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Social Impact of 3D Printed Houses in Romania

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Abstract

The lack of affordable housing in Romania, particularly in major urban areas, has been exacerbated by the rising costs of establishment, community expansion, and economic disparity. Several people think that a 3D printing construction could reduce costs, accelerate assembly and improve natural longevity. Despite its own possibility, the current revolutionary technique is not in its right moment and is not effectively strengthened in the Romanian real estate market. This thesis deals with the institutional, market, and social obstacles that have hindered the widespread acceptance of 3D printed houses, as well as the ways in which these obstacles might affect the affordability of housing in the state. The study analyses several approaches to measure affordability, such as residual revenue and a broad socio-economic position that sees housing as essential for sustained financial stability. It also provides a theoretical framework for the acceptance of new ideas and review fiction on top of long-term construction as well as linear manufacturing, which is often linked to increased efficiency and reduced environmental impact. A number of methodologies were applied, with the academic principle established through a comprehensive analysis of the existing literature. A survey was carried out to estimate the amount of knowledge, known risks, and circumstances of adoption. Moreover, to establish a professional perspective, a pair of interviews was carried out, one with a representative of a traditional construction company and another with a 3D printing construction company. The study used both descriptive and interpretive study strategies. The results suggest that traditional resistance to adapt does not cause a reduced acceptance of 3D printed housing. Survey participants are optimistic and recognize benefits such as faster construction and cost reduction. However, they are more interested in aspects such as longevity, safety, resale value and regulatory approval. Sustainability does not significantly influence buyers perceptions. The main obstacles are unclear regulations, the lack of official building codes, restrictions on the amount of funding and insurance coverage, and the limited number of current illustrations. According to the study, the technical skills by themselves are not sufficient to make substantial progress. For a successful operation, cooperation between institutions, clear legislation, and easily available funding are essential.

Keywords: 3D printed house; housing affordability; romanian housing market; innovation adoption

Abstract in Italiano

La carenza di alloggi accessibili in Romania, soprattutto nelle principali aree urbane, è stata aggravata dall'aumento dei costi di sviluppo, dall'espansione delle comunità e dalle disuguaglianze economiche. In questo contesto, la costruzione tramite stampa 3D è considerata una possibile soluzione per ridurre i costi, accelerare i tempi di realizzazione e migliorare la durabilità degli edifici. Tuttavia, nonostante il suo potenziale innovativo, tale tecnologia non è ancora pienamente integrata nel mercato immobiliare romeno. La presente tesi analizza gli ostacoli istituzionali, economici e sociali che limitano la diffusione delle abitazioni stampate in 3D e il loro impatto sull'accessibilità abitativa. Vengono esaminati diversi approcci alla misurazione dell'accessibilità, tra cui il metodo del reddito residuo e una prospettiva socio-economica che considera la casa come elemento centrale per la stabilità finanziaria a lungo termine. Lo studio propone inoltre un quadro teorico sull'adozione delle innovazioni e una revisione della letteratura relativa alla costruzione sostenibile e ai processi produttivi lineari, associati a maggiore efficienza e minore impatto ambientale. La ricerca adotta una metodologia mista. L'analisi teorica si basa su una revisione approfondita della letteratura esistente. È stato inoltre condotto un questionario per valutare il livello di conoscenza, i rischi percepiti e le condizioni di adozione della tecnologia. Due interviste, una con un'impresa edile tradizionale e una con un'azienda specializzata nella stampa 3D, hanno fornito una prospettiva professionale. I risultati mostrano che la resistenza al cambiamento non rappresenta il principale ostacolo. I partecipanti riconoscono vantaggi quali rapidità e riduzione dei costi, ma attribuiscono maggiore importanza a durabilità, sicurezza, valore di rivendita e approvazione normativa. Le principali barriere riguardano l'incertezza legislativa, la mancanza di codici edilizi specifici, l'accesso limitato a finanziamenti e assicurazioni e il numero ridotto di casi realizzati. La cooperazione istituzionale e un quadro normativo chiaro risultano essenziali per una diffusione efficace.

Parole chiave: casa stampata in 3D; accessibilità abitativa; mercato immobiliare romeno; adozione dell'innovazione

Contents

1 Introduction

Housing affordability is a widespread challenge worldwide, impacting both developed and developing economies. In many countries, costs like rent and mortgage payments tend to rise faster than household incomes, leaving less money for other essential needs and making it increasingly difficult for more people to afford housing (Grimsley, et al., 2024) (Saiz, 2023). Demographic shifts, like quick urbanization and rising populations, have intensified this issue by boosting the demand for urban housing without matching the supply (Kallergis, Angel, Blei, Sanchez, & Lamson-Hall, 2018). Consequently, young and middle-class families in both high-income and middle-income nations are finding it more challenging to secure safe and suitable housing (Grimsley, et al., 2024). A significant policy challenge in global urban development initiatives, including the United Nations' Sustainable Development Goals, is housing affordability. This issue not only impacts individuals financial stability but also influences social outcomes, opportunities for economic advancement, and overall quality of life (Contributors, Sustainable Development Goals 11, n.d.).

The problem in Romania has gotten worse in recent years, and housing costs are rising too high. In large cities like Bucharest, Cluj-Napoca, and Timișoara, the cost of living has increased, but earnings haven't kept up (Newsroom, 2025) (Imobiliare.ro, 2025). Young individuals and first-time buyers who are having a hard time finding housing are greatly impacted by this. The Romanian real estate market (Romania Real Estate Market: Analysis of Prices, Rental Yields and Investment Opportunities, 2025). This issue is becoming worse every year.

The main factors which contribute to this issue are the higher prices of building materials, energy, and labor, resulting in the rise of construction cost (infoConstruct, 2025). Additionally, the longer construction times associated with traditional building processes might result in delays and unforeseen costs that are passed on to customers in the form of increased prices. But the problem is not simply with building expenses, cities like Bucharest are drawing people who are seeking better jobs and better infrastructure, which means there are fewer places to live and a housing supply and demand imbalance. This indicates that there is a disparity between the cost of homes and the number of people who can afford them.

Lastly, rather than paying rent, Romanians would rather own their home. Those searching for reasonably priced homes find it challenging as a result. Families that are regarded as middle class are currently having difficulty locating a home that they can afford.

In this environment, innovative ideas such as technologies that can speed up construction and reduce costs are being suggested to develop and deliver homes that meet modern family needs. To reduce their carbon footprint and promote sustainability for future generations, some are adopting eco-friendly materials and practices.

Although these practical challenges and new solutions show how urgent the housing issue is, it is important to clarify what is meant by “housing affordability”. Before looking at whether new construction methods can solve the problem, it is necessary to understand the concept from a theoretical perspective.

There isn't a universally accepted criteria for what constitutes inexpensive housing. The majority of studies examine whether people can afford their homes by contrasting their income with the cost of rent or mortgage payments (LĂZĂRESCU & DIACON, 2020). This method has drawbacks, too, since it ignores other necessary costs like food, transportation, and medical care. For instance, if a household has limited financial flexibility due to heavy debt or other financial obligations, they may still find it difficult to buy housing even with a high income. Furthermore, this approach makes the assumption that income levels stay constant, which isn't always the case (Soaita, 2020).

To better understand affordability, researchers examine remaining income after housing expenses. They also factor in elements impacting the overall cost of home maintenance, including location, property size, and job stability (Soaita, 2020). For instance, living in a neighborhood with limited public transportation options might lead to higher housing costs because owning a car becomes necessary. Similarly, residing in an area with high crime rates may require extra security precautions (Dewilde, Turnbull, Gielens, Seo, & Czirfusz, 2025). Since people have different goals and values regarding their housing needs, two families with the same income might perceive home affordability differently.

Some people consider how supply and demand affect home prices economically. When demand is high and supply is limited, prices usually increase, making it hard for many clients to afford housing (Financiare, 2024). Customers aiming to build new homes or repair existing properties might face challenges if the market slows due to factors like labor shortages, land scarcity, and rising construction expenses. The

Romanian construction industry is experiencing new pressure from escalating costs and increased economic uncertainty (Dragan, 2025).

Governments can sway the housing market by passing laws that increase risk and uncertainty for builders. These laws may involve building codes, local regulations, environmental permits, and other construction requirements. Experts highlight that social considerations like safety, durability, and long-term value heavily influence people's home-buying choices. Because these factors affect buyers' well-being and quality of life, they can be more impactful than the purchase price itself (Dewilde, Turnbull, Gielens, Seo, & Czirfusz, 2025).

In conclusion, social, structural, and economic factors all influence the affordability of housing. Studies suggest that current perspectives may overlook the practical impacts of innovative construction methods on home affordability. For example, modern techniques such as prefabricated or modular buildings can be faster and cheaper to build than traditional methods, but they may require a higher upfront investment or alternative financing options (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021) (The Rise of Modular Construction: Benefits and Innovations, n.d.).

These theoretical frameworks detail why housing costs are increasing, but they also raise an important question: can changing the construction process reduce costs and improve affordability? This question points to the potential of exploring alternative construction methods as a solution to the housing affordability problem.

Long execution delays, heavy dependence on personnel, and material waste are among the inefficiencies that hinder the traditional construction process and increase housing costs (Housing, n.d.). To address these issues, innovative strategies have been developed to boost productivity and reduce building expenses (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021).

One approach is modular construction, providing better control over the production environment, such as temperature, material quality, and work accuracy. Components are manufactured in a factory and transported to the site for assembly. This method reduces errors during construction and significantly shortens the overall build time compared to traditional methods (Xu, et al., 2022).

Modular construction enables simultaneous management of various project phases. For example, site preparation and foundation work can happen at the same time as factory module production. This method helps reduce labor costs and speeds up the project timeline. However, modular construction also has drawbacks. Large prefabricated components often need specialized equipment and logistics for transport, which can raise costs, particularly when the site is distant from the production plant (Sakin & Kiroglu, 2017). Additionally, size restrictions on modules may constrain design options, leading to more uniform and less adaptable designs.

Using eco-friendly materials and sustainable designs offers an alternative approach to building homes. Builders often select lightweight, recycled, and reclaimed materials such as plastic and wood. These choices can reduce costs in the long run, decrease waste, and contribute to energy conservation (Tasneem, n.d.).

Enhanced insulation and sophisticated heating systems showcase energy-efficient design methods that can greatly impact performance (Sanguinetti, Almazam, Humaidan, & Colistra, 2019). These practices help lower heating and cooling costs while decreasing the overall carbon footprint. Furthermore, sourcing products locally supports waste management initiatives and reduces emissions from transportation.

When buying a new house, the advantages of eco-friendly options aren't always obvious at first. These choices can sometimes require higher upfront costs than conventional ones, which can be challenging for those with limited budgets. Furthermore, many people lack familiarity with these new materials and techniques, raising concerns about their long-term durability (Can, et al., 2021).

Automation and digitalization have driven advancements in the building industry. Technologies such as robotic construction, automated manufacturing, and building modeling aim to reduce errors and boost productivity. These solutions provide better control over planning and execution compared to traditional methods. However, only a small handful of companies currently utilize these technologies due to their high costs and the need for specialized expertise.

Additive manufacturing, or 3D printing, has attracted interest in residential construction in this era of technological progress. This method allows for automated, layer-by-layer building, helping to cut down on labor and material waste (Contributors, Construction 3D printing, n.d.). It can be used to create residential buildings, as demonstrated by several pilot projects (Becher, n.d.) (Carolo & Haines, 2024). Despite this, most 3D printing applications in construction remain small-scale and have not yet spread throughout the typical home market.

Considering all factors, different building methods offer opportunities to solve specific structural problems in housing development. However, their limited distribution means their adoption mainly relies on technical efficiency.

One of the newest developments in residential construction is 3D printed homes. This technique uses large 3D printers that layer materials, usually a special type of concrete, to build walls and structural parts. (Contributors, Construction 3D printing, n.d.) (Becher, n.d.). This method enables significant automation in the construction process, minimizing the need for manual labor compared to conventional techniques (Carolo & Haines, 2024). Small houses have been printed within days in several pilot projects, often showcased as an example of how construction time could be significantly reduced (Portugal's First 3D Printed House Demonstrates Speed and Cost Efficiency of 3D Construction Printing, 2024) (3D Printed House Tecla, n.d.).

One of the key benefits of 3D printed homes is the potential for lower construction costs. Automation decreases labor expenses by needing fewer workers. Moreover, the printing method allows for more precise resource use, minimizing waste (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021). For example, walls are printed only where necessary, eliminating the need for extra temporary supports or formwork. These benefits are often emphasized as key advantages given rising housing costs. Regarding design, 3D printing is promoted as a versatile construction method because the printer relies on a digital model, allowing for the creation of complex shapes and unique layouts without significant additional expenses (Hafza, 2025). In practice, this facilitates the creation of curved walls or complex patterns more easily than with traditional building methods. To reduce technological risks, most current projects focus on simpler designs (Becher, n.d.).

Another benefit of 3D printed housing is its environmental impact; it reduces material waste, utilizes resources more efficiently, and can incorporate sustainable materials (García-Alvarado, Moroni-Orellana, & Banda-Perez, 2021). Additionally, some projects use energy-efficient design features like integrated insulation or compact building shapes (Ali, 2019). While the long-term performance of 3D printing materials is still under evaluation, these features could contribute to decreasing the building's environmental impact over time.

Despite these advantages, 3D printed housing is still not widely used, and the majority of projects, such as display homes or emergency shelters, are still experimental or small-scale (Dancel, 2019). For example, some printed homes have been constructed as pilot social housing initiatives or for disaster-affected areas. Although these instances show that 3D printing is technically feasible, they usually do not reflect the circumstances of the ordinary housing market (Agnihotri & Bhattacharya, 2023).

Additionally, real-world challenges hinder the adoption of 3D printing in housing construction. These include regulatory frameworks that are often not designed for this type of building, causing delays in approval processes, and the hesitance of financial institutions to offer loans or insurance for structures made with innovative methods (Agnihotri & Bhattacharya, 2023). These factors may influence developers' and purchasers' inclinations to use 3D printed homes.

3D printed housing is often seen as a promising solution to housing challenges, especially regarding efficiency and cost reduction. However, the gap between its technological capabilities and actual implementation in housing markets indicates that other issues need to be considered. Despite the technological promise of 3D printing, its limited deployment in real-world projects suggests that non-technical factors play a role in its adoption. Besides efficiency and sustainability, factors like market conditions, regulatory frameworks, and consumer trust are crucial in determining whether this technology can be adopted on a large scale beyond pilot projects.

Various interconnected issues are hindering the widespread adoption of 3D printed homes in the residential market. While technological advancements have made home construction quicker and more efficient, numerous other factors also impact the decision to purchase a home. The high cost of homeownership is a significant financial concern for many, prompting them to be more cautious and deliberate in their choices (Romania Residential Market Report, 2024).

A significant barrier is the lack of confidence in new construction methods. Many potential homeowners are unfamiliar with 3D printed homes and worry about their durability, safety, and long-term performance. These concerns often include whether the walls will last, the home's resilience against various weather conditions, and the ease of repairs if issues occur. Furthermore, visible cracks or material deterioration can raise doubts and deter people from selecting an unconventional type of home (García-Alvarado, Moroni-Orellana, & Banda-Perez, 2021). Another key challenge is navigating the regulatory environment. Evaluating or approving new technologies like 3D printing can be difficult because building codes and standards are usually designed around traditional construction methods (Realworld Law Construction, 2025).

Financial challenges that hinder obtaining financing for these homes further diminish buyer confidence. Due to their cautious approach, banks and insurance firms might hesitate to provide mortgages or insurance for homes constructed with non-traditional methods. Even if the price is reduced, this may make the home less appealing, as buyers might not afford it. Additionally, buyers see a greater risk because the future market value of 3D printed homes remains uncertain (Barac, 2025).

Social and cultural factors shape perceptions of these homes. Brick and concrete houses are typically seen as safer and more valuable, whereas traditional building methods are often viewed as reliable and durable, especially in regions like Romania (Sipos-Gug, 2024). Rather than considering 3D printed homes as permanent solutions, they are frequently regarded as experimental or short-term. Construction companies face challenges in adopting 3D printing, as they must integrate new technologies alongside conventional methods. The limited adoption of 3D printed housing stems from a range of technological, financial, social, and cultural issues that need to be tackled (Dewilde, Turnbull, Gielens, Seo, & Czirfusz, 2025).

When taking into account these interconnected barriers, it is clear that the slow uptake of 3D printed housing cannot be attributed only to the current level of technological development. Instead, it shows a more complex relationship involving market trends, legal frameworks, and public perceptions of new innovations in housing.

The previous sections discussed the increasing issue of rising housing costs, the limitations of traditional construction methods, and the potential of alternative solutions like 3D printed homes. Although 3D printing offers notable technical benefits, these homes are still rare in the real estate market. This situation highlights the need to explore the reasons behind the slow adoption of this technology, especially given growing worries about affordability.

From a technical standpoint, 3D printed housing offers notable benefits such as reduced labor costs, faster construction, and less material waste. These advantages make 3D printed homes appealing to both developers and buyers. However, few projects have been completed, and private buyers rarely opt for this type of housing for long-term residence. This discrepancy between the technology's potential and its actual use indicates that factors beyond cost and efficiency influence housing choices. The adoption of 3D printed homes seems to be impacted by social perceptions, regulatory approvals, financial backing, and confidence in build quality. Although these aspects are often discussed individually, they are rarely analyzed together in research, especially regarding new housing technologies. This is especially relevant in

Romania, where 3D printed homes are still experimental, and the housing market faces growing affordability issues.

This thesis investigates the factors affecting the acceptance of 3D printed housing in Romania, focusing on the main question, “What are the main barriers that hinder 3D printed houses in Romania and why?”. It seeks to understand how social, economic, and institutional factors influence people's willingness to adopt this innovative building method, going beyond just technical aspects. Most existing research emphasizes technical feasibility, environmental impact, or economic efficiency of 3D printed structures, but limited attention has been given to how potential users in Romania perceive and accept these homes. Considering the country's unique housing preferences and ongoing affordability issues, no studies have thoroughly explored the social and cultural factors influencing acceptance of 3D printed houses there. The primary goal of this dissertation is to determine why these homes are not widely adopted, despite their benefits and rising costs of traditional housing.

2 Housing Affordability and 3D Printing in Construction

Housing affordability is not only a matter of cost, it is a significant social and economic issue that influences overall quality of life and social stability (Stone, 2010) (Housing, n.d.). The availability of reasonably priced housing influences people's future planning, work prospects, and housing preferences. Families are often forced to make tough choices about their living arrangements when housing becomes costly (Un-Habitat, 2020).

Housing affordability significantly impacts social inequality. While higher-income individuals can manage increasing housing costs, lower and middle-income households encounter greater financial challenges (Dewilde, Turnbull, Gielens, Seo, & Czirfusz, 2025). As a result, individuals and families might struggle to afford independent living, which can postpone key life milestones such as moving out or starting a family (Mulder & Billari, 2010). Deeper structural issues with the housing sector are reflected in these decisions.

The affordability of housing is also heavily affected by economic factors. When households allocate a large portion of their income to housing, less money is available for essentials such as healthcare, education, and savings. This situation can restrict economic mobility and increase vulnerability to unexpected events like job loss or changes in interest rates (Stone, 2010) (Housing, n.d.). In this sense, home affordability directly influences the overall economy, with effects that go beyond just the housing sector.

Urbanization and labor markets are tightly linked to housing affordability. When workers cannot afford to live near their jobs, commuting times rise, and cities might become more segregated. This can pose challenges for essential workers like teachers and healthcare staff to find housing in areas where their services are most needed (Housing, n.d.) (Can, et al., 2021). These issues show how affordability challenges can influence the functioning of local economies and towns.

It is important to consider the wider social and economic impacts of home affordability issues. Since homeownership is often associated with stability and success, housing expectations and norms also influence affordability challenges. As these goals become harder to attain, households may feel increased frustration and insecurity (Un-Habitat, 2020). Grasping these elements is crucial for creating effective solutions that address the root causes of affordability issues, not just their surface symptoms.

2.1 Affordability Pressures in the Romanian Context

In Romania, these issues are not just theoretical; they directly impact households' ability to find suitable housing. Housing affordability has become increasingly strained, especially in major cities. While macro-level price-to-income ratios suggest Romania has one of the most affordable housing markets in the EU, this perception does not reflect the real difficulties faced by many households (Dewilde, Turnbull, Gielens, Seo, & Czirfusz, 2025) (Barac, 2025).

The gap between income growth and housing costs is a key factor affecting affordability. Although earnings in Romania have increased in recent years, housing prices in cities like Bucharest and Cluj-Napoca have risen faster at times, especially since 2020 (Newsroom, 2025) (Romania House Price Index, n.d.). Consequently, even families with stable jobs may find themselves needing to allocate more of their income to rent or mortgage payments. This situation heightens their vulnerability to economic shocks and reduces their financial flexibility.

Another significant factor is the rise in building expenses discussed earlier. The selling prices of new residential units increase because higher labor and material costs are passed on to consumers (infoConstruct, 2025) (Romania - Labour cost index: Construction, n.d.). Developers have limited ability to lower prices without hurting profitability due to rising production costs and regulatory constraints. Consequently, new homes are often priced in higher ranges, reducing middle-class access. Over time, affordable options tend to shift toward older buildings or outlying areas.

The affordability challenges are intensified by financing conditions. Although property prices stayed steady despite a sharp rise in mortgage interest rates in 2023 and 2024, monthly payments still increased (Romania: Loans to households; for house purchase; over 10 years' initial rate fixation (new business), n.d.). Higher down payment requirements and increased borrowing costs pose substantial obstacles for many first-time buyers. Consequently, numerous households postpone buying a home, stay with their parents longer, or depend on family financial assistance. These responses reveal fundamental affordability challenges rather than individual preferences.

Romania's strong cultural inclination towards owning homes significantly influences the market. Renting is often regarded as a short-term option rather than a long-term choice, partly because the EU has one of the highest homeownership rates (Housing in Europe – 2025 edition, n.d.). This societal norm adds upward pressure on prices, especially in sought-after urban areas, increasing demand for owner-occupied homes. At the same time, the limited availability of high-quality rental properties reduces market flexibility and makes it harder for households to adjust to changing economic conditions.

Romania has the highest homeownership rates in the European Union (Housing in Europe – 2025 edition, n.d.). Competition is fierce for buying or renting, especially in popular city districts, since many see renting as temporary rather than a long-term option. The limited availability of quality rental apartments constrains housing choices, while rising property values attract more people to buy. This situation poses difficulties for families whose income or employment status changes.

In certain areas, cost considerations become apparent. Prosperous cities with many schools and job opportunities tend to have high housing prices due to strong demand. Conversely, quieter towns often have cheaper housing but may offer lower incomes and less developed transportation, services, and roads. While relocating to suburban or rural areas typically lowers housing costs, longer commutes can increase transportation expenses, thereby decreasing total savings. Therefore, the cost of daily living is heavily influenced by your choice of location.

2.2 Evolution of Housing Prices

In recent years, Romanian home prices have fluctuated unpredictably, making it challenging to forecast their direction. Despite occasional slowdowns and demand variations across cities, the overall trend has been upward since 2020. The national House Price Index helps analyze this pattern; starting from 2015, Romania's index was approximately 166 in the third quarter of 2025. This suggests that prices kept rising even after the initial pandemic-driven surge (Romania House Price Index, n.d.).

In 2021 and the first half of 2022, when households actively engaged in the home market and financing was accessible, there was a significant shift. People sought larger homes or better locations not only to enhance their lifestyles but also because housing was regarded as a secure investment. The relatively low mortgage rates during this period, ranging from 3.7% to 4.6% in 2021 and remaining below 5% until mid-2022, supported rising home prices and made purchasing more attractive (Romania: Loans to households; for house purchase; over 10 years' initial rate fixation (new business), n.d.).

By the end of 2022 and 2023, the market environment had shifted considerably, with higher financing costs and rising uncertainty (Romania Real Estate Market 2024). Generally, demand tends to decline; however, in Romania's housing market, this was not observed. Many buyers, particularly those buying new homes, either paused their purchases or cut back on their budgets due to the sharp increase in mortgage rates, which rose to approximately 6% and 7% in 2023 and 2024 (Romania Real Estate Market: Analysis of Prices, Rental Yields and Investment Opportunities, 2025). In many markets, a significant rise in interest rates usually leads to price declines. However, Romania's market responded differently. Instead of dropping sharply due to limited supply and homeowners' reluctance to sell, it decelerated as more deals were negotiated and fewer transactions occurred.

Price stability in 2022 was maintained despite declining demand, thanks to high construction costs. During this period, Romania's building material costs peaked, with the construction material cost index reaching about 139, up from 100 in 2021. Developers struggled to lower prices without significantly impacting their profits, as input costs remained high and demand persisted. As a result, the market often favored slower sales over steep price cuts.

The housing market differs across cities. In areas with strong job markets and universities, prices tend to stay stable due to steady demand, while less developed regions often see stagnation. When affordability decreases, people make compromises that affect pricing trends. Some choose smaller apartments, move to nearby areas with lower prices per square meter, even if it means longer commutes. Some also choose older buildings. This example shows how "price growth" can influence real decisions that impact people's lives.

In summary, Romania's housing market has recently experienced price rises due to strong demand, limited supply, and higher construction costs. Measures to curb this growth involve increasing borrowing rates and decreasing buyers' purchasing power. This context is important for this thesis because it indicates that price increases are not the sole factor affecting housing prices. It also emphasizes how buyers adjust their behavior based on financial limitations, which in turn impacts new construction prospects.

2.3 Limitations of Traditional Construction

The housing industry in Romania has traditionally relied on conventional building methods. However, data and research reveal several drawbacks of these techniques, including reduced productivity, longer timelines, and higher costs. A major concern is the continuous rise in building expenses, primarily driven by increasing prices for essential materials such as cement, insulation, and finishing supplies (Romania Construction Cost Index: 2021=100: NACE 2: ow Material Costs, n.d.). In 2024, the building cost index rose approximately 14.7% from 2023, with certain materials experiencing price increases of over 20% within a year. These rising costs are significantly affecting buyers, especially as affordability remains a challenge (Romania Construction Cost Index: 2021=100: NACE 2: ow Material Costs, n.d.). Both academic research and labor market data highlight the ongoing dependence on manual labor in the country. Conventional construction work continues to demand skilled workers, and recent labor cost statistics indicate this trend is growing. Significant wage hikes and a shortage of skilled workers primarily drive the construction labor cost index's roughly 30% yearly increase by the end of 2023 (Romania - Labour cost index: Construction, n.d.). Companies often delay projects or increase prices to cover higher costs caused by labor shortages or quick pay raises. This creates a vicious cycle where rising labor costs slow project progress and further inflate total costs.

Romania's traditional construction industry frequently experiences delays and slow progress, primarily as a result of poor automation, weather-related problems, shortages of materials, and difficulties coordinating across several teams. For instance, it can take more than a year to complete the construction of a typical residential complex. These timelines can be further prolonged by labor shortages and rising material prices, which will increase overall costs. In addition to delaying project completion, these delays may also lower the build's ultimate quality.

Traditional construction methods, like formwork, cutting materials, and replacing parts, not only cause delays but also generate significant waste. Although often overlooked, this waste raises consumer costs. It persists mainly because of labor-intensive, manual workflows, despite ongoing efforts to minimize it. These inefficiencies build up over multiple projects, often less noticeable than direct price hikes. Additionally, conventional approaches struggle to adapt swiftly to changing housing demands, resulting in supply shortages and higher expenses (Construction and demolition waste, n.d.) (Waste statistics, n.d.).

The building industry still offers opportunities for innovation despite these challenges. Technologies like modular construction and 3D printing can boost productivity, reduce waste, and speed up project delivery. However, implementing these methods demands significant investment in new equipment and infrastructure, which could limit their widespread adoption (Zohourian, Pamidimukkala, Kermanshachi, & Almaskati, 2025). As Romania's housing sector expands, it is crucial to tackle these challenges and explore innovative, cost-effective solutions that focus on efficiency and ingenuity. This approach can help developers offer more affordable, efficient, and sustainable housing alternatives.

3 3D Printed Housing as a Solution to the Housing Crisis: Opportunities and Barriers in the Romanian Context

Structures and building components are created layer by layer through 3D printing, beginning with a digital model. This method employs computer-controlled machines to accurately deposit material where necessary, as opposed to traditional approaches that involve assembling bricks or blocks on-site. In construction, this process is commonly called additive manufacturing (Contributors, Construction 3D printing, n.d.).

Large-scale printers that extrude cement-based materials through a nozzle are used in the majority of construction applications for 3D printing. Traditional formwork is not necessary because the printer follows a predefined path to construct walls and other structural components. This strategy is different from conventional building techniques, which frequently call for specific tools and workers at every stage of the procedure. Systems that show how 3D printing can be utilized on-site have been created by companies such as WASP, COBOD, and CyBe; these systems often use robotic arms or gantry systems to control the printing motion (3D Printed House Tecla, n.d.) (Portugal's First 3D Printed House Demonstrates Speed and Cost Efficiency of 3D Construction Printing, 2024) (3D Printing Houses, n.d.).

A digital design is the first step in the entire building process. Computer-aided design (CAD) software is used to create models, which are subsequently converted into machine instructions. The shape, layer thickness, and printing speed are specified in these instructions. Shape or layout changes don't require new molds or tools because the design directly directs production. It is commonly highlighted that this digital technique differs significantly from conventional construction approaches (Becher, n.d.) (Carolo & Haines, 2024).

In 3D printing for construction, materials are essential. These concrete combinations are not the same as regular concrete. They must set quickly to support the weight of later layers while also flowing smoothly through the nozzle. Research highlights the importance of controlling printability, drying time, and material strength because failure to do so could result in the structure bending or collapsing during the printing process (Tobi, et al., 2018) (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021) (Oberti & Plantamura, 2015).

Construction 3D printing uses a variety of printing techniques. While some systems produce components off-site that are assembled later, others print whole walls right on-site. The majority of real-world usage to far have been temporary buildings, experimental housing, or low-rise residences. For instance, the demonstration homes in Portugal and Sweden and the TECLA house in Italy show that this technology is primarily utilized in pilot projects rather than large-scale manufacture (Portugal's First 3D Printed House Demonstrates Speed and Cost Efficiency of 3D Construction Printing, 2024) (3D Printed House Tecla, n.d.) (Jonsson, n.d.).

3D printing for construction is frequently viewed as a part of the larger movement in the construction sector toward automation and digital transformation. By combining several processes, like forming, positioning, and finishing structural components, into a single, continuous operation, it expedites the building process. But it also creates new dependencies, such as the need for specific tools, software, and personnel knowledgeable about digital systems and construction (Fernandez, Caldaz, & Reales, 2023) (Ferretti, 2022).

All things considered, the use of 3D printing in construction represents a change in building design and construction. This technology challenges traditional methods by combining automated processes, material behavior, and digital design. Although the technical aspects are widely recognized, its influence on housing markets and construction systems is still evolving, opening the door for further analysis of its benefits and drawbacks in the parts that follow.

3.1 Economic Viability: Cost Comparison with Traditional Construction in Romania

When discussing whether 3D printed housing is "worth it" with the straightforward premise is that, since printing is quicker and requires fewer on-site workers, it should be less expensive. Popular explanations, which sometimes assert that homes can be built in a matter of hours at much lower cost, seem to support this rationale (Becher, n.d.). A closer look at what is actually being compared, however, shows that the term "cost" is used loosely. In some cases, it refers only to the printed shell; in others, it encompasses finishes and systems; and in yet others, it covers almost everything, giving the impression that comparisons are more positive than they actually are.

Labor is often the first factor considered for legitimate reasons. A printer can offer a consistent, automated process that lowers labor needs and accelerates delivery, replacing many manual, on-site tasks involved in traditional construction (Wilson, Mativenga, & Marnewick, 2024). However, labor doesn't disappear; it shifts. Fewer workers with specific skills are needed to handle repetitive tasks such as operating the printer, mixing, maintaining equipment, and managing digital workflows, instead of employing a large workforce. This shift is especially significant in countries like Romania, where wages are lower than in many Western nations, meaning the expected "labor saving" advantages are less impactful compared to areas with higher labor costs.

Material utilization is often seen as an opportunity for cost savings. Since material is only deposited where it's needed, the layer-by-layer approach helps minimize waste, which is crucial when discussing the cost and sustainability of 3D printing construction. (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021) However, printable mixes do not necessarily match regular concrete in terms of consistency, control, and additives. This suggests that while waste reduction is possible, increased costs for mix quality and process control are likely. Whether these are "free savings" depends on the project size and supply chain maturity; more often, they are shifting expenses.

Key statements often focus on timing. For instance, Portugal's demonstration project shows that printing structural walls can be completed in just 18 hours, at an estimated cost of about €1,500 per square meter. This is considered cost-effective compared to local market standards (Portugal's First 3D Printed House Demonstrates Speed and Cost Efficiency of 3D Construction Printing, 2024). These examples highlight what can be achieved with a well-organized approach. However, they also underscore an important point often overlooked: printing mainly covers the structural shell. Windows, insulation, plumbing, electrical systems, roofing, and interior finishes still require time and are usually built using traditional methods. As a result, the overall schedule may not be as drastically shortened as headlines suggest, even though it can be reduced.

Uncertainty remains a subtle, underlying concern. In a market where 3D printed homes are uncommon, developers often factor risk into their prices, and buyers may worry about repairs or resale value. The limited market history also makes banks hesitant to finance such projects. Thus, "can it be built cheaper?" isn't the only question—another is whether it can be sold under normal circumstances. These concerns are separate. Additionally, current analyses indicate that the technology continues to develop and adapt to architectural needs, which influences market confidence (García-Alvarado, Moroni-Orellana, & Banda-Perez, 2021).

This thesis adopts a cautious stance on the cost issue, viewing 3D printing as a set of circumstances that may or may not be relevant in the Romanian market, rather than assuming the technology naturally lowers home prices in Romania. It is more relevant to focus on where costs could realistically change, such as labor, time, and waste, and where new expenses might emerge, like equipment, specialized staff, approvals, and risks. Rather than providing a single final figure for comparison with traditional construction, this approach highlights the importance of understanding these factors. This perspective underpins the subsequent sections, which explore technical and market constraints, as these significantly influence whether "cheaper in theory" truly translates into "cheaper in practice" in the marketplace.

3.2 Performance Advantages of 3D Printed Housing

The capability of 3D printed housing to significantly reduce construction time is one of its most notable advantages. Walls and other structural parts can be assembled much more quickly compared to traditional methods because of the continuous and automated printing process. Studies show that the main structure of a house can be completed in just a few days, or even hours, depending on the size and complexity of the design. This greatly accelerates the most time-consuming parts of the building process. It is important to note that this does not mean the entire house will be finished within that timeframe.

One key aspect of 3D printed housing is its efficient use of materials. Traditional building methods often lead to material waste due to issues like formwork problems, cutting errors, and construction mistakes (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021) (Fernandez, Caldaz, & Reales, 2023). In contrast, 3D printing minimizes waste and enhances resource efficiency by placing material only where it is required, following precise paths. This level of precision supports better resource management, which is especially beneficial for complex architectural designs.

Another important consideration regarding 3D printed housing is its structural performance. Research indicates that, with careful control of material composition and printing settings, printed concrete elements can achieve adequate compressive strength suitable for low-rise residential buildings (Tobi, et al., 2018) (Fernandez, Caldaz, & Reales, 2023). Other studies investigate ways to improve structural behavior, such as adding steel bars or fibers. While these innovations are still being developed, they suggest that with appropriate design, printed structures can meet necessary structural requirements.

One key advantage of 3D printed housing is its flexibility in design. Since modifications in shape or wall structure don't need extra tools or molds, the printer can easily follow a digital model (Carolo & Haines, 2024) (Hafza, 2025). This enables more efficient structural performance and load distribution, allowing designers to incorporate features such as curved walls, variable thickness, or built-in cavities with minimal additional effort. In theory, this means that structures can adapt more swiftly to environmental and functional needs without becoming more difficult to produce.

3D printed housing is often associated with environmental benefits. Compared to traditional building methods, it offers advantages like less material waste, optimized designs, and the use of potentially sustainable materials (García-Alvarado, Moroni-Orellana, & Banda-Perez, 2021) (Ali, 2019). Life cycle assessments suggest that, in some cases, 3D printed homes can be more environmentally friendly than conventional structures, especially when material use and construction waste are minimized.

Automation in 3D printing greatly impacts site safety and labor needs. By reducing the need for large construction teams (Becher, n.d.) (3D Printing Houses, n.d.), working conditions improve, and the risk of accidents decreases. The process becomes safer and more consistent with fewer workers involved in physically intensive tasks.

In conclusion, the advantages of 3D printed housing include speed, material efficiency, design flexibility, and potential environmental benefits, all contributing to its strong performance factors. These features are driving the increasing popularity of this technology as a possible alternative to traditional construction methods (Becher, n.d.) (Carolo & Haines, 2024). However, most performance claims are based on controlled environments and experimental projects, so it is important to examine practical limitations and economic viability more carefully in the sections that follow.

3.3 Technical and Market Limitations of 3D Printed Houses

Although 3D printing houses offer apparent benefits in terms of performance and efficiency, they nevertheless pose significant technical and commercial challenges which limit their use. Such a restriction is often observed in educational analysis, experimental undertakings, and demonstration homes, which explain why wide adoption remains restricted (Contributors, Construction 3D printing, n.d.).

Support and architectural measures constitute a major technical impediment. In particular, 3D printing houses are produced using solid bulges which perform proficiently inferior to compaction but which also pose problems together with support and tensile strength. Unlike traditional reinforced concrete, where steel parallel bars are laid down in a mold prior to pouring, 3D printing requires a different approach, such as fiber reinforced mixture, manual interpolation, or hybrid arrangements, which combine conventional and printed parts. Since these techniques can guarantee acceptable robustness, Leticia Fernandez (2023) and A L Mohd Tobi et al. (2018) memorandum that they are not yet standardizing and regularly lowering the level of automation, which was originally fascinated by 3D printing (Tobi, et al., 2018) (Fernandez, Caldaz, & Reales, 2023).

Material conduct is another significant restriction. In order to be rigid enough to support the weight of the next layer and remain fluid enough for a smooth bulge, the printable solid must satisfy the requirements of the conflict specification. External factors such as temperature and humidity, which may affect the bonding of the layers and the quality of the top surface (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021) (García-Alvarado, Moroni-Orellana, & Banda-Perez, 2021). In addition, the EPFL investigation focused on the difficulties of extending uniform material performance outside control settings, in particular at the manufacturing facility (Oberti & Plantamura, 2015).

It should also be more restrictive in terms of the size of the building, with a mainly documented 3D printing house project centered on a low rise or single story structure. Additional obstacles such as load transmission, vertical support, and increased stability are added to a multi-story building. Therefore, the various companies, in the context of educational circumstances inquiries and company illustrations, continue to be narrower in order to fly housing, emergency shelter, or presentation units rather than to the increasingly dense urban sectors (Dancel, 2019) (Carolo & Haines, 2024).

Market restrictions are closely related to the aforementioned technical roadblock. For the buyer, however, the 3D printed house is still unknown. The case studies and qualitative analysis show that the buyer tends to attach reliability and sustainability to traditional components and construction methods. Visible features admire the layer wall texture; otherwise unusual coating may damage the interpretation of the standard, even if the architectural performance is acceptable (Agnihotri & Bhattacharya, 2023) (Becher, n.d.).

There is a particular difficulty in integrating them with traditional assembly systems in this regard. For printed walls, roofs, insulation, windows, plumbing, and electrical installations are nevertheless necessary, and these are usually completed using traditional methods. As a consequence, concerns may arise in addition to coordination in hybrid formation processes. Among the above integration levels, there is a frequent delay in time and cost overproduction which reduces the efficiency gains expected from automated printing (Fernandez, Caldaz, & Reales, 2023) (Ferretti, 2022).

Regulatory uncertainty further hinders market adoption. Building codes and approval procedures were designed for traditional construction and often do not provide clear guidance for printed structures. Even if printed houses meet performance criteria, the certification and approval processes can be delayed because of the absence of specific standards and limited long-term performance data. This uncertainty impacts developers, insurers, and financial institutions, all of whom are crucial to the housing market (Contributors, Construction 3D printing, n.d.) (Hossain, Zhumabekova, Paul, & Kim, 2020).

Overall, these technical and market constraints indicate that 3D printed housing is both a technological and systemic challenge. While the technology works under certain conditions, these conditions are not yet widely adopted in mainstream construction. This clarifies why 3D printed housing is still mostly experimental despite its often-promoted potential.

3.4 Barriers to Adoption in the Romanian Context

The adoption of 3D printed housing in Romania is influenced not only by the general technical and market limitations discussed earlier, but also by a set of local barriers that shape how new construction technologies are received. These barriers are linked to regulation, market structure, financing practices and social perception and they interact in ways that make adoption slower than what technical performance alone would suggest.

The regulatory environment presents a major challenge. Most of Romania's building codes are rooted in traditional methods such as masonry and reinforced concrete. While these standards ensure safety and consistency, they offer limited flexibility for alternative construction techniques outside established categories. Broader reviews on 3D printing in construction indicate that in the absence of clear regulations for evaluating printed structures, approval processes tend to become more lengthy and complex (Contributors, Construction 3D printing, n.d.). In reality, this suggests that developers considering 3D printing might face additional administrative steps, testing requirements, or delays, increasing costs and uncertainty.

Financing represents another significant obstacle. Housing construction in Romania depends heavily on bank financing, both for developers and private buyers. Financial institutions tend to be conservative and rely on familiar construction types when assessing risk. Because 3D printed houses have limited market history, banks may hesitate to provide standard mortgage products or may apply stricter conditions. This issue is not unique to Romania, but it becomes more relevant in markets where affordability is already under pressure and buyers rely strongly on credit to access housing (Becher, n.d.).

Market structure also affects how new technologies are adopted. In Romania, the construction sector is mainly dominated by traditional firms with established processes, supplier networks, and a workforce trained in conventional building methods. Implementing 3D printing requires substantial upfront investment in equipment and training, which is hard to justify without clear market demand. Companies like COBOD and CyBe highlight that cost savings via 3D printing rely on economies of scale, but these benefits are difficult to achieve in markets where projects remain small and unproven (Portugal’s First 3D Printed House Demonstrates Speed and Cost Efficiency of 3D Construction Printing, 2024) (3D Printing Houses, n.d.).

Social perception and buyer preferences further restrict adoption. In Romania, owning a home is closely linked to long-term security, durability, and resale value. Buyers tend to trust traditional materials like brick and reinforced concrete, viewing them as established and dependable. Conversely, printed houses might be seen as experimental or temporary, despite meeting technical standards. Case studies and market discussions highlight that visible features, such as textured layered walls or unfamiliar layouts, can influence acceptance more than technical specifications (Carolo & Haines, 2024) (Agnihotri & Bhattacharya, 2023).

Another barrier relates to the limited number of local examples. While international projects such as the TECLA house in Italy or demonstration houses in Portugal and Sweden show what is technically possible, Romania lacks well-known reference projects that buyers and institutions can point to as proof of reliability. Research on innovation adoption suggests that visibility and repetition matter and without local precedents, new technologies struggle to gain trust (3D Printed House Tecla, n.d.) (Jonsson, n.d.).

Ultimately, a gap exists between potential and readiness. Academic research on sustainable, affordable housing via 3D printing emphasizes long-term advantages like cost savings, resilience, and environmental performance. However, realizing these benefits requires conditions such as standardized procedures, supportive regulations, and market acceptance, which are not yet fully established in Romania (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021) (Everett & Soto, 2022).

This study explores the primary barriers to adopting 3D printed housing in Romania, addressing the lack of a tailored analysis for this market. While international research covers the technical possibilities of 3D printing in construction and generally discusses challenges like regulation, cost, and public acceptance, there's limited systematic research on the specific hurdles faced in Romania. In particular, existing studies don't sufficiently examine how regulatory policies, financing options, market structure, and social perceptions interact to slow down widespread adoption. This research aims to fill that gap by investigating not only what barriers exist but also why they persist and how they collectively impede the growth of 3D printed housing in Romania.

3.5 Potential versus Practical Constraints

The idea of 3D printed housing is highly promising. Many of the claims surrounding the technology speak directly to the problems that housing markets are struggling with: construction that is too slow, too expensive and too dependent on manual labor. Seeing walls printed in a matter of hours or entire small houses produced in a few days, naturally creates the impression that a different way of building is not only possible, but already here. Projects such as the TECLA house or the demonstration homes built in Portugal and Sweden make this promise visible and tangible (3D Printed House Tecla, n.d.) (Portugal’s First 3D Printed House Demonstrates Speed and Cost Efficiency of 3D Construction Printing, 2024) (Jonsson, n.d.).

At the same time, the distance between these examples and everyday housing production is hard to ignore. What is shown in presentations and case studies often represents ideal conditions, where the technology is carefully prepared, closely monitored and applied at a limited scale. In real housing projects, construction rarely unfolds in such a controlled way. Printing usually addresses only part of the building process, most often the structural shell, while many other stages still rely on conventional methods. When those stages are added back into the picture, the overall advantage becomes less dramatic than the initial promise suggests (Carolo & Haines, 2024).

There is also the question of scale, which quietly shapes how potential turns into reality. Many of the benefits associated with 3D printing become meaningful only when the technology is used repeatedly and systematically. At small scale, high equipment costs, setup effort and regulatory uncertainty can easily outweigh the gains from faster printing or reduced waste. Studies that examine full-scale printed houses point out that results vary widely depending on project size and context and that early success does not automatically translate into broader economic viability (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Full-Scale 3D-Printed House, 2021).

Beyond numbers and performance indicators, there is a more subtle constraint related to trust. Housing is not only a technical product; it is a long-term commitment, often the largest investment people make. Even when printed houses perform well in tests, they still need to be accepted by buyers, supported by banks and approved by authorities. Case-based analyses show that new construction technologies often struggle in this phase, not because they fail technically, but because they feel unfamiliar and therefore risky (Agnihotri & Bhattacharya, 2023).

In Romania, this tension between promise and reality becomes particularly visible. Affordability pressures create a clear reason to look for alternatives, yet the conditions required for 3D printing to fully deliver its advantages are not firmly in place. Regulation, financing practices and industry routines still favor familiar solutions, even when they are expensive or slow. As a result, the technology remains present mainly as an idea of what could be possible, rather than a normal option on the housing market.

4 Research Methodology

4.1 Literature Review and Keyword Selection

To identify current research papers on 3D printed houses and housing affordability, the investigation began with a literature survey. A set of keyword combinations was created and consistently used across various websites to streamline the search process. Appendix A lists all the keywords and combinations used.

The review aimed to find foundational academic and industry literature on platforms like Google, Google Scholar, Scopus, ResearchGate, Semantic Scholar, Science.gov, and Academia.edu. It started with initial searches using technical terms such as "3D printed house," "3D printed home," and "3D printed construction." The keyword strategy was progressively refined and expanded with targeted combinations to include broader themes emerging from the literature, such as regulatory frameworks, material performance, market adoption, and societal perceptions, once a relevant base of publications was established.

Table 4.1: General Keywords.

<table>
<tr><th>Keyword 1</th><th>+</th><th>Keyword 2</th><th>+</th><th>Keyword 3</th></tr>
<tr><td>“3D printed”</td><td>+</td><td>“house”
“home”
“building”
“construction”</td><td rowspan="2">+</td><td rowspan="2">“projects”
“case study”
“technology”
“materials”
“academic research”
“thesis”
”article”
“scholarly article”</td></tr>
<tr><td colspan="3">“Additive Manufacturing in Construction”</td></tr>
</table>

After identifying key technical terms associated with 3D printed housing, the keyword combinations listed in Table 4.1 were used as the main structure for conducting the literature review. These combinations emphasize the technological and construction related aspects of 3D printed housing, allowing for the discovery of foundational research from both academic and industry sources. This initial set of keywords served as the foundation for building a focused and relevant collection of literature on additive manufacturing within construction industry. Based on these keyword combinations, a total of 40 relevant results were obtained.

Table 4.2: Social impact keyword combinations.

Keyword 1	+	Keyword 2	+	Keyword 3	+	Keyword 4
"Social Impact of"	+	"3D printed"	+	"house" "home" "building"	+	"projects" "case study" "technology" "materials" "academic research" "thesis" "article" "scholarly article"
		"affordable housing initiatives"				

In the context of the keyword combination supply on Table 4.2, the social impact of the 3D printed house has been analyzed, and the structure of the technological base established during the original search. In particular, in order to carry out investigations focusing on communal results, housing affordability, and the wide socioeconomic consequences of 3D printing. Using this keyword combination, 12 relevant research articles on the social impacts of 3D printed homes were formed.

This phase of the search made it possible to conduct an inquiry into the ways in which 3D printing technologies contribute to the evolution of the community and low-cost housing, going beyond technical performance.

Table 4.3: Traditional vs 3D printed Keywords.

Keyword 1	+	Keyword 2	+	Keyword 3	+	Keyword 4	+	Keyword 5
"Traditional" "Conventional"	+	"house" "housing" "building methods"	+	"vs"	+	"3D printed"	+	"housing" "homes" "house"

Using the keyword combinations in Table 4.3, literature comparing additive manufacturing techniques with conventional methods of housing construction was found in order to contextualize 3D printed housing within the larger construction landscape. These searches provided a comparison between established building practices and new 3D printing technologies by concentrating on variations in construction procedures, efficiency, cost, and housing outcomes. They produced 16 pertinent articles based on these keywords.

A more comprehensive evaluation of the potential advantages and difficulties of 3D printed housing was made feasible by this comparison method. These fundamental principles were further integrated with more general ideas about materials, market adoption, legislation, and environmental impact. Appendix A contains the full list of keywords.

4.2 Design of Interviews and Survey

After completing the literature review, the next step was the development of primary data collection tools, which were interviews addressed to 3D printing construction companies and traditional construction companies, as well as, a survey with the aim to answer the question "What are the main barriers that hinder 3D printed houses spread in Romania and why?".

An analytical framework created during the literature review directed the development of interview and survey questions, which were customized to fit the Romanian housing and construction sector. To maintain consistency between expert interviews and the public perception survey, a common set of thematic dimensions was employed rather than separate questions for each method.

These theme areas emphasize common issues and factors found in academic research on 3D printed homes, including cultural attitudes towards construction, financial viability, regulatory frameworks, social acceptance, and technological readiness. Afterwards, these themes were adapted to fit each group's perspective.

4.2.1 Topics selection for the interview with the 3D printing construction company

The interview with the 3D printing building company sought to gather insights from a forward-thinking individual directly involved in developing and applying this technology. The questions first aimed to gather descriptive and contextual details, then moved on to interpretative and strategic insights.

To better understand the respondent's background, operational scope, and technical expertise, questions about the company's history were included. Since 3D printed housing is still emerging in Romania, this context was particularly important for understanding the opportunities and challenges covered later in the discussion.

Questions about technology and materials were selected based on literature topics related to structural performance, material reliability, and adaptation to local climate conditions. These questions aimed to determine whether technical limitations are a major obstacle in Romania or if the technology is already well-developed.

This section emphasizes regulatory and market challenges, as regulation and permit acquisition are often cited in academic research as key barriers to innovation in construction. The questions here aimed to explore how these general regulatory obstacles translate into practical issues, such as securing permits, interacting with local authorities, and obtaining financing and insurance.

Including social and cultural barriers highlights that housing involves more than just technical aspects; it also encompasses social factors. Questions about community reactions, traditional building methods, and possible stigma aimed to identify whether resistance to 3D printed houses stems from distrust or cultural norms and expectations about housing.

The economic questions centered on how buyers view the value, durability, and cost of housing, rather than just on construction efficiency. This deliberate approach recognizes that affordability is often shaped by perception and trust, not only by price.

Finally, the questions about the future outlook were included to allow the respondent to synthesize their earlier responses and reflect on long-term adoption paths. These question help identify which changes the respondent considers are most important for increasing acceptance in the coming years.

The complete interview guide for the 3D printing construction company can be found in Appendix B.

4.2.2 Topics selection for the interview with the Traditional construction company

The purpose of the interview with the traditional construction company was to gain insights from a seasoned professional in the field, where continuity, experience, and well-established methods are essential. The participants selected reflect a deliberate shift from innovation towards adaptability, resistance, and a cautious approach.

To place the respondent within the context of the Romanian construction industry, questions about the company's background and the current state of the market were included. This provides a framework for interpreting responses based on the perspective of someone with extensive experience, rather than relying on personal or arbitrary opinions.

To assess how knowledgeable traditional construction experts are about this technology and whether their views are shaped by firsthand experience or limited exposure, questions about awareness and perception of 3D printed housing were included. These questions also aimed to explore opinions on the quality, durability, and reliability of 3D printed homes in relation to regulatory standards.

The section on cultural and social factors was given special attention, as research suggests that construction practices can be influenced by tradition, trust, and craftsmanship. Questions related to established methods, customization, and the significance of the "human touch" were included to understand how these values might impact the acceptance of automated construction techniques.

The questions on economic aspects were designed to explore perceived impacts on costs, competitiveness, and workforce dynamics. Rather than focusing on short-term effects, these questions aimed to uncover concerns about long-term transformations within the construction industry.

The future outlook section was added to determine whether traditional construction companies view 3D printing as a threat, an opportunity, or a complementary approach. This topic offers insights into how traditional and innovative construction methods can either coexist or collaborate effectively.

The complete interview guide for the traditional construction company can be found in Appendix C.

4.2.3 Topics selection for the Customer Survey

The survey was created to examine public perceptions, preferences and the likelihood of adoption of 3D printed housing in Romania. In particular, it was guided by the following central question: “What are the main barriers that hinder the spread of 3D printed housing in Romania and why?” rather than addressing this question directly, the survey operationalizes it through a set of topics that capture different dimensions of potential resistance and acceptance. The topics included in the survey followed a structured logic, starting with gathering information about the respondents and gradually moving toward awareness, evaluation and potential willingness to adopt this type of technology. This progression was meant to reflect how housing choices are typically formed, beginning from personal context and requirements and moving toward attitudes and intentions.

The original question focused on language clarity to make sure respondents could easily understand and engage with the survey.

The screening and profile questions aimed to gather data on participants' socio-demographic and housing characteristics. These included age, current housing type, location, such as urban, peri-urban and rural, ownership status , like owned or rented, and budget range for potential future purchases. These factors significantly influence housing preferences and attitudes toward alternative building methods. For instance, rural residents or homeowners may perceive 3D printed houses differently than urban renters. The budget range question was essential for understanding perceptions of affordability and determining whether 3D printed housing fits their financial situations.

The decision driver section was introduced to identify overall housing priorities independently of 3D printing considerations. It focused on questions about cost, location, size, sustainability, and energy efficiency, establishing a basis for understanding what people value most in a house. This serves as a reference point for comparing traditional housing preferences with attitudes towards 3D printed homes. Additionally, scale questions gauging openness to unconventional housing methods aimed to assess respondents' general attitudes toward innovation, which often influence their willingness to adopt new technologies.

An explanatory video was provided before the awareness and perception set of questions to establish a baseline of understanding what a 3D printed house is. This step was necessary to reduce misunderstanding and ensure that responses were based on the same reference point, especially given the novelty of the technology.

The awareness and perception topic was chosen to evaluate both existing knowledge and reactions to 3D printed houses. The question regarding prior awareness helps distinguish between opinions formed before the survey and those influenced by the explanatory video. Questions about first impression, concerns and perceived benefits were designed to capture intuitive and emotional responses, such as safety, durability or appearance, which are especially significant in housing decisions.

A separate emphasis was placed on social acceptance, especially through the question regarding being the first in a community to own a 3D printed home. This topic was included explore possible stigma, social pressures or concerns about standing out, which are particularly relevant in the Romanian housing context where conformity and established solutions are commonly favored.

The section on adoption potential was selected to transform general opinions into specific decision-making factors. Questions were designed to explore situations where respondents might consider buying a 3D printed house, with the goal of uncovering key elements that influence acceptance, including cost, proven durability, and energy efficiency. Including a question about external plastering aimed to evaluate willingness to accept aesthetic changes and adherence to local building regulations, both of which could play a significant role in acceptance. A question about recommendations was also included to examine ways to build trust. Factors such as seeing the house in person, following regulations, and receiving long-term guarantees suggest conditions that make respondents more inclined to actively support the technology, rather than just passively accept it.

Finally and open-ended question was included to let respondents share their thoughts, worries and suggestions that might not have been covered by the predefined options. This question helps uncover new topics or individual experiences connected to 3D printed housing.

Overall, the survey topics were selected to move from personal context to perceptions and then to the intention to adopt. This structure supports the exploratory purpose of the research and enables the recognition of main concerns and obstacles to acceptance among future potential buyers of 3D printed houses in Romania.

The complete set of survey questions is included in Appendix D.

4.3 Selection of Participants and Data Collection Process

Participants were chosen through a purposive, context-sensitive method due to the early development of 3D printed housing in Romania. Because few actors are involved in this sector, the selection concentrated on individuals with direct experience or relevant expertise in residential construction and housing markets.

To locate an appropriate company for the interview, the initial step involved identifying construction firms in Romania that either utilized or developed 3D printing technologies. This process included conducting online searches, examining industry publications, reviewing company websites, and accessing other public sources of information related to construction innovation. As a result of this research, it was discovered that, at the time of the study, only one local company possessed the required equipment and was currently operating a 3D printing system tailored for construction applications. Although this company had not yet completed major residential projects, it was regarded as the most significant entity within the country due to its technical knowledge and advancements in the field. The company was contacted directly and agreed to take part in the interview.

The process of identifying participants from the traditional construction sector followed a process similar to that used for the other group, but it presented greater difficulties. Several efforts were made to locate and involve professionals working in residential construction, including checking online company directories, professional networking and reaching out directly to firms engaged in housing activities. Despite these efforts, many participants either failed to respond or chose not to take part, often because they were not familiar with 3D printed construction methods or were unable to commit due to time constraints.

As a result, only one expert from the construction industry was willing to participate. This person was chosen based on their substantial experience in the construction field, especially in projects related to residential buildings.

The customer survey sought to collect data from the general public, including individuals who may play a role in making decisions about housing. The survey was carried out online through widely available digital platforms, and participation was entirely optional. Those without previous experience in construction or housing technologies were specifically invited to take part, and a total of 108 responses were collected.

Overall, the selection of the participants and the data collection shows the challenges faced in an emerging market, where both the use of technology and professional involvement are still limited. Even with these challenges, the combination of expert interview and a public perception survey provides a balanced and coherent foundation for analyzing the barriers to wider adoption of 3D printed houses in Romania.

4.4 Methodological Scope and Limitations

This methodology aligns with the exploratory scope of the research and is influenced by the early development stage of 3D printed housing in Romania. A primary limitation is the small number of actors at the national level, at the time, only one company had the necessary technology for 3D printed construction, limiting possible interviewees. This is not methodological in nature, but rather a direct consequence of the early phase of market development for this technology in Romania.

A key limitation is the lack of completed, fully occupied 3D printed residential projects in Romania. Consequently, the interviews and survey focus on perceptions, expectations and concerns instead of actual experiences. Respondents considered hypothetical scenarios, which could affect their views on risks, costs and benefits. Nonetheless, this aligns with the research goal, which is to identify acceptance barriers before large-scale adoption, not to evaluate post-occupancy performance.

The survey component of this study has certain limitations. It was carried out online, and participation was not mandatory, which could result in a sample that does not accurately reflect the entire Romanian population. Therefore, the results should not be considered as representative of the whole housing market. Instead, the survey is intended to uncover common trends, repeated concerns, and prevailing opinions regarding 3D printed housing among potential homebuyers. This method aligns with exploratory research that focuses on understanding social and cultural acceptance rather than making exact statistical forecasts.

Furthermore, interviews with construction professionals offer personal insights shaped by their experience, background, and industry role. While this introduces some subjectivity, it also adds valuable depth and context often absent in purely quantitative methods. Incorporating perspectives from both innovative and traditional sectors helps address this limitation by providing a variety of contrasting viewpoints.

Despite these limitations, the selected approach offers a clear and appropriate framework to tackle the research question. Combining a structured literature review, targeted interviews, and a perception-based survey, the study merges technical expertise with social and market insights. This mixed-method strategy enables a comprehensive investigation into the reasons behind the limited adoption of 3D printed housing in Romania and underpins the analysis in the following chapters.

4.5 Data Analysis Process

The analysis of the data was carried out in several stages and followed a gradual process. Because the research aims to explore barriers and perceptions rather than to test strict statistical hypotheses, the approach was mainly descriptive and interpretative. The idea was to first understand what respondents and professionals are saying and only afterwards look at how these perspectives connect.

The process started with the survey data which collected 108 responses, these answers were reviewed and organized separately at first. The responses were counted and grouped into their respective categories and percentages were calculated in order to better understand how answers were distributed. Charts were created for every question to visually represent the data. This helped identify where responses were concentrated and where there was hesitation or neutrality. The goal was not yet to interpret relationships between answers, but simply to clearly show what the participants reported regarding housing priorities, openness to innovation, awareness of 3D printed houses, perceived risks, advantages and possible adoption conditions. Looking at each question individually allowed for a structured and transparent presentation of the data.

Following the initial step, the survey responses were examined more broadly. Rather than analyzing each answer in isolation, the focus shifted to understanding how different parts of the survey related conceptually. This method sidestepped statistical correlation tests or complex quantitative analysis. Instead, it involved identifying patterns across sections and assessing whether certain attitudes were stable or context-dependent. At times, respondents exhibited a mix of openness and hesitation, necessitating a more interpretive approach to grasp the data.

This second phase enabled the analysis to go beyond basic frequency counts. It revealed how respondents might assess perceived benefits versus potential risks, even if they didn't explicitly express it. The survey results started to show not just what people believe, but how they approach this type of housing.

Once the survey analysis reached a stable understanding, the interviews were examined. Every interview was read several times to understand the tone and outlook of the respondents. The responses were then organized into broader themes like market readiness, regulatory environment, durability concerns, cultural factors, and economic implications. This thematic organization was crucial for comparing the two interviews, even though they came from different types of companies.

The analysis of the interview covered not just the content but also the way issues were framed. Sometimes, uncertainty was depicted as a technical matter, while at other times, it was seen as an institutional or regulatory constraint. Noticing these subtle differences was crucial, as the framing exposes fundamental structural distinctions between established and emerging players in the construction industry.

After examining both the survey data and the interview responses on my own, the next step was to combine and analyze them together. The purpose was not to force consistency between the two, but to determine if public opinions match the experiences and challenges faced by professionals in the field. In some instances, the worries expressed by survey participants corresponded with the institutional or regulatory challenges mentioned in the interviews. However, in other cases, there were noticeable differences in what was emphasized.

By reviewing both sources together, it became clearer whether the reluctance toward 3D printed housing stems from cultural, economic, technical, or broader structural reasons. The survey alone was insufficient to fully explain these reasons, and the interviews alone could not show how widespread certain views were. Only by looking at both methods side by side did a more complete understanding start to emerge.

The overall approach used was descriptive and interpretative. It began with identifying common perceptions, then looked for patterns, and finally explained these patterns within the context of Romania's construction and regulatory environment. Given the exploratory nature of the study and the limited number of individuals involved in 3D printed construction across the country, this method was considered more appropriate than complex statistical techniques. The intent was not to generalize findings to the entire population, but to understand the reasons behind the slow adoption of this technology at this point in time.

5 Stakeholder Perspectives on 3D Printed Housing Adoption in Romania

In reference to the survey questions outlined in Appendix A, respondents submitted their responses to each item, resulting in the findings presented in the following sections.

5.1 Profile of Contestants

Figure 5.1 provides an overview of the age distribution within the survey sample, which is important because age typically influences housing requirements, willingness to take risks, and financial capacity to buy a property. To interpret it, examine the age ranges (X axis) and assess the size of each group (Y axis). The largest category reflects the most common age group among respondents, whereas smaller categories highlight the ages that are less frequently represented in the survey.

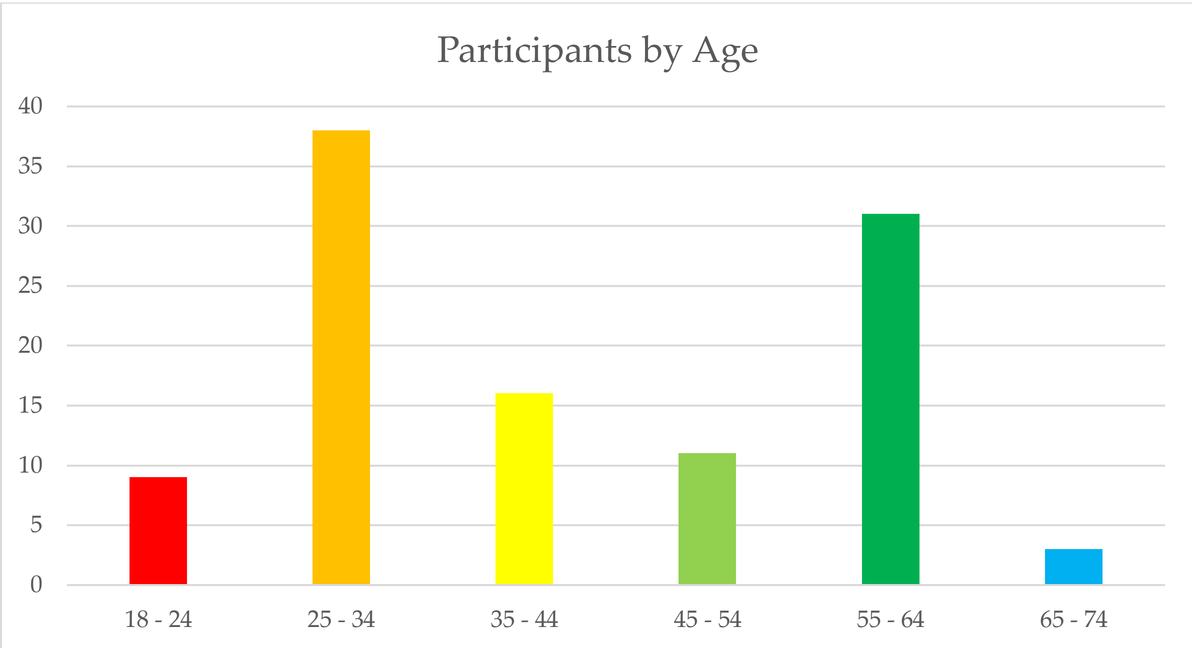


Figure 5.1: Number of Participants by Age.

The participant age distribution mainly consists of two groups: 25 to 34 and 55 to 64. Most respondents are in the 25 to 34 range, a group often facing challenges in affording housing and considering their first home purchase. The second largest group includes those aged 55 to 64, who have extensive experience in homeownership, maintenance and long-term investments. Fewer participants are in the 35 to 44 and 45 to 54 brackets, with smaller numbers in the 18 to 24 and 65 to 74 ranges. Overall, the sample features individuals making either immediate housing decisions or planning for long-term investments, both of which influence their perspectives on construction quality and associated risks.

Figure 5.2 illustrates the relationship between tenure status (owning vs renting) and different types of residences (apartment, house or dorm room), which helps to understand respondents' baseline of housing security and commitment level. To interpret it, start by identifying the tenure status (X axis) along with each type of residence, and then assess the size of each group (Y axis). The main focus should be on the comparison between owners and renters within the same residence type, as well as the comparison between different types of residences.

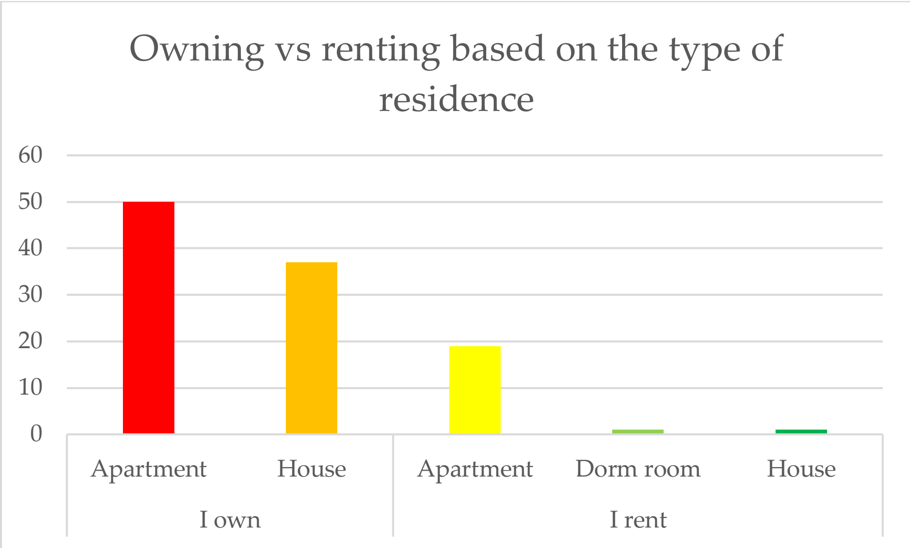


Figure 5.2: Owning vs Renting based on the Type of Residence.

The findings clearly distinguish between ownership and rental trends based on residence type. Apartments tend to have a fairly even split between owners and renters, while houses are mostly owner-occupied. Renting a house is quite rare among respondents. This pattern aligns with the broader Romanian housing landscape, where owning a home is strongly associated with long-term stability and financial security. Consequently, housing choices are seen as permanent commitments rather than short-term arrangements. This mindset significantly influences the acceptance of new construction methods, which might be viewed as untested or uncertain.

5.2 Housing Decision Priorities

Figure 5.3 shows which factors are most important to respondents when selecting a home, including aspects like location, price, size, sustainability, and design. To interpret it, examine de list of factors found in the legend on the right side of the graph and compare their reported significance, indicated by bar lengths. The factors with the highest value are the most important, highlighting the key considerations that influence decision-making the most.

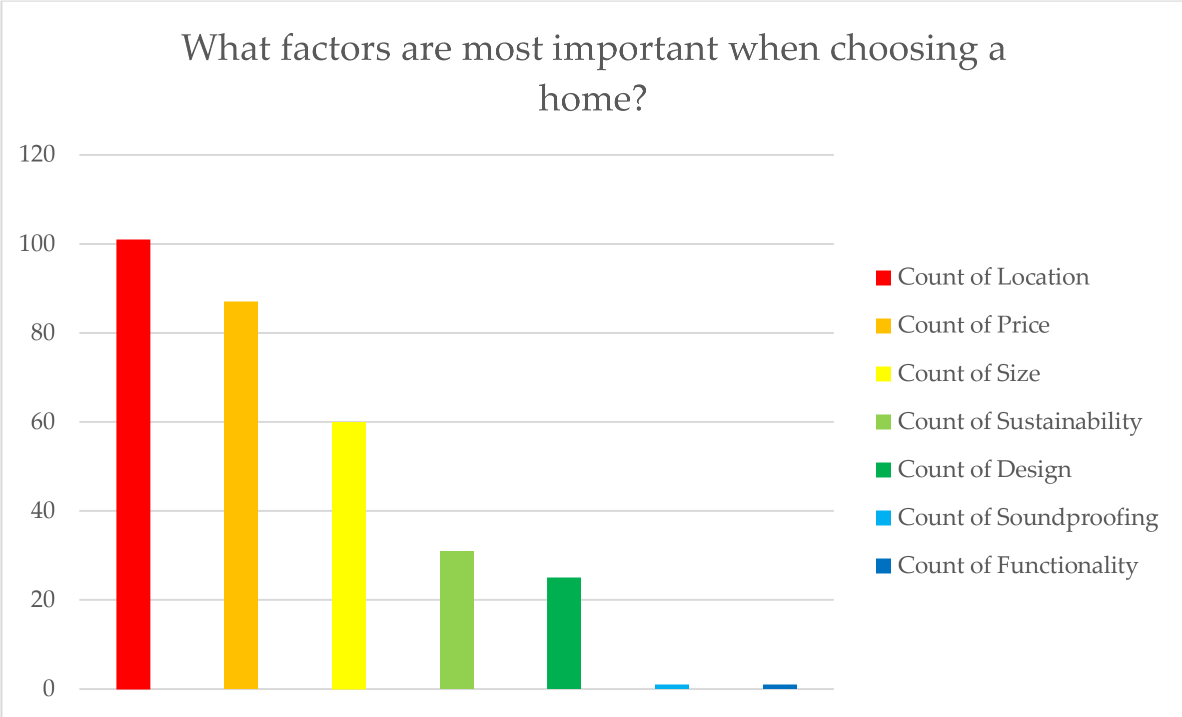


Figure 5.3: Importance of Factors when Choosing a Home.

Among the factors assessed, location and price are the most important to respondents' housing priorities. These two criteria are chosen by the vast majority, showing that affordability and access to preferred areas mostly drive housing decisions. Size is a secondary factor, while sustainability and architectural design are much less important. Aspects like soundproofing and functionality receive little attention, probably because they are seen as basic expectations rather than key features. This hierarchy indicates that innovative housing options are unlikely to succeed unless they directly tackle cost and location issues, since environmental or design advantages alone do not seem enough to influence choices.

Figure 5.4 illustrates the extent to which respondents prioritize energy efficiency when selecting housing options, this is helpful for understanding whether long-term operating costs affect their choices. To interpret the data, read through the response categories (Y axis) and observe where most responses are concentrated (X axis). A tendency toward the higher importance categories suggests that energy efficiency plays a significant role in their decision-making process.

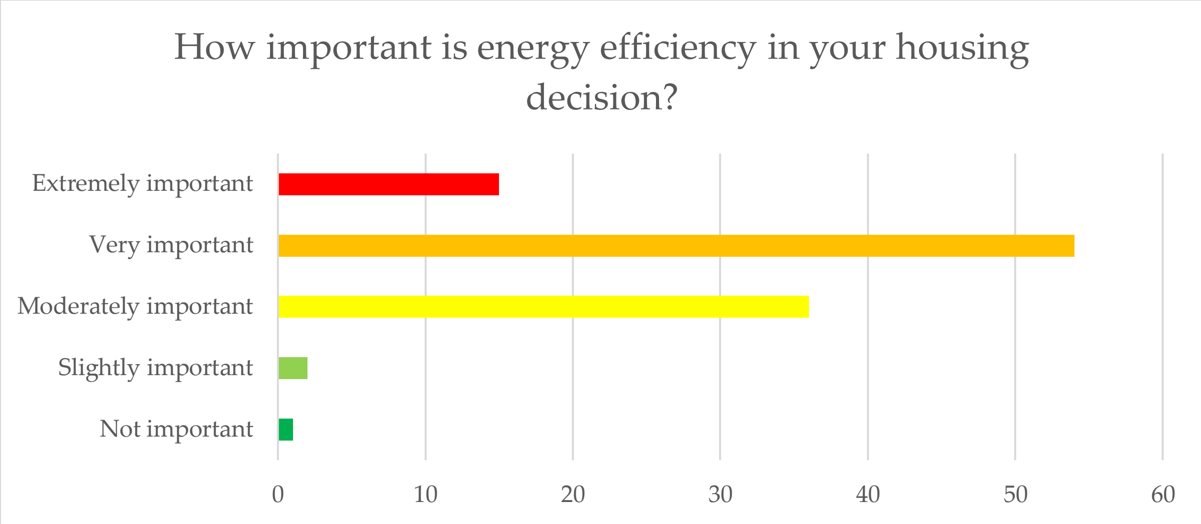


Figure 5.4: Importance of Energy Efficiency in Housing Decision.

Most respondents view energy efficiency as highly important. Only a small number see it as less important, while the majority consider it very or extremely important. This reflects an increasing awareness of long-term costs, especially regarding heating and energy use. Although initial affordability is still a key factor, respondents also take future expenses into account when assessing housing options. Consequently, energy efficiency acts as a valuable criterion that can enhance a housing option's attractiveness, particularly when long-term reliability is valued.

Figure 5.5 illustrates how respondents evaluate the importance of initial price compared to overall lifecycle costs, including maintenance, energy usage, and durability. To interpret it, read through the response categories (Y axis) and observe where most responses are concentrated (X axis). The distribution among these indicates whether buyers primarily think in terms of purchase price or total cost of ownership.

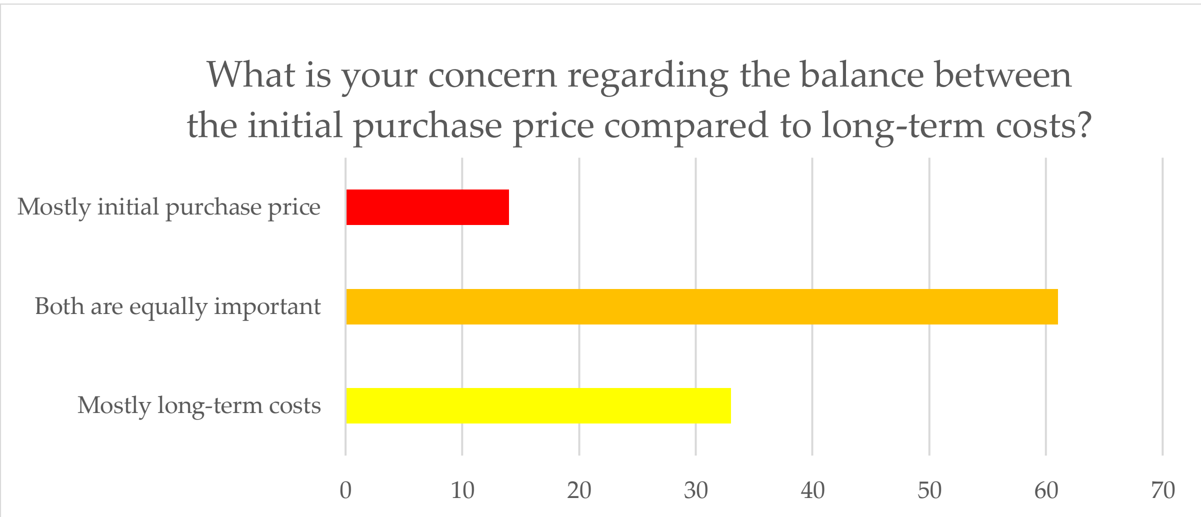


Figure 5.5: Initial Purchase Cost Compared to Long-term Costs.

Most respondents regard the initial purchase cost and long-term expenses as equally significant when assessing their importance. Although many highlight long-term costs, only a few concentrate solely on the upfront price. This suggests that housing affordability is seen as a long-term financial obligation rather than a one-time purchase. Buyers typically consider the overall value, which includes maintenance, energy expenses, and durability. Consequently, the cost advantages of alternative building techniques must be credible throughout the entire lifespan of the home to be persuasive.

5.3 Openness to Innovation

Figure 5.6 reflects general openness to unconventional design, which provides useful background but does not indicate the same thing as willingness to adopt new technologies. To interpret it, read through the response categories (Y axis) and observe where most responses are concentrated (X axis). A distribution that is heavier in the middle suggest a cautious attitude.

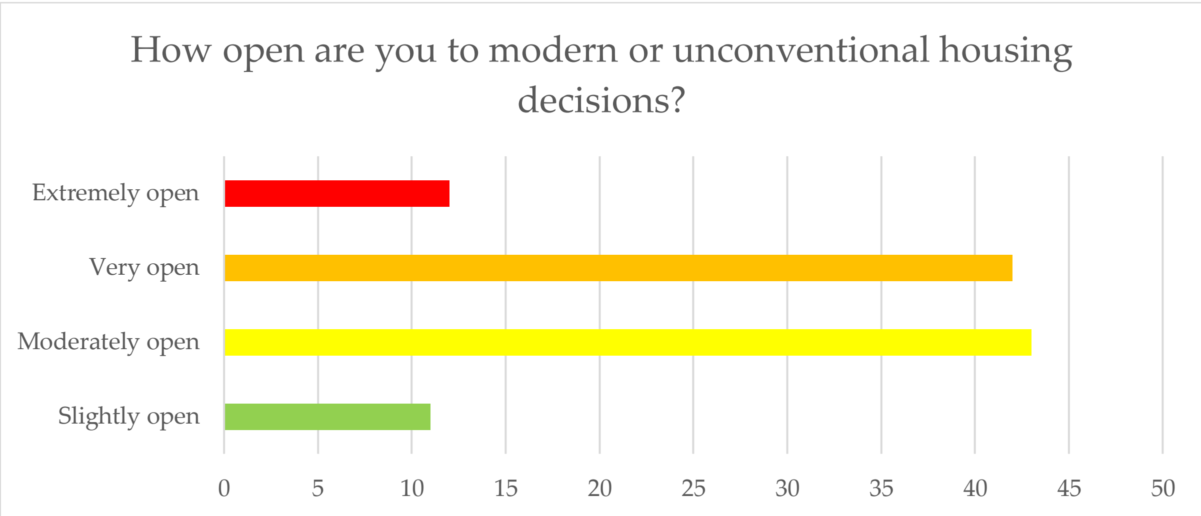


Figure 5.6: Openness to Modern or Unconventional Architecture.

Most respondents see themselves as moderately or highly receptive to modern or unconventional architectural ideas. However, the segment that is extremely open is still quite small, with a noticeable minority showing only slight openness. This pattern suggests a cautious acceptance rather than full enthusiasm. While innovative housing ideas are not widely rejected, they are approached with caution, especially when they involve long-term financial or personal commitments. Therefore, being open to new architecture does not necessarily mean a willingness to adopt unfamiliar construction technologies.

5.4 Awareness and Perception of 3D Printed Houses

Figure 5.7 shows whether respondents were familiar with 3D printed houses prior to the survey, which influences how well-developed their opinions are likely to be. To interpret the graph, start by identifying the "Yes" and "No" answers(X axis) and then assess the size of each group (Y axis). A significant portion of the "Yes" group suggests that the concept is already known to the public. On the other hand, a considerable portion of the in the "No" group indicates that awareness is not evenly spread and may need further education and exposure to become more widespread.

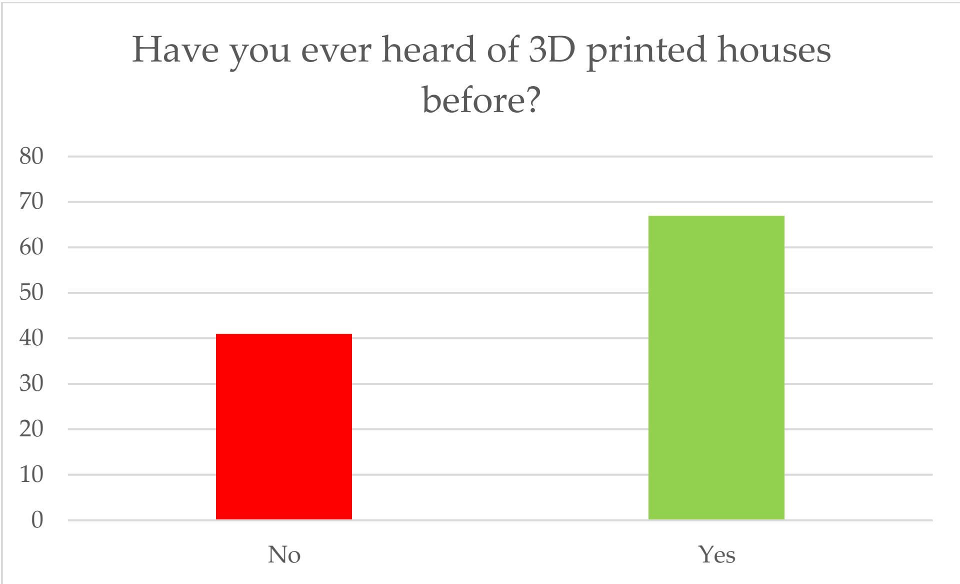


Figure 5.7: Awareness of 3D Printed Houses.

Most respondents have heard of 3D printed houses before the survey, although a notable minority have not, indicating uneven public awareness. This limited familiarity could cause uncertainty, as lack of knowledge tends to lead to assumptions rather than informed judgments. Even among those aware, understanding is probably superficial, reflecting that public knowledge about 3D printed housing is still in its early stages in Romania.

Figure 5.8 presents the initial impressions that respondents have with 3D printed houses, such as innovation, sustainability, affordability, looks, and safety concerns. To interpret it, identify each impression category (X axis) and compare the amount of answers for each one.

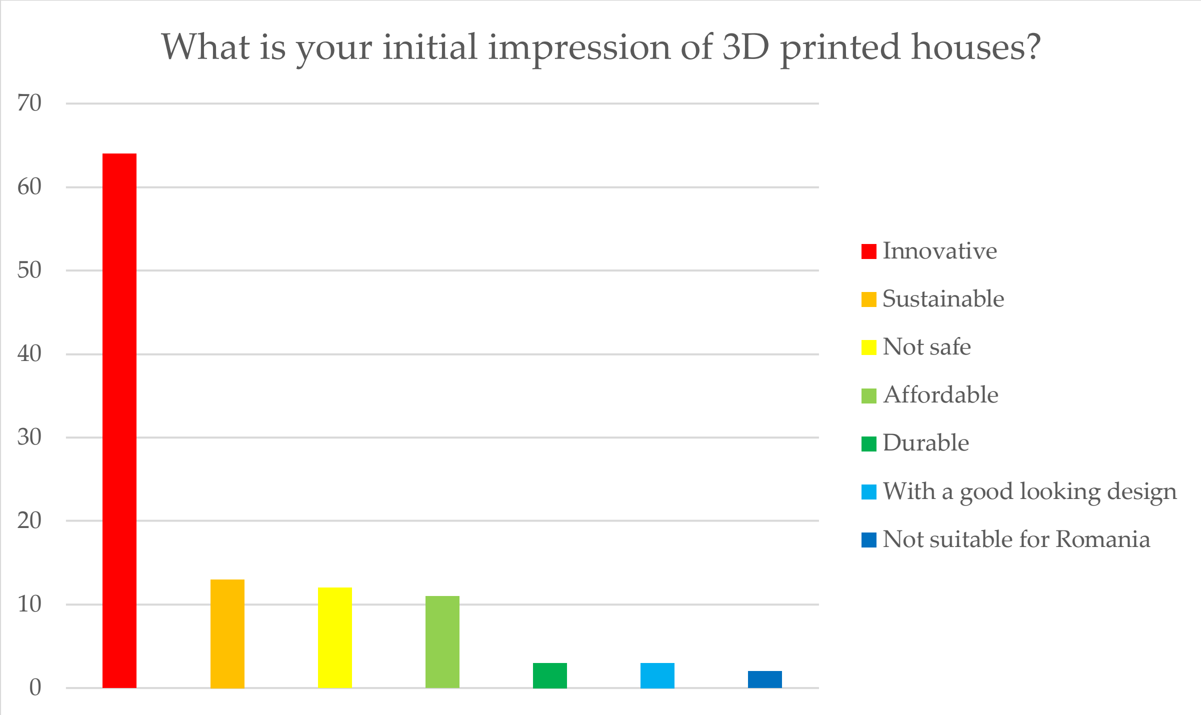


Figure 5.8: First Impression of 3D Printed Houses. 42%AI

The most common initial impression of 3D printed houses is that of innovation, suggesting the technology is seen as advanced and new. Nonetheless, this positive view is mixed. Fewer respondents mention sustainability and affordability, while a similar number express safety concerns. Very few link 3D printed houses with durability or high-quality design and a small percentage see them as unsuitable for Romania. These results imply that although the concept draws interest, it does not inherently foster confidence in its long-term performance.

5.5 Risk, Trust and Perceived Barriers

Figure 5.9 illustrates the primary concerns that are commonly identified, such as durability, construction quality, safety, aesthetics, thermal comfort, and resale value, which help to identify the key obstacles to adoption. To interpret it, identify each concern category on the right side of the graph, the legend, and compare the amount of answers for each one. The bigger categories represent the most critical issues that need to be addressed, while the smaller ones reflect secondary concerns or more specific objections.

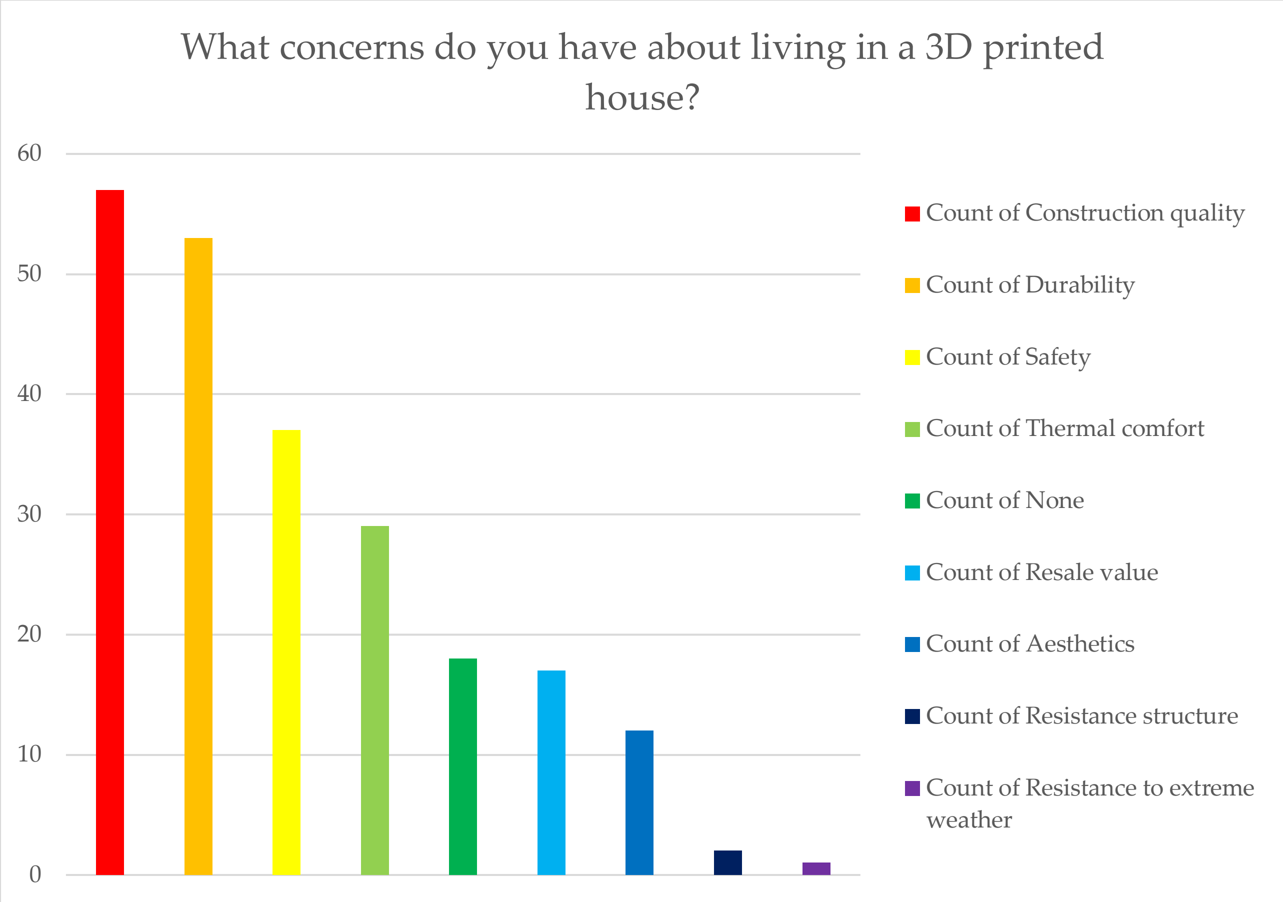


Figure 5.9: Concerns about 3D Printed Houses.

Respondents mainly focus on construction quality and durability as the primary perceived risks. Safety and thermal comfort are also key concerns, highlighting worries about structural integrity and living conditions. Resale value is significant, showing respondents think about both personal use and future marketability. Aesthetic concerns are less common, indicating that functionality and structure matter more than appearance. A small group reports no concerns at all, suggesting they are already open to the technology.

Figure 5.10 illustrates the willingness to act as an early adopter, which highlights the difference between hesitation and readiness. To interpret it, read through the response categories (Y axis) and observe where most responses are concentrated (X axis).

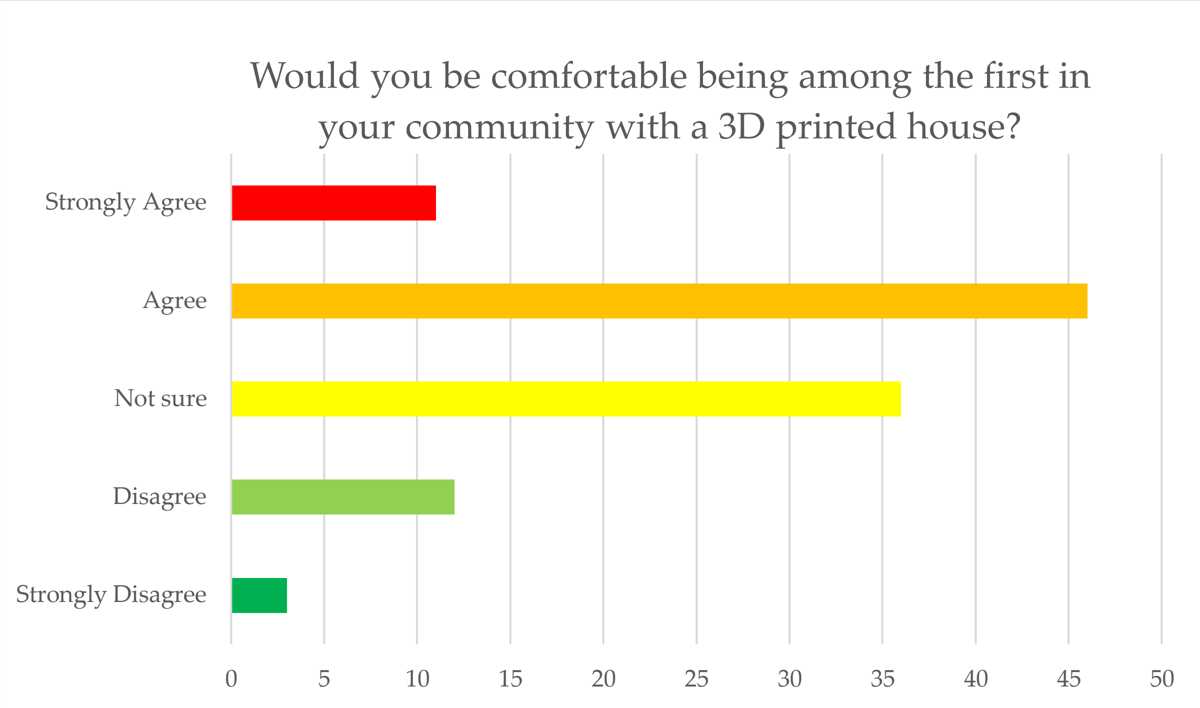


Figure 5.10: Acceptance of 3D Printed Houses.

Responses to this statement indicate considerable uncertainty. While more people agree than disagree about being among the first in their community to live in a 3D printed house, the majority select the neutral option. This reflects hesitation rather than rejection, suggesting openness but caution due to perceived risks associated with early adoption. Such uncertainty underscores the absence of clear reference points and highlights the crucial role of trust and visibility in housing adoption choices.

5.6 Perceived Advantages and Adoption Conditions

Figure 5.11 shows the perceived benefits of 3D printing, usually including cost and speed, as well as other potential advantages like design flexibility, environmental impact, and energy efficiency. To interpret it, locate each concern category on the right side of the graph and in the legend, then compare the number of responses for each.

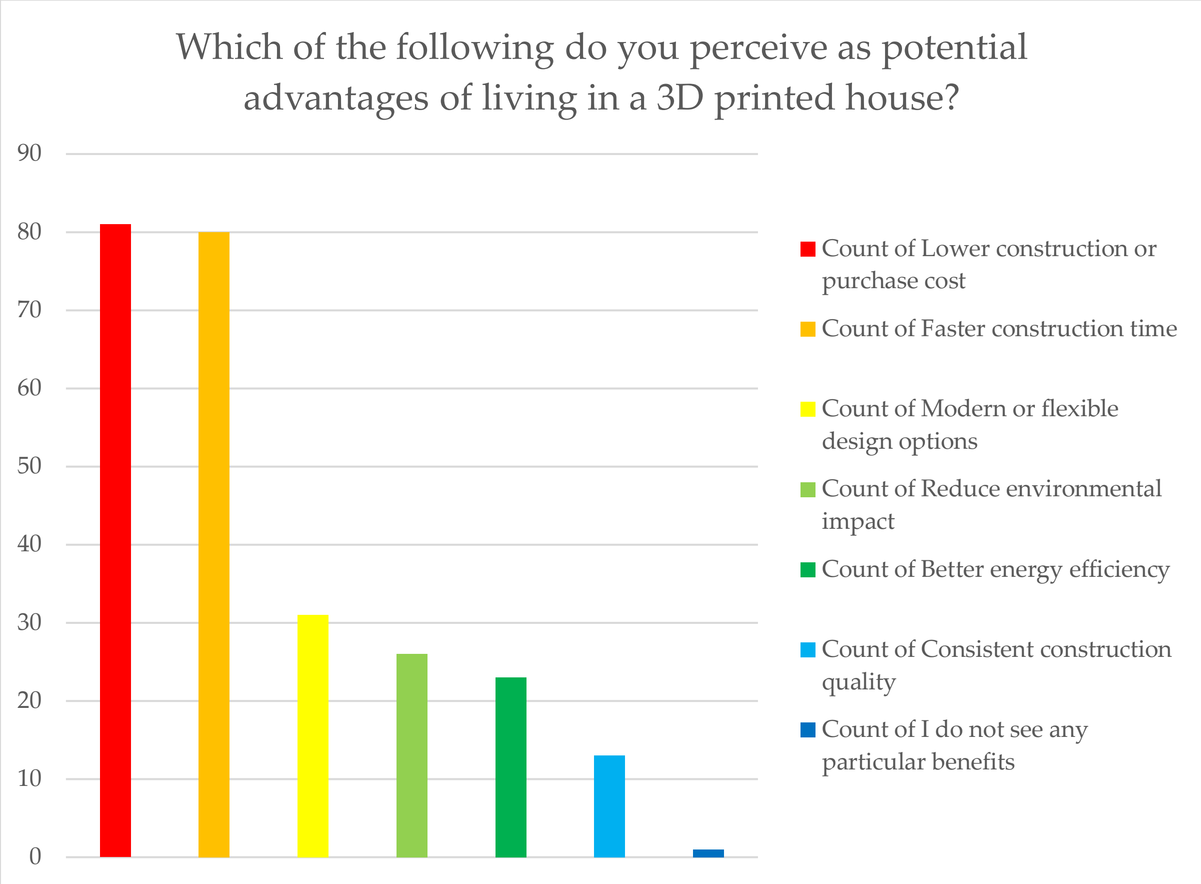


Figure 5.11: Belief of Advantages of 3D Printed Houses.

Respondents clearly identify the primary advantages of 3D printed housing, mainly lower costs and faster construction times. This shows a strong awareness of the technology's economic and efficiency benefits. Smaller groups also recognize other advantages like flexible design, lower environmental impact, and better energy efficiency. The rare mention of consistent construction quality indicates that automation's reliability is not yet fully trusted. Overall, the results show that while the benefits are well understood, some concerns remain.

Figure 5.12 illustrates the actual factors that would encourage someone to make a purchase, such as affordability, durability, speed, and energy efficiency. To interpret it, identify each concern category on the right side of the graph, the legend, and compare the amount of answers for each one.

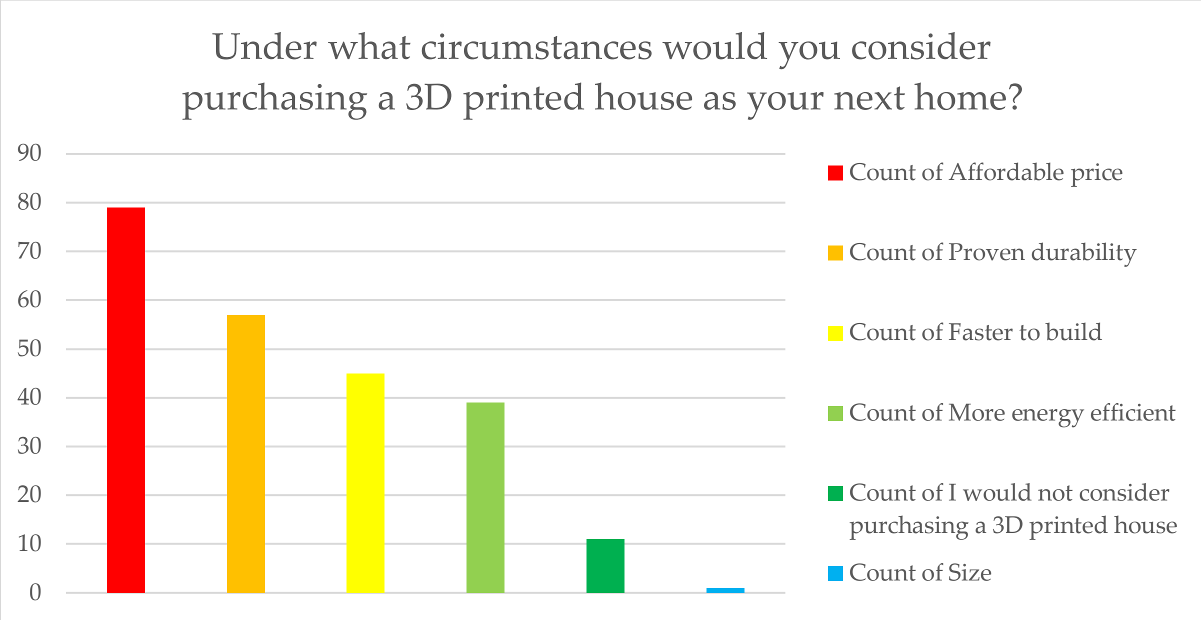


Figure 5.12: Consideration Factors for Buying a 3D Printed House.

The most compelling factor that would motivate respondents to buy a 3D printed house is affordability. Durability, however, is a close second, highlighting the need for evidence and reassurance. Factors like faster construction and better energy efficiency also matter, but are less critical than cost and reliability. A small number of respondents strongly oppose the idea, indicating a firm resistance within a minority. Overall, the results suggest that economic benefits must be backed by credible performance guarantees.

Figure 5.13 shows acceptance related to appearance, particularly whether respondents would be willing to accept aesthetic modifications, such as plastering, to conform to established norms. To interpret the graph, start by identifying the "Yes" and "No" answers (X axis) and then assess the size of each group (Y axis).

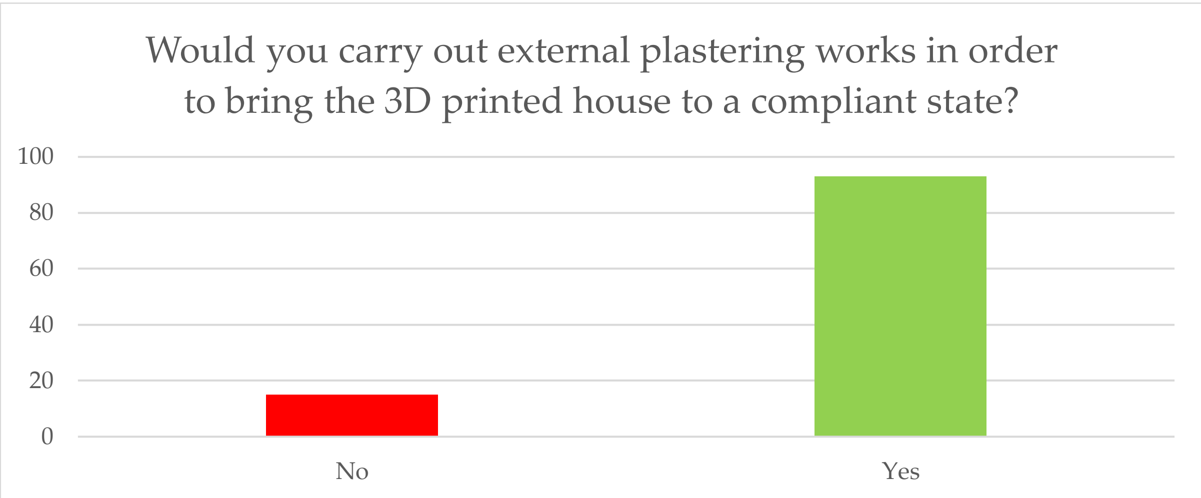


Figure 5.13: Aesthetics Preferences.

Most respondents are willing to perform external plastering on a 3D printed house to meet standards or be acceptable. Only a few are unwilling. This implies that resistance isn't about the structural design itself but more about its look or how it deviates from local norms. Respondents seem receptive to hybrid approaches that blend new construction techniques with traditional finishes, showing a pragmatic attitude towards acceptance.

5.7 Recommendation of 3D Printed Houses

Figure 5.14 illustrates the factors that would influence respondents to recommend 3D printed houses to others, such durability guarantees, the opportunity to see real examples, compliance with regulations, and environmental benefits. To interpret it, identify each concern category on the right side of the graph, the legend, and compare the amount of answers for each one.

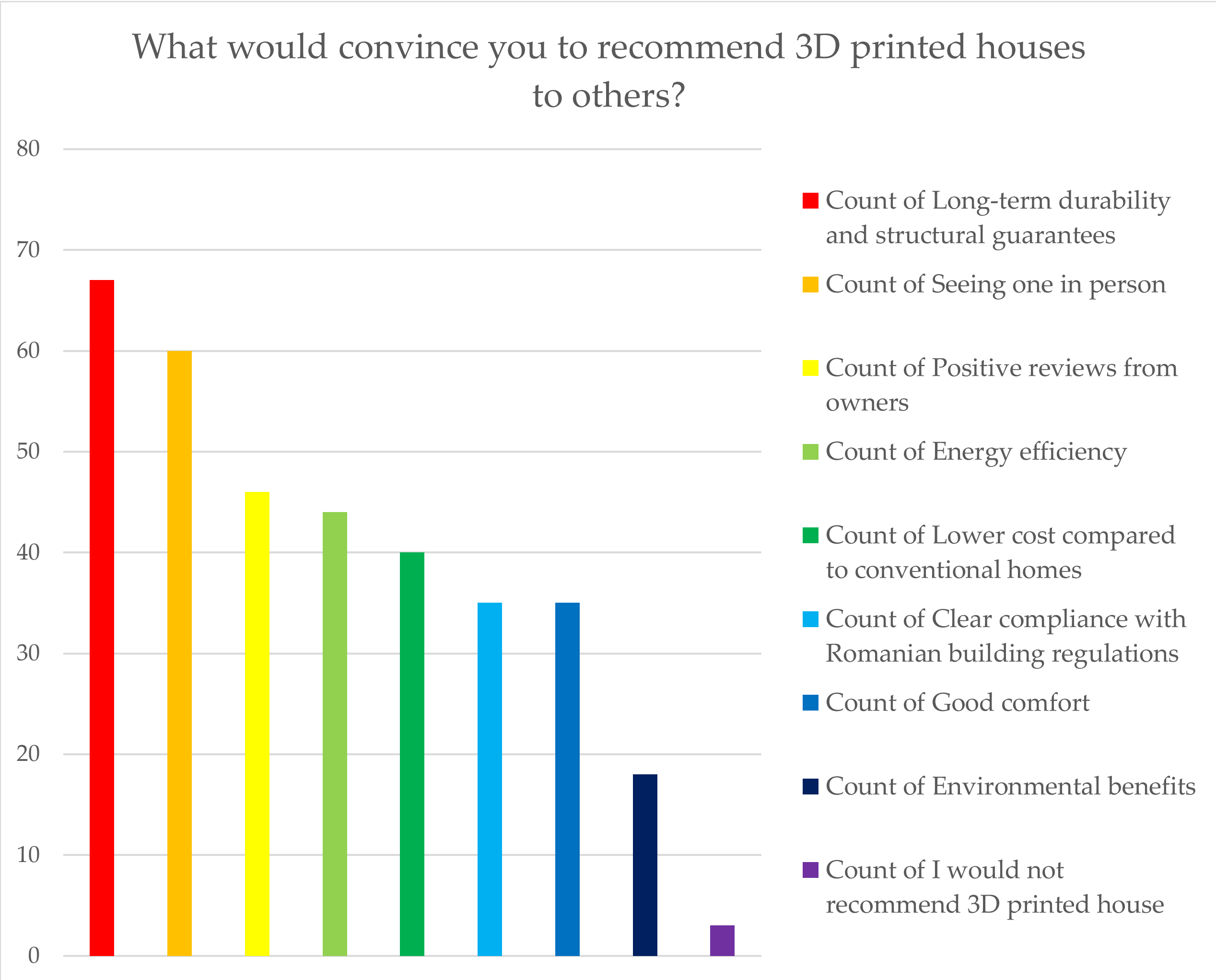


Figure 5.14: Recommendation Factors for 3D Printed House.

The primary factor influencing willingness to recommend 3D printed houses is the assurance of long-term durability and structural guarantees. Opportunities to see finished houses in person are valuable, emphasizing the need for tangible reference projects. Positive feedback from existing owners greatly boosts trust and highlights the importance of social proof. Adherence to Romanian building codes, quality living conditions, energy efficiency, and lower costs further build confidence. Although environmental advantages are acknowledged, they are less influential. Overall, the findings indicate that recommendations are primarily based on evidence, visibility, and institutional approval rather than innovation.

5.8 Open-ended Question

The open-ended question, "Is there anything you would like to share about 3D printed houses?" elicited responses that pointed to key themes and challenges. Many participants emphasized the need for increased media coverage to raise awareness and educate potential beneficiaries about the benefits and opportunities of 3D printing technology. One respondent noted, "A much greater media coverage of 3D printed houses is necessary to properly inform potential beneficiaries," highlighting that a major barrier to adoption is the lack of broader education and awareness among stakeholders such as policymakers, developers, and consumers.

Furthermore, respondents highlighted several areas needing additional research and development. For example, one participant noted, "This is something new and the long-term advantages and disadvantages are not known. You can only see that at the time of purchase". This suggests a potential need for more comprehensive testing and evaluation of 3D printed houses to better understand their long-term performance and durability.

Other respondents highlighted particular challenges regarding market entry and regulatory frameworks. For instance, one inquired, "Not sure what are the design codes for such a house type," pointing to a need for more explicit guidance. Others expressed excitement about 3D printing technology, with one remarking it is "Very interesting. A topic for the future". Overall, the feedback suggests that despite some obstacles, many remain hopeful about the potential of 3D printed houses and are eager to see them become a reality.

5.9 Interviews Comparison

The comparative structure of the two interview guides was deliberately designed to capture not just variations in opinions, but also differences in positions, exposure to risks and the extent of institutional involvement between a traditional construction company and a 3D printing construction company in Romania. While both groups function within the same national construction ecosystem, the questions highlight significant differences in how they deal with uncertainty, regulations and innovation.

5.9.1 Market Readiness and Adoption

Table 5.1 highlights how a traditional construction company and a 3D printed construction company define market readiness for 3D printed housing. To interpret it, begin with the interview questions (Row 2), followed by the responses from both perspectives (Row 3).

Table 5.1: Market Readiness Comparison between Interviews.

	Traditional Construction Company	**3D Printing Construction Company**
Question	How do you think Romanian customers would respond to 3D printed houses and what factors would most influence their acceptance or rejection?	How ready is the Romanian construction and housing market to absorb 3D printed housing at scale, in terms of regulation, acceptance and market?
Answer	Romanian customers are likely to be cautious initially. Price will play a key role, if the product is substantially cheaper, interest is likely to increase. Nevertheless, here, long-term safety, resale value and acceptance by banks and insurers are top concerns. Acceptance will largely rely on official approvals, existing practical examples and positive feedback from early users.	The Romanian market is in the process of accepting the concept, but is not ready for the introduction of a finished product. Although public interest is high, the lack of technical approval reduces confidence compared to conventional technologies.

A traditional construction company was asked to speculate on how Romanian customers would respond to 3D printed housing and which factors would influence acceptance or rejection. This question positions the traditional construction company as observer of market behavior, relying primarily on accumulated client interactions and past experience. Their responses therefore reflect an interpretative perspective, grounded in assumptions about consumer psychology, risk aversion and cultural conservatism.

In contrast, the 3D printing construction company were asked to assess the readiness of the Romanian housing market in terms of regulation, acceptance and scalability. This question places them in an active system-testing role, as they are directly confronted with regulatory institutions, permitting authorities and market entry barriers. The comparison between these questions reveals a critical divergence: while traditional company frame readiness as a matter of consumer trust, 3D printing company frames readiness as an institutional condition. This distinction is essential, as it indicates that perceived lack of demand may in fact be a secondary effect of unresolved legal and administrative constraints.

5.9.2 Risk, Trust and Durability

Table 5.2 highlights how a traditional construction company and a 3D printed construction company define their views on quality and durability for 3D printed housing. To interpret it, begin with the interview questions (Row 2), followed by the responses from both perspectives (Row 3).

Table 5.2: Quality Comparison between Interviews.

	Traditional Construction Company	**3D Printing Construction Company**
Question	How do you perceive the quality and durability of 3D printed houses compared to traditional construction?	What are the main quality and durability concerns Romanian buyers raise and how do you address them?
Answer	From my point of view, this remains a major uncertainty. Traditional construction has been thoroughly tested for decades, providing insights into how materials age, crack and respond to climate. With 3D printed houses, I believe quality could be achieved, their long-term durability over 30-50 years is still unproven, especially locally.	We address durability through certified laboratory testing of our geomortar, including compressive strength, weather resistance and long-term performance, as well as advanced structural software simulations that verify load-bearing capacity and seismic behavior.

The traditional construction company presents 3D printed housing as uncertain. Conventional building techniques are seen as reliable because they have been used for many years, with materials regularly checked for signs of aging, cracking and how they respond to different weather conditions. This long history gives professionals confidence in the long-term behavior of buildings over 30 to 50 years. On the other hand, despite the potential for high quality 3D printed structures, their long-term durability is still seen as unproven.

In this context, the absence of real, local, long-term data on how these structures perform is seen as a major weakness. It is not that the technology is being rejected outright, but rather a lack of time-based evidence to support it. Traditional construction is viewed as predictable and stable, while 3D printing is still seen as needing to show that it can endure real-world conditions beyond what is tested in the laboratory.

The 3D printing construction company takes a different approach. Instead of stressing uncertainty, it emphasizes how durability is ensured. The response points to certified laboratory tests of geomortar, covering compressive strength, weather resistance and long-term performance. It also references advanced structural software simulations that verify load-bearing capacity and seismic resilience. Thus, the argument rests on measurable technical validation.

However, this perspective indirectly indicates that long-term real-world data in Romania is still lacking. The claims of durability are primarily based on controlled tests and simulations, not on buildings that have been standing for decades. While this response is more technical and solution-focused compared to the typical skepticism of the traditional company, it still depends on a predictive approach.

Overall, the comparison highlights a contrast between historical validation and technological validation. Traditional construction depends on accumulated experience and proven performance over time. In contrast, 3D printing relies on engineering calculations, laboratory certifications, and digital simulations. This distinction clarifies why there is still cautiousness in the Romanian market, although technical testing can show strength and durability, trust in construction methods tends to develop gradually, based on years of observed results.

5.9.3 Regulation as Perceived Risk Versus Operational Constraint

Table 5.3 highlights how a traditional construction company and a 3D printed construction company perceive the regulations for 3D printed housing. To interpret it, begin with the interview questions (Row 2), followed by the responses from both perspectives (Row 3).

Table 5.3: Comparison between Regulatory Opinions between Interviews.

	Traditional Construction Company	**3D Printing Construction Company**
Question	How do you perceive the regulatory reliability of 3D printed houses?	How do regulations, permitting processes and local authorities currently affect the feasibility of 3D printed housing projects in Romania?
Answer	From my point of view, regulatory clarity is a concern, Romanian building codes are strict and without clear regulation and approval, many professionals and clients may hesitate.	Regulations and permitting are currently a key challenge for 3D printed housing in Romania, as the legislation does not yet explicitly cover geomortar 3D printed systems. Authorities are working to adapt and modify the legal framework to allow the use of geomortar in construction.

The traditional construction company speaks from a position of stability. For them, the main concern is regulatory clarity. Romanian building standards are strict and because 3D printed houses are not yet clearly regulated, this leads to hesitation. Traditional construction methods are familiar, have been used for decades and their performance in local climate conditions is well understood. In contrast, 3D printing is seen as uncertain, even if the technical performance could be acceptable, the absence of clear approval processes and long-term data on local performance makes engineers and clients cautious. This hesitation is not about rejecting the technology itself, but rather about the lack of consistent and reliable rules.

On the other hand, the 3D printing construction company views the issue more practically. They focus on what is achievable right now. Current regulations do not explicitly 3D printed houses made with geomortar and while authorities are working to change the legal framework, the process is still in progress. Since there are no registered 3D printed buildings in Romania exposed to long-term weather, approvals are handled case by case. This leads to longer approval times and dependency on how local officials interpret existing laws. The challenge is operational, not only theoretical.

When looking at both viewpoints, it becomes clearer that both are responding to the same regulatory gap, but from different positions within the industry. The traditional company highlights uncertainty and risk as part of the system. The 3D printing company, on the other hand, focuses on adapting and working within that system. One speaks from the comfort of an established regulatory structure, while the other operates within a developing field that is still trying to fit into existing structures.

5.9.4 Cultural and Social Factors

Table 5.4 highlights how a traditional construction company and a 3D printed construction company see the social and cultural factors in Romania in relation to 3D printed houses. To interpret it, begin with the interview questions (Row 2), followed by the responses from both perspectives (Row 3).

Table 5.4: Social Factors Comparison between Interviews.

	Traditional Construction Company	**3D Printing Construction Company**
Question	How do you think Romanian customers would respond to 3D printed houses and what factors would most influence their acceptance or rejection?	To what extent do traditional construction practices and Romania's self-building culture influence acceptance of 3D printed houses?
Answer	Romanian customers are likely to be cautious initially. Price will play a key role, if the product is substantially cheaper, interest is likely to increase. Nevertheless, here, long-term safety, resale value and acceptance by banks and insurers are top concerns. Acceptance will largely rely on official approvals, existing practical examples and positive feedback from early users.	These factors have a significant influence on how 3D printed houses are perceived and accepted, particularly in the early stages. Many buyers still equate quality and safety with traditional methods like masonry and reinforced concrete, trusting what they know and often involving personal or family participation in constructing their own homes. This results in slower acceptance, as 3D printing remains unfamiliar and more difficult to assess using the informal knowledge people rely on for conventional building techniques.

Both answers indicate that Romanian customers generally exhibit a cautious stance towards innovation, specifically speaking about 3D printed houses in this case, though they highlight different aspects of this attitude.

The traditional construction company focuses more on market and financial acceptance, suggesting that while there might be increasing interest in 3D printed houses if prices are much lower, buyers continue to worry about long-term safety, the resale value of such properties and whether banks and insurers will acknowledge and support this type of housing. This indicates a cautious outlook where acceptance depends heavily on formal recognition, official approvals and the existence of real-world examples that have proved to work.

In contrast, the 3D printing construction company focuses more on cultural and behavioral aspects. It highlights how deeply rooted traditional construction practices and the self-building culture are in Romania, where many buyers rely on familiar materials and techniques and they often base their decisions on personal or family experience. Since 3D printing construction does not fit easily into this informal knowledge system, acceptance of this technology tends to be slower and more hesitant, even before considering financial factors.

Overall, the two perspectives together suggest that adoption of 3D printed housing in Romania is influenced by both institutional trust, such as banks and regulations and cultural traditions linked to conventional building methods, which collectively make it more difficult for this technology to obtain widespread acceptance compared to traditional housing.

5.9.5 Economic Impact and Competitive Positioning

Table 5.5 highlights the economic implications, focusing on the effects on pricing and the workforce for a traditional construction company, compared to the buyer's perception of value and the trade-offs between cost and durability for a 3D printing company. To interpret it, begin with the interview questions (Row 2), followed by the responses from both perspectives (Row 3).

Table 5.5: Economic Impact Comparison between Interviews.

	Traditional Construction Company	3D Printing Construction Company
Question	Do you see 3D printing construction as affecting your pricing, competitiveness or workforce? If so, in what ways?	From the buyer's perspective, how does the cost, perceived value and long-term durability of 3D printed houses compare to traditional housing in Romania?
Answer	Potentially, yes. If 3D printing significantly reduces construction time and labor costs, it could impact traditional pricing models. While it may lessen the need for some manual labor roles, it is likely to increase demand for technicians, engineers, and operators.	From the buyer's perspective, 3D printed housing in Romania is still emerging, making comparisons to traditional methods somewhat uncertain. While projects indicate that costs can be competitive, mainly due to lower labor expenses, quicker construction times, and less material waste, the experimental nature of the technology means prices are unpredictable and vary by case. Buyers appreciate the fast delivery, design flexibility, and improved energy efficiency potential offered by more uniform wall structures. However, hesitation remains because there are no existing examples in Romania. Regarding durability, homes will be constructed using geomortar, which is still under testing and validation and has not yet fully complied with Romanian building regulations. As a result, their structural behavior and long-term performance are being evaluated through laboratory tests and pilot projects.

Both interviews emphasize labor and construction time as the main variables influenced by 3D printing, but they do so from different perspectives within the market.

The traditional construction company approaches the topic with caution, viewing cost reductions as a potential future possibility rather than a current reality. From this perspective, 3D printing in the construction industry is considered a potential disruptor to current pricing models if it can significantly lower labor and construction times on a large scale, which suggests uncertainty rather than immediate impact.

Regarding competitiveness, the traditional construction firm mainly links potential changes to internal factors like pricing pressures and the need for workforce adjustments. It concentrates on how the company might need to restructure if 3D printing becomes more widespread. Conversely, the 3D printing construction company views competitiveness from the customer's perspective, emphasizing faster delivery, flexible design options, and possible energy efficiency gains. It also recognizes that current competitiveness is constrained because the technology remains experimental, and completed 3D printed houses in Romania are yet to be realized.

The traditional construction company considers workforce implications by predicting a gradual transition from manual labor roles to more technical positions like engineers and machine operators. This indicates a focus on how innovation might change employment patterns rather than completely eliminate jobs. Meanwhile, the 3D printing construction company's response lacks discussion of workforce issues, possibly implying that their current focus is more on technical validation than on workforce organization.

The response from the 3D printing construction company mainly highlights buyer perception and trust. While customers appreciate quicker construction times, they remain cautious because of the newness of the technology and the absence of long-term local examples. In contrast, the traditional construction company does not directly address buyer perception, possibly relying on established norms and the widespread acceptance of conventional building methods.

The main distinction between the two interviews is in long-term durability and risk. The 3D printing construction company admits that their geomortar material is still undergoing testing and validation, and it does not yet fully comply with Romanian regulations. This makes its long-term performance uncertain and primarily based on lab results. In contrast, the traditional construction company makes no mention of durability, implying that conventional methods are stable, regulated, and their performance is well-established. These responses suggest that, although 3D printing construction has promise, it is currently viewed as an emerging and uncertain alternative rather than a direct substitute for traditional housing in Romania.

5.9.6 Future Outlook

Table 5.6 highlights the future outlook regarding how 3D printing is perceived, whether as a threat, opportunity, or complement, and what factors could boost its adoption over the next 5 to 10 years. To interpret it, begin with the interview questions (Row 2), followed by the responses from both perspectives (Row 3).

Table 5.6: Future Outlook Comparison between Interviews.

	Traditional Construction Company	**3D Printing Construction Company**
Question	Looking ahead 10 years, do you see 3D printing construction as a threat, an opportunity or a complementary solution? And why?	What would most effectively increase Romanian consumer adoption of 3D printed housing over the next 5-10 years?
Answer	I view it more as a complementary approach rather than a direct threat. It can be very beneficial for specific projects such as affordable housing, rapid construction or standardized designs. However, traditional construction will remain essential for custom homes, renovations and complex projects. In the long term, I think the industry will combine both approaches, using technology where it makes sense, but still depending on human expertise and experience.	The completion of the first certified construction would demonstrate reduced execution time, reduced labor requirements and no material losses, thereby facilitating increased confidence in the technology.

According to the response from the interview with a traditional construction company, their main concern about 3D printing is that it should be viewed as a complementary solution in the coming decade. This perspective shows a preference for working alongside new technologies instead of trying to replace existing methods. In contrast, the dominant framing emphasizes hybridization and integration, indicating a more balanced and thoughtful approach towards 3D printing's potential role in the industry.

Looking at the response from the 3D printing construction company, it is clear that their focus is quite different from the traditional construction company. They emphasize certification, registered buildings and institutional validation as key factors in boosting the acceptance within the next 5 to 10 years. Without these factors, the adoption of their technology remains restricted to experimental or research projects, no matter how much public interest or technological readiness there may be.

In general, the differing view illustrate that traditional construction company affords to focus on long-term integration and hybrid approaches, while the 3D printing construction company is mainly focused on short-term validation and survival within the current system. As a result, their approach is less about strategic coexistence and more focused on achieving the minimum institutional requirements needed to enter the market and achieve broader acceptance.

6 Synthesis of findings: Why adoption is Low

6.1 Internal Comparison of Survey Results

Before incorporating interview insights, it is essential to analyze the internal relationships within the survey data. Comparing specific survey indicators reveals percep-tion patterns, hesitations, and conditional acceptance more clearly. These comparisons help explain how respondents frame their thoughts about innovation, risk, and adoption.

6.1.1 Openness versus Early Adoption

Figure 6.1 presents a direct comparison between two concepts, general openness to unconventional housing options and the willingness to be among the first to live in a 3D printed house. To interpret it, examine the two distributions side by side.

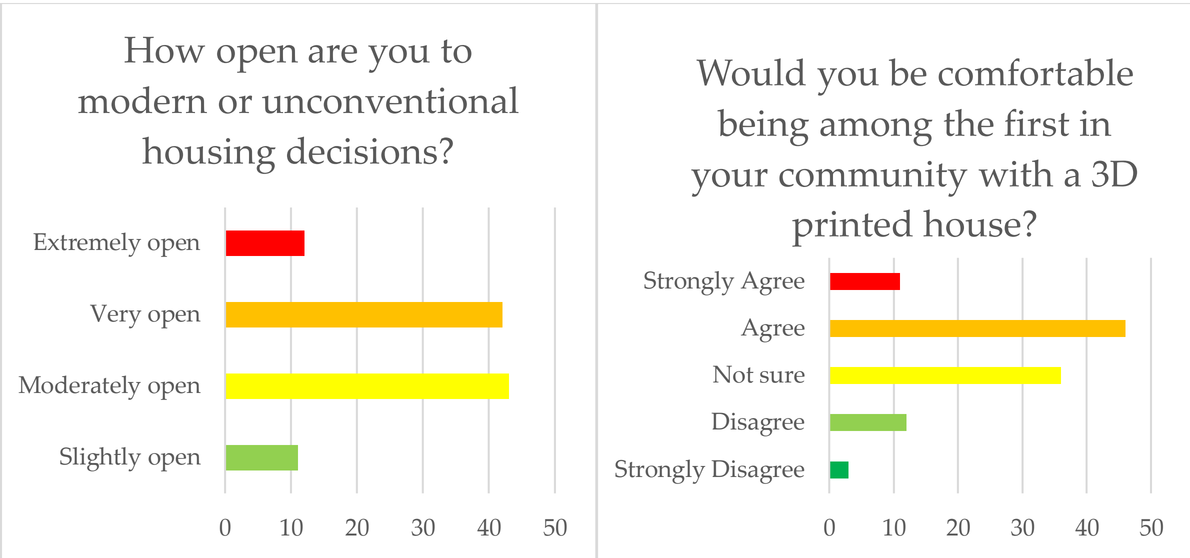


Figure 6.1: Comparison between Openness and Early Adoption.

When comparing respondents' overall openness to modern or unconventional housing with their willingness to be among the first in their community to live in a 3D printed house, the results reveal a consistent trend rather than a contradiction. Most respondents view themselves as either very open or moderately open to unconventional housing options. Their enthusiasm for innovation is also evident in their responses to the early adoption question, where the majority agree with the idea of being among the first to live in a 3D printed house.

While there is general consensus, many respondents who are "not sure" clarify that openness does not mean complete confidence. People appear open to new ideas but remain cautious. Rather than completely rejecting early adoption, many endorse it only under certain conditions. This indicates their willingness depends on factors such as additional assurances, concrete examples, or official support. Overall, it reflects less resistance and more cautious openness driven by uncertainty.

This finding sharpens the theoretical expectation found in studies on automated and digital construction systems, by Xu et al., 2022 (Xu, et al., 2022), which suggests that innovation adoption is usually associated with positive attitudes towards new technologies. Although respondents show openness, the results imply that attitude alone doesn't drive adoption in the housing sector. In Romania, this openness seems to be influenced by perceived long-term risks, indicating that housing innovation behaves differently than consumer technology adoption, where trying new products typically involves lower risks.

This comparison implies that low adoption isn't solely due to cultural conservatism or rejection of innovation. The survey shows openness to adoption, but still, being receptive doesn't remove the perceived risks involved.

6.1.2 Awareness versus First Impressions

Figure 6.2 highlights the difference between general awareness and the initial impression of respondents, allowing to differentiate between knowing about something and having confidence in it. To interpret it, examine the two distributions side by side.

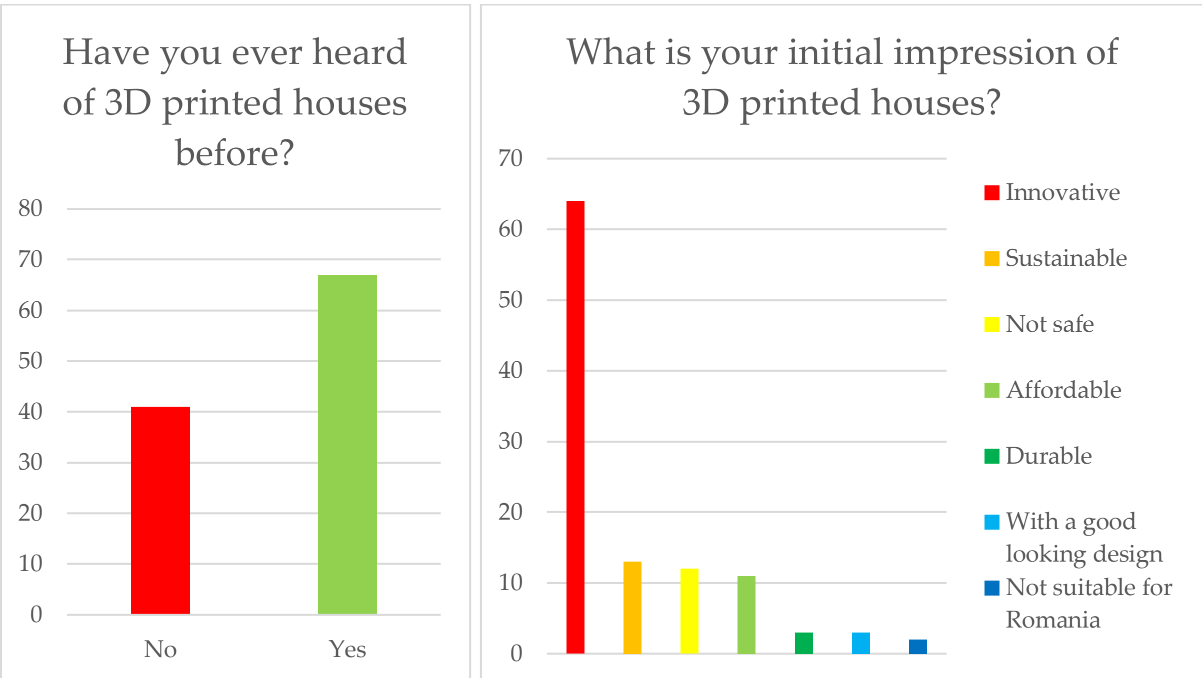


Figure 6.2: Awareness of 3D Printed Houses vs First Impressions.

When comparing how aware respondents are of 3D printed houses with their first impressions of this building method, a noticeable gap emerges between merely knowing about the concept and feeling confident in it. Although most participants had heard of 3D printed housing before the survey, their initial opinions remained vague. Innovation is frequently cited as the main association with 3D printing, but it is often accompanied by concerns about safety, durability over time, or its appropriateness for the Romanian context.

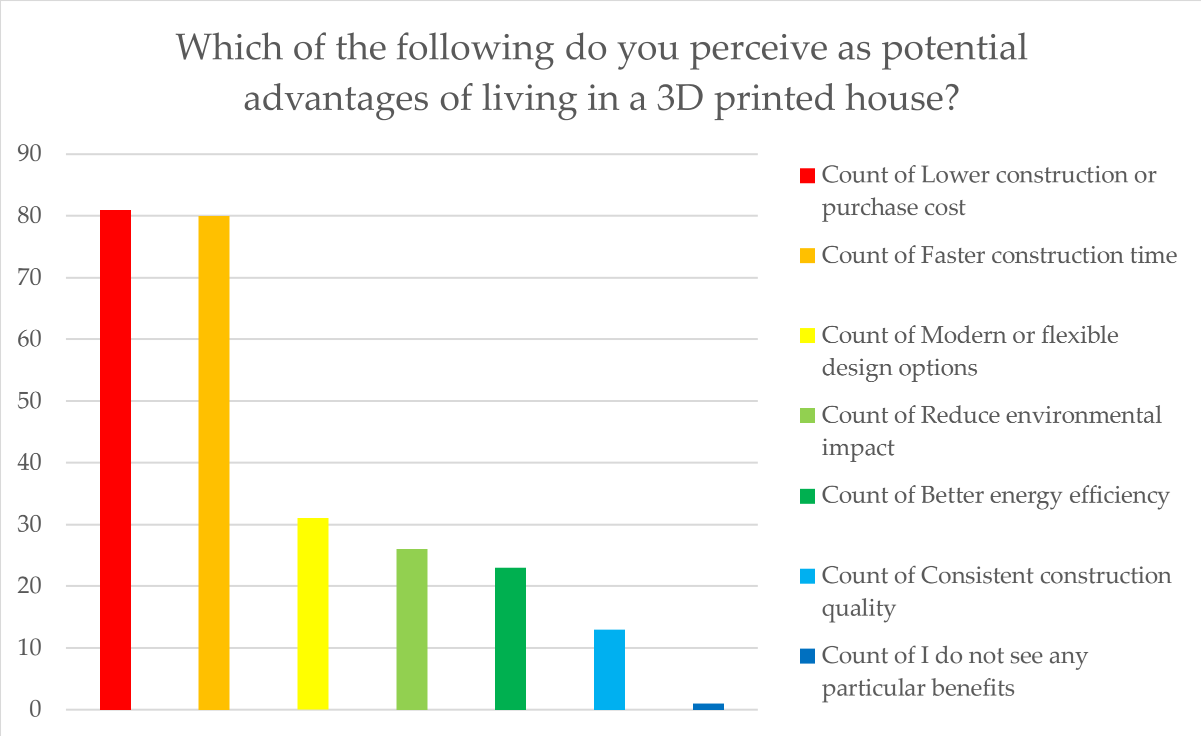
This suggests that awareness of a topic alone does not equate to full understanding or trust. Learning about 3D printed housing, often through media or online sources, tends to spark curiosity rather than reassurance. The weak association between 3D printed housing and durability or proven quality indicates that many people's knowledge remains superficial. Consequently, simply being informed about a technology does not sufficiently reduce people's concerns.

This insight relates to the residual income approach proposed by Stone, 2010 (Stone, 2010), which conceptualizes housing affordability not merely as a price-to-income ratio, but as a matter of post-housing financial resilience and household security. Unlike other markets where awareness can slowly foster familiarity and trust, housing choices are closely linked to financial stability and long-term welfare. Therefore, simply exposing people to information doesn't fully legitimize new construction technologies.

This internal contrast between awareness and confidence reinforces the idea that information exposure does not automatically generate legitimacy. Awareness may create curiosity, but not assurance.

6.1.3 Perceived Advantages versus Perceived Risks

Figure 6.3 illustrates how respondents perceive benefits compared to their concerns, to determine which factor influences their decisions more. To interpret it, examine the two distributions side by side.



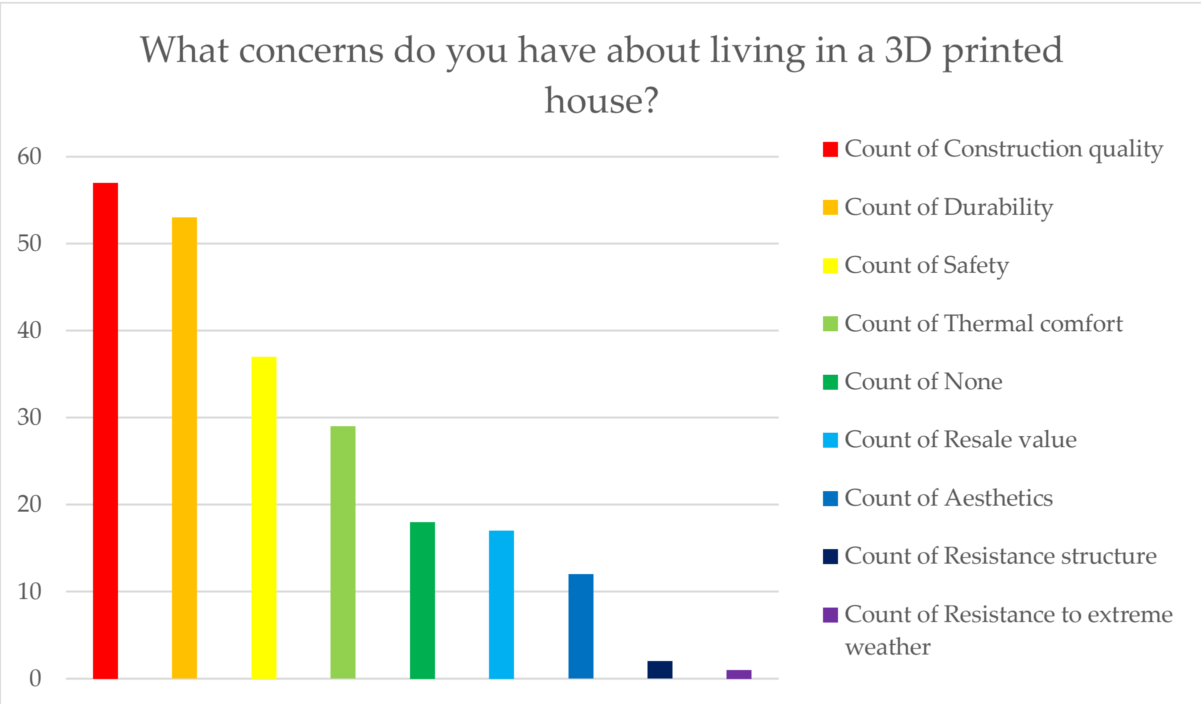


Figure 6.3: Perceived Advantages vs Perceived Risks.

A comparison between the perceived benefits of 3D printed housing and the concerns raised by respondents shows a more complicated picture than just a balance between positive and negative views. Although many respondents identify reduced construction costs and quicker building times as clear benefits, these advantages seem less important compared to worries about the long-term durability, safety and performance of such housing.

Speed and cost are mentioned right away, showing that the general idea of 3D printed housing as efficient and affordable has been well received by respondents. However, when considering personal use, the way people evaluate these options changes. Respondents do not seem to treat advantages and risks as equally important. Instead, they place more weight on risks when making decisions. Factors like how long the housing will last, its structural safety and its value over time are seen as essential, not something that can be overlooked.

This suggests that respondents are not focused on whether 3D printing is efficient, but rather whether it is safe enough to justify long-term investment. Even with benefits present, uncertainty remains a key issue. In other words, the advantages people see are additional benefits, but the risks are fundamental. As long as these structural concerns are not resolved, the positive aspects like faster construction do not greatly change the overall perception of 3D printed housing.

This finding supports the multidimensional affordability framework grounded in the residual income approach, by Stone, 2010 (Stone, 2010), where housing is evaluated not merely through cost efficiency but through long-term financial resilience and perceived security. Although previous studies highlight performance efficiency as a competitive advantage of 3D printed housing, as mentioned by Abdalla et al., 2021 (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021) and Xu et al., 2022 (Xu, et al., 2022), the results demonstrate that efficiency gains do not override concerns related to structural stability and lifecycle value.

An additional and somewhat surprising insight arises when examining sustainability. Drawing on the multidimensional affordability perspective, which frames housing as a matter of long-term financial resilience and household stability (Stone, 2010 (Stone, 2010), UN-Habitat, 2020 (Un-Habitat, 2020)), alongside the studies that position additive construction as an environmentally efficient innovation characterized by reduced material waste and optimized resource use (Abdalla et al., 2021 (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021), Sakin et al., 2017 (Sakin & Kiroglu, 2017)), one might anticipate that environmental performance and reduced material waste would be more significant factors in respondents' assessments. Much of the literature portrays 3D printed housing as a sustainable option because it typically involves less material waste, more efficient resource use and possible improvements in energy efficiency. With the growing emphasis on sustainability in the construction sector, it seems logical to expect that respondents would strongly link 3D printing with environmental benefits. Nevertheless, the survey findings do not support this assumption. Sustainability is viewed as a secondary or less important advantage compared to factors like cost and speed. While energy efficiency is generally considered important in housing decisions, respondents do not strongly associate this concern with 3D printed housing specifically. As a result, environmental performance does not play a major role in shaping how this technology is perceived.

This results partially challenges the sustainability-driven innovation narrative found in studies on additive construction, where reduced environmental footprint and material efficiency are presented as primary drivers of technological adoption (Abdalla et al., 2021 (Abdalla, Fattah, Abdallah, & Tamimi, Environmental Footprint and Economics of a Ful-Scale 3D-Printed House, 2021), Sakin et al., 2017 (Sakin & Kiroglu, 2017)). While academic literature frequently positions reduced material waste and environmental efficiency as central advantages of 3D printing, the survey results indicate that such arguments do not strongly influence buyer perception in the Romanian housing market. This suggests that theoretical drivers of innovation may operate differently depending on economic context and local priorities.

This absence of sustainability as a dominant driver is particularly relevant when considering the theoretical expectations developed earlier in the thesis. It suggests that, within the Romanian housing context, economic stability and structural reliability remain more influential than environmental positioning when evaluating new construction technologies.

6.2 Comparison of Survey Findings with Interview Insights

6.2.1 Perceived Risk versus Professional Experience

The survey findings show that respondents' main concerns revolve around durability, safety, long-term strength and resale value. At the same time, respondents indicate that guarantees, visible examples and official approval would increase their willingness to adopt or recommend 3D printed housing. This suggests that hesitation is not rooted in rejection, but in uncertainty.

The interview with the traditional construction company provides a structural explanation for this uncertainty. The representative emphasizes that traditional construction has been "thoroughly tested for decades," allowing professionals and clients to observe how materials behave over time, how they crack, age or respond to climate conditions. By contrast, 3D printed houses are described as lacking this long-term track record, particularly in the Romanian context. Even if quality "could be achieved," durability over 30–50 years remains unproven locally. The 3D printing company confirms this limitation from the opposite perspective. Durability claims rely mainly on laboratory tests and simulations and no registered residential construction has yet been exposed to long-term weathering in Romania. This creates a gap between theoretical performance and lived validation. 40%

When comparing these findings, it becomes clear that the survey respondents' concerns are not abstract fears. They reflect a rational reaction to the absence of empirical precedent. Buyers appear to respond to concerns that professionals themselves also identify. In this sense, survey hesitation and professional caution are not contradictory, they are mutually reinforcing.

6.2.2 Regulatory Constraints and Their Structural Impact on Adoption

Interestingly, survey participants seldom mention regulation directly. Instead, they stress the importance of guarantees, long-term security, and institutional approval. At first glance, this could imply that regulation is not seen as a significant concern by potential buyers.

The interviews highlight that regulation fundamentally supports many of these issues. The traditional construction expert points out that Romanian building codes are strict, and without regulatory clarity, both professionals and clients may feel hesitant. The 3D printing firm adds that 3D printed construction doesn't fit into recognized masonry categories under Romanian laws, so buildings can't currently be registered. Without registration, banks won't issue mortgages, and insurance companies may not fully insure such properties. When considering the survey's focus on "official approval" and "acceptance by banks and insurers' alongside the interviews, a clearer pattern appears: buyers may not explicitly mention regulatory hurdles, but their expectations are implicitly linked to legal recognition. What the survey presents as a demand for guarantees is really dependent on legal classification and institutional validation.

This comparison shows that the adoption barrier operates on two levels. At the surface level, buyers express concern about safety and resale value. At the structural level, these concerns are linked to regulatory uncertainty and financial exclusion. Thus, the survey captures symptoms, while the interviews reveal the underlying mechanism.

6.2.3 Cultural Attitudes and Conditional Openness to Innovation

The survey results demonstrate that respondents are generally open to innovation and even moderately comfortable with the idea of early adoption, although a significant number remain "not sure." This suggests conditional acceptance rather than strong resistance.

The traditional construction interview adds nuance by describing a “fear of being a test case,” noting that “nobody wants to be the first if something goes wrong later”. This observation resonates directly with the presence of the “not sure” category in the survey. The hesitation visible in the data is not hostility toward technology, but reluctance to assume disproportionate risk.

At the same time, the 3D printing company reports that public response has been “very positive” and that interest is high across age groups. This reinforces the idea that cultural resistance is not absolute. The public is curious and receptive, but receptiveness alone does not override structural uncertainty.

Together, these findings suggest that Romanian housing culture is not fundamentally anti-innovation. Rather, it is risk-sensitive. Innovation may be accepted once it is normalized and institutionalized, but not when it is perceived as experimental.

6.2.4 Complementarity versus Disruption

Another insight arises when examining how industry players perceive the future of 3D printing. Typically, companies do not view 3D printing as a threat; instead, they see it as a complementary method that can coexist with traditional construction practices. Tasks such as foundations, roofing, installations, and finishes would still rely on conventional expertise.

This view supports the survey result showing that respondents are willing to modify 3D printed houses using traditional finishes like plastering. Instead of seeking a complete overhaul, both buyers and professionals seem receptive to hybrid approaches.

This indicates that a gradual integration approach, instead of a disruptive replacement narrative, might be more appropriate for the Romanian context.

7 Proposed Solutions to Increase Adoption of 3D Printed Houses in Romania

This chapter elaborates on two main aspects: insights from Chapters 5 and 6, and findings from existing literature regarding common challenges in housing innovations. Chapter 5 highlights a discrepancy between respondents' perceived benefits, such as faster construction and cost savings, and their confidence in making a purchase. Although they acknowledge advantages, concerns about long-term value, durability, and safety become more evident when considering actual residency in such housing. This aligns with other research indicating that housing decisions are long-term and high-stakes. Consequently, uncertainty is often seen as a cost that may outweigh initial expenses. The survey data supports this pattern, showing that risks tend to be valued more than benefits when significant investments are involved.

Chapter 6 explores the remaining "hesitation" and why it persists despite the technology's viability. Interviews reveal that printed houses do not align with current approval and registration categories, showing a mismatch with institutional standards. These homes face market challenges, such as difficulties in obtaining insurance and mortgages, unless properly registered. Essentially, the trust and safety concerns identified in Chapter 5 are rooted in systemic and governance-related issues. Since widespread adoption relies on social and institutional acceptance, these proposals shift focus from persuasion to addressing these compatibility issues.

7.1 Regulatory Integration and Standardization

Regulatory integration remains essential because uncertainties in approval and classification act as barriers. The public perceives a building method as "not fully validated" because it is not explicitly acknowledged within Romania's current construction regulations, placing it in a regulatory gray area. Chapter 6 elaborates on this issue: registration is impossible if the system does not fit existing construction categories, which hampers standard market functions such as insurance and mortgages. Institutional uncertainty indicates technical risk, even if not directly stated, linking back to Chapter 5, where durability and safety are emphasized.

To make it easier to approve and register 3D printing construction companies in Romania, a clear and transparent administrative and technical framework should be put in place. This framework should feature a comprehensive national approval system that includes testing, documentation, and inspection procedures for printed structural systems. It involves assessing structural performance, testing material behavior and durability under local conditions, and conducting regular on-site quality inspections that consider material mixing, curing, environmental factors, and process traceability. Adopting this approach is crucial for ensuring safety and consistency. Moreover, establishing a clear and structured approval process can help reduce institutional uncertainty, which is a major factor in trust issues discussed in Chapter 5.

Romania's regulatory landscape is becoming increasingly linked to the wider European system. Although there is no specific EU regulation for 3D printed houses, national authorities' evaluations of innovative construction methods are gradually influenced by EU updates on materials, documentation, and performance standards. As a result, additive manufacturing is unlikely to be accepted unofficially forever. Romania has the opportunity to define the legal status of printed housing by strengthening its regulatory framework, rather than leaving it ambiguous. This effort not only benefits the local sector but also supports broader European harmonization initiatives.

Proposing a regulated "pilot permitting" system similar to a regulatory laboratory aims to allow a select group of initiatives to operate under stricter oversight while still securing permits and registration. This approach is not intended for approving risky experiments. If the government offers a dependable validation process, some market segments may follow, as Chapter 5 indicates that many respondents are hesitant about early adoption rather than opposed. However, 3D printed houses remain mainly a demonstration category until pilots lead to legal registration, which does not alter risk perceptions. Essentially, Romania needs at least a few legally recognized homes that are approved, registered, inspected, and documented.

7.2 Financial Mechanisms and Market Inclusion

Financial integration is crucial because, in Romania, a home only gains true market value when it can be financed and insured like other assets. As noted in Chapter 5, respondents view affordability in terms of stability and long-term expenses, rather than only initial construction costs. They acknowledge benefits such as lower construction costs and quicker project completion. Nonetheless, these benefits are futile if the property cannot be insured, mortgaged, or sold. Chapter 6 emphasizes this problem by discussing registration and categorization issues that directly impact access to insurance and mortgages.

Developing pilot mortgage and insurance products linked to certified 3D printing systems is a practical approach. Initially, these should be limited, as broad adoption might face resistance due to significant risks and uncertain pricing. By conducting a small-scale trial connecting a single certified printer to a few banks and an insurer, 'unknown risk' can be converted into 'managed risk.' Since systematic monitoring yields valuable data, rather than predicting housing failure, this trial should include warranties and explicit inspection criteria. Over time, this data will help banks and insurers standardize the product, forming the basis for actuarial models and valuation standards.

If necessary, temporary public risk-sharing can provide as a temporary fix. According to theory, early-stage businesses face uncertainty costs as a result of the inherent technological risks and the absence of precedent. At this point, promoting risk reduction helps establish industry norms. This reflects continuing arguments in the literature about how institutions facilitate innovation adoption and supports the findings in Chapter 5 that people tend to resist accepting advantages when hazards are not adequately recognized.

7.3 Demonstration, Building Trust and Public Acceptance

Given the gap between awareness and confidence reflected in the results, the third proposal focuses on building trust through tangible evidence. As discussed in Chapter 5, respondents often link 3D printed housing with innovation but do not necessarily view it as robust or consistently high in quality. Even well-informed people remain cautious; awareness by itself does not eliminate doubts. The literature review suggests that trust in new technologies depends mainly on experience, observing real-world examples rather than just hearing claims, and the data here supports this.

Romania needs comprehensive reference projects that serve educational purposes and provide proof of quality. These projects should display completed homes with top-notch finishes, sustainable maintenance, and verified thermal comfort, going beyond superficial presentations. Access should be granted to the general public, engineers, inspectors, banks, and insurers, as these projects influence approval, permissions, and funding. In Chapter 6, the absence of a local track record is mentioned as a challenge, since printed construction is seen as having less long-term reliability compared to traditional methods. Building this validation requires reference projects that are carefully monitored and transparently documented.

An improved communication strategy that better aligns with respondents' values is recommended. Since buyers recognize that a house is more than just its walls, a sign stating 'printed in 24 hours' might be misleading. Durability and safety are primary concerns during decision-making, as shown in Chapter 5. Communication should emphasize warranties, demonstrated performance, ease of maintenance, and the clear differences between printed and traditionally made parts. Although this marketing approach may seem less exciting, it more accurately reflects the actual purchasing process.

7.4 Industry Integration and Hybrid Models

Since the results indicate that acceptability increases when technology aligns with existing practices, industry integration should be considered the fourth key factor. As essential components like roofing, installations and finishing still rely on traditional skills, Chapter 6 highlights that traditional construction professionals often view 3D printing as an addition rather than a complete replacement. Survey findings also show that homes with traditional finishes, such as plastering, tend to be more widely accepted. Both indicators suggest that a mixed delivery model, rather than a "disruption narrative', is the most effective approach.

In practice, this involves promoting project configurations where a traditional contractor manages foundations, roofing, mechanical, electrical, plumbing, insulation, and finishing, while a 3D printing firm supplies the structural shell. The customer ultimately gets a single, cohesive package with clear warranties and accountability. This approach reduces resistance by reorganizing existing roles instead of threatening them within the building industry. It also encourages adoption because, despite the new structural method, the finished product keeps its familiar look and function.

7.5 Energy Performance Alignment and Policy Leverage

The fifth recommendation builds on previous discussions about energy efficiency and sustainability. Chapter 5 notes that emphasizing the link between energy savings, comfort, and cost reduction had a stronger influence on Romanian respondents than focusing solely on sustainability. This suggests that environmental claims alone may not be enough to encourage adoption. Since performance aspects are highly valued in Romania, highlighting benefits related to household expenses and winter warmth is more effective.

The study raises questions about the gap between consumer priorities and policy messages, challenging the common belief in Europe that sustainability messaging alone can speed up the adoption of new construction methods. Environmental performance may not motivate Romanians morally or emotionally but becomes relevant when connected to personal financial benefits. Public campaigns focusing on carbon reduction or climate responsibility might be less effective without linking these to tangible home benefits, like cheaper heating or more comfort. This creates a disconnect between consumer choices and legislative sustainability goals, making it crucial to address this gap for successful implementation.

Sustainability deserves reconsideration rather than neglect. Improving energy performance is vital for reducing costs and increasing comfort, especially in areas with high winter heating bills. In this context, energy efficiency directly influences affordability and quality of life, supporting the earlier focus on cost-effectiveness in the thesis. When evaluating 3D printed housing, it’s important to prioritize actual performance over manufacturing speed. With proper insulation and design, digital fabrication can ensure consistent geometry, potentially improving airtightness and reducing variability. Nonetheless, these advantages must be confirmed through real-world testing instead of assumptions. Without solid performance data, claims about energy efficiency risk being mere marketing rhetoric rather than verified facts.

For the case study project, details about official energy certifications and thermal comfort monitoring should be provided. Clear, detailed reporting will boost trust and support the thorough assessment approach outlined in Chapter 5. Furthermore, ensuring printed homes meet current performance standards aligns with existing building regulations and supports the integration of additive manufacturing into the national and European construction sectors. While sustainability isn't a top priority for Romanian consumers now, rising performance standards will eventually influence all housing types. Demonstrating compliance and consistency will help promote the long-term adoption of additive manufacturing in the built environment.

In summary, simply promoting sustainability won’t speed up adoption in Romania. However, linking environmental performance to comfort, financial stability, and measurable building quality makes it more meaningful. The challenge isn’t abandoning sustainability but integrating it into a framework aligned with consumer priorities.

7.6 Implementation Roadmap and Sequencing

Since the findings indicate conditional readiness rather than full willingness, applying earlier ideas gradually and systematically is likely more effective. While individuals and professionals are open to change, Chapter 6 shows they often hesitate to be early adopters, especially when institutional barriers are strong. This suggests that rapid or substantial changes might increase skepticism instead of reducing it.

Since they establish the institutional basis necessary for funding and insurance systems, defining certification processes and clarifying legal frameworks are essential first steps toward a more balanced approach. Without a clear approval and registration system, financial integration faces structural limitations. Clarifying these rules can enable the launch of registered pilot initiatives and supervised reference centers, which can serve as concrete examples. This evidence-based approach will gradually diminish uncertainties both technically and symbolically. As documentation improves and performance metrics replace assumptions, financial products are likely to evolve from experimental pilots into more standardized offerings. Ultimately, scaling productivity will depend less on technological modifications and more on the development of the supporting system.

Chapters 5 and 6 conclude by emphasizing that the main challenge isn't convincing stakeholders to accept 3D printed homes. Instead, it lies in fully integrating new technology into existing companies. When a printed home can undergo the same processes as traditional property, including approval, registration, insurance, financing, viewing, and sales, the market perspective changes. This shift moves the focus from questioning its validity to making straightforward comparisons. Consequently, this suggests that adoption is more than a fleeting trend and might follow a clear and structured path.

8 Conclusions and Reflections

This study investigates why 3D printed homes are not yet widely adopted in Romania, despite their technological capabilities and international recognition, particularly amid rising housing affordability pressures. Based on interviews with professionals, market data, surveys, and existing literature, the findings indicate that the challenges are systemic rather than purely technological.

The survey shows that Romanians are not fundamentally against innovation in construction. Many respondents see benefits like quicker building times and lower costs. They also are open to modern or unconventional housing options, but this willingness depends on other factors. When choosing personally, they prioritize long-term reliability, resale value, durability, and safety. Thus, while they value innovation conceptually, managing risks remains essential for their investment decisions.

Second, the survey results show that the risks perceived by respondents closely match the issues discussed during interviews. To clarify how materials age, crack, and respond to stress over time, a traditional construction expert mentioned that conventional building methods have extensive performance data under local climate conditions. In contrast, Romania lacks long-term, locally validated examples of 3D printed houses, leading to concerns that cannot be fully addressed by simulations or laboratory tests. The 3D printing company states that durability claims are mainly based on approved tests and predictive models, rather than on buildings that have survived Romanian weather for decades. This gap between real-world experience and technological validation seems to be a key factor in the hesitation observed.

Third, indirect structural barriers affecting buyer perceptions include financial and regulatory issues. Survey participants often highlight the need for official approval, bank acceptance, and reassurance about resale value, though they rarely mention regulations explicitly. Interviewees highlighted that 3D printed homes in Romania don't fit well into existing construction categories, complicating registration, insurance, and mortgage processes. This institutional uncertainty partly stems from concerns over durability. Even if a home's structural safety meets technical standards, it might be regarded as riskier if registering, financing, or insuring it proves difficult.

Fourth, the analysis results show that the uncertainties identified by the respondent are closely aligned with the issues identified during the interview. Traditional building experts note that conventional design methods consider performance data below the local climate conditions to better understand how building elements age, crack, and respond to stress beyond immediate loads. However, Romania currently lacks reliable, locally validated models for 3D printed houses that address issues beyond those covered by simulations or laboratory tests. 3D printing companies claim that their sustainability assertions are mainly based on approved trial results and predictive models, rather than structures that account for Romanian weather conditions tested over decades. This difference highlights a need to identify uncertainties in the expertise and validation processes used.

Fifth, buyers' perceptions are affected by indirect organizational barriers such as fiscal and supervisory challenges. Contestants often mention the need for official approval, deposit trust, and assurance of sale value, though they rarely cite the law directly. Participants observed that 3D Printing Houses are rarely referenced in academic writing aligned with existing assembly groups in Romania, complicating registration, insurance, and mortgage procedures. As a result, doubts about organizational stability often relate to concerns about sustainability. Even with a technically solid organizational structure, a house might still be considered risky if registration, financing, or insurance processes are difficult to address in formal documentation.

Another important finding relates to sustainability. The survey results show that sustainability is not the primary factor driving adoption in Romania, even though academic literature often highlights the environmental benefits of 3D printed housing, such as reduced material waste and increased resource efficiency. Respondents focus on energy efficiency mainly for its long-term cost savings and comfort, rather than for environmental reasons. This suggests that the messaging around innovation should be adapted to local priorities, where structural reliability and financial stability are more important than ecological concerns.

This thesis concludes that low adoption of 3D printed homes among Romanian consumers is not due to a rejection of innovation. Instead, it results from these homes not being fully integrated into the existing institutional, financial, and regulatory systems that establish standards for safe housing options. While the technology performs effectively, the essential systemic alignment remains incomplete.

This study provides a theoretical explanation of how innovation spreads in high-risk markets, highlighting that housing differs from consumer goods and digital products. The adoption of residential property relies on factors such as long-term security, official recognition, intergenerational value, and tangible benefits. This supports the notion that in capital-intensive and socially influenced industries, uncertainty represents a cost that can often outweigh direct financial considerations.

The research shows that institutional theory can encourage innovation. While a technology may enhance efficiency, its broad adoption depends on how well it fits with legal frameworks, funding models, and existing professional practices. Without this alignment, the innovation remains in a transitional state, neither fully adopted nor rejected. The 3D printed house in Romania serves as an example of this transitional phase.

The data shows that highlighting only the speed or innovation of 3D printed housing isn't enough. Homebuyers prioritize structural guarantees, government support, and local real-world examples over marketing claims of fast delivery. As a result, the emphasis should move from just technological progress to areas such as certification processes, participation in pilot programs, integration with financial systems, and detailed performance tracking.

Although this research offers valuable insights, it is important to recognize its several limitations.

The primary limitation originates from Romania's early stages in 3D printed housing development. At the time of the study, only one company had functional 3D printing technology suitable for construction, and no long-term residential projects were fully established. Consequently, survey respondents and interviewees assessed hypothetical or preliminary scenarios instead of actual post-occupancy experiences. Therefore, their perceptions were rooted in expectations rather than proven results.

Another limitation is the size and composition of the qualitative sample. Interviews were conducted with just one representative from a typical construction firm and one from a 3D printing company. While their insights offered valuable depth and allowed for meaningful comparison, the results may not fully represent the Romanian building sector as a whole. Incorporating a wider range of specialists could uncover additional insights or alternative perspectives.

The survey, although helpful in identifying trends and patterns, was carried out online and depended on volunteers. Consequently, the sample might not fully reflect the demographic and socioeconomic diversity of the Romanian population. The results should be viewed as insights into the respondents' current opinions rather than a statistically accurate representation of the entire market.

Since 3D printed housing is still emerging, legal and market conditions could change quickly. Some constraints discussed in this thesis may decrease or shift in the coming years as legislation develops and more pilot projects gather performance data. The findings of this study represent a key moment in Romania's technological development.

Considering these limitations and the developing state of the field, various avenues for future research can be suggested.

Initially, extensive research on registered 3D printed dwellings will gather crucial empirical data. Tracking aspects like structural integrity, maintenance costs, thermal comfort, and occupant satisfaction over five to ten years will shift the focus from mere assumptions about durability to verified performance metrics.

Second, future research could broaden the professional sample to involve architects, structural engineers, local government officials, bank representatives, and insurance organizations. Gaining insight into how each stakeholder assesses risk and responsibility would offer a more comprehensive understanding of the institutional ecology shaping adoption.

Third, conducting comparative research between Romania and other European countries with advanced 3D printed homes can help identify which barriers are context-specific and which are universal. This study would also assess if sustainability plays a more significant role in adoption in nations with diverse economic situations or legislative incentives.

Fourth, economic modeling studies could identify when 3D printed housing in Romania reaches cost competitiveness. Since many benefits rely on repetition and economies of scale, establishing the minimum project size needed would offer valuable insights for policymakers and developers.

Exploring buyer psychology and risk perception related to housing innovation could offer valuable theoretical insights into how long-term investment decisions are made amidst uncertainty. This understanding would benefit not just the 3D printing industry but also other emerging construction technologies.

This thesis reveals that 3D printed housing in Romania is not being rejected, but is being closely monitored. Buyers are conditionally open, professionals exhibit cautious interest, and institutions are gradually adapting, yet full acceptance has yet to be obtained. The primary difficulty is not the structural integrity of printed walls, but rather the exterior framework that generates legitimacy, insurability, and long-term confidence.

To become a mainstream choice rather than merely an experiment, 3D printed housing must go through the same approval, registration, financing, insurance, and resale processes as traditional residences, with no exceptions or ambiguities. Achieving this level of systemic integration can minimize perceived risks while increasing the influence of benefits in decision-making.

While 3D printing alone cannot resolve Romania's housing affordability issues, driven by land prices, urban policies, and macroeconomic factors, it can contribute to a broader strategy. This approach, which includes regulatory reforms, increased financial inclusion, and transparent performance monitoring, could foster a more diverse and potentially more efficient construction industry.

In Romania, 3D printed houses is now becoming from potential to standard practice. The technology has been demonstrated to function, the public is cautiously interested, and the industry is progressively stepping in. The next stage is to achieve full integration rather than only demonstrate feasibility.

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A Appendix A

Category	Keyword combinations
General	3D printed house 3D printed house projects 3D printed house case study 3D printed house technology 3D printed house materials 3D printed house academic research 3D printed house thesis 3D printed house article 3D printed house scholarly article 3D printed home 3D printed home projects 3D printed home case study 3D printed home technology 3D printed home materials 3D printed home academic research 3D printed home thesis 3D printed home article 3D printed home scholarly article 3D printed building 3D printed building projects 3D printed building case study 3D printed building technology 3D printed building materials 3D printed building academic research 3D printed building thesis 3D printed building article 3D printed building scholarly article 3D house building 3D house building projects

	3D house building case study 3D house building technology 3D house building materials 3D house building academic research 3D house building thesis 3D house building article 3D house building scholarly article 3D home building 3D home building projects 3D home building case study 3D home building technology 3D home building materials 3D home building academic research 3D home building thesis 3D home building article 3D home building scholarly article additive manufacturing in construction additive manufacturing in construction projects additive manufacturing in construction case study additive manufacturing in construction technology additive manufacturing in construction materials additive manufacturing in construction academic research additive manufacturing in construction thesis additive manufacturing in construction article additive manufacturing in construction scholarly article concrete 3D printing concrete 3D printing projects

	concrete 3D printing case study concrete 3D printing technology concrete 3D printing materials concrete 3D printing academic research concrete 3D printing thesis concrete 3D printing article concrete 3D printing scholarly article construction 3D printing construction 3D printing projects construction 3D printing case study construction 3D printing technology construction 3D printing materials construction 3D printing academic research construction 3D printing thesis construction 3D printing article construction 3D printing scholarly article 3D printed villages 3D printed villages projects 3D printed villages case study 3D printed villages technology 3D printed villages materials 3D printed villages academic research 3D printed villages thesis 3D printed villages article 3D printed villages scholarly article 3D printed residential construction 3D printed residential construction projects 3D printed residential construction case study 3D printed residential construction technology 3D printed residential construction materials

	3D printed residential construction academic research 3D printed residential construction thesis 3D printed residential construction article 3D printed residential construction scholarly article
Social	Social impact of 3D printed houses Social impact of 3D printed houses projects Social impact of 3D printed houses case study Social impact of 3D printed houses technology Social impact of 3D printed houses materials Social impact of 3D printed houses academic research Social impact of 3D printed houses thesis Social impact of 3D printed houses article Social impact of 3D printed houses scholarly article Social impact of 3D printed homes Social impact of 3D printed homes projects Social impact of 3D printed homes case study Social impact of 3D printed homes technology Social impact of 3D printed homes materials Social impact of 3D printed homes academic research Social impact of 3D printed homes thesis Social impact of 3D printed homes article Social impact of 3D printed homes scholarly article housing affordability 3D printing 3D printed affordable housing 3D printed social housing

	3D printed homes for low-income 3D printed homes for low-income case study 3D printed homes for low-income academic research 3D printed homes for low-income article 3D printed homes for low-income scholarly article 3D printed houses for low-income 3D printed houses for low-income case study 3D printed houses for low-income academic research 3D printed houses for low-income article 3D printed houses for low-income scholarly article 3D printed emergency housing 3D printed housing accessibility 3D printed public housing 3D printed houses for the homeless 3D printed homes for the homeless 3D printed housing market acceptance 3D printed housing for developing countries
Environmental	environmental impact of 3D printed houses environmental impact of 3D printed houses case study environmental impact of 3D printed houses academic research environmental impact of 3D printed houses article environmental impact of 3D printed houses scholarly article environmental impact of 3D printed homes environmental impact of 3D printed homes case study

	environmental impact of 3D printed homes academic research environmental impact of 3D printed homes article environmental impact of 3D printed homes scholarly article 3D printed house sustainability 3D printed house sustainability case study 3D printed house sustainability academic research 3D printed house sustainability article 3D printed house sustainability scholarly article 3D printed home sustainability 3D printed home sustainability case study 3D printed home sustainability academic research 3D printed home sustainability article 3D printed home sustainability scholarly article 3D printed house environmental impact 3D printed house environmental impact case study 3D printed house environmental impact academic research 3D printed house environmental impact article 3D printed house environmental impact scholarly article 3D printed home environmental impact 3D printed home environmental impact case study 3D printed home environmental impact academic research 3D printed home environmental impact article

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	3D printed home green building scholarly article
	eco-friendly 3D printed house
	eco-friendly 3D printed home
	green 3D printed house
	3D printed house carbon footprint
	3D printed house CO2 emissions
	3D printed house waste reduction
	3D printed house life cycle assessment
	3D printed house life cycle assessment case study
	3D printed house life cycle assessment academic research
	3D printed house life cycle assessment article
	3D printed house life cycle assessment scholarly article
	LCA of 3D printed houses
	recycled materials in 3D printed houses
	local materials in 3D printed houses

	3D printed house environmental performance 3D printed house environmental performance case study 3D printed house environmental performance academic research 3D printed house environmental performance article 3D printed house environmental performance scholarly article 3D printed house durability 3D printed house circular economy 3D printed house sustainable development goals SDGs and 3D printed housing
Comparison	traditional house vs 3D printed house traditional house compared to 3D printed house conventional construction vs 3D printing innovation in 3D printing construction
Policy	housing policy 3D printing legal issues 3D printed buildings construction regulations for 3D printed houses regulatory challenges for 3D printed houses building code for 3D printed houses policy frameworks for 3D printed houses cost analysis for 3D printed houses economic impact for 3D printed houses 3D printed house regulation 3D printed house smart cities 3D printed house standards 3D printed housing policy 3D printed housing regulatory challenges

Material	concrete 3D printing 3DCP 3D concrete printing recycled plastic for 3D printed houses PLA for 3D printed houses Polylactic acid for 3D printed houses ABS for 3D printed houses earth-based materials for 3D printed houses composite materials for 3D printed houses innovative materials for 3D printed houses material sustainability for 3D printed houses material selection for 3D printed houses

B Appendix B

Company Background

- Can you briefly describe your company's experience with 3D printed housing in Romania and the type of projects you have completed?
- What type of 3D printing technology and materials do you use in Romania and how these are adapted to local climate and building expectations?

Regulatory & Market Challenges

- How ready is the Romanian construction and housing market to absorb 3D printed housing at scale, in terms of regulation, acceptance and market?
- Compared to traditional construction, where does 3D printed housing face the greatest resistance in Romania today and what would need to change to reduce these barriers?
- How do regulations, permitting processes and local authorities currently affect the feasibility of 3D printed housing projects in Romania?
- How do financial institutions, such as banks and insurance companies, currently perceive 3D printed homes in Romania?

Social & Cultural Barriers

- How do Romanian communities and potential buyers typically react to 3D printed housing projects?
- To what extent do traditional construction practices and Romania's self-building culture influence acceptance of 3D printed houses?
- Is there any stigma or perceived status difference associated with living in a 3D printed house in Romania?

Economic

- From the buyer's perspective, how does the cost, perceived value and long-term durability of 3D printed houses compare to traditional housing in Romania?
- What are the main quality and durability concerns Romanian buyers raise and how do you address them?

Future Outlook

- What would most effectively increase Romanian consumer adoption of 3D printed housing over the next 5-10 years?

C Appendix C

Company Background & Market Position

- Can you briefly describe your company's experience, the types of residential projects you typically deliver and the regions you operate in Romania?

Awareness & Perception of 3D Printing

- What is your understanding of 3D printing construction technology and how familiar are you with its use in Romania?
- How do you perceive the quality and durability of 3D printed houses compared to traditional construction?
- How do you perceive the regulatory reliability of 3D printed houses?
- How do you think Romanian customers would respond to 3D printed houses and what factors would most influence their acceptance or rejection?

Cultural & Social Factors

- How important are experience, tradition and proven methods in gaining client trust in the Romanian construction market?
- What cultural or social barriers do you believe exist in Romania when it comes to adopting new construction technologies like 3D printing?
- How important are craftmanship, customization and the "human touch" to Romanian clients and how might this affect acceptance of automated construction?

Economic

- Do you see 3D printing construction as affecting your pricing, competitiveness or workforce? If so, in what ways?
- If 3D printing construction becomes widespread in Romania, how would your business model need to adapt?

Innovation & Adaptation

- What role, if any, do you see for traditional construction companies in collaborating with or complementing 3D printing construction companies?

Future outlook

- Looking ahead 10 years, do you see 3D printing construction as a threat, an opportunity or a complementary solution? And why?

D Appendix D

Language

1. What language do you speak?
    a. Română
    b. English

Screening

1. How old are you? (Single choice)
    a. 18-24
    b. 25-34
    c. 35-44
    d. 45-54
    e. 55-64
    f. 65-74
    g. 75-84
2. What type of housing do you currently live in? (Single choice)
    a. Apartment
    b. House
    c. Other
3. Where is your current home located? (Single choice)
    a. Urban area
    b. Peri-urban (The outskirts of a city)
    c. Rural area
4. Do you currently own or rent your home? (Single choice)
    a. I own
    b. I rent
5. What price range would you consider for your next home? (Single choice)
    a. Under 50.000€
    b. 50.000-100.000€
    c. 100.000-150.000€
    d. 150.000-200.000€
    e. Over 200.000€

Decision Drivers

1. What factors are most important when choosing a home? (Please select at most 3 options)

   a. Price
   b. Location
   c. Size
   d. Design
   e. Sustainability
   f. Other

2. How important is energy efficiency in your housing decisions? (Likeart)
   a. Not important
   b. Slightly important
   c. Moderately important
   d. Very important
   e. Extremely important
3. What is you concern regarding the balance between the initial purchase price compared to long-term costs? (Likeart)
   a. Only initial purchase price matters
   b. Mostly initial purchase price
   c. Both are equally important
   d. Mostly long-term costs
   e. Only long-term costs matter
4. How open are you to modern or unconventional housing decisions? (Unconventional – Construction using innovative or alternative methods) (Likeart)
   a. Not open at all
   b. Slighlty open
   c. Moderately open
   d. Very open
   e. Extremely open

Explanatory Video

Before continuing, I would kindly ask you to take a look at this video to understand what is a 3D printed house.

Awarness and Perceptions

1. Have you heard of 3D printed houses before this survey?
    a. Yes
    b. No
2. What is your initial impression of 3D printed houses? (Single choice)
    a. Innovative
    b. Affordable
    c. Sustainable
    d. Durable
    e. With a good looking design
    f. Not safe
    g. Not suitable for Romania
    h. Other
3. What concerns do you have about living in a 3D printed house? (Multiple choice)
    a. Durability
    b. Construction quality
    c. Safety
    d. Resale value
    e. Thermal comfort
    f. Aesthetics
    g. None
    h. Other
4. Which of the following do you perceive as potential advantages of living in a 3D printed house? (Multiple choice)
    a. Lower construction or purchase cost
    b. Faster construction time

c. Better energy efficiency
d. Modern or flexible design options
e. Reduced environmental impact
f. Consistent construction quality
g. I do not see any particular benefits
h. Other

5. Would you be comfortable being among the first in your community with a 3D printed house? (Likeart)
    a. Strongly disagree
    b. Disagree
    c. Not sure
    d. Agree
    e. Strongly agree

Adoption potential

1. Under what circumstances would you consider purchasing a 3D printed house as your next home? (Multiple choice)
    a. Affordable price
    b. Proven durability
    c. Faster to build
    d. More energy efficient
    e. I would not consider purchasing a 3D printed house
    f. Other
2. Would you carry out external plastering works in order to bring the 3D printed house to a compliant state?
    a. Yes
    b. No
3. What would convince you to recommend 3D printed house to others? (Multiple choice)

a. Seeing one in person
b. Positive reviews from owners
c. Lower cost compared to conventional homes
d. Environmental benefits
e. Clear compliance with Romanian building regulations
f. Long-term durability and structural guarantees
g. Good comfort
h. Energy efficiency
i. I would not recommend 3D printed houses
j. Other

Open Question

1. Is there anything else you would like to share about 3D printed houses?

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