analysis |
| Contech | Construction Technology |
| DLT | Distributed Ledger Technologies |
| DT | Digital Twin |
| HTMT | Heterotrait-Monotrait Ratio |
| IoT | Internet of Things |
| IRR | Internal Rate of Return |
| MR | Mixed Reality |
| NPV | Net Present Value |
| O&M | Operation and Maintenance |
| PLS-SEM | Partial Least Squares Structural Equation Modeling |
| SEM | Structural Equation Modelling |
| UAV | Unmanned Aerial Vehicle |
| VC | Venture Capital |
| VIF | Variance Inflation Factor |
| VR | Virtual Reality |

# 1. INTRODUCTION

When it is compared to other sectors, the Architecture, Engineering, and Construction (AEC) industry is considered as not so technology friendly and unproductive sector [1]. According to Brilakis *et al.* [2], even though this situation is creating a lot of improvement area for construction industry, it is hard to reach the other industries' digitization level such as manufacturing or oil and gas. In this respect, Construction Technology (Contech) start-ups play a critical role to make Contech applications more available and increase the digitalization level of the construction industry. However, start-ups need to be backed by investors to survive and improve their product and services. This study aims to develop a model to assess the factors affecting financiers' Contech investment motivations and Contech share in their portfolios. An online questionnaire survey was designed for Contech start-up investors. The collected data was analyzed by using Structural Equation Modeling (SEM) to test the conceptual model. The study is expected to make both theoretical and practical contributions by exploring the Contech start-up environment, defining factors influencing Contech investors' decision, proposing a model consisting of both financial and non-financial factors, and proposing appropriate criteria for future studies. Following sections explain the research background, gap in the literature, aim and objectives of the study, methodology, scope and limitations, and organization of the study.

## 1.1. Background of the Research

The construction industry has always been behind the other sectors in adopting emerging technologies. Accordingly, the gap between the productivity of construction and other sectors has been considerably increasing recently [3]. As Berlak *et al.* [4] highlighted, digitalization substantially impacts construction productivity by reducing cost and increasing efficiency. Therefore, digitalization has gained importance in the construction industry over the past decade due to its critical potential for improvement. For example, the adoption of Building Information Modeling (BIM) stimulated the digitization process of the construction industry over ten years.

BIM provides numerous benefits by creating more semantic models for the architecture, construction, engineering, and facility management (AEC-FM) industry. BIM's benefits are not limited to 3D modeling for the AEC-FM industry. As researchers have become familiar with the concept, BIM has been implemented for different cases. For example, Zhang *et al.* [5] utilized BIM for fall hazard identification, Wu *et al.* [6] used GIS-BIM for Virtual Facility Energy Assessment, and Chen and Luo [7] cretaed a BIM quality model to develop existing quality management procedure.

On the other hand, numerous emerging technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and cloud computing have gained significant popularity in many industries. Especially with concepts like Digital Twinning (DT), many of these beneficial technologies are integrated to create a virtual representation of an entity by enabling real-time data transmission between the physical and digital environments [8]. Considering the construction management literature, the number of articles focusing on these types of emerging technology adoption has also been increasing in the past few years (e.g., [4, 9–13]). Accordingly, besides BIM, the AEC-FM industry gradually becomes acquainted with novel technology applications in this complementary environment. Especially, after Industry 4.0 has become a groundbreaking revolution for industries in this century, the construction industry has also influenced this computer-based system and it resulted in Construction 4.0 [14]. Industry 4.0 refers to the automation of systems utilizing cyber-environments created with technologies such as AI, and Construction 4.0 is the term that was adopted from this concept. Thanks to this accelerating adoption process the AEC-FM industry has the potential to be more successful [15].

However, even though the numbers of studies focusing on emerging technologies has been increasing, the construction sector is still one of the least digitized industries, and each step for digital transformation is crucial for the future of the AEC-FM sector. In this respect, technology start-ups play a pivotal role in adopting emerging technologies. These ventures produce new applications, hardware, and software that help companies provide a solution for particular needs [16].

When we consider the distinct dynamics of construction, architecture, and real estate industries, start-ups have innovative solutions to facilitate the whole phases of construction projects from designing to maintenance applications (e.g., [10, 17–19]). Blanco *et al.* [20] presented use ares of Construction technologies (Contech) throughout the entire process of a project. Their benefits start from the design phase by enabling the control of all kind of document. Then, they contribute to preconstruction activities such as estimating and planning. Next, Contech facilitates the activities during construction phase such as design/material/equipment/document management, field productivity, quality controll and safety. Finally, Contech might contribute to O&M phase via remote controlling. As Gruszka *et al.* [21] highlighted, the aim of start-ups is not to replace existing construction companies. Their objective is to present automated and smart alternatives to solve the problems in conventional applications of the industry. This attempt has a critical role because according to BCG's report [22], digitalization could save from $0.7 to 1.2 trillion annually in the construction phase, and $0.3-0.5 trillion in the O&M stage.

Considering the benefits of Contech ventures to the digitalization of the construction sector, investments in such start-ups need to be increased to create a more innovative and productive environment. Forcael *et al.* [14] state that emerging technology investments make way for development in performance and productivity, which are the most critical needs for the construction industry. Start-ups create unique solutions for different problems of the sector and develop their products/services until the acquisition by a larger vendor. Afterward, these services gain a place in the industry and increase the digitalization level. Thus, getting enough financial is crucial for these small companies. Accordingly, understanding Contech investors' behaviors is quite important for the improvement of construction technology start-ups.

Early-stage company investors' decision-making processes has always been discussed by several researchers for decades. Most of them evaluated these types of investment from a general perspective and prioritized decision-making factors (e.g., [23–27]). On the other hand, a limited number of articles focused on technology-related investments (e.g., [28–31]), and no research focuses on investments in construction technology

start-ups. Therefore, considering the importance of emerging technology applications for the construction industry, focusing on the investments in ventures contributing to the digitalization of the AEC-FM industry is an important step for Contech start-up environment.

## 1.2. Problem Definition and Statement

As Brilakis *et al.* [2] state, construction technology start-ups propose unique technology services, and they need capital to have sustainable and yielding digital operations for the AEC-FM sector. Even though construction technology start-ups seem to be the key for digital development of the industry, they may have some challenges to get financial from investors. According to the research of Blanco *et al.* [16], construction technology investments will accelerate, and investment amounts will increase in the following decades. According to CB Insights, the number of investors focusing on construction technology ventures increased considerably between 2012 and 2016. The number of Contech investors in this period is presented in Figure 1.1.

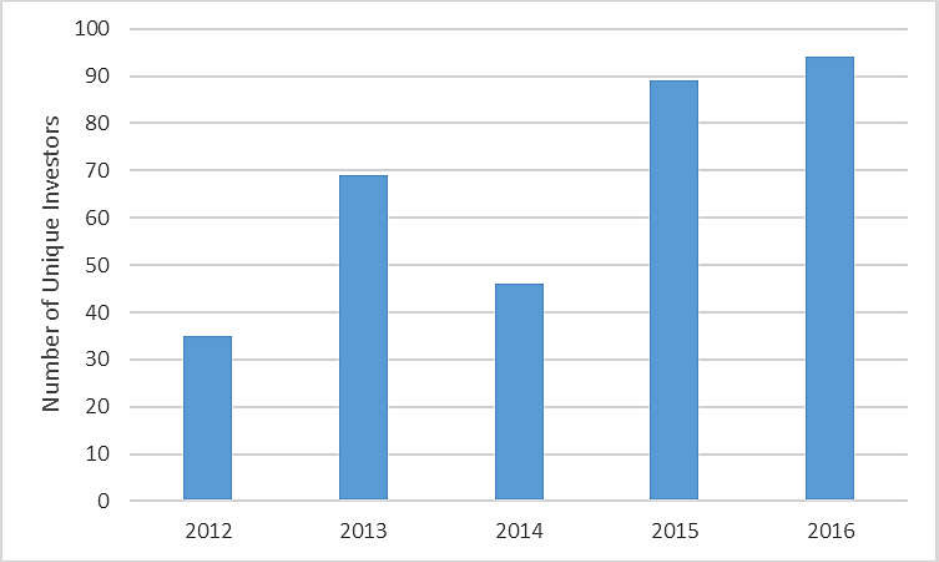


Figure 1.1. Investors of Contech Ventures.

Nevertheless, as Bacon [32] stated, deciding the appropriate technology investment is crucial for investors to maintaining institutional sustainability under competitive conditions. Therefore, digital technology investments such as Venture Capital (VC) directly affect the start-ups' work and the technology integration of the construction industry. However, even though the interest of investors into Contech venture has been increasing, no study has investigated the Contech start-up investments, and there is an important gap in the construction management literature. Therefore, there is a need for an investigation of Contech investor decision-making criteria to facilitate both Contech start-ups and their investors.

## 1.3. Aim and Objectives of the Study

This study aims to develop a model in order to evaluate factors affecting the Contech investment motivation and investment level of financiers. By including not only business factors (Investment Characteristics, Market and Product Characteristics, Legal Factors), but also environmental and non-financial factors (Entrepreneur Characteristics, Environmental Factors, Investor Characteristics, and Investor Background), this research provide a comprehensive model for the AEC-FM start-up literature. The objectives of the study are i) to discover the Contech start-ups and their investment environment, ii) to form a conceptual framework through the literature review and interviews with professionals, iii) to develop appropriate criteria for AEC-FM start-up financing decision-making process through an extensive literature review, and iv) to reveal the relations between the factors of the model.

## 1.4. Research Methodology

This study includes an extensive literature review to create the conceptual framework and hypotheses, to define factors affecting Contech start-up investors, and to determine the appropriate participant profiles. Following the literature review, an online meeting was held with professionals to develop a model consisting of financial and non-financial factors. Afterward, an online questionnaire including three sections was designed for Contech start-up investors. In total, 48 responses from several counties

were participated in the survey.

In order to analyze and interpret the data obtained from the questionnaire, Structural Equation Modeling (SEM) was preferred by considering the model consisting of interrelated dependence. This study attempted to conduct a Covariance-based structural equation modelling (CB-SEM) analysis initially. However, because of the low response rate, Partial Least Squares Structural Equation Modeling (PLS-SEM) was utilized for data analysis. Firstly, validity of factors selected through the literature review was tested. Secondly, relations between the factors were analyzed and the hypotheses were tested. Finally, the results were discussed in detail and recommendations were provided for future studies.

## 1.5. Scope and Limitations

The scope of this study comprises examining the factors affecting Contech start-up investors' decision-making and the relations between the factors. This study is only limited to AEC-FM technology start-ups investors' opinions.

Because the Contech start-up environment is one of the newly developing areas, the respondent profile is quite limited. Moreover, because no study has investigated the factors influencing Contech start-ups or their investors, the factors used in the questionnaire and the model were obtained from the business administrations and management studies, rather construction management. Lastly, the study utilizes expert judgment, and literature for hypotheses development and analysis, which means it is based on subjective opinions.

## 1.6. Organization of the Study

This study consists of 6 chapters. The first chapter briefly proposes the study background, problem definition and statement, related studies, aims and objectives, research methodology, scope and limitations, and organization of the study. The second chapter focuses on the literature on the digitalization process of the construction

industry, Contech start-ups, and start-up investments. This chapter highlights the importance of innovative AEC-FM technology firms to enhance the digitalization level of the construction sector. Also, investment factors and investor decision-making processes were mentioned in this chapter. The third section presents and explains the research methodology of this study. In this chapter, the conceptual framework, model hypotheses, questionnaire survey, collected data, and SEM implementations were explained in detail. The fourth section presents data analysis, findings, and chapter five presents discussions of the results. Finally, chapter six summarizes the conclusions of the study. Conclusion section also includes the contributions of the study, and recommendations for future studies. The Appendix section provides the tables regarding the questionnaires, descriptive statics, and PLS-SEM software screen captures.

# 2. RESEARCH BACKGROUND

This chapter presents the literature review on the digitalization of the construction industry and explains the importance of emerging technologies and the current situation of the technology adoption of the AEC-FM industry. The role of Contech start-ups in this process and the critical role of AEC-FM technology start-up investments were discussed in detail under this section. The main participants in start-up financing and the critical role of VC is mentioned. This section also presents the decision-making process of start-up investors.

## 2.1. Digitalization of the Construction Industry

As the AEC-FM industry needs to be more agile and productive because of its inefficiency, the acceleration of digitalization has become inevitable. By integrating emerging technologies, almost every phase of construction application has got a chance for improvement. Therefore, the AEC-FM sector has started to adopt developing technology concepts by following other industries such as manufacturing. When the construction management literature is considered, one of the most popular concepts which are applied in this industry is Building Information Modeling (BIM). Even though the most popular application in the construction industry is BIM, McKinsey's report (2018) revealed that numerous applications such as robotics, digital twins, artificial intelligence, supply chain optimization, and marketplaces play a significant role in the construction technology ecosystem. As Figure 2.1 shows, each dot represents a distinct technology, and the lines presents their collocations for different concepts. For example, to create a digital twin of a construction project, laser scanning, drone-enabled yard inspection, virtual learning, and design simulation are used together.

As these technologies become more popular in the industry, the number of astudies focusing on technology integration into the construction sector has been increasing recently. Forcael *et al.* [14] investigated Construction 4.0 and conducted a literature review under the "umbrella concept" of digitalization of the construction industry.

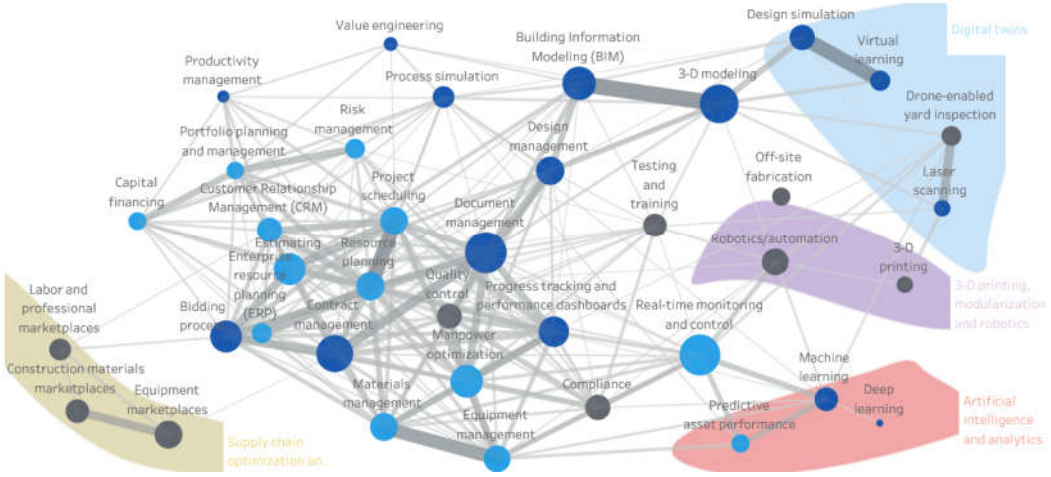


Figure 2.1. Mapping the construction technology ecosystem [16].

The research utilized seven keywords including IoT, big data, AI, and BIM, and revealed the number of articles focusing on these topics for purposes of the AEC-FM industry. Finally, they selected the articles published in ten related journals. Figure 2.2 presents the result of this literature review. According to the results, starting from 2015, IoT has been the most popular technology mentioned in the construction management literature with 44 articles in total. Then, BIM (35 articles) AI-Robotic (33 articles) and 3D printing (33 articles) followed IoT.

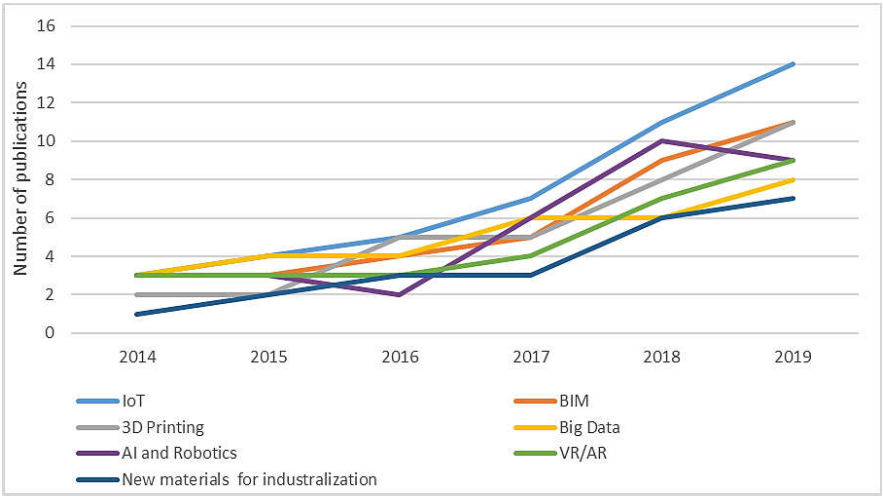


Figure 2.2. Technology-related publications between 2014-2019.

Material-related technologies were the least focused topic among seven technologies. Internet of Things is an important concept for industries for the last decade. IoT was developed by researchers at MIT and it defines tools forming a network that communicates remotely via wireless sensors [33]. The application areas of IoT are extensive, and in the construction industry, it creates opportunities for smart cities, smart homes, and manufactured applications such as off-site construction. Therefore, the popularity of IoT seems to dominate the construction industry more in the future.

Even though technologies like IoT and AI are quite popular, there are several studies focusing on different emerging technologies in the literature. For example, Elghaish *et al.* [10] evaluated the roles of drones and immersive technologies in the construction industry. As the study highlights, Unmanned Aerial Vehicles (UAVs), namely drones, are substantial for industries owing to their data collection abilities. UAVs can be utilized for different purposes such as visualization, automated surveying, and occupational safety.

On the other hand, Elghaish and colleagues [10] mentioned the industry's embracement of immersive technologies that are virtual reality (VR), augmented reality (AR), and mixed reality (MR). The study discussed how these applications facilitate the construction process by utilizing them for project control and monitoring, facilities management, provision of project information on-site, team collaboration, training and education, and quality management. Especially for the last decade, construction safety-related studies have frequently benefited AR and VR technologies [34–37]. As Li *et al.* [38] stated, VR/AR applications provide several benefits in safety applications by providing a risk-free visualization of a complex workplace for hazard identification, safety training, and education.

Moreover, one of the most attractive features of emerging technologies is that they are eligible to be integrated with different technologies for distinct purposes. According to Barricelli *et al.* [39], technologies such as Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), and the integration of them have pioneered Digital Twin (DT) technology improvements. The Digital Twin concept involves the combinations

of numerous technology tools and applications such as drones, laser scanning (Lidar), virtual learning, and simulation [16]. El Saddik [8] declares that because the digital twin idea can be implemented in lots of technologies, this concept will not be unique to the manufacturing industry.

El Saddik [8] broadens the definition and defines the digital twin as a concept enabling the seamless data transfer between the physical, and digital world. Moreover, this idea helps to observe, analyze and optimize the whole operations of physical systems. Owing to its functionality, DT has attracted prominent attention from the academic and industrial applications of construction. Considering the characteristics of the concept consisting of wireless sensors and data integration, DT seems to replace BIM implementation with increasing popularity. According to Volk *et al.* [40], because of the ambiguous data and connections in the BIM, creating a new BIM report needs a lot of work.

In their study, Lu *et al.* [11] aimed to design digital twin models not only at the building level but also city level. They developed a virtual representation of the West Cambridge site of the University of Cambridge. Their digital twin merges various data from different sources and analyzes them effectively. This model helps people to communicate with buildings or cities. Thus, the model supports decision-makers in operation and maintenance (O&M) phases. As the study aims, the entire process of a real DT application in terms of both building and city stage is presented. The author states that the study is a roadmap for asset management practitioners, policymakers, and researchers to promote the implementation and development of DT at the building and city levels.

When we consider the improving technology integration process of the construction technology, the amount of digital data has been increasing day by day. As a consequence, cloud computing concept has been frequently used in the construction sector. National Institute of Standards and Technology [41] defines Cloud Computing as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and

services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". This technology is used for different purposes in the construction management literature. For example, Bello *et al.* [42] conducted a study that is based on an extensive literature to discover use areas and benefits of cloud computing for construction projects.

The authors concluded that cloud computing is a facilitator for integrating other innovative applications (AR/VR, BIM, big data, etc.) in the AEC-FM sector. The study listed benefits of cloud computing such as creating a large storage environment, enabling collaboration among workers, and security.

Eventually, this digital transformation of the construction industry has also affected payment applications. Thus, blockchain technology has been frequently discussed for the construction sector recently. Li *et al.* [43] discussed distributed ledger technologies (DLT)/Blockchain applications and listed seven categories utilizing DLT: Smart Energy, Smart Cities and the Sharing Economy, Government, Smart Homes, Intelligent Transport, BIM and Construction Management, and Business Models and Organizational Structures. The authors highlighted the great potential of DLT for construction digitalization and its capability to solve the problems stemming from this technological transformation. As Perera *et al.* [9] state, "Blockchain being a decentralized distributed ledger provides several advantages; creating immutability, transparency, trust, security, auditability, single source of truth among others, has started to disrupt a number of industries such as finance, insurance, logistics, energy and transportation by its promising advantages and various applications".

As the literature shows, emerging technology applications possess a critical potential for the construction industry. However, the spread of these technology practices in the construction industry will only be possible through the contribution of ventures focusing on a specific technology product and service. Accordingly, technology start-ups have become a vital player in the digitalization journey of the construction sector.

## 2.2. Start-up Environment and Technology Trends

Start-ups are newly established companies providing a unique product for the market and are considered disruptive in their industries [44]. According to McKinsey's report [16], the number of start-ups is increasing, even though there are different undesired situations such as legal and cultural environment, and they contribute to the competitive financial and high-tech environment.

Moreover, start-up growth rates may give us a clue about the industrial trends and hot topics. The Global Startup Ecosystem Report [45] clustered start-ups in accordance with their sub-sector and analyzed their growth. Figure 2.3 shows start-up sub-sectors that are in growth phase.

As the graph shows, early-stage funding of five sub-industries (Agtech & New Food, Blockchain, Advanced Manufacturing & Robotics, AI & Big Data, and Fintech) increased dramatically. The report states that, in this category, AI and Big Data accounts for 27 per cent of entire start-ups, while Agtech & New Food has the least share with 2%.

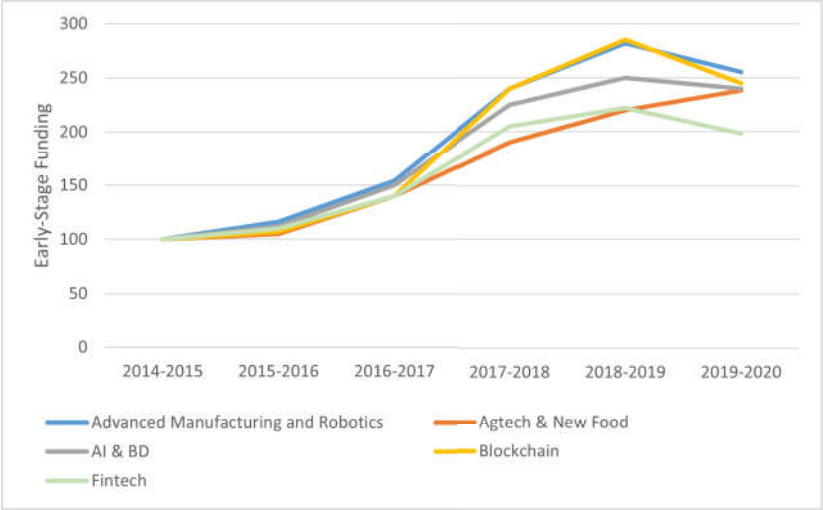


Figure 2.3. Start-up Sub-Sectors in the Growth Phase.

According to GSER2021 [45], there are five start-up sub-sectors in Mature Phase: Cybersecurity, Edtech, Cleantech, Life Sciences, and Gaming. Start-ups belong to these industries has gained an increase around 33% in Series A funding. Figure 2.4 shows the early-stage funding rates of sub- industries in the mature phase. Also, as the report showed that AdTech and Digital media start-up funding decreased over the years.

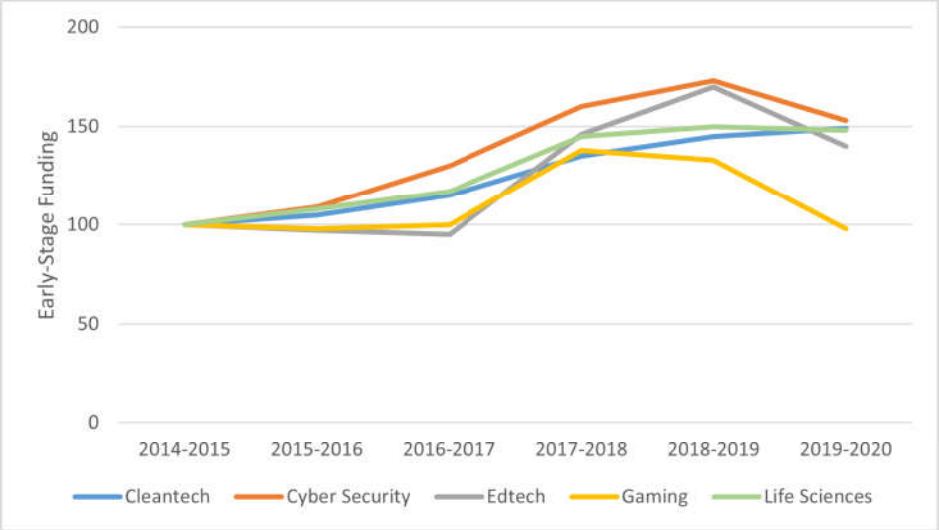


Figure 2.4. Start-up Sub-sectors in the Mature Phase.

Accordingly, when the concentration of start-up funding on AI, Big Data, and blockchain is considered, it is expected that the number of Contech start-ups utilizing these technologies for AEC-FM purposes to be high compared to others.

## 2.3. The Major Role of Start-ups for Construction Digitalization

Innovative start-ups play a locomotive role in technology adoptions of the industries [46]. Considering the accelerating transformation of the construction industry, technology start-ups have a great importance in the digitization process of the sector. These ventures, which focus on construction technologies, produce new applications, hardware, and software that helps companies to provide a solution for particular needs [16]. Therefore, their contributions have been highlighted in the recent studies discussing the emerging construction technologies.

Bogue [47] examined the use of robots in the construction sector and introduced several technology start-ups focusing on construction robotics. For example, the study mentions a drone start-up founded in 2013 which provides high-quality drones, cloud-based software, and big data analytics for construction and engineering companies. By offering the integration of data capturing and analyzing, this venture provides an effective solution for construction field works such as earthwork operations. The study also refers to another construction technology start-up that designs autonomous robots integrated with GPS and LIDAR. The venture aims to facilitate construction applications such as material transfer and piling by developing more intelligent equipment rigged with emerging technologies. Bogue's study [47] also pointed out the interests of big construction companies in start-ups and stated that the growing number of innovative start-ups lead to acceleration in robot use in the construction industry.

Similarly, the study of Perera *et al.* [9], which evaluates the role of blockchain technology in the construction sector, mentioned a blockchain technology start-up, and highlighted the role of such initiatives in blockchain acceleration in the construction sector. This start-up combines BIM and blockchain to provide an open collaboration and data interconnection. By enabling data integrity protection, smart contracts, and decentralized storage, the start-up provides smart, accountable, and secure BIM applications for built environments.

Of course, Contech start-ups are not limited to robotics or blockchain. Numerous small technology companies create a more innovative environment for the AEC-FM industry throughout the project life cycle. In their report, Blanco *et al.* [20] presented the use cases of construction technologies and start-ups' focuses on the AEC-FM industry. According to the study, one of the contributions of start-ups is digital design support for the industry. Especially for documentation and mobile solutions for design activities needed on site are quite helpful for engineers and workers.

Regarding pre-construction activities, technology start-ups facilitate bid estimates, analyses of market performance and previous data, and provides marketplaces for stakeholders to contact.

According to the report, the phase where construction startups provide the most solutions is the construction phase. For the construction stage, start-ups provide digital visuals and enable remote and more accurate control. They enable updating the documents from the construction site using hyperlinks. On the other hand, scheduling and material activities also can be tracked online. Several start-ups create services for field productivity and occupational safety. Using technologies such as IoT, AI, and drones, productivity can be followed automatically, and react fastly when an accident happens. Moreover, contract management is also digitized by technology ventures. Document updating and contractor communication can be conducted online through "Sofware as a Service" (SaaS).

After the construction phase is completed, technology ventures can support facility management phases via remote monitoring, predictive analysis with simulations, and asset management. Especially for energy monitoring and management, technology solutions are highly beneficial in terms of real-time data tracking/collection, big data analysis and simulations.

Blanco *et al.* [20] presented a figure showing the use areas of start-ups' services and the investment level they received. Larger circles indicate higher amount of company and investment. Figure 2.5 illustrates the density of the start-ups according to their service area. As the figure shows, even though most construction technology start-ups focus on design management, document management, pre-construction, and resource planning, newly founded start-ups provide solutions for performance dashboards, quality control, safety, and productivity. Also, the number of start-ups focusing on scheduling and material management has increased over the last five years. These ventures constitute one of the main steps of innovative technology adoption in construction. This process starts with academic studies, followed by start-up applications, and the acquisition of these small ventures by larger companies [2]. Accordingly, technology start-ups are one of the cornerstones in the technology revolution of the AEC-FM industry. However, start-ups need financial support to survive and develop innovative technology services needed in the industry [48]. Therefore, start-up investments are vital for the development of a digital construction environment.

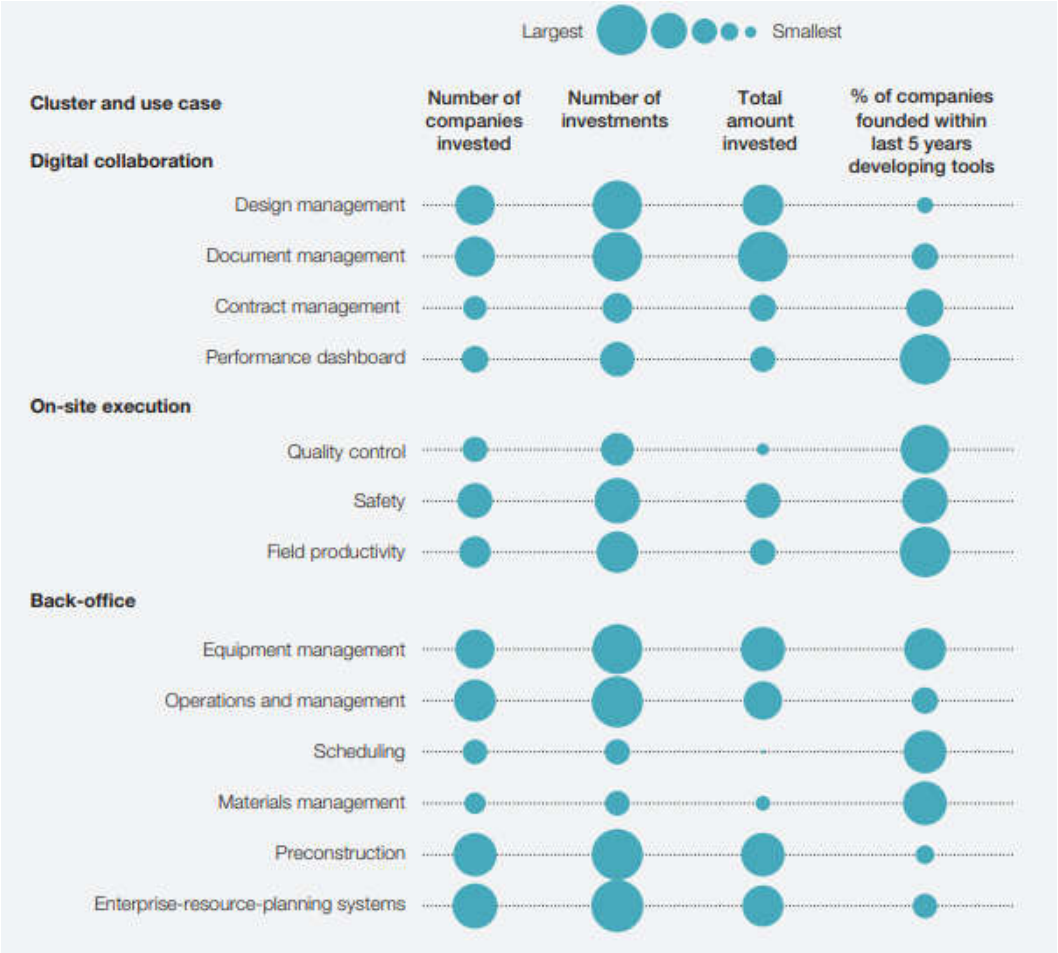


Figure 2.5. Top Funding Sources for Start-ups [20].

## 2.4. Start-up Financing

Finding an adequate amount of financial backing is one of the essential issues for small companies to manage and develop their businesses [49]. Investment issues have been frequently mentioned by researchers as an obstacle for entrepreneurs [50].

Blanco *et al.* [20] stated that between 2011 and 2017, Contech ventures recieved a $10 billion investment. According to the report, Contech start-ups in the document management area received the highest amount of money ($1.7 billion) and equipment management is also backed up by investors and got $1.4 billion from 2011 to 2016. Even though the majority of the investments belonged to VCs, they are also supported by other sources. Generally, a start-up can get funding from angel financing, crowdfund-

ing, small business credit cards, VC, and small business loans [51]. Angel investors individually invest in newly established companies, and they get ownership equity; crowdfunding is a funding system consists of multiple individuals' funds; VC companies support early-stage companies financially and provide strategics support; small business loans are provided by traditional or alternate bankers such as banks [51]. A start-up may get investments from different sources at the same time.

Oranburg [50] states that early-stage companies initially use personal funds such as savings, or uses money of their friends and family. Oranburg [50] presented a chart illustrating the top funding small company resources based on the study of Soetanto and Van Geenhuizen [52]. Figure 2.6 shows the distribution of start-up financing according to the resource type.

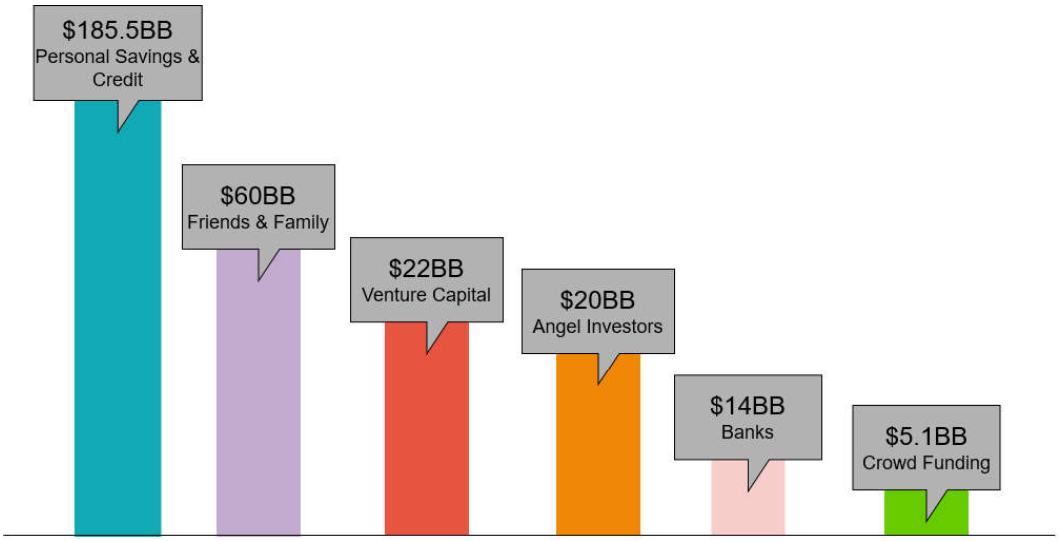


Figure 2.6. Top Funding Sources for Start-ups.

Even though start-ups utilize entrepreneurs' or their family's money in very early stages, investments of professionals such as venture capitalists and angel investors contribute much more money per financing round [50].

Kaplan and Strömberg [53] state that venture capitalists, especially, offer a solution by providing financial support for entrepreneurs having novel ideas without

money. Therefore, most successful innovative technology companies were backed by such financing sources before growing and impacting markets. As obtaining financing is a difficult task for an entrepreneur during these stages, knowing about the potential investors and their investment criteria is one of the most critical issues [24].

### 2.4.1. Start-ups and Venture Capital

As it was mentioned, VCs have a critical role in the future of start-ups compared to other investors. Most research evaluating small-company funding utilized data collected from VCs. Therefore, this section evaluates VCs' relations with start-ups.

VCs back companies not only financially but also managerially. According to Kaplan and Stromberg [53], VCs are conscious investors who observe, choose, and evaluate the companies that they invest in. VCs provide several benefits for start-ups such as the support in employee hiring. More importantly, because VCs have a large network and supply chain, VCs assist these ventures to find and reach proper customers. Several studies in the business literature have investigated VCs' investments in start-up firms [50, 54–56].

Kanniainen and Keuschnigg [54] evaluated VC finance and presented important results related to the VC portfolio. The results of the study showed that the number of firms which invested in, and the executive advice are related to each other, and there is an optimal size in the start-up numbers. Moreover, the study states that VCs don't prefer to invest and dispense advice to too many companies. These results also show that Contech start-ups' could have difficulties finding VCs that support them.

Hellmann and Puri [55] evaluated the influence and importance of VC on the improvement of start-ups. According to the results of the study, VCs are interest in start-ups' professional attitudes such as marketing and human resource actions. Also, ventures that are backed by VCs show different behavior in terms of managerial team. In a nutshell, as the study highlights that compared to other conventional financiers, VCs have a crucial impact on small companies.

Bocken [56] assessed VCs' investments in sustainable start-ups and showed the need for these start-ups for the support of venture capitalists. Similarly, this article found that venture capitalists provide not only financial support but also professional consultations and networking. The results argue that business-related factors such as a durable business model are among key success criteria, while the absence of appropriate investors and volatile investment approach are among failure factors.

## 2.5. Investors' Decision-making Process

Because start-ups inherently possess uncertainty, high-risk, and high-growth potential, investing in emerging technology start-ups is not a straightforward process for investors, as well [57]. Accordingly, determining the investment decision-making criteria of investors is quite critical for not only technology start-ups but also their investors. Even though several studies focused on investment criteria of VC, business angels, and other start-up investors from a general perspective [23–27], a limited number of articles focused on technology-related investments [28–31]. Also, none of these technology start-up-related studies was not construction-specific.

For example, Block *et al.* [26] evaluated investment criteria of VC, business angels, and family offices. The study evaluated seven attributes including Profitability, Revenue growth, Track record management team, Current investors, Business model, Value-added of product/service, and International scalability. The results of the study showed that revenue growth is the most important investment factor, and it is followed by high value-added of the product/service and track record of the management team factors. VCs and BAs are prone to attribute more importance to revenue growth, rather than profitability. Moreover, Gompers *et al.* [27] focused on the VC's decision-making processes during pre-investment screening, structuring investments, and post-investment monitoring phases. The study evaluated the Management team, Business model, Product, Market, Industry, Valuation, Ability to add value and Fit criteria as important factors for investment selection. Besides, the authors discussed financial metrics used by investors. The study results revealed that the management team is the most critical factor for venture capitalists when they make investment decisions.

Nevertheless, A few studies focused on technology investment decision-making criteria used by investors financing small innovative companies. Bachher and Guild [28] determined decision factors of early-stage technology investors throughout research conducted with business angels, private venture capitalists, and public VC funds. The study evaluated 95 criteria under five categories: i) characteristics of the entrepreneur, ii) characteristics of the market, iii) characteristics of the venture offering, iv) investor requirements, and v) characteristics of the investment proposal. The study findings showed that the entrepreneur characteristics category is the most important one for investors when they evaluate technology investments.

Moreover, while business angels considered venture offering (product/service) as a key decision-making criterion, private venture capitalists regarded market characteristics, such as the attractive growth potential of the market, as critical factors for their investment decision. Besides, Masini and Menichetti [30] evaluated behavioral factors affecting renewable energy technology investors' decisions. The participants of the study consisted mostly of VC and private equity firms (%37). The authors evaluated the A-priori belief, policy preferences, and technological risk attitude of investors. The findings revealed that a-priori beliefs of investors, which are confidence in technology effectiveness and confidence in market efficiency, positively affect investors' financial support for renewable energy technologies.

On the other hand, even though such investments in early-stage technology companies are quite critical for the digitalization of the construction industry, no study has investigated the decision-making criteria of construction technology investors in the literature. Therefore, this study aims to determine investors' decision-making criteria when evaluating technology start-ups providing technology service/products to create a more digitalized AEC-FM industry.

# 3. RESEARCH METHODOLOGY

This study proposes a model to discover factors affecting the motivation and investment level of financiers supporting AEC-FM technology start-ups. The model also allows for the evaluation of indirect relations among criteria. After forming the proposed framework, main factors were determined through extensive literature, and a survey was designed for Contech start-up investors. Finally, collected data was analyzed using Structural Equation Modeling (SEM). Figure 3.1 shows the steps of the study's research methodology.

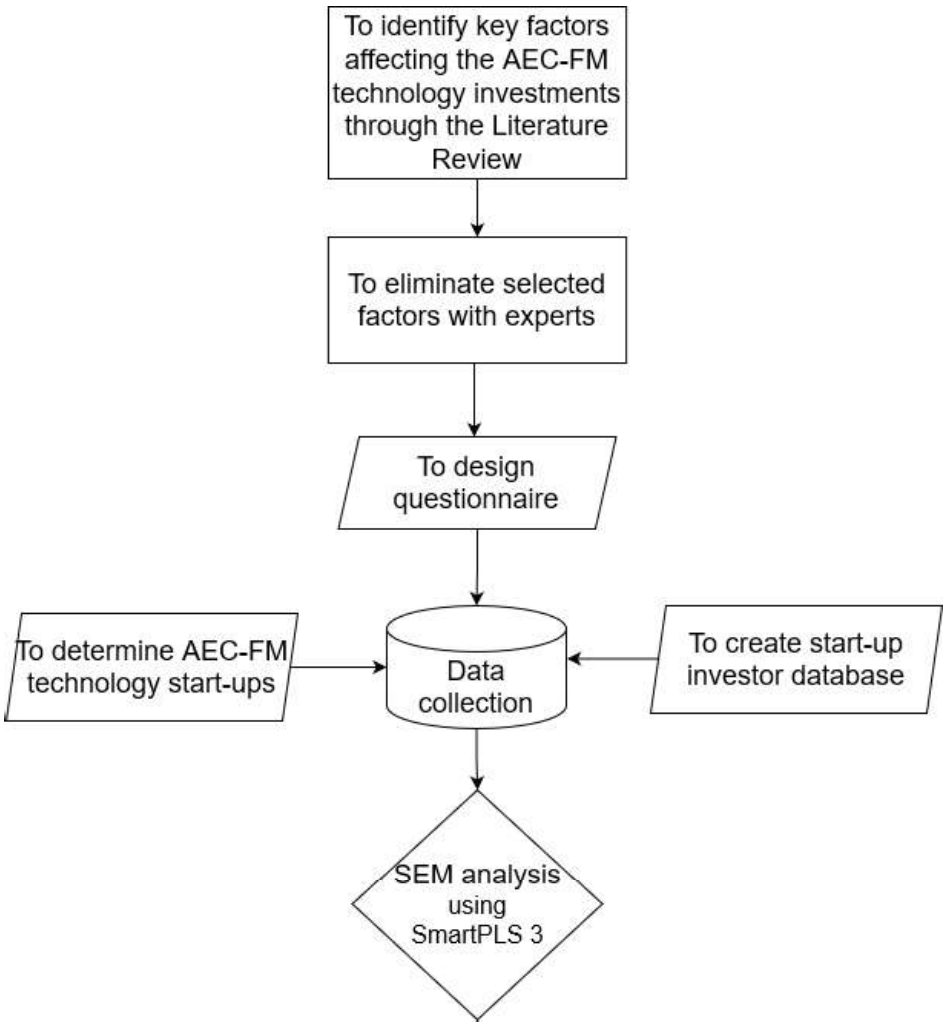


Figure 3.1. Steps of Research Methodology.

### 3.1. Research Framework and Hypotheses Development

Even though various research has determined the decision-making factors affecting investors' opinions, no study has investigated drivers of Contech start-up investments and factors influencing investor motivation. To deeply discover the nature of the Contech investment domain, establishing suitable factor the evaluation is highly important. By considering the existing literature on start-up investments and collaborating with two experts who are experienced in the technology investment domain, this study proposes a research framework (Figure 3.2). In this study, investors' decisions were evaluated through two dependent factors that are investors' Contech investment motivation and Contech investment share in their portfolios. These decision factors were expected to be influenced by Investor Familiarity, Investor Characteristics, Environmental Factors, Entrepreneur Characteristics, Investment Characteristics, Market and Product Characteristics, and Legal Factors. Following sections state the hypotheses of the research presented in Figure 3.2.

In order to define factors influencing Contech start-up investors, an extensive literature review was conducted. As a result of the literature review, 40 criteria were defined by utilizing 12 academic papers focusing on capital investments. The factors were evaluated through interviews with two academicians and two professionals experienced in the technology investment domain. 16 factors were eliminated because of the unsuitableness for start-up investments, while others were merged and paraphrased. Also, 4 factors that were not mentioned in previous studies were added to the list by experts. Finally, 28 criteria were listed under 7 categories. Tables 3.1-3.6 show the final list of clusters, factors, and reference information.

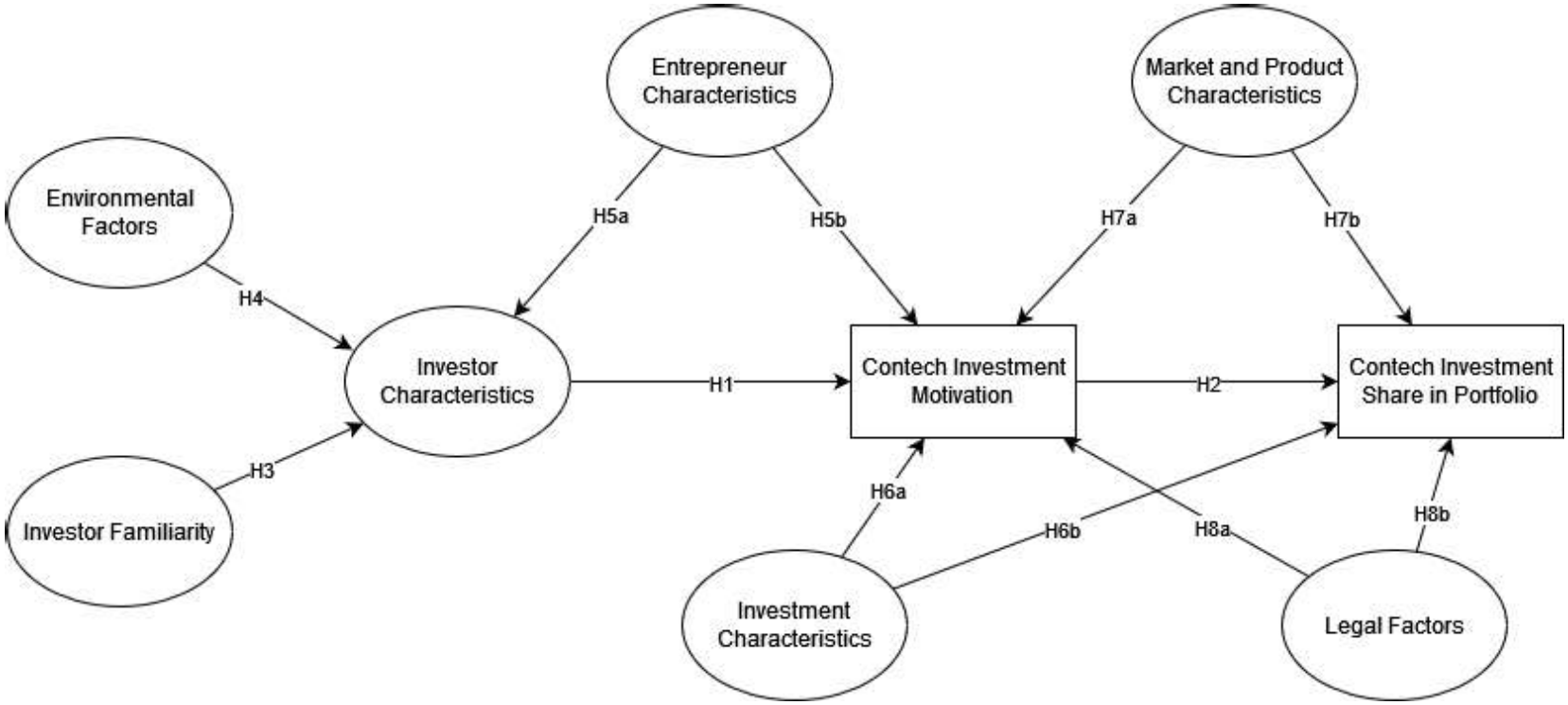


Figure 3.2. Conceptual Model.

### 3.1.1. Investor Characteristics

Shane [58] states that because each human being does not have the same knowledge and experiences, investors might variously perceive the characteristics and capability of a venture. Therefore, investors' characteristics and background play a critical role in their decision-making process.

For example, investors' educational and working experience background creates a basis for their upcoming investments because of their familiarity with the service or product. According to Masini and Menichetti [30], these types of personal experiences related to investors' educational and industrial practices lead to a priori beliefs. Based on the study of Masini and Menichetti [30] on renewable energy technologies, we can say that in terms of construction technologies, the feasibility and appropriacy in the market play a critical role in making the venture successful. Therefore, to invest in such a venture, investors need to be familiar with the product and have a perspective that this venture is capable of success in the market.

Moreover, VCs are frequently defined as "risk-prone" in the literature [26], and the risk attitude of the investor directly impact their investment decisions. As Masini and Menichetti [31] state, radical technology investments are quite risky, and investors' approach directly affects their decision and investment level. As innovative construction technologies are novel and involve uncertainty, it is expected that risk-taker Contech investors who lean towards technology innovations tend to be more motivated to invest more in Contech technologies. In a nutshell, the experience background of investors and their product/service familiarity, which contribute to a priori belief about the sufficiency of the technology, directly impact the reliance of the venture and cause more investment [31]. Hypotheses related to investor characteristics were listed below:

- **H1:** Investor Characteristics have a direct impact on Contech Investment Motivation.
- **H2:** Investor's Contech Investment Motivation have a direct impact on Contech Investment Share in Portfolio.

- **H3:** Investor's Familiarity with construction technologies have a direct impact on Investor Characteristics.

Table 3.1 presents items added to the questionnaire to measure the characteristics of investors.

Table 3.1. Investor Characteristics Items.

| **Clusters** | **Code** | **Factors** | **References** |
|---|---|---|---|
| Investor Familiarity | InvFam | Familiarity with the technology | [30, 31] |
| Investor Characteristic (INV) | INV1 | Level of risk acceptance for radical technological innovations | [30] |
| | INV2 | Level of confidence in emerging digital technologies | [31] |
| | INV3 | Patience to see profit | Expert Opinion |

### 3.1.2. Environmental Factors

Several researchers have discussed the role of the institutional environment of investors in their decision-making processes. Institutional isomorphism, which means the homogeneity of institutions [59], leads investors to adopt the standards of their organization's environment. Accordingly, Masini and Menichetti [31] discussed that institutional isomorphism has an impact on investors' decision-making attitudes, and they evaluated this effect through successful cases from the industry (mimetic isomorphism) and the advertence of experienced executives and consultants (normative isomorphism). The authors predict to observe a relationship between these environmental factors and investor' Renewable Energy (RE) technology adoption. Shao *et al.* [60] investigate the decision-making process of infosec investors, and the result of their study showed that investors considerably tend to apply "let's follow others" in their decision process. Especially for new technology investment, investors might be under external pressure much more than the conventional sectors.

Considering innovative construction technologies are newly improving areas, environmental factors might influence investors' attitudes and decisions who consider Contech start-ups to invest. Hypothesis related to environmental factors is:

- **H4:** Environmental Factors have a direct impact on Investor Characteristics.

Table 3.2 presents items added to the questionnaire to measure investors' perception of environmental factors.

Table 3.2. Environmental Factors.

| **Clusters** | **Code** | **Factors** | **References** |
|---|---|---|---|
| Environmental Factors (ENV) | ENV1 | Influence of peers (other investors) | [30] |
| | ENV2 | Influence of key market participations (consultants) | [30] |
| | ENV3 | Influence of local and global agenda | Expert Opinion |

### 3.1.3. Entrepreneur Characteristics

As most of the AEC-FM-related technology firms are at the start-up level, and VCs are known for their investment in small-size companies, this study assumes that construction technology investors highly consider entrepreneur's team-related factors to decide their investment because the uncertainty is high for start-ups. Previous studies showed that some VC and private equity companies consider the management team of the venture much more important than the business factors and found out that investors highlight the importance of the management team frequently [27,61]. According to the results of Gomper's study [27], an entrepreneur's management team is the most important criterion for venture capitalists. Similarly, according to Rostamzadeh *et al.* [24], entrepreneurs' characteristics and the ability of the management team are of great importance for investors to decide the investment. Management-related fac-

tors, such as education and personal background, directly affect the possibility of a venture being successful [24]. Especially for technology-focused investments and collaborations, which have a high level of uncertainty, these types of factors play critical roles in the decision phase. For example, Cui *et al.* [29] showed the importance of some success drivers such as trust and communication, and organization stability for selecting new technologies and innovations providers. In a nutshell, this study assumes that entrepreneur characteristics play a critical role in the investment decisions of construction technology start-up investors. Hypotheses related to entrepreneur characteristics were listed below:

- **H5a:** Entrepreneur Characteristics have a direct impact on Investor Characteristics.
- **H5b:** Entrepreneur Characteristics have a direct impact on Contech Investment Motivation.

Table 3.3 presents items added to the questionnaire to measure investors' perception on Entrepreneur Characteristics.

Table 3.3. Entrepreneur Characteristics Items.

| **Clusters** | **Code** | **Factors** | **References** |
|---|---|---|---|
| Entrepreneur Characteristics (ENT) | ENT1 | Experience, technical, industrial skills | [23, 62] |
| | ENT2 | Managerial capabilities and business awareness | [23, 28, 62–64] |
| | ENT3 | Ability to react to risks | [24, 25, 28, 63, 64] |
| | ENT4 | Trust and communication | [24, 25, 29] |
| | ENT5 | Reputation of management | [62, 63] |
| | ENT6 | Sustainable and value-added product development capacity, vision, and competitive strategy | [63] |
| | ENT7 | Well-defined scope and strong focus | Expert Opinion |

### 3.1.4. Investment Characteristics

Factors related to investment characteristics and investor requirement cannot be ignored when evaluating a new technology investment. Sapienza and De Clercq [65] states that even though each newly established company possesses some risks, high-tech-based companies can be more challenging for investors. Especially, it is expected venture capitalists to be patient to see the profit of technology investments because the development and marketability of products or services of these kinds of ventures could take longer than anticipated [66]. Considering the inherent riskiness of construction technology start-up investments stemming from its limited examples, evaluating financial criteria such as the potential of high return and exit opportunities is a necessity for VCs. On the other hand, several studies in the literature evaluate VC investments as high-risk and high-growth-based ventures [26,67,67]. The principal consideration of VCs is the capacity of the company to increase its scale [68], and it causes to shorten the period of returns. Besides, because of the uncertainty of future cash flows, using financial evaluating methods might not be efficient to evaluate the investments of VCs [27]. Therefore, we can assume that utilizing qualitative methods rather than NPV or IRR is more reliable for VCs when deciding on construction technology investment level. Hypotheses related to investment characteristics were listed below:

- **H6a:** Investment Characteristics have a direct impact on Contech Investment Motivation.
- **H6b:** Investment Characteristics have a direct impact on Contech Investment Share in Portfolio.

Table 3.4 presents items added to the questionnaire to measure investors' perception on Characteristics of Investment.

Table 3.4. Investment Characteristics Items.

| **Clusters** | | **Factors** | **References** |
|---|---|---|---|
| Investment Characteristics (INVM) | INVM1 | Growth rate projections | [25, 69] |
| | INVM2 | Potential profit and cash flow of investment | [24, 25, 62, 64, 69] |
| | INVM3 | Continuity to company portfolio | [62] |
| | INVM4 | Exit opportunity | [23, 24, 62, 69] |
| | INVM5 | Favorable tax treatment | [25] |

### 3.1.5. Market and Product Characteristics

Market and product characteristics have frequently included in models of studies evaluating investments and investor decision-making (e.g., [23–25]). When we consider the improving market conditions of emerging technology-related products/services, one of the most important criteria that need to be assessed by the investors is market-related factors. VCs aim to invest in companies that promise to provide an expected return, and market features such as the potentials for innovative products should be highly considered in the decision-making process by investors [28]. As Rostamzadeh *et al.* [24] stated, investors might predict their investment's outcomes by conducting market research and assessing the target market in detail. On the other hand, when it comes to technology start-ups, fragmentation of markets is also important for both entrepreneurs and investors. Market fragmentation refers to diversification and segmentation of a market into different competitive parts [70]. Fragmentation leads markets to be heterogeneous and it directly affect the dynamics of the market and the performance of the venture [71]. Therefore, it is considered by investors when evaluating technology companies.

Moreover, besides the market conditions, product characteristics directly affect the decisions of VCs. The product features such as uniqueness or innovativeness directly

impact its competitiveness and attractiveness in the market [25]. Dhochak and Sharma [25] showed that VCs tend to be interested in the uniqueness and market acceptability of the product or service in their investment decision-making process. Also, according to Zinecker and Bolf [62], products' potential to compete has the highest significance for investors. Hypotheses related to legal factors were listed below:

- **H7a:** Market and Product Characteristics have a direct impact on Contech Investment Motivation.
- **H7b:** Market and Product Characteristics have a direct impact on Contech Investment Share in Portfolio.

Table 3.5 presents items added to the questionnaire to measure investors' perception on Market and Product Characteristics.

Table 3.5. Market and Product Characteristics Items.

| **Clusters** | | **Factors** | **References** |
|---|---|---|---|
| Market and Product Characteristics (MP) | MP1 | Established ecosystem and infrastructure level | [24] |
| | MP2 | Fragmentation of the market | [64] |
| | MP3 | Competitive advantage | [23, 25, 62, 69] |
| | MP4 | Product superiority (innovativeness, uniqueness) | [23, 24, 62, 64] |
| | MP5 | Market acceptability | [23, 25, 64, 69] |

### 3.1.6. Legal Factors

The diffusion and standardization of a new technology highly depend on regulations and governmental issues. Both investors and technology entrepreneurs are open to being affected by the regulatory environment throughout their project life cycle. Dhochak and Sharma [25] highlighted the role of institutional criteria in VCs' decision-making process. The legal framework of start-up investments and entrepreneurship

have a critical role in early-stage ventures providing innovative technologies for the improvement of the company [31].

Poor and unsteady legal systems and policies may cause the investors to face ambiguity [72]. On the other hand, because these factors influence not only VCs' decisions but also the entire economic environment of nations, they play a critical role in VCs' aims for their portfolios [73, 74]. Cui *et al.* [29] stated that as technology and the market get developed, the ambiguity decreases, and the company focus on their technologies then accordingly, laws and regulations of authorities become a critical mean to compete. For this reason, it can be predicted that it affects the decision of the investors on construction technology investments.

Hypotheses related to market and product characteristics were listed below:

- **H8a:** Legal Factors have a direct impact on Contech Investment Motivation.
- **H8b:** Legal Factors have a direct impact on Contech Investment Share in Portfolio.

Table 3.6 presents items added to the questionnaire to measure investors' perception on Legal Factors.

Table 3.6. Legal Factors.

| **Clusters** | **Code** | **Factors** | **References** |
|---|---|---|---|
| Legal Factors (LG) | LG1 | Strength of legal rights/legal framework | [25, 72] |
| | LG2 | Strength of investment policies | [31, 72] |
| | LG3 | Strength of entrepreneurship policies | [72] |
| | LG4 | Eligibility of the venture's corporation type for investment | Expert Opinion |

## 3.2. Questionnaire Survey

A questionnaire survey is designed and utilized to collect data for the study. An online questionnaire was prepared to reach Contech investors from different countries. The questionnaire aims to collect general information related to participants and the information related to their Contech investments. Also, it includes not only qualitative but also quantitative inquiries.

The questionnaire consists of three sections. The first part of the questionnaire includes common questions related to respondents such as profile investor profile (VC, Engineering company, etc.), company name, and position. In the second part, respondents were asked to select their Contech investment and to rank their investment motivation and Contech share in their portfolio. Most of the respondents invested in more than one Contech technology. Finally, they were asked to evaluate 28 factors presented in the previous section and clustered under seven categories based on their experiences using a 5-point Likert scale (1= very low, 2= low, 3= medium, 4=high, 5= very high). The survey was presented in Appendix A.

Initially, AEC-FM technology start-up companies and their investors were identified by utilizing professional social media platforms. Due to the Contech start-up environment being still developing and it is hard to observe established technology markets in developing countries like Turkey, this study is not focusing on a specific country. Because start-up investors are not limited to country-based markets and have diversified portfolios, the participation of investors from different countries is expected not to affect the homogeneity of the data. Therefore, approximately 800 questionnaires were sent to investors who work in start-up financing environment in different countries. 48 of 800 questionnaires were returned, which resulted in a response rate of 6%.

Compared to published papers in the construction management literature that utilizing SEM for data analysis, response rate of this study is quite low (e.g., Ozorhon and Oral [75] had 33%; Sambasivan *et al.* [76] had 77.5% response rate). Considering

the improvement of Contech start-up environment, the number of investors focusing on this area is quite limited. Therefore, this study analyzes the proposed framework through 48 questionnaires. Even though there are several studies suggest the use of SEM with low sample size (e.g., 30), most of the article states that sample size should be higher than 100. Therefore, this study analyzes collected 48 questionnaire data utilizing partial least square estimation (PLS-SEM), rather than covariance-based SEM (CB-SEM).

### 3.3. Structural Equation Modeling Analysis

Because this study's conceptual framework is complex and has relationships among independent latent variables, structural equation modeling (SEM) is used to test the hypotheses.

SEM method, which assesses multivariate data, is used for analyzing the relationships between one or more independent and dependent variables. The method has been utilized by several researchers who focus on different topics in construction management are for decades [75, 77–79]. SEM is a theory-based approach and indicates a range of statistical analyses as confirmatory methods to test hypotheses through empirical data. As a more comprehensive and systematic approach, SEM is defined as "second generation multivariate analysis" in the literature [80].

Unlike first generation-generation statistical analysis such as multiple regression, factor analysis, and analysis of variance [75], SEM provides the ability to evaluate complex problems in a structured way and enables researchers to modify their models [81]. On the other hand, assessing direct and indirect relations simultaneously differentiates SEM from other methods.

SEM allows the creation of hypothetical models including both observed variables and unobserved (latent) variables. Latent variables, which indicate one of the most important concepts of this method, are measured indirectly using related observed variables. Moreover, because the approach relies on theories, the model needs to have

a dependable theoretical background. A two-stage method is frequently used in the literature to evaluate whether the data support the model: measurement model and structural model [81]. These two models provide an extensive confirmatory evaluation for construct [82]. The measurement model provides an assessment for observed variable reliability and the way of measuring the hypothetical constructs with regards to observed variables, while the structural model evaluates the relations between construct and examines hypothetical effects [83].

Figure 3.3 shows an example of measurement and structural models adopted from Xiong *et al.* [84]. Where Y1 and Y2 are latent variables; X1 to X6 are observed variables; e1 to e6 are measurement errors, b1 to b6 and r1 indicate path coefficients which represent direct effects between variables.

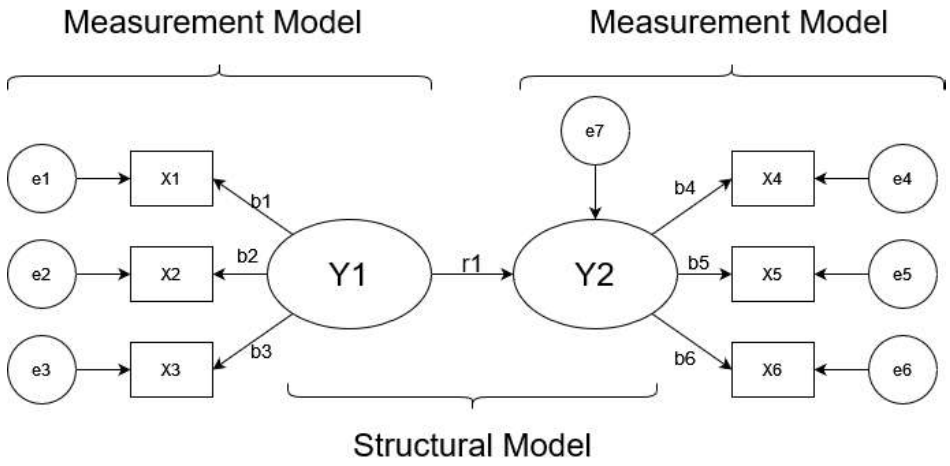


Figure 3.3. Schematic Diagram of Structural Equation Model.

### 3.3.1. Partial Least Squares Structural Equation Modeling (PLS-SEM)

There are two approaches utilized in SEM, which are covariance-based SEM (CB-SEM) and component-based analysis that uses partial least square estimation (PLS-SEM) [85]. Even though CB-SEM needs a large amount of data, PLS-SEM can deal with small-size and non-normal data [86]. Hair *et al.* [87] examined PLS-SEM and CB-SEM and recommended the use of PLS-SEM when the sample size is under 100.

Therefore, as Darko *et al.* [88] state, PLS-SEM has become prominent in the construction management literature [89–93]. For example, Aibinu *et al.* [90] evaluated the relations between the organizational justice factors and cooperative behavior using survey data consisting of 41 contractors' questionnaires. Moreover, Alashwal and Abdul-Rahman [91] searched for construction projects' process of inter-project learning throughout 36 data collected from large construction sites, and Darko *et al.* [88] determined the effects of barriers, drivers, and promotion strategies on green building technology applications with survey include 43 professionals' data. Therefore, this study utilizes PLS-SEM by using SmartPLS 3 software to determine the factors affecting Contech investors' motivation and Contech investment share in their portfolio through a questionnaire survey with 48 data.

3.3.1.1. Evaluation of the Measurement Model. PLS-SEM analysis starts with evaluation of measurement model, and it tests whether measurement variables explain corresponding latent variables. To do so, several variables are such as composite reliability, convergent validity, and discriminant validity evaluated.

- **Composite reliability (CR) and Cronbach's alpha:** Composite reliability and Cronbach's alpha values refer to the consistency of the model. They show that measurement (observed) variables' compatibility with the latent variables. Namely, they explain to what extent latent item is explained by corresponding observed variables. The values range from 0 to 1, and it should be over 0.7 for a reliable model [94, 95].
- **Convergent validity:** Convergent validity is evaluated to assess the positive correlations between measurement item which belong to the same construct item [86]. AVE value and factor loadings are the indicator of convergent validity. AVE value should be over 0.5 for a satisfactory model [80]. For factor loadings, several different thresholds are suggested from different researchers. For example, Hulland [96] suggested to use items having 0.5 or higher factor loading to reach a desired convergent validity, while some researches presented the threshold as 0.6 [97] and 0.7 [98].

- **Discriminant validity:** In order to test the discriminant validity of construct variables, Fornell-Larcker Criterion, Cross Loadings, and Heterotrait-Monotrait Ratio (HTMT) values were assessed. Discriminant validity tests what extent to which a latent factor differs from others [96]. Fornell- Larcker Criterion compares the correlations of latent variables and the square root of the AVE of each latent factor. The diagonal values indicate the square root of the AVE score of latent variables, and they are expected to be higher than the correlation between other latent variables.

3.3.1.2. Evaluation of the Structural Model.

- **Collinearity (VIF):** The variance inflation factor (VIF) assesses the collinearity of indicators in a partial least square SEM analysis [98].
  Observed variables that have a VIF value exceeding 5 have a significant collinearity problem. In the best-case scenario, VIF values are around 3 and lower.
- $\boldsymbol{R^2}$ **:** Additionally, $R^2$ values of each dependent construct variable are provided by SmartPLS 3. $R^2$ is the coefficient of determination, and the software calculates it by utilizing the traditional regression method [99]. The $R^2$ value of 0.25 is considered weak, while 0.50 and 0.75 are considered moderate and substantial [98, 100, 101]. However, models having low $R^2$ values could also be trustable for different contexts [89, 98].
- $\boldsymbol{f^2}$ **:** Moreover, the effect size ($f^2$) of each independent variable on the dependent construct is evaluated. As Hair *et al.* [98] states, the path coefficients and effect sizes are considerably similar. Effect size values higher than 0.02, 0.15, and 0.35 indicate small, medium, and large effect sizes ($f^2$), respectively [102].
- **Path coefficient:** The path coefficients indicate the independent variable's level of influence on the dependent variable, and higher path coefficients mean superior association [89]. The path coefficient values ranging between 0.5 and 1.00 stand for a strong effect, values between 0.3 and 0.5 indicate a moderate effect, and values ranging between 0.1-0.3 indicate a weak influence.
- **t-value and p-value:** The structural model is tested using the bootstrapping

function of the SmartPLS 3. The paths having a t-value greater than 1.96 are considered statistically significant at the 0.05 level (p-value $\leq 0.05$).

- **Model fit:** Even though the software provides model fit values, presenting them in a report is not suggested by researchers. Hair *et al.* [87] states that authors need to be careful when considering and reporting model fit in PLS-SEM. Because these indices are still under research, the PLS-SEM team state that not present in the report (SmartPLS).

Table 3.7 and Table 3.8 summarize the criteria for PLS-SEM analysis evaluation.

Table 3.7. Metrics Used to Interpret PLS-SEM Measurement Model Results.

| **Criteria** | **Recommended Value** |
|---|---|
| Factor loadings | $\geq 0.7$ (or $\geq$0.4 for exploratory studies) |
| Cronbach's alpha | $\geq 0.7$ |
| Convergent validity | AVE $\geq 0.5$ |
| Discriminant validity-Fornell-Larcker | Diagonal values >following items |
| Discriminant validity-HTMT | For conceptually similar constructs: <0.85 |

Table 3.8. Metrics Used to Interpret PLS-SEM Structural Model Results.

| **Criteria** | **Recommended Value** |
|---|---|
| $R^2$ | >0.25: weak; >0.50: moderate; >0.75: substantial |
| $f^2$ (effect size) | 0.02-0.15: small; 0.15-0.35: medium; >0.35: high effect |
| t-value | >1.96 |
| VIF value | <3 |

# 4. RESEARCH RESULTS

## 4.1. Respondents' General Information

### 4.1.1. Respondent Profiles

The participants of this study consist of professionals who invested in technology start-ups focusing on the AEC-FM industry. Even though most of the respondents were working in investing domain, several respondents work in engineering companies that have different investments. In total, 48 respondents participated in the study. Figure 4.1 illustrates the information about the age of respondents. As it can be seen, 35% of respondents were 31-40-year-old, and both 41–50-year-olds and 20–30-year-olds consist of 25% of total participants. It can be inferred that young investors who are not over 50 years old could be more open to a new investing area, and their familiarity with such technologies might be higher compared to older ones.

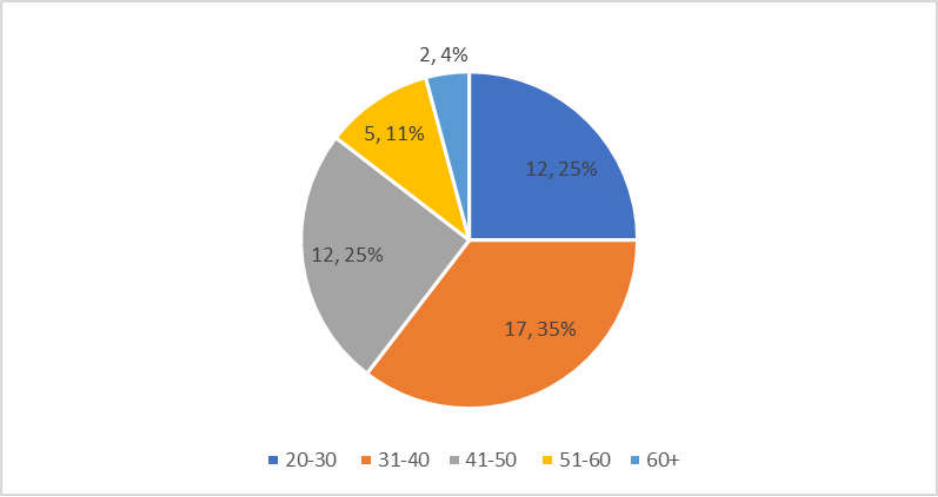


Figure 4.1. Age of Respondents.

Figure 4.2 shows the distribution of respondents' experience in start-up investment domain. As the figure shows, over the half of respondents have 5-10 years (25%)

and over 10 years (29%) experience in this domain. On the other hand, participants who invested in Contech start-up without an experience was only 4%. We can say that experienced investors are more willing to finance such a new start-up environment.

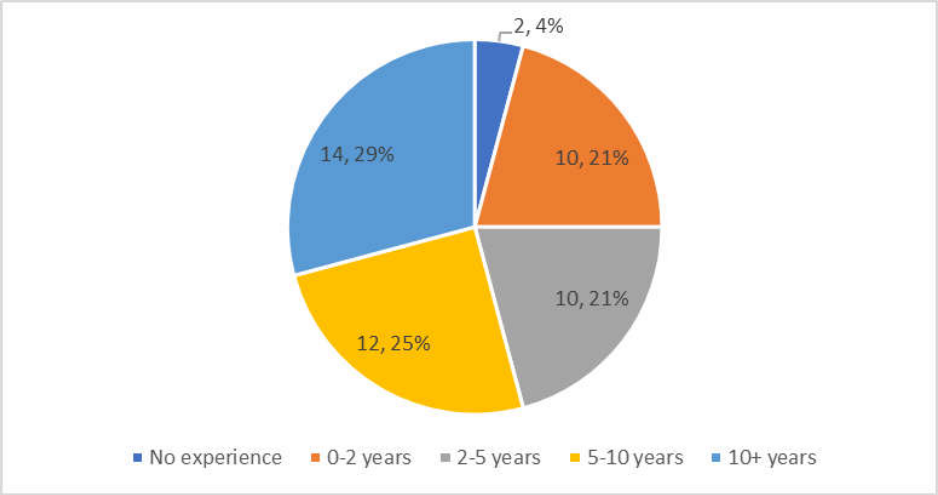


Figure 4.2. Experience in Contech Investment Domain

Education level of respondents was presented in Figure 4.3. The figure shows that more than half of respondents (56%) have a master's degree, and 29% of participants have 4-year college education.

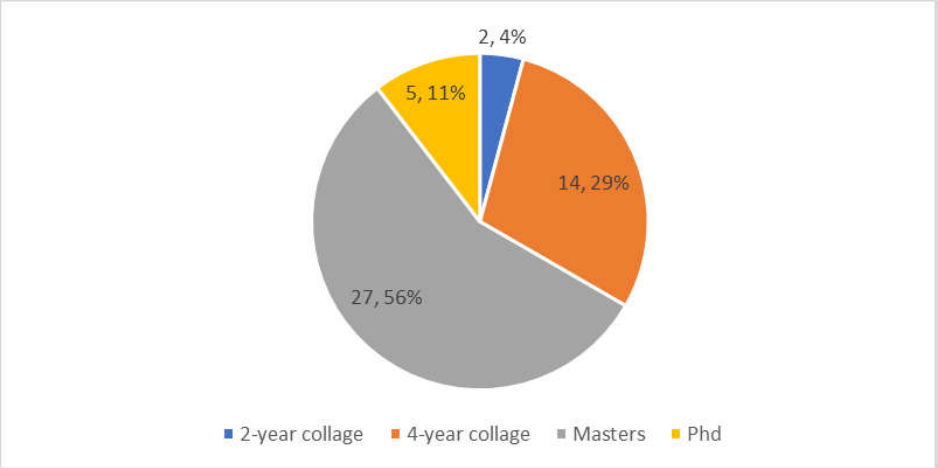


Figure 4.3. Education Level of Respondents.

If we consider the services and provides of Contech start-ups, it can be said that investors who have a background in the industry tend to finance engineering activities. When the importance of familiarity with the product/service is considered, it is reasonable for investors having an engineering education to invest more.

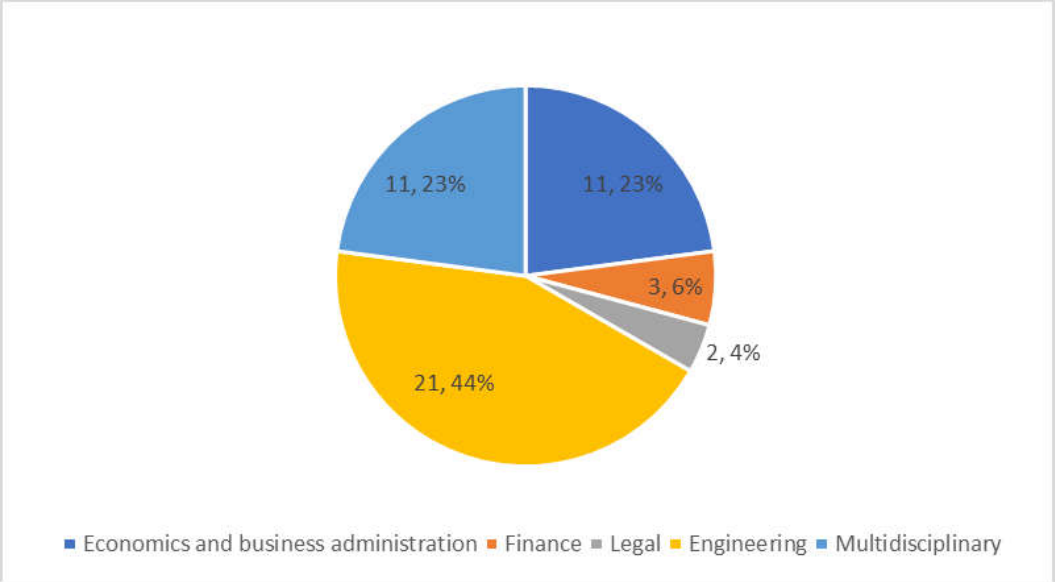


Figure 4.4. Educational Background of Respondents

### 4.1.2. Investor Company Information

Questionnaire participants were asked to provide their company and position information. The investor profile of respondents was presented in Figure 4.5 As the figure shows, VC firms predominantly consist of an investor profile with 73%. VCs have a key role in start-ups surviving and producing innovative technologies. Therefore, it is not a surprising result for a study focusing on Contech start-up investments. On the other hand, private companies constitute 13% of investors.

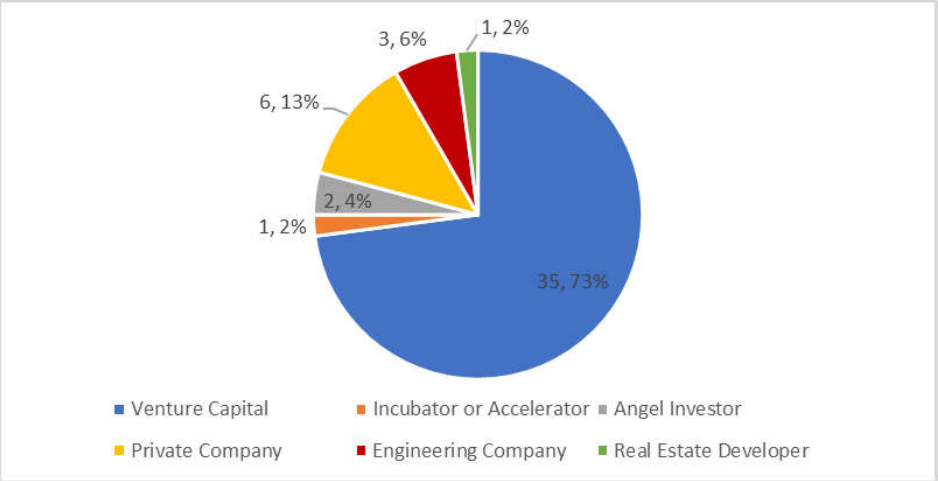


Figure 4.5. Investor Profile.

The companies of the participants of this study are in different countries. Figure 4.6 illustrates the locations of respondents' companies, and it shows that American investment companies (36%) comprise the majority. Because of the VC industry in the US and the start-ups' density located in Silicon Valley (California), this was an inevitable outcome. Even though 13% of respondents didn't indicate the company information, 17% of respondents' companies were in Turkey.

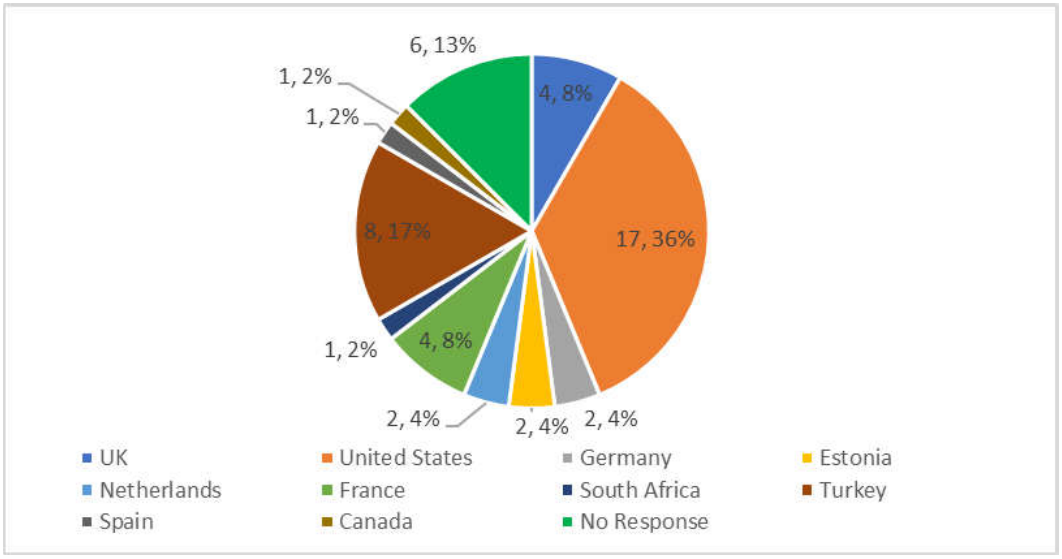


Figure 4.6. Company Location.

The respondents were asked to provide their position in their investment companies. Figure 4.7 shows the responsibilities of participants. Figure shows that most of the participants worked in partners (31%), directors (13%), and managers (10%). In a nutshell, the respondents have key roles in their companies investing in AEC-FM technology start-ups.

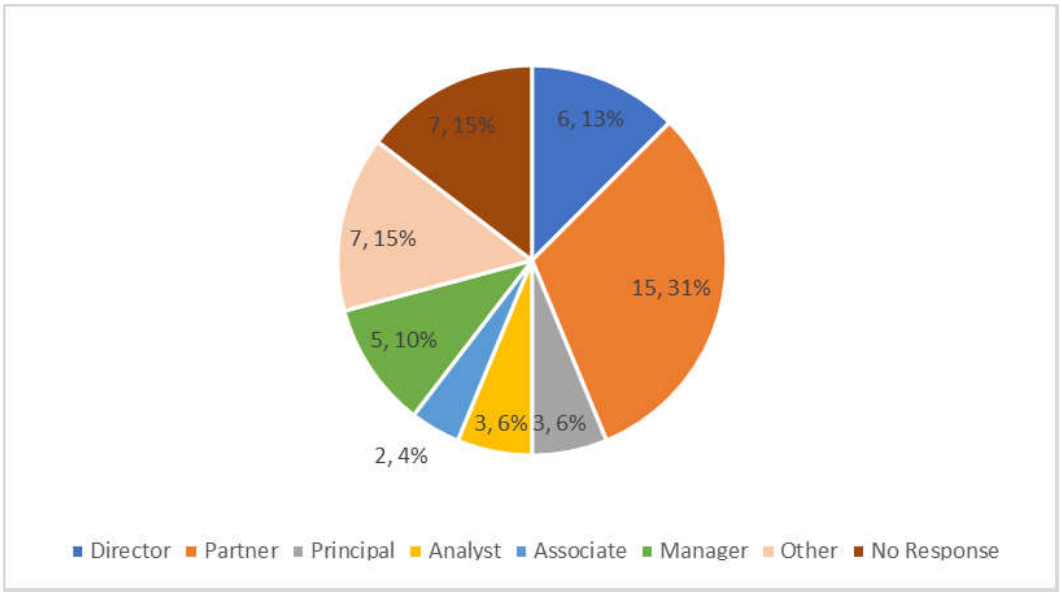


Figure 4.7. Job Description.

### 4.1.3. Invested Technologies

The respondents were asked to indicate their AEC-FM start-up technologies that they invested. Most of the participants invested in more than one Contech technologies.

Figure 4.8 shows the frequency of Contech technologies. The most invested technologies were artificial intelligence (AI), Internet of Things (IoT), 3D modeling, and Digital Twin (DT).

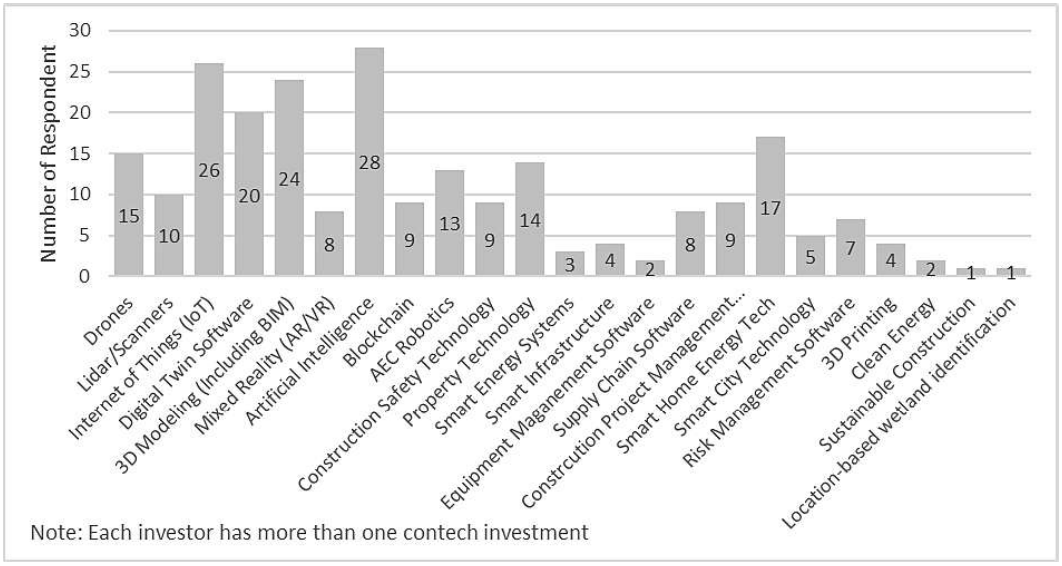


Figure 4.8. Invested AEC-FM Technologies.

## 4.2. Descriptive Statistics

Descriptive statics table of each measurement variable is presented in Appendix B. The table shows maximum and minimum values, mean, variance, standard deviation, and skewness and kurtosis (normality indicators) values.

For normally distributes data, skewness values should range between -2 and +2, while kurtosis values should range between -7 and +7 [103]. Descriptive statics of the data showed that except for one variable (ENT4), all items are ranked below the limits. However, even though SEM analysis assumes the data have a normal distribution, PLS-SEM analyzes non-normal data. Therefore, besides PLS-SEM enables an analysis with small data, it is not an obligation to use normally distributed data.

To evaluate the overall motivation of Contech investors and their Contech investment level, descriptive statistics of these factors were analyzed. According to Aibinu and Al-Lawati [89], mean values with 4 or above on a 5-point Likert scale indicates that participants have a high level of willingness. Table 4.1 shows the results of the descriptive analysis.

The findings show that even though investors are highly motivated to invest in AEC-FM technologies (mean=3.98), their Contech investment share is not that high in their portfolios (mean=2.60). The following sections present the findings of measurement and structure models to reveal the influence of latent factors on these criteria.

Table 4.1. Descriptive Statistics of Investor Motivation and Investment Level.

| | **Mean** | **Median** | **Std. Deviation** |
|---|---|---|---|
| **Contech Investment Motivation** | 3.980 | 4.000 | 0.829 |
| **Contech Investment Share in Portfolio** | 2.604 | 2.000 | 1.410 |

Following figures present the mean values of each observed item of latent variables. Figure 4.9 shows that investor-related factors' mean values range around 4. Mean value of Investor familiarity with technology that they invested in (InvFam) 3.92. This result also indicates that these investors have a background on such innovative technologies.

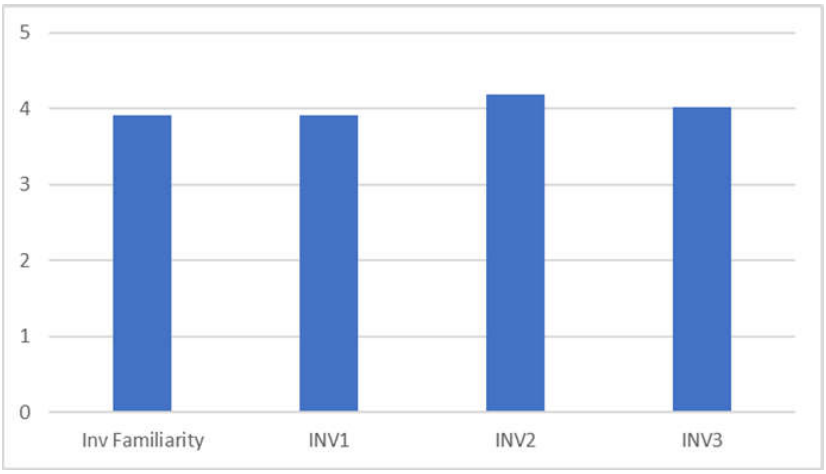


Figure 4.9. Mean Values of Investor Characteristics.

On the other hand, Level of risk acceptance for radical technological innovations (INV1), Level of confidence in emerging digital technologies (INV2), and Patience to

see profit (INV3) have means of 3.92, 4.19, and 4.02, respectively. Because investors invest with a-priori beliefs, it is not a surprising result that they have high level of risk acceptance level, confidence, and patience for such investments.

The mean values of observed variables under entrepreneur characteristics category were presented in Figure 4.10 Trust and communication (ENT4) has the highest mean value (4.52). Considering newly founded technology start-ups don't have a track record, investors need to evaluate them assessing management team's communication skills.

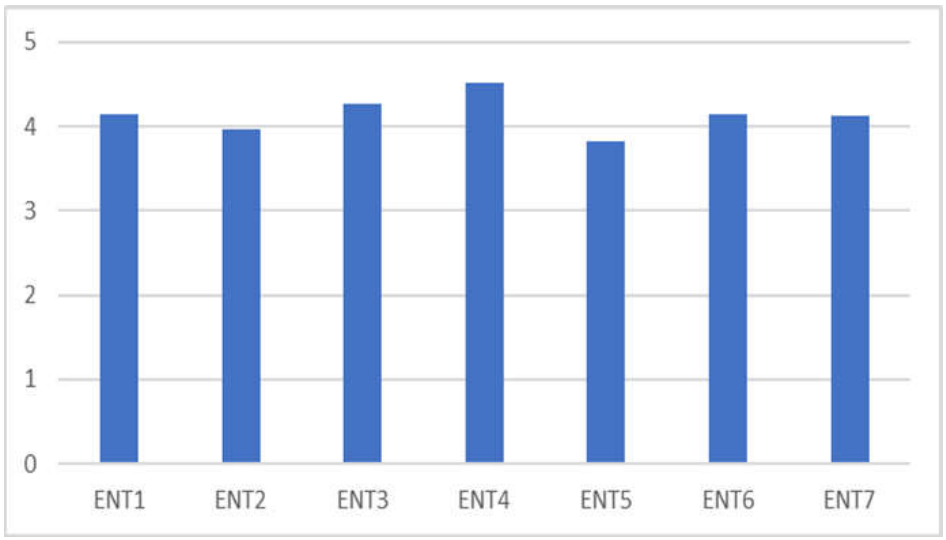


Figure 4.10. Mean Values of Entrepreneur Characteristics.

Figure 4.11 indicates the mean values of market and product related factors. Among five criteria, Established ecosystem and infrastructure level (MP1) factors has the lowest mean value (3.12). Even though this factor has a critical significance for investors, this process could be longer for the construction industry because when compared to other more digitized sectors. On the other hand, Competitive advantage (MP3) has the highest mean rank which is 4.35.

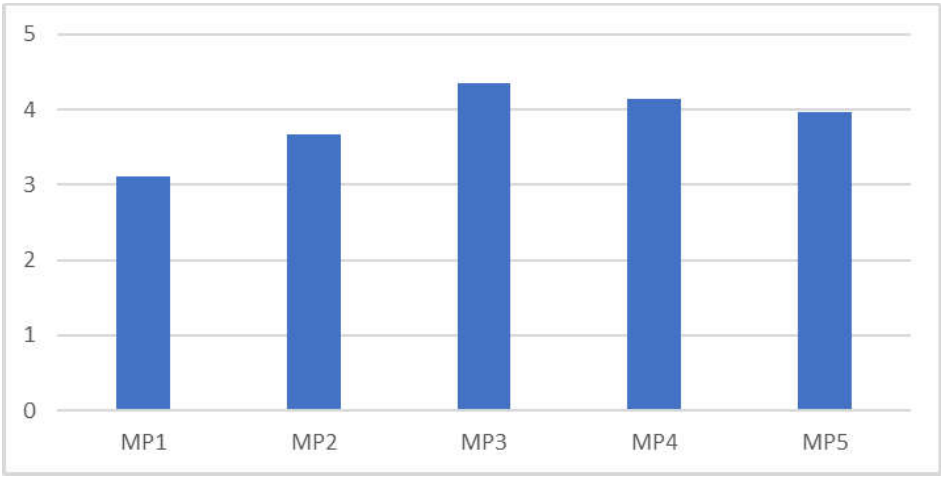


Figure 4.11. Mean Values of Market and Product Characteristics.

Figure 4.12 shows mean values of items related to Investment Characteristics and Exit opportunity (INVM4) has the highest value (4.13). The timing of exit is crucial for investors due to most of investors uses funds with a defined period [27]. Compared to other observed variables, Favorable tax treatment (INVM5) has the lowest mean value which ranked (2.40).

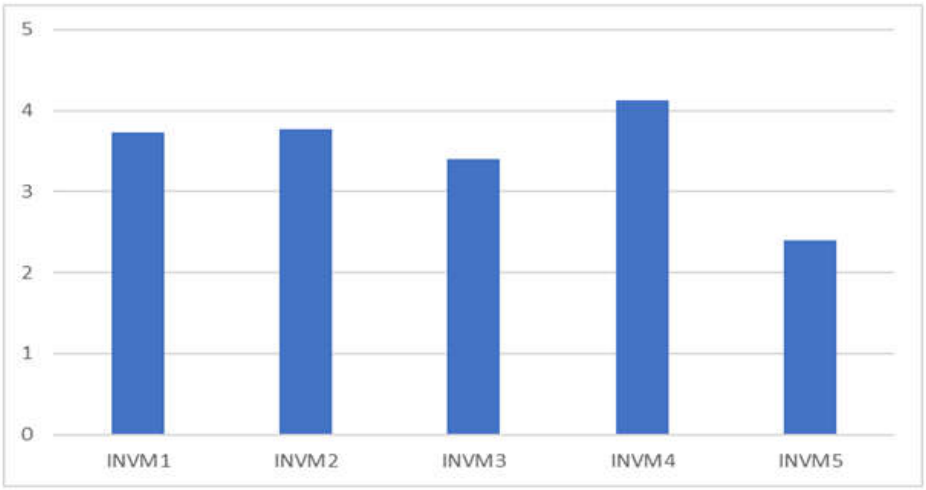


Figure 4.12. Mean Values of Characteritics of Investment Factors.

On the other hand, mean values of legal factors are presented in Figure 4.13 and they ranked around 3. Eligibility of the venture's corporation type for investment (LG4) has the highest value with 3.56, while Strength of investment policies (LG2) is

the lowest ranked criterion with 3.02.

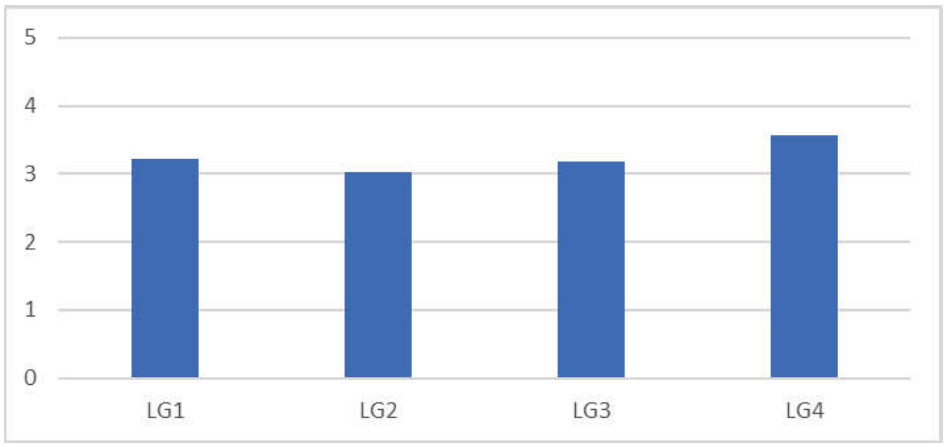


Figure 4.13. Mean Values of Legal Factors.

Lastly, Figure 4.14 presents the mean values of environmental factors. Compared to other latent variables, environmental factors have the lowest ranked variables. The mean values of Influence of peers, Influence of key market participations, and Influence of local and global agenda were 2.94, 2.71, 2.83, respectively.

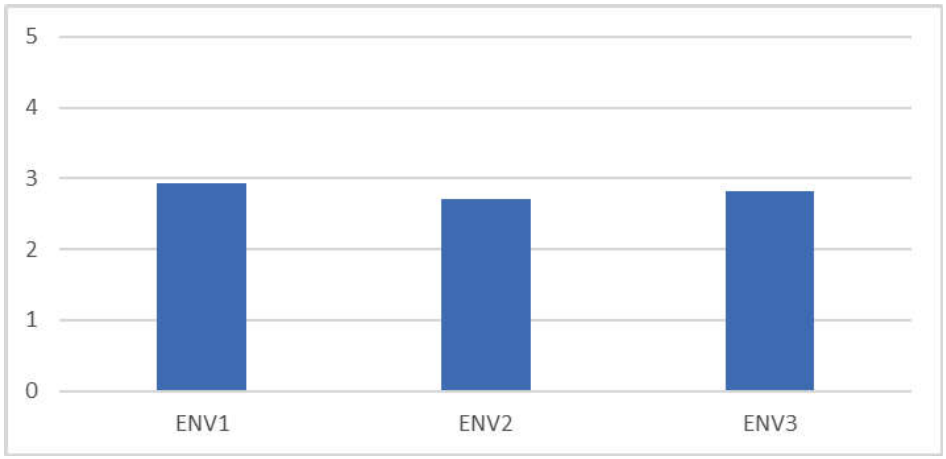


Figure 4.14. Mean Values of Environmental Factors.

## 4.3. PLS-SEM Model Results

### 4.3.1. Measurement Model Results

This section presents the results of the measurement model, namely confirmatory factor analysis (CFA). Firstly, the factor loadings of the measurement items were evaluated. Table 4.2 presents 7 latent variables and corresponding 28 measurement items. As Table 3 shows, we excluded items having a factor loading lower than 0.6 (ENT1, MP3, MP4, INVM4, LG4) and insignificant ones (ENV3) from the model. After deleting not significant factors, we repeated the analysis and listed edited factor loadings, which are statistically significant and higher than 0.6, in Table 4.2. Note that investor familiarity, investor motivation, and share in the portfolio consist of one measurement item, factor loading of these items were found 1.000.

Subsequently, Cronbach's alpha coefficient, composite reliability, and average variance extracted (AVE) scores of each latent variable were evaluated. As Table 4.3 shows, Cronbach alpha and composite reliability values are higher than 0.7, which indicates a good level of reliability. Moreover, as Hulland [96] suggested, convergent validity needs to be assessed when a latent variable is measured by more than one item. AVE value is an indicator of convergent validity, and it should be over 0.5 for a satisfactory model [80].

As Table 4.3 shows, all AVE values were higher than 0.5 for each latent variable of the model. In order to test the discriminant validity of construct variables, Fornell-Larcker Criterion, Cross Loadings, and Heterotrait-Monotrait Ratio (HTMT) values were assessed. Discriminant validity tests what extent to which a latent factor differs from others [96].

Table 4.4 shows the Fornell- Larcker Criterion table that compares the correlations of latent variables and the square root of the AVE of each latent factor. The diagonal values indicate the square root of the AVE score of latent variables, and they are expected to be higher than the correlation between other latent variables.

Table 4.2. Factor Loadings of Measurement Items.

| **Latent Variables** | **Code** | **Factor Loading** | **Final Loading** |
|---|---|---|---|
| Investor Characteristics | INV1 | 0.805 | 0.804 |
| | INV2 | 0.856 | 0.858 |
| | INV3 | 0.839 | 0.838 |
| Environmental Factors | ENV1 | 0.922 | 0.957 |
| | ENV2 | 0.878 | 0.864 |
| | ENV3 | 0.618 | **Excluded** |
| Entepreneur Characteristics | ENT1 | 0.194 | **Excluded** |
| | ENT2 | 0.674 | 0.676 |
| | ENT3 | 0.813 | 0.812 |
| | ENT4 | 0.807 | 0.807 |
| | ENT5 | 0.687 | 0.688 |
| | ENT6 | 0.802 | 0.801 |
| | ENT7 | 0.62 | 0.62 |
| Investment Characteristics | INVM1 | 0.799 | 0.794 |
| | INVM2 | 0.802 | 0.804 |
| | INVM3 | 0.677 | 0.681 |
| | INVM4 | 0.137 | **Excluded** |
| | INVM5 | 0.697 | 0.703 |
| Market and Product Charact. | MP1 | 0.775 | 0.833 |
| | MP2 | 0.7 | 0.789 |
| | MP3 | 0.349 | **Excluded** |
| | MP4 | 0.214 | **Excluded** |
| | MP5 | 0.808 | 0.768 |
| Legal Factors | LG1 | 0.762 | 0.809 |
| | LG2 | 0.885 | 0.861 |
| | LG3 | 0.812 | 0.794 |
| | LG4 | 0.529 | **Excluded** |

Table 4.3. Cronbach's Alpha, Composite Reliability, and AVE Values.

| **Latent Variable** | **Cronbach's alpha** | **CR** | **AVE** |
|---|---|---|---|
| Entrepreneur Characteristics (ENT) | 0.841 | 0.877 | 0.545 |
| Environmental Factors (ENV) | 0.81 | 0.908 | 0.831 |
| Investment Characteristics (INVM) | 0.743 | 0.834 | 0.559 |
| Investor Characteristics (INV) | 0.781 | 0.872 | 0.695 |
| Legal Factors (LG) | 0.766 | 0.862 | 0.675 |
| Market and Product Characteristics (MP) | 0.714 | 0.839 | 0.635 |

As Table 4.4 shows, the bold diagonal value of each latent variable is higher than correlations among other constructs. Besides, Table 4.5 presents cross-loadings of measurement items. We see that there is no cross-loading problem of measurement factors because they have the highest value for their corresponding latent variable.

Table 4.4. Fornell- Larcker Criterion.

| **Latent Variable** | **ENT** | **ENV** | **INVM** | **INV** | **LG** | **MP** |
|---|---|---|---|---|---|---|
| Entrepreneur Ch. (ENT) | **0.738** | | | | | |
| Environmental Factors (ENV) | 0.099 | **0.912** | | | | |
| Charact. of Inv. (INVM) | 0.114 | 0.083 | **0.747** | | | |
| Investor Characteristics (INV) | 0.495 | -0.306 | -0.015 | **0.834** | | |
| Legal Factors (LG) | 0.241 | -0.024 | 0.399 | 0.300 | **0.822** | |
| Market and Product Ch. (MP) | 0.296 | -0.239 | 0.262 | 0.336 | 0.299 | **0.797** |

Table 4.5. Cross loadings of Measurement Variables.

| **Measurement Items** | **ENT** | **ENV** | **FIN** | **INV** | **LG** | **MP** |
|---|---|---|---|---|---|---|
| ENT2 | **0.676** | 0.241 | 0.222 | 0.128 | 0.133 | -0.035 |
| ENT3 | **0.812** | -0.096 | 0.101 | 0.521 | 0.345 | 0.268 |
| ENT4 | **0.807** | -0.046 | 0.101 | 0.411 | 0.176 | 0.427 |
| ENT5 | **0.688** | 0.231 | 0.067 | 0.234 | 0.041 | 0.140 |
| ENT6 | **0.801** | 0.216 | 0.053 | 0.414 | 0.120 | 0.138 |
| ENT7 | **0.620** | 0.046 | -0.037 | 0.189 | 0.148 | 0.414 |
| ENV1 | 0.099 | **0.957** | 0.022 | -0.334 | -0.041 | -0.248 |
| ENV2 | 0.078 | **0.864** | 0.170 | -0.193 | 0.010 | -0.172 |
| INVM1 | 0.136 | 0.033 | **0.794** | 0.098 | 0.175 | 0.360 |
| INVM2 | 0.031 | 0.017 | **0.804** | -0.079 | 0.355 | 0.276 |
| INVM3 | 0.117 | 0.178 | **0.681** | -0.195 | 0.362 | 0.055 |
| INVM5 | 0.049 | 0.070 | **0.703** | 0.098 | 0.402 | 0.359 |
| INV1 | 0.411 | -0.173 | 0.086 | **0.804** | 0.192 | 0.165 |
| INV2 | 0.499 | -0.110 | 0.003 | **0.858** | 0.290 | 0.164 |
| INV3 | 0.329 | -0.447 | -0.113 | **0.838** | 0.268 | 0.478 |
| LG1 | 0.185 | -0.066 | 0.261 | 0.384 | **0.809** | 0.286 |
| LG2 | 0.260 | 0.107 | 0.350 | 0.126 | **0.861** | 0.229 |
| LG3 | 0.127 | -0.132 | 0.401 | 0.203 | **0.794** | 0.209 |
| MP1 | 0.269 | -0.140 | 0.426 | 0.196 | 0.401 | **0.833** |
| MP2 | 0.118 | -0.051 | 0.131 | 0.277 | 0.195 | **0.789** |
| MP5 | 0.317 | -0.360 | 0.102 | 0.317 | 0.143 | **0.768** |

### 4.3.2. Structural Model Result

The structural model was tested using the bootstrapping function of the SmartPLS 3. Figure 4.15 and Table 4.6 show the structural model obtained results. The paths having a t-value greater than 1.96 are considered statistically significant at the 0.05 level. Therefore, hypotheses H1, H3, H4, H5a, H6c, H7a, and H7b were supported with respect to the t-value results. Figure 4.15 represents significant paths with a continuous line, while insignificant paths are presented with dashed lines. The software's model outcome is presented in Appendix C.

The path coefficients indicate the independent variable's level of influence on the dependent variable, and higher path coefficients mean superior association [89]. The path coefficient values ranging between 0.5 and 1.00 stand for a strong effect, values between 0.3 and 0.5 indicate a moderate effect, and values ranging between 0.1-0.3 indicate a weak influence.

The results showed that H5a and H6b hypotheses have a strong effect, H1, H7a, and H7b have a moderate effect, H3 and H4 have a weak influence on corresponding dependent criteria. The findings of the study showed that Entrepreneur Characteristics and Investment Characteristics don't have a direct impact on Investment Motivation.

Moreover, no direct influence has been found between Investment Motivation and Contech Share in Investor Portfolio.

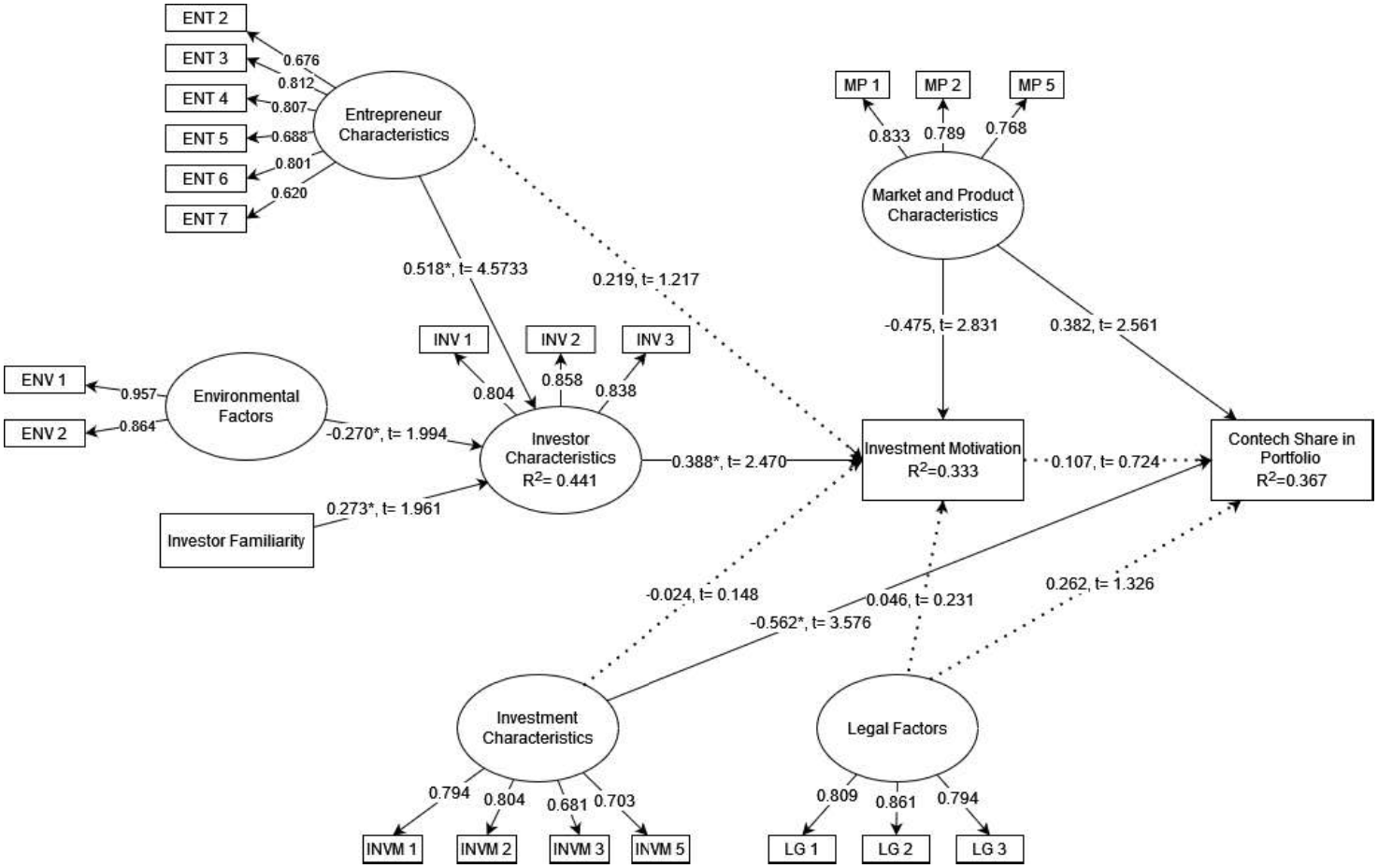


Figure 4.15. Structural Model of Factors Affecting Contech Investments.

Table 4.6. Structural Model Results.

| **Hypothetical Path** | **Path Coef.($\beta$)** | **t-Value** | **p-Value** | **Result** |
|---|---|---|---|---|
| H1: Investor Characteristics –>Investment Motivation | 0.388 | 2.470 | 0.014 | **Supported** |
| H2: Investment Motivation –>Investment Share in Portfolio | 0.107 | 0.724 | 0.469 | Not supported |
| H3: Investor Familiarity –>Investor Characteristics | 0.273 | 1.961 | 0.050 | **Supported** |
| H4: Environmental Factors –>Investor Characteristics | -0.270 | 1.994 | 0.047 | **Supported** |
| H5a: Entrepreneur Characteristics –>Investor Characteristics | 0.518 | 4.573 | 0.000 | **Supported** |
| H5b: Entrepreneur Characteristics –>Investment Motivation | 0.219 | 1.217 | 0.224 | Not supported |
| H6a: Investment Characteristics –>Investment Motivation | -0.024 | 0.148 | 0.883 | Not supported |
| H6b: Investment Characteristics –>Investment Share in Portfolio | -0.562 | 3.576 | 0.000 | **Supported** |
| H7a: Market and Product Characteristics –>Investment Motivation | -0.475 | 2.831 | 0.005 | **Supported** |
| H7b: Market and Product Characteristics –>Inv. Share in Portfolio | 0.382 | 2.561 | 0.011 | **Supported** |
| H8a: Legal Factors –>Investment Motivation | 0.046 | 0.231 | 0.817 | Not supported |
| H8b: Legal Factors –>Investment Share in Portfolio | 0.262 | 1.326 | 0.186 | Not supported |

Additionally, $R^2$ values of each latent variable was obtained from SmartPLS 3. $R^2$ is the coefficient of determination, and the software determines it by utilizing the traditional regression method. The $R^2$ value of 0.25 indicates weak, while 0.50 and 0.75 are considered moderate and substantial [98, 100, 101]. However, models having low $R^2$ values could also be trustable for different contexts [89,98]. Table 4.7 shows that 36.7% of changes in Investor Characteristics, 33% of changes in Contech Investment Motivation, and 44% changes in Contech Investment Share in Portfolio stem from the independent constructs affecting these latent variables.

Moreover, the effect size ($f^2$) of each independent variable on the dependent construct is evaluated. As Hair *et al.* [98] states, the path coefficients and effect sizes are considerably similar.

Effect size values higher than 0.02, 0.15, and 0.35 indicate small, medium, and large effect sizes ($f^2$), respectively [102].

As it was stated in the previous section, VIF values need to be under 3 for a collinearity-free model [98]. Table 4.8 shows VIF values of observed variables, and it confirms that there is not a collinearity issue in the model.

Table 4.7. Effect Sizes of Variables.

| **Dependent Const.** | $R^2$ | **Independent Construct** | $f^2$ | **Inference** |
|---|---|---|---|---|
| Investor Characteristics | 0.367 | Entrepreneur Characteristics | 0.468 | Large Effect |
| | | Environmental Factors | 0.117 | Medium Effect |
| | | Investor Familiarity | 0.119 | Medium Effect |
| Contech Inv. Motivation | 0.333 | Entrepreneur Characteristics | 0.052 | Medium Effect |
| | | Investment Characteristics | 0.001 | Small Effect |
| | | Investor Characteristics | 0.150 | Medium Effect |
| | | Legal Factors | 0.002 | Small Effect |
| | | Market and Product Characteristics | 0.268 | Medium Effect |
| Contech Inv. Share in Portfolio | 0.441 | Investment Characteristics | 0.404 | Large Effect |
| | | Investment Motivation | 0.016 | Small Effect |
| | | Legal Factors | 0.084 | Small Effect |
| | | Market and Product Characteristics | 0.188 | Medium Effect |

Table 4.8. VIF Values.

| **Observed Items** | **VIF** |
|---|---|
| ENT2 | 2.001 |
| ENT3 | 1.853 |
| ENT4 | 2.138 |
| ENT5 | 2.004 |
| ENT6 | 1.944 |
| ENT7 | 1.563 |
| ENV1 | 1.865 |
| ENV2 | 1.865 |
| FIN1 | 1.441 |
| FIN2 | 1.655 |
| FIN3 | 1.475 |
| FIN5 | 1.488 |
| INV1 | 1.547 |
| INV2 | 1.911 |
| INV3 | 1.598 |
| LG1 | 1.308 |
| LG2 | 2.006 |
| LG3 | 1.910 |
| MP1 | 1.719 |
| MP2 | 1.507 |
| MP5 | 1.280 |

# 5. DISCUSSION

This study revealed the factors influencing investors' Contech motivation and investment share in their portfolio. 12 hypotheses were assessed throughout the relations of investor familiarity, investor characteristics, entrepreneur characteristics, environmental factors, investment characteristics, market and product characteristics, and legal factors with investor motivation and investment level. 7 of 13 proposed hypotheses were accepted, while 6 of them were rejected. Because this study is the first research attempting to discover factors affecting AEC-FM start-up investment, it can be regarded as an exploratory work. Also, the model results revealed the $R^2$ values of dependent variables. According to these results, 33% change in Contech Investment Motivation and 44% change in Contech Investment Share in Portfolio are explained by the model's latent variables having a relationship with them. These values are trustable to interpret the model according to previous literature (e.g., [89, 98]), this model is formed by utilizing several studies evaluating investor decision-making in different contexts. Therefore, this study proposes a base for the evaluation of AEC-FM technology start-up investments. Figure 5.1 and 5.2 present the conceptual representation of initial and final models.

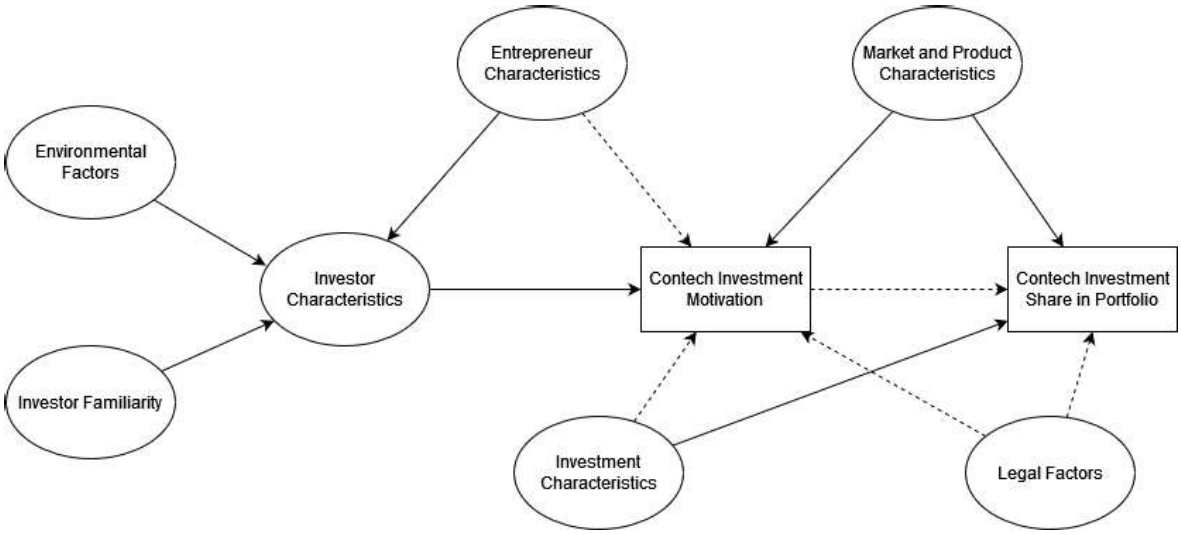


Figure 5.1. Initial Model.

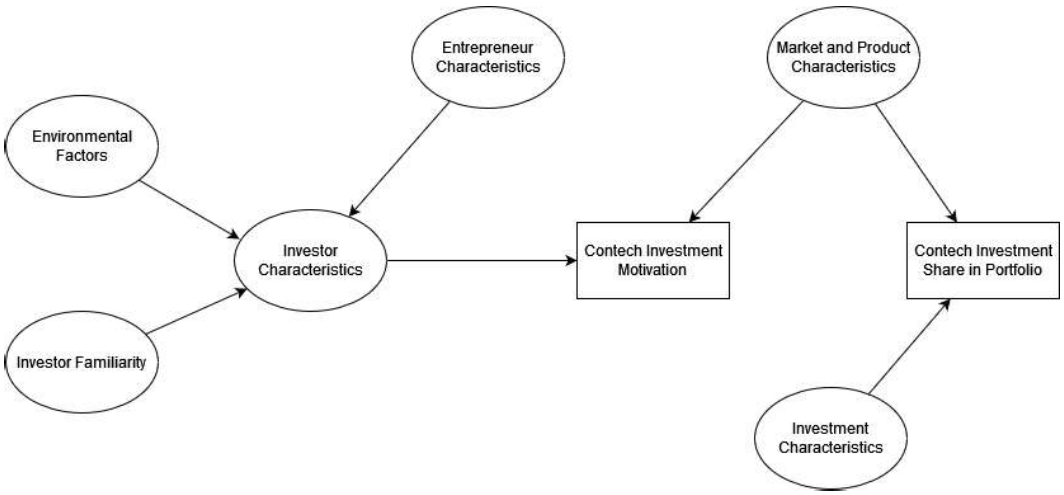


Figure 5.2. Final Model.

## 5.1. Evaluation of Contech Investments

According to Brilakis *et al.* [2] the digitalization process of the construction industry starts with academic studies evaluating the use of emerging technologies for construction industry purposes and, it is followed by start-ups' applications with innovative tools and services. Therefore, academic research is one of the critical factors affecting the start-up environment. When we compare the frequency of Contech start-ups' service/product that participants of this study invested in and academic publications utilizing emerging technologies, the top three solutions showed high similarity. According to the research of Forcael *et al.* [14], the most popular technologies mentioned in the construction management literature were IoT, computer-aided design, and AI and robotics, respectively. Similarly, the current study's result also showed that these three technologies are the most preferred product/services by start-up investors to invest. These technologies were followed by digital twin software. Because the digital twin concept depends on these technologies, the improvement level of them will directly influence the development of digital twin solutions. Robotic technologies for the AEC-FM were also found to be preferable for investors and were funded by 13 of the 48 participants. When robotics and AI are evaluated together, it can be said that this category will be the technologies that might dominate the future construction industry.

Table 5.1. Comparison of Technologies used in the AEC-FM Sector.

| **Ranking** | **Survey result** | **Forcael *et al.* [14]** |
|---|---|---|
| 1 | AI | IoT |
| 2 | IoT | Computer-aided design (BIM) |
| 3 | 3D modeling (including BIM) | AI and robotics |

Also, GSER2021 [45] presented that start-ups focusing on advanced manufacturing and robotics, AI, and blockchain (not Contech-specific) has been receiving the highest amount of funding since 2017. The findings of this study showed that blockchain for AEC-FM was funded by 9 participants and not ranked in the top three technologies. This outcome might present the difference between the construction industry from other sectors. Although blockchain has a great potential for the future, there are some barriers for the adoption in the construction sector such as data privacy and scalability [9].

## 5.2. Evaluation of Model Results

### 5.2.1. Investor Characteristics

The first hypothesis was related to the impact of Investor Characteristics on Contech Investment Motivation. As a result of PLS-SEM analysis, this hypothesis was found significant ($\beta$=0.388, t=2.470, $\alpha$=0.014), and it was accepted. As previous studies argue that a priori beliefs have a significant influence on investor decisions (e.g., [30, 31]). Especially when we consider that venture capitalists constitute the majority of the participants and VCs are known as risk-takers, their level of risk acceptance is of a high importance effect on their investment motivation [26]. Additionally, investors' confidence in emerging technologies such as innovative AEC-FM technologies is another important criterion that determines investor motivation. The results of this hypothesis also support previous studies. For example, Masini and Menichetti [31] found that the confidence degree of investors in renewable energy (RE) technologies

has a positive impact on their investment decisions. Similarly, these kinds of deductive considerations of investors are expected to be influential on the investment motivation in Contech technologies. Regarding factor loadings of observed variables of Investor Characteristics, the most significant item was Level of confidence in emerging digital technologies (INV2) (0.858). Even though the application of innovative technologies in the construction industry is not quite common, investors who financed AEC-FM start-ups have a confidence in emerging technologies. Also, Patience to see profit (INV3) was also a significant factor (0.838). Because start-ups gradually improve their companies and generate profit, investors need to be patience for getting their profit. Klingler-Vidra [104] highlighted the importance of patient capital and concluded that venture capitalists are key patient participants for growing start-ups.

On the other hand, the second hypothesis of this study argues that the Contech Investment Motivation of financers directly affects the Contech share in their portfolio. However, the study outcomes showed that investors' motivation does not have a significant influence on their Contech investment level ($\beta$=0.107, t= 0.724, $\alpha$= 0.469). This result indicates that even though investors have a high level of motivation, they do not allocate a high level of money to Contech start-ups compared to other investments in their portfolios. Because emerging Contech technology start-ups are quite young companies and their successful examples are limited, investors may tend to invest less in companies such as AEC-FM start-ups. We expect that, as innovative Contech start-ups spread and their investors get positive results from their investments and successful examples are noticed, a positive influence can be observed between investment motivation and investment level. On the other hand, the mean values of these observed variables showed that investors have a high level of motivation (3.98), while they have a low share in their portfolio (2.60). Therefore it may take time to observe an acceleration in the digitalization level of the AEC-FM industry, and investors might need to be supported and encouraged by the industry, authorities, and other participants.

The third hypothesis proposed that Investor Familiarity has a direct impact on Investor Characteristics. The bootstrapping results prove that investors' familiarity with the Contech investments has a significant and positive impact on investor charac-

teristics ($\beta$=0.273, t= 1.961, $\alpha$=0.050). Considering the effect of personal experiences on people's perception and evaluation [30], this result reveals that the higher familiarity with AEC-FM technologies leads to a higher positive investor attitude.

### 5.2.2. Environmental Factors

The fourth hypothesis of the study presented that Environmental Factors have a direct impact on Investor Characteristics. The PLS-SEM results approved that environmental criterion significantly and negatively impacts investor characteristics ($\beta$=-0.270, t=1.994, $\alpha$=0.047). Investors' institutional environment, which includes similar investment companies and consultants, inevitably influences investors' perspectives and decision-making processes [31, 60].

The results of Masini and Menichetti's study [31] also showed that the pressure of peers and consultants has a negative impact on RE technology investments. The authors highlighted that the investors evaluate these factors as enforcement, rather than an incentive. In terms of Contech start-up investments, this study presents a similar result and confirm that Contech investors are negatively influenced by external factors.

Regarding factor loadings, after one insignificant factor dropped, loading of Influence of peers (ENV1) rose to 0.957. Peer pressure is quite important for investor when they are deciding. This pressure could negatively or positively affect investor decisions. For example, Khanna and Mathews (2011) states that herding can be beneficial for investors making their early decisions while it could be not useful for others because it leads information loss. The results showed that the majority of survey participants are experienced in this investment domain for over 10 years. Therefore, it can be said that they have enough experience not to rely on only peer pressure.

### 5.2.3. Entrepreneur Characteristics

This study claimed that Entrepreneur Characteristics have a direct impact on Investor Characteristics (H5a) and Contech Investment Motivation (H5b). The results of the PLS-SEM analysis showed that Entrepreneur characteristics have a significant and positive effect on investor's attributes ($\beta$=0.518, t=4.573, $\alpha$=0.000), while it doesn't have a direct and significant influence on Contech investment motivation ($\beta$=0.219, t=1.217, $\alpha$=0.224). Entrepreneur characteristics were considered the most critical factors for innovative company investments by several researchers (e.g., [24,27]). In terms of AEC-FM technology start-up investments, we may say that entrepreneurs' features such as managerial skills, trust, and risk acceptance level affect investors' patience and attitude towards emerging technologies. Especially for newly established companies similar to Contech start-ups, investors mostly don't have the company's detailed track record and cash flows [27]. Therefore, investors generally evaluate a company's managerial team-related factors when they evaluate technology start-ups. Moreover, because these types of start-ups have a high level of uncertainty, entrepreneur characteristics play a critical role in investors' trust in the technology and the company.

Regarding factor loadings, the most critical item was Entrepreneur's sustainable and value-added product development capacity, vision, and competitive strategy (ENT6) with 0.801, while the least significant one was Well-defined scope and strong focus (ENT7) with 0.620. It is not a surprising result because start-up investors make long-term investments and sustainability is quite important for financiers.

### 5.2.4. Investment Characteristics

The study proposed that Investment Characteristics have a direct influence on Contech Invstment Motivation (H6a), and Contech Investment Share in Portfolio (H6b). The results showed that Investment Characteristics only significantly influence Contech Investment Share in Portfolio. Therefore, while H6a rejected ($\beta$=-0.024, t= 0.148, $\alpha$=0.883), H6b ($\beta$=-0.562, t=3.576, $\alpha$=0.000) is accepted. The study results of Bachher and Guild [28] showed that investor requirements, which include factors such as

the return of investment, ranked as the fourth out of five categories for early-stage technology investors. Also, as Kollman and Kuckerts [23] showed that the uncertainty of potential returns on investment is high at the beginning of the investment process. Therefore, we can say that although investors might have foresight before the investment, the characteristics of investments don't have critical importance for the initial investment motivations of investors. Instead, they directly impact investment level decisions after financial considerations are made.

The path coefficient shows that Investment Characteristics have a strong negative effect on Contech share in the investor portfolio. This result indicates that even the investment has desirable financial conditions, the investment share in the portfolio can be lower. One of the reasons for these findings could be due to the nature of Contech start-ups. One of the reasons for this result could be the limited number of Contech start-ups. Also, this high-tech AEC-FM sector has been evolving in recent years. On the other hand, some venture capitalists diversify their portfolios and are distribute resources to different sectors [105]. In terms of rejected hypothesis (H6a), as we mentioned before, most start-up investors tend to evaluate small companies qualitatively, rather than considering cash flows and quantitative analysis such as NPV and IRR [27]. Therefore, investment features and financial factors may not directly affect investors' attitudes and motivation.

Among Investment Characteristics factors, Potential profit and cash flow of investment (INVM2) has the highest factor loading (0.804). Similarly, the research results of Rostamzadeh *et al.* [24] also showed that "potential for high returns" ranked the highest among five factors. Even though start-ups mostly don't have cash flows belongs, investors tend to foresight and evaluate their potential profit and cash flow. On the other hand, Continuity to company portfolio (INVM3) was the least significant factor (0.681). Considering the result of the model, it can be said that even though investment's continuity to portfolio is not possible, their investment level could be high.

### 5.2.5. Market and Product Characteristics

This study introduces two hypotheses under market and product category. H7a and H7b claim that Market and Product Characteristics have a direct impact on Contech investment motivation and Contech Investment Share in Portfolio, respectively. Both hypotheses were supported ($\beta$=-0.475, t= 2.831, $\alpha$=0.005), ($\beta$=0.382, t=2.561, $\alpha$=0.011). This result supports previous studies by showing the importance of market and product features of the investment (e.g., [106, 107]). According to results, market and product features of AEC-FM technology start-ups affected investors' investment motivation negatively, while a positive influence is observed on investment share in their portfolio.

When we consider that investors, especially venture capitalists, make risky investments, market factors such as ecosystem and infrastructure issues may end up with a high investment motivation. Moreover, venture capitalists are very good at discovering and understanding ingoing markets and this makes them prospering and competitive in the market [108, 109].

Factor loadings of Market and Product Characteristics were significant, and Established ecosystem and infrastructure level (MP1) has the highest loading (0.833). Rostamzadeh *et al.* [24] highlighted the importance of BA's in start-up investments and the findings showed that "Well-established distribution channel" has a high significance for their investments. Fragmentation of the market also found significant. For technology industry, this concept have a critical role because it may affect dynamics of the market by causing clients to be forced to demand a single product-service [70].

### 5.2.6. Legal Factors

Lastly, two hypotheses under the eighth category were proposed in this study. The results showed that Legal factors don't have significant effect on Investor motivation (H8a, $\beta$=0.046, t=0.231, $\alpha$=0.817), and Contech investment share in portfolio (H8b, $\beta$=0.262, t=1.326, $\alpha$= 0.186). Cui *et al.* [29] stated that "as technology and the

market gets developed, the ambiguity decreases, and the company focus on their technologies then accordingly, laws and regulations of authorities become a critical means to compete". Because AEC-FM innovative technologies are still improving, and the market has not been well established, legal factors don't possess a significant role in investor decisions.

Similarly, the findings of Masini and Menichetti's study [31] showed that "Confidence in policy effectiveness" does not have a significant effect on renewable energy level of investors. According to the authors, the efficiency of legal procedures can be observed through the investor attitudes, and the legal authorities' awareness of investor behavior is critical to establishing more reliable laws.

Policies and regulations play a vital role for start-ups in their initial stages for the improvement of emerging technologies because they don't feel the pressure of the rivalry of the market yet [31]. The actions of authorities for regulating the rights of entrepreneurs and investors might be crucial for small ventures. Therefore, these results may lead legal authorities to strengthen the legal framework of start-up investment for the faster development of technology ventures.

In terms of factor loadings, Strength of investment policies (LG2) was the most significant item (0.861). Besides, Strength of legal rights/legal framework (LG1) and Strength of entrepreneurship policies (LG3) also performed well with 0.809 and 0.794, respectively. Weak policies and legal rights can lead to unhealthy relationships and miscommunication between entrepreneurs and investors, which can negatively affect the performance of start-ups [72]. Therefore, the future of Contech start-ups highly depends on the legal environment.

# 6. CONCLUSION

The AEC-FM industry is regarded as an unproductive area due to the low digitalization level compared to other sectors. Considering the potential of digital applications for the industry, emerging technology adoption has become a necessity for the construction industry. However, because it has a complex environment and unique problems, enhancing the digitalization level of the sector without technology start-ups focusing on digital solutions for the AEC-FM industry cannot be possible. Accordingly, investments in such ventures directly affect the digital transformation process of construction applications. Therefore, understanding perceptions of Contech investors is an important step for the development of construction technology start-up environment.

This study aimed to determine the factors affecting the decisions of Contech start-up investors. In order to investigate the relations of factors with investor motivation and investment level, the research proposed a model for the evaluation of factors evaluating Contech investors' decision-making process. The model consists of Investor Characteristics, Environmental Factors, Investment Characteristics, Investor Familiarity, Legal Factors, Market and Product Characteristics, and their relations with investment motivation and Contech share in investor portfolio were assessed. The model also includes interrelations among factors. A total of 48 samples from different countries were used to analyze the data utilizing PLS-SEM method. According to the findings, artificial intelligence (AI), Internet of Things (IoT), 3D modeling, and Digital Twin (DT) were the most invested technologies used for AEC-FM purposes. The results revealed that even though Contech start-up investors have a high level of investment motivation (mean value=3.98), their Contech related investments' share in the portfolio is not too high (mean value=2.60).

The results of the bootstrapping analysis are:

- Investor Characteristics/Attitude have a direct and positive influence on Contech investment motivation of investors (H1: accepted, $\beta$=0.388, t=2.470, $\alpha$=0.014).

- Contech investment motivation of investors have not a significant impact on Contech Investment Share in Portfolio (H2: rejected, $\beta$=0.107, t= 0.724, $\alpha$= 0.469).
- Investor familiarity has a direct and positive effect on Investor Characteristics (H3: accepted, $\beta$=0.273, t= 1.961, $\alpha$=0.050).
- Environmental Factors have a direct and negative effect on Investor Characteristics (H4: accepted, $\beta$=-0.270, t=1.994, $\alpha$=0.047).
- Entrepreneur characteristics have a direct and positive impact on Investor Characteristics (H5a: accepted, $\beta$=0.518, t=4.573, $\alpha$=0.000) and have not a significant influence on Contech Investment Motivation (H5b: rejected, $\beta$=0.219, t=1.217, $\alpha$=0.224).
- Investment Characteristics have not a Contech Investment Motivation (H6a: rejected, $\beta$=-0.024, t= 0.148, $\alpha$=0.883) while it have a direct and negative effect on Contech Investment Share in Portfolio (H6b: accepted, $\beta$=-0.562, t=3.576, $\alpha$=0.000).
- Market and Product Characteristics have a direct and negative influence on Contech Investment Motivation (H7a: accepted, $\beta$=-0.475, t= 2.831, $\alpha$=0.005), and have a direct and positive impact on Contech Investment Share in Portfolio (H7b: accepted, $\beta$=0.382, t=2.561, $\alpha$ =0.011).
- Legal Factors have not a significant effect on Contech Investment Motivation (H8a: rejected, $\beta$=-0.046, t= 0.231, $\alpha$=0.817) and Contech Investment Share in Portfolio (H8b: rejected, $\beta$=0.262, t=1.326, $\alpha$ =0.186).

As a result, the current study proposed 12 hypotheses in total, and 7 of them were accepted. Because a limited number of studies investigated the technology start-up environment, and no academic research evaluated Contech start-up investments, this study presents an exploratory work to provide a guideline for both investors and entrepreneurs. The results of the study could help both Contech start-ups and their investors by guiding their decisions. Moreover, future works might utilize and improve this model to understand the AEC-FM high-tech start-up environment.

## 6.1. Contributions of the Study

The number of studies focusing on emerging technology use in the construction industry has been increasing for the last decade. However, although technology start-ups providing unique technology solutions for the construction industry have a critical role in the digitalization process of the sector, there is a gap in the literature investigating these companies and the investments in innovative Contech start-ups. This research contributes to the literature by reviewing the role of start-ups in the digitalization of the construction industry and the importance of investors in this process. Moreover, suitable factors to evaluate Contech start-up investments were proposed, and a model to discover the effects of these criteria on investor motivation and investment level was presented. Existing studies assessing investor decision-making mostly focused on only financial or non-financial factors, this research developed a model consisting of financial and non-financial factors and evaluates the interrelations between them. Therefore, the findings enable investors to evaluate financial and non-financial criteria in the same model. The proposed model might be a basis for researchers who aim to focus on AEC-FM technology start-ups and start-up investments. Besides, because the study has been conducted based on data collected from different countries and technologies, the results can be utilized by researchers investigating technology ventures in other industries.

On the other hand, this study has several practical contributions. First of all, it presents insights for start-up industry by showing the attributes of Contech start-up investors and the trend technologies preferred by them. Investors who are planning to back Contech start-ups might utilize the results of this study to evaluate the market and current AEC-FM technology trends. More importantly, this study presents a model for investor to evaluate their possible Contech start-up investments by evaluating the venture considering the factors proposed in the model. Especially for young investors, the study's result might be a guide in the decision-making process.

Moreover, the research contributes practically by helping newly founded start-ups to find a proper investor to survive and grow their business. Especially, young

start-up companies can utilize the results of the research in evaluating factors for the development of their business. As Brilakis *et al.* [2] state, the digitalization process of the construction sector follows academic studies, start-up practices, and start-ups acquisition. By considering the findings of this study, Figure 6.1 presents a road-map for Contech start-ups to contribute to the digitalization of the construction industry. Ventures can follow the steps for improving their start-ups, getting investment, and contributing to the digitalization of the industry.

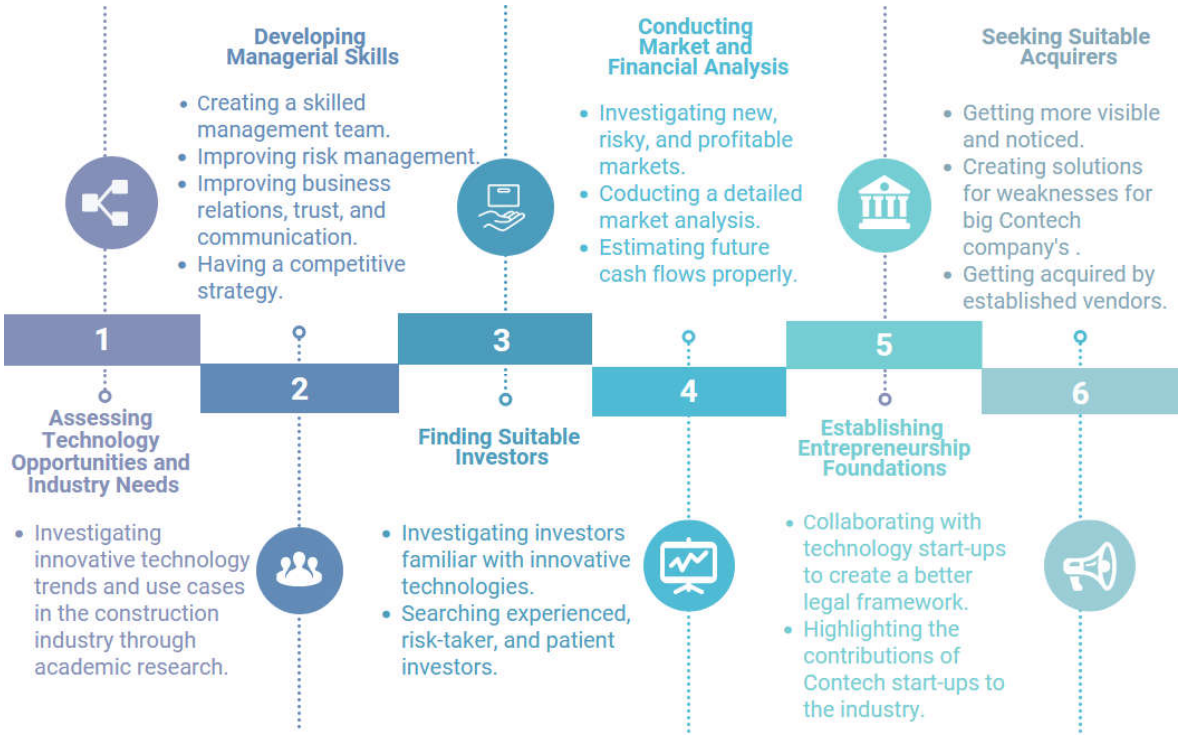


Figure 6.1. Roadmap for Contech Start-ups.

Considering the results of this research, AEC-FM technology start-ups can understand the general profile of investors financing innovative Contech ventures and their perspectives when evaluating such start-ups. Moreover, because the study includes participants having international Contech start-up investments, the result of this study is not limited to only one country or region. The results can be utilized by investors and start-ups located in different countries. Developing countries such as Turkey, which have a limited number of Contech start-ups, might benefit from the

findings of the study for evaluating the importance of innovative start-ups in industry digitalization. It is seen that most participants from Turkey have international Contech start-ups investments. In order to create a construction technology market in Turkey, entrepreneurs can follow the provided roadmap to establish an early-stage start-up, and incubators and accelerators can support entrepreneurs. Also, as the results show, investor familiarity with technology plays an important role in investment decision-making. Therefore, innovative construction technologies can be promoted in developing countries to make local investors more familiar.

Lastly, the result of the study revealed that legal factors are found not to affect investor decisions, and their factor loadings were found relatively low. The authorities might benefit from these results to take actions to improve the legal framework and strengthen entrepreneurs' and investors' policies for a more productive investment environment. Thus, Contech start-ups and investors can contribute more to the digitalization of the AEC-FM sector with a trustable legal environment.

## 6.2. Limitations of the Study and Future Work

The main limitation of this study is the number of participants. Even though the PLS-SEM method is preferred to analyze the data because the data is lower than 100, utilization of CB-SEM could have given more dependable results. Larger sample size may cause different outcomes. However, because the construction industry is quite behind other sectors in terms of digitalization, the number of AEC-FM start-ups and investors is limited. This situation also prevented the conduct of a pilot survey study. Even though the questionnaire items were selected and revised with experts, a pilot questionnaire could have been helpful to understand whether the factors were properly understood by the participants. Thus, eliminated factors could have been included in the model.

Moreover, the results depend on the personal experiences of investors. Therefore, this study proposes its findings based on subjective evaluations. Lastly, the questionnaire used in the study was an online survey, and participants might misunderstand

the questions when surveying rather than face-to-face interviews.

Future works related to AEC-FM start-ups can develop the current model by including different observed variables to understand the AEC-FM high-tech start-up environment. Besides, the number of participants could be increased, and CB-SEM could be implemented to make a comparison with PLS-SEM. A pilot questionnaire is also highly recommended for future studies. This study evaluates Contech start-up investments in general. Therefore, future studies may assess the decision-making process of investors for specific start-up types and their funding rounds.

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# APPENDIX A: QUESTIONNAIRE SURVEY

**PART 1**

1. **Please select investor profile.**

☐ Incubator or Accelerator ☐Venture capital ☐ Private equity or hybrid ☐Angel Investor

☐Banks, hedge funds, pension funds and insurance companies

☐Private companies ☐Engineering/other

2. **Company name**

.....

3. **Position in the company**

.....

4. **Education Level**

☐ Less than High school ☐ High school ☐ 2-year collage ☐ Master's ☐Phd

5. **Educational Background**

☐Economics and business administration ☐Finance ☐Legal ☐Engineering ☐Multidisciplinary

6. **Age of respondents**

☐From 20 to 30 years ☐From 31 to 40 years ☐ From 41 to 50 years ☐ From 51 to 60 years ☐More than 60 years

7. **Experience in AEC-FM technology investing domain.**

☐ No experience ☐ Less than 2 years ☐ From 2 to 5 years ☐ From 5 to 10 years ☐ More than 10 years

Figure A.1. Part One.

**PART 2**

1. **Which of the following technologies has you or your company invested in? (You may select multiple)**

| **Hardware** | **Software** |
|---|---|
| ☐ Wireless Sensors (IoT) | ☐ Digital Twin Software |
| ☐ Drones | ☐ 3D modelling |
| ☐ LIDAR/Scanners | ☐ Sensor (IoT) Software/Hardware |
| ☐ Mixed Reality (VR and AR) for AEC industry | ☐ Building Information Modeling (BIM) |
| ☐ Artificial intelligence for AEC industry | ☐Property Management software |
| ☐ Blockchain for AEC industry | ☐Robotics |
| ☐ Smart home energy technologies | ☐ Other…... |

2. **Please select the degree of your investment motivation before invested in the related technology.**

☐Very Low ☐Low ☐Medium ☐High ☐Very High

3. **What is/was the share of the technologies you have marked above in your investment portfolio?**

☐ %0-%20 ☐ %20-%40 ☐ %40-%60 ☐ %60-%80 ☐ %80-%100

Figure A.2. Part Two.

**PART 3**

In this section, the respondent is requested to indicate to what extent the following factors are realized in the investment process of SELECTED TECHNOLOGIES IN THE PREVIOUS SECTION.

**Please evaluate following factors considering your (investor) characteristics.**

| Characteristics of Investor | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Familiarity with the technology that you/your companies invested in | ☐ | ☐ | ☐ | ☐ | ☐ |
| Level of risk acceptance for radical technological innovations | ☐ | ☐ | ☐ | ☐ | ☐ |
| Level of confidence in emerging digital technologies | ☐ | ☐ | ☐ | ☐ | ☐ |
| Patience to see profit | ☐ | ☐ | ☐ | ☐ | ☐ |

**Please evaluate following factors considering the features of technology ventures that you invested in.**

| Characteristics of Entrepreneur | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Experience, technical and industrial skills | ☐ | ☐ | ☐ | ☐ | ☐ |
| Managerial capabilities, experience, and business awareness | ☐ | ☐ | ☐ | ☐ | ☐ |
| Ability to react to risks | ☐ | ☐ | ☐ | ☐ | ☐ |
| Trust and Communication | ☐ | ☐ | ☐ | ☐ | ☐ |
| Reputation of management | ☐ | ☐ | ☐ | ☐ | ☐ |
| Sustainable and value-added product development capacity, vision, and competitive strategy | ☐ | ☐ | ☐ | ☐ | ☐ |
| Well defined scope and strong focus | ☐ | ☐ | ☐ | ☐ | ☐ |

**Please evaluate following factors considering the External Pressure affecting your technology investment.**

| Environmental Factors | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Influence of peers (other investors) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Influence of key market participations (consultants etc.) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Local and global agenda | ☐ | ☐ | ☐ | ☐ | ☐ |

Figure A.3. Part Three.

**Please evaluate following factors by considering the market characteristics of the technology that you invested in.**

| Characteristics of the Market and Product | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Established ecosystem and infrastructure | ☐ | ☐ | ☐ | ☐ | ☐ |
| Fragmentation of the market | ☐ | ☐ | ☐ | ☐ | ☐ |
| Competitive advantage | ☐ | ☐ | ☐ | ☐ | ☐ |
| Product superiority (innovativeness, uniqueness, solving a market problem) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Market acceptability | ☐ | ☐ | ☐ | ☐ | ☐ |

**Please evaluate following factors considering the investment characteristics (Financial-Economic) of the technology that you invested in.**

| Characteristics of the Investment | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Growth rate projections | ☐ | ☐ | ☐ | ☐ | ☐ |
| Potential profit and cash flow of investment | ☐ | ☐ | ☐ | ☐ | ☐ |
| Continuity to company portfolio | ☐ | ☐ | ☐ | ☐ | ☐ |
| Clear exit opportunity | ☐ | ☐ | ☐ | ☐ | ☐ |
| Favorable tax treatment | ☐ | ☐ | ☐ | ☐ | ☐ |

**Please evaluate following factors considering the Institutional, Political and Regulatory Environment affecting your technology investment.**

| Legal Factors | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Strength of Legal rights/legal framework | ☐ | ☐ | ☐ | ☐ | ☐ |
| Strength of investment policies | ☐ | ☐ | ☐ | ☐ | ☐ |
| Strength of entrepreneurship policies (voting power etc.) | ☐ | ☐ | ☐ | ☐ | ☐ |
| Eligibility of the venture's corporation type for investment | ☐ | ☐ | ☐ | ☐ | ☐ |

Figure A.4. Part Three (cont.).

# APPENDIX B: DESCRIPTIVE STATISTICS

Table B.1. Descriptive Statistics of Investor Characteristics Items.

| **Criteria** | **Min.** | **Max** | **Mean** | **Std. Dev.** | **Variance** | **Skewn.** | **Kurt.** |
|---|---|---|---|---|---|---|---|
| Inv. Fam. | 2 | 5 | 3.92 | .964 | .929 | -.572 | -.555 |
| INV1 | 2 | 5 | 3.92 | .964 | .929 | -.572 | -.555 |
| INV2 | 1 | 5 | 4.19 | .867 | .751 | -1.404 | 2.982 |
| INV3 | 2 | 5 | 4.02 | .978 | .957 | -.754 | -.363 |

Table B.2. Descriptive Statistics of Entrepreneur Characteristics Items.

| **Criteria** | **Min.** | **Max** | **Mean** | **Std. Dev.** | **Variance** | **Skewn.** | **Kurt.** |
|---|---|---|---|---|---|---|---|
| ENT1 | 1 | 5 | 4.15 | .850 | .723 | -1.373 | 3.127 |
| ENT2 | 1 | 5 | 3.96 | .898 | .807 | -.835 | 1.147 |
| ENT3 | 2 | 5 | 4.27 | .792 | .627 | -1.068 | 1.080 |
| ENT4 | 1 | 5 | 4.52 | .799 | .638 | -2.555 | 8.493 |
| ENT5 | 1 | 5 | 3.83 | 1.038 | 1.078 | -.961 | .776 |
| ENT6 | 1 | 5 | 4.15 | .875 | .766 | -1.488 | 3.175 |
| ENT7 | 1 | 5 | 4.13 | .890 | .793 | -1.198 | 2.092 |

Table B.3. Descriptive Statistics of Market and Product Characteristics Items.

| **Criteria** | **Min.** | **Max** | **Mean** | **Std. Dev.** | **Variance** | **Skewn.** | **Kurt.** |
|---|---|---|---|---|---|---|---|
| MP1 | 1 | 5 | 3.12 | .959 | .920 | .344 | -.201 |
| MP2 | 2 | 5 | 3.67 | .808 | .652 | -.066 | -.425 |
| MP3 | 2 | 5 | 4.35 | .668 | .446 | -.999 | 1.831 |
| MP4 | 3 | 5 | 4.15 | .714 | .510 | -.222 | -.969 |
| MP5 | 2 | 5 | 3.96 | .683 | .466 | -.367 | .456 |

Table B.4. Descriptive Statistics of Investment Characteristics Factors.

| **Criteria** | **Min.** | **Max** | **Mean** | **Std. Dev.** | **Variance** | **Skewn.** | **Kurt.** |
|---|---|---|---|---|---|---|---|
| INVM1 | 1 | 5 | 3.73 | 1.005 | 1.010 | -.601 | -.072 |
| INVM2 | 1 | 5 | 3.77 | 1.016 | 1.031 | -.913 | .800 |
| INVM3 | 1 | 5 | 3.40 | 1.067 | 1.138 | -.430 | -.088 |
| INVM4 | 2 | 5 | 4.13 | .890 | .793 | -.631 | -.564 |
| INVM5 | 1 | 5 | 2.40 | 1.198 | 1.436 | .489 | -.546 |

Table B.5. Descriptive Statistics of Legal Factors.

| **Criteria** | **Min.** | **Max** | **Mean** | **Std. Dev.** | **Variance** | **Skewn.** | **Kurt.** |
|---|---|---|---|---|---|---|---|
| LG1 | 1 | 5 | 3.23 | 1.134 | 1.287 | -.200 | -.459 |
| LG2 | 1 | 5 | 3.02 | 1.082 | 1.170 | -.043 | -.533 |
| LG3 | 1 | 5 | 3.19 | .891 | .794 | -.010 | -.160 |
| LG4 | 1 | 5 | 3.56 | 1.109 | 1.230 | -.604 | -.039 |

Table B.6. Descriptive Statistics of Environmental Factors.

| **Criteria** | **Min.** | **Max** | **Mean** | **Std. Dev.** | **Variance** | **Skewn.** | **Kurt.** |
|---|---|---|---|---|---|---|---|
| ENV1 | 1 | 5 | 2.94 | 1.156 | 1.336 | -.219 | -.796 |
| ENV2 | 1 | 5 | 2.71 | 1.220 | 1.488 | -.069 | -1.154 |
| ENV3 | 1 | 5 | 2.83 | 1.209 | 1.461 | -.194 | -.888 |

# APPENDIX C: SmartPLS 3 MODEL

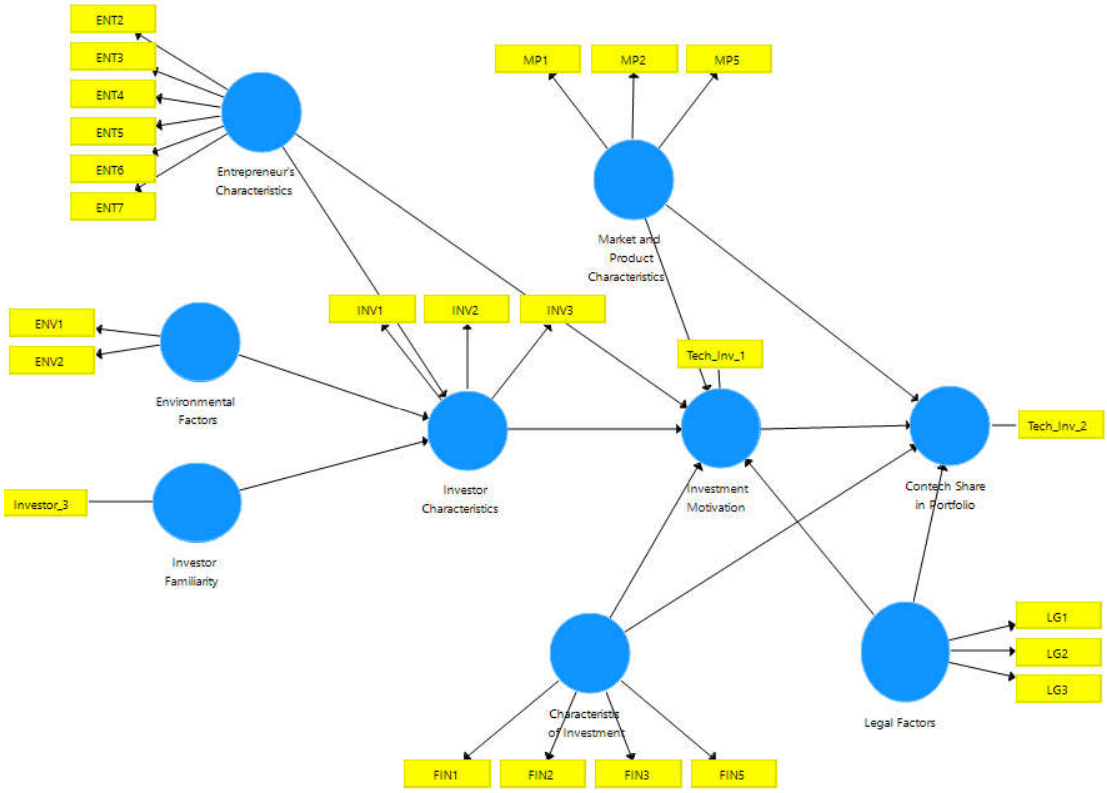


Figure C.1. SmartPLS 3 Model.