Review Of Architectural Changes In The Context Of Technology During The Industrial Revolutions And Their Social Impacts

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ABSTRACT

If we consider the organization of space to be at the core of architecture, and recognize technology as a key force in shaping that space, then understanding how technology influences spatial design becomes essential. Advances in inventions and emerging technologies have fundamentally transformed human life. Yet, despite their rapid proliferation, technologies inevitably become outdated and are replaced by newer innovations. This study seeks to explore the dynamic relationship between technology and architectural space. The central question it addresses is: how has architectural space evolved under the influence of technology? More specifically, in what ways have technological advancements provided new tools and opportunities for architects to respond to the evolving needs of human societies? Focusing on the framework of the industrial revolutions, the study first examines the four major industrial revolutions and their broader effects. It then analyzes their specific impact on architecture, identifying key influential factors in each period. Employing a qualitative, descriptive-analytical approach, the research draws upon documentary and archival sources. This paper aims to contextualize architectural transformations within the technological shifts of each industrial revolution. By identifying the technological drivers behind architectural changes, the research offers architects a more informed outlook on how future innovations may continue to shape the built environment.

Keywords: Technology, Industrial Revolutions, Architecture, Social Factors.

Introduction

Humans have continuously invented and developed technologies to improve their lives in the best possible way. Today, these technologies impact nearly every aspect of our daily existence.

The pace of technological progress over the last century—particularly following World War II—has accelerated dramatically, becoming one of the most significant forces driving changes in behavioral patterns, lifestyles, individual and social values, needs, occupations, and even aesthetic preferences. As a result, architecture, which provides the setting for all human and social interactions, has inevitably had to adapt to these transformations.

To date, the world has experienced three industrial revolutions. The first industrial revolution began around 1873, marked by humanity's successful harnessing of mechanical power and a systematic shift away from reliance on animal labor. Central to this revolution was the development of the steam engine. The second industrial revolution, spanning the late 19th and early 20th centuries, introduced new methods of industrial production that further transformed society.

Digital systems, modern communication technologies, and the advancement of contemporary computers marked the onset of the third industrial revolution, bringing innovations such as smartphones and social media into everyday life. This revolution's brilliance coincided with the peak of the information technology era.

The fourth industrial revolution is marked by the fusion of the physical, digital, and biological spheres, profoundly transforming all sectors, including the economy and industry.

After experiencing three waves of development, humanity now enters the fourth wave—often referred to as the convergence of sciences. This integration encompasses disciplines such as biological sciences, cognitive sciences, nanotechnology, green technology, and digital technology, reflecting the understanding that addressing complex problems requires a multidisciplinary approach. Central to these convergent technologies is the enhancement and augmentation of human capabilities.

Advancements in human cognitive and physical capacities, combined with significant improvements in our ability to solve long-standing challenges, signal the dawn of a new era. The 1414 World Conference (Islamic calendar) emphasized the pivotal role of convergent technologies in elevating human performance and excellence. According to the conference's organizers, the impact of these technologies on societies like Iran's is expected to be even more profound than on Western societies.

As this fourth wave of civilization unfolds, we are confronted with a critical choice: whether to align with the trajectory of Western civilization in adopting these technologies or to chart a distinct, appropriate path for Iranian society—an immense challenge. The ultimate aim of this convergence is to maximize efficiency.

Looking ahead, technological innovations are poised to take on an almost miraculous character. Costs related to transportation and communication will decline, and global product supply chains will become increasingly efficient. These reductions in business costs will foster new markets and drive economic growth. However, as economists such as Erik Brynjolfsson and Andrew McAfee have noted, such transformative shifts may also exacerbate inequality, particularly in the labor market. Automation and machines replacing human labor risk widening the gap between capital and labor. Yet, these same technologies also have the potential to create new security and employment opportunities.

Objectives

1. To identify the effective factors through which technology impacts structural changes in life and, consequently, architecture as the context of human activities.
2. To identify major technological trends influencing the future of architecture.

Research Questions

1. How has technology, as an influential factor in the development of human civilization, caused fundamental changes in the structure of human life and, consequently, architecture?
2. What are the leading technologies for the coming years, and how can they change the way of life and the tangible and psychological environment of society?

Research Background

A review of prior research on architectural transformations in the context of technology during the industrial revolutions reveals that most studies have primarily focused on the first and second industrial revolutions, emphasizing mainly historical perspectives. Information related to the third industrial revolution and its impact on architecture is comparatively limited. Furthermore, there is no comprehensive study addressing the fourth industrial revolution in architecture; discussions in this area tend to concentrate on specific examples such as the Internet of Things or innovative materials. Below, some relevant sources related to this research topic are briefly introduced.

Faizabadi, in his study titled *"Technological Approach: The Necessity of Today's Iranian Architecture,"* discusses how, over the past century, cities worldwide—especially in developing societies—have experienced an influx of industrial and technological innovations in building materials and construction methods. However, many contemporary Iranian architects and urban planners, with a strong emphasis on cultural identity, have tended to overlook these technological and scientific advancements. This has led to a misconception that technology conflicts with culture and indigenous architecture, and that cultural identity is limited to replicating traditional architectural forms. According to Faizabadi, this approach not only failed to revive cultural identity but also caused the architectural community to inadequately address new needs and social relationships. The result has been buildings lacking both architectural and engineering soundness, and devoid of cultural expression. He argues that when technology is harmonized with cultural criteria, it can actually reinforce indigenous and national identity. (Faizabadi, 2009)

Parvizi and colleagues, in their study titled *"Examining the Quality of Technology's Entry into the History of Modern Architecture,"* highlight how, following the industrial revolution, technology emerged as a powerful and increasingly influential tool for architects and engineers, enabling them to bring their design ideas closer to realization. This progression eventually culminated in the rise of "high-tech" architecture, where technology itself became the core essence of architectural expression. However, the intrinsic opposition of technology to nature raised serious concerns among environmentalists and spurred the emergence of new architectural tendencies. The significance of

technology within architecture has fluctuated considerably since its introduction. By examining the nature and quality of these changes, the study aims to clarify technology's future role in architecture. To this end, the research investigates the evolution of technology in architectural practice by analyzing its diverse applications in building design. (Parvizi et al., 2015)

Kyakjuri and Bahrami, in their study titled *"Examining the Role of the Industrial Revolution in the Formation of Artistic Movements Influential in Modern Architecture,"* argue that architectural history reveals how social, economic, political, and other forces across different periods not only have roots in past events but also shape the future trajectory of architecture. The industrial revolution, often viewed as unrelated to architecture, is in fact a pivotal historical moment rooted in Renaissance humanism and the valorization of reason and intellect. Moreover, it initiated significant changes in construction methods, the adoption of new materials, and the integration of new technologies in buildings—key elements underpinning the modern architectural style. As a result, the philosophy of modernity found tangible expression in architecture, marking the beginning of a new era in the early 18th century. This research aims to elucidate the influential factors behind the emergence of modern architecture and to identify the artistic movements shaped by these factors, which in turn played a crucial role in advancing the modern style. (Kyakjuri and Bahrami, 2016)

Vajjanzadeh, in his study titled *"Application of Nanotechnology in Architecture,"* explores the extensive impact of nanotechnology on human life and its interplay with the environment and buildings. He advocates for the gradual replacement of traditional construction materials with nanomaterial-based alternatives, which could revolutionize the construction industry. Moreover, he suggests that architectural designs inspired by morphological principles and nanotechnology insights may offer solutions to the current trend of form-centered buildings. (Vajjanzadeh, 2014)

Ziari, in his study titled *"Socio-Cultural Transformations Resulting from the Industrial Revolution in the Spatial Development of Tehran,"* investigates the cultural, social, and economic changes during the 19th and 20th centuries driven by modernism, rapid urban expansion, and the rise of megacities and metropolitan areas. He focuses on the profound shifts in spatial and physical urban organization, aiming to analyze the socio-cultural effects of the industrial revolution (modernism) on Tehran's urban evolution. (Ziari, 2003)

Research Methodology

Given the research focus on the industrial revolutions and its intended objectives, this study is generally categorized as applied research. The data collection method employed is historical research. Utilizing a documentary-historical approach with a retrospective viewpoint, historical data regarding the four industrial revolutions and their impacts were gathered as verified facts. By compiling and presenting the chronological sequence of events during each revolution, the study was able to analyze phenomena and establish cause-and-effect relationships to assess the influence of these historical developments.

For data analysis, a qualitative descriptive approach was adopted, relying on documentary sources. Through detailed description, explanation, and clarification of the industrial revolutions, alongside examining their underlying causes and contexts, the study aimed to uncover the implicit meanings within these events. By situating the revolutions within social, technological, and economic frameworks, the data were interpreted to extract the key influential factors in each revolution period relevant to architecture.

Research Findings

Review of the Industrial Revolutions and Their Effects

First Industrial Revolution (1750 – 1850)

The discovery and substitution of human and animal power with alternatives like steam engines in the eighteenth century triggered a remarkable leap, bringing about profound transformations in agriculture, mining, manufacturing, transportation, and technology. These changes, in turn, significantly impacted economic, social, and cultural conditions. Within two centuries following the industrial revolution, the average annual per capita income across countries worldwide increased sixfold.

Table 1: Factors Causing the Industrial Revolution and Their Points of Impact (Author)

Number	Factor	Point of impact
1	Advancement in agriculture	Gradual accumulation of technical information

2	Water transportation (invention of the compass)	Expansion of waterborne trade
3	Invention of the printing press	Dispersion of information

The Industrial Revolution first took root in England due to a combination of factors accumulated over several centuries, including internal political reforms, the expansion of commercial colonization, growth of the naval fleet, the rise of the middle class, and advancements in military and administrative affairs. These developments created a favorable and well-coordinated environment in terms of land, labor, capital, management, and governance, which laid the foundation for industrial progress in the country. The revolution was most prominently reflected in three key sectors: textiles, coal mining, and iron smelting. Major transformations included the shift from manual labor to machine-based production, the invention of new chemical materials and iron production techniques, increased utilization of steam and water power, the manufacture of machine tools, and the rise of mechanized factories.

The onset of this revolution brought profound changes to every level of civilization across the globe. The expansion of heavy industries introduced new construction materials such as cast iron, steel, and glass—materials with which architects and engineers had little prior experience in designing or constructing buildings of such scale and complexity.

Simultaneously, the Industrial Revolution, coupled with the rise of capitalism, disrupted the traditional balance between economic and non-economic spheres. The market's influence extended into all areas of life, turning almost everything into a commodity. The prevailing belief in the supremacy of industry and financial success overshadowed other values. In this transformed urban landscape, economic, political, and social conditions also shifted dramatically: guilds gradually vanished, artisans and laborers faced increased job insecurity, and competitive markets for both labor and goods expanded significantly.

Social Impacts

Given the prevailing ideology of the era—which prioritized individualism and utilitarianism—and the strong endorsement of private property rights, the government largely pursued a policy of non-intervention. The transition from artisanal to factory-based production led to significantly longer working hours, with 12 to 14-hour workdays becoming typical in nineteenth-century urban centers. At the dawn of the Industrial Revolution, workers' wages were extremely low. To supplement family income, women often brought their children to work in unhealthy, cramped, and suffocating factory environments. For instance, in England around 1750, approximately 14% of factory laborers were children under the age of 14. This widespread child labor contributed to rising illiteracy rates, increased mental and psychological health problems, and a surge in juvenile crime. During the Industrial Revolution, each technological innovation led to new machines replacing groups of workers, resulting in widespread unemployment. The combination of job losses and rising prices caused by industrial changes deepened poverty and hardship for many people. As a result, numerous individuals were forced to beg or scavenge leftover food from restaurants in order to survive. This issue was especially acute in London.

Charles Dickens, the renowned English writer during the Industrial Revolution, highlighted the plight of children in England in his novel *Oliver Twist*. At the onset of the Industrial Revolution, England's demographic distribution was such that one-fifth of the population lived in cities while four-fifths lived in rural villages. By the mid-19th century, this balance shifted to an equal split between urban and rural populations. Today, approximately four-fifths of England's population resides in cities, with only one-fifth living in villages.

Table 2: Chronological Sequence of Events of the First Industrial Revolution (Author)

date	Events:
1709	British industrialist Abraham Darby developed a method to extract iron from iron ore using coal instead of wood.
1712	Thomas Newcomen, an Englishman, invented the first steam engine to pump water out of mines.
1764	James Hargreaves, an English carpenter and weaver, invented the spinning jenny machine for spinning cotton fabrics.
1769	James Watt, a Scottish engineer, invented an advanced steam engine capable of efficiently powering machines.
1779	The first iron bridge was constructed in Coalbrookdale, England.
1785	Edmund Cartwright introduced a power-driven weaving machine.
1793	Eli Whitney, an American, invented a device to separate cotton fibers

	from seeds and other waste materials.
1825	The first railway was opened in northern England, and two years later, the first railway in America became operational.
1839	The Canadian ship Royal William was the first steamship to cross the Atlantic Ocean powered by its own engine.
1856	James Nasmyth invented the steam hammer.
1857	The invention of the blast furnace by Henry Bessemer made mass production of steel possible.
1859	The elevator was invented.

Table 3: Impact of the First Industrial Revolution on Social Changes (Author)

Technological Revolution	Social changes
The First Industrial Revolution	Growth of cities and the emergence of a new working class. Decline of traditional social hierarchies and the rise of new social classes based on wealth and education. Development of new social movements such as the labor movement and the women's suffrage movement. Expansion of new ideas about democracy and social justice.

Impacts of the First Industrial Revolution on Architecture and Urban Planning

Factories during this era became fundamental urban units. Coal mining was highly active, and the extensive production of iron alongside the use of steam power stood out as key features of economic output in this period.

The primary components of the new urban complex were factories and railways, transforming cities into vast slums. Factories occupied the city center, dominating all aspects of urban life. Early factories were strategically located near water sources since large quantities of water were necessary for steam generation and cooling machinery. Simultaneously, rivers were the cheapest means for disposing of waste materials. There was no urban planning or legislation at that time to prevent factories from being established within residential areas or to control environmental pollution.

The nineteenth-century city was, in effect, a large slum. Neighborhoods were not yet distinct or separated. Modern municipal governments had not yet been established. Waste accumulated on the streets, with pigs serving as the only form of waste collection.

Pollution led to contagious diseases and illnesses caused by the lack of sunlight. Furthermore, air pollution from toxic gases emitted by factories resulted in cancer and other deadly diseases. Throughout the nineteenth century, urban dwellers had shorter life expectancies compared to rural populations, and cities sustained their numbers mainly through migration. Water scarcity was another significant problem. In 1809, when London's population reached one million, water was available only from underground sources in homes. Some districts had access to water only three days per week. Although iron pipes were manufactured as early as 1746, their widespread use did not begin until 1817. Essential urban services were lacking in the emerging industrial city. The era of industry and mass production neglected improving living conditions until the late nineteenth century. Toward the century's end, plumbing systems, toilets, gas lighting, public baths, water storage facilities for entire cities, and sewage systems were introduced.

Starting in 1870, public health concerns grew, medical knowledge advanced, and awareness of environmental pollution increased. Initially, demands for better urban environments came from the educated middle and upper classes, who were the first to relocate to suburban areas. Gradually, governmental bodies took on responsibilities such as waste management and water supply.

Thomas Southcliffe Ashton, author of *The Industrial Revolution*, highlights trade with foreign countries—which broadened people's perspectives—as the most crucial factor in England's Industrial Revolution. He also notes the intellectual influence of Francis Bacon and Newton on Italy's scientific atmosphere. The Industrial Revolution affected all sectors, including the military, medicine, and chemistry (Ashton, 2005).

Key outcomes of the Industrial Revolution in England include the construction of the first iron bridge in 1779, the establishment of the first railway network in 1825, and significant increases in agricultural and livestock production. The growth and proliferation of factories with tall, dense chimneys led to the

destruction of forests and green spaces, increased smoke and air pollution, and the accumulation of coal piles and waste heaps.
In light of these advances in production methods and the use of new materials, a new architectural structural form emerged during this period, with its most important characteristics summarized below (Qabadian, 2014: 25).

Table 4: Notable Buildings of the First Industrial Revolution (Author)

Notable Buildings	**Feature**
The Severn River Bridge	Abraham Darby Bridge (1779), one of the earliest examples of a bridge built with cast iron beams, has a span of 30 meters and a height of 15 meters.
The Wear River Bridge	Built in Sunderland, England (1793-1796) using cast iron beams, it had a span of 72 meters.
Clifton Suspension Bridge	Clifton Suspension Bridge (1836) in Bristol, England, was constructed with a span of 214 meters.
Metal Frame of the Spinning Factory	Metal frame was used as the building's structural system in Shrewsbury, England (1796-1797). In this building, the exterior walls were brick and load-bearing, while cast iron beams and columns were used for the internal structure.
The Grand Crystal Palace Building	(1851) This building was the first architectural work made entirely of modern materials—iron and glass—whose components were prefabricated in a factory and assembled on site, although the roof covering was constructed in a traditional style, using a semicircular arch.

Table 5: Impact of the First Industrial Revolution on Architecture (Author)

Technological Revolution	Architectural Changes
First Industrial Revolution	Use of new materials such as iron and steel. Development of new construction techniques like mass production and prefabrication. Emergence of new building types, including factories, warehouses, and rental housing. Development of new architectural styles, such as Victorian and Neoclassical architecture.

Second Industrial Revolution — Late 19th to Early 20th Century

During this period, scientific advancements by modern pioneers such as Niels Bohr, Thomas Alva Edison, Nikola Tesla, and Albert Einstein paved the way for the development of power plants and internal combustion engines. These breakthroughs led to inventions like the telephone, automobile, airplane, and many others, which profoundly transformed the world. In this era, the potential to enhance management by improving effectiveness, efficiency, and overall productivity was demonstrated. Concepts such as the division of labor—where workers specialized in specific tasks—and mass production through assembly lines became widespread practices, greatly boosting productivity.

Standardization and optimization were among the most significant achievements of this revolution, giving rise to mass production lines globally. The emergence of mass production was largely a response to rapid population growth and major events like the world wars.

Table 6: Chronological Sequence of Events of the Second Industrial Revolution (Author)

date	**event**
1876	Invention of the telephone.
1879	Thomas Edison invented electricity.
1885	Karl Benz invented the first gasoline-powered automobile.
1906	Air conditioning.

Table 7: Impact of the Second Industrial Revolution on Social Changes (Author)

Technological Revolution	Architectural Changes
Second Industrial Revolution	Emergence of new industries and professions. Expansion of education and literacy levels. Development of new forms of mass media and communication. Growth of urban population and decline of rural population. Emergence of new social movements, such as the civil rights movement and the feminist movement.

Impacts of the Second Industrial Revolution on Architecture and Urban Planning

No phenomenon in the history of urban planning has altered the fabric and form of cities as much as the automobile. The car changed the scale of cities and removed them from a human scale. Modernity brought key institutions and buildings into the city, including universities, ministries, railway stations, museums, city halls, courts, and parliaments (Qabadian, 2014: 25).

Suburban areas were developed between 1850 and 1920. The emergence of suburbs was closely tied to the growth of railways, and in later stages, gained momentum with the rise of subways and automobiles. By 1950, suburban living became common in Europe and the United States. Improvements in urban conditions coincided with the discovery of electricity, the telephone, radio, underground transit systems, and automobiles—all of which were heavily influenced by technological advances. Furthermore, by the end of the 19th century, most Western countries had enacted laws concerning public health, sanitation, and education.

The creation of highways and the rise in automobile use, along with the need to provide parking facilities, became distinguishing features of modern cities. Cars largely replaced trains. The shift of part of the transportation system underground, such as the metro, began in Europe in 1905. The development of highways also expanded during this period.

Key architectural and urban impacts included:

- Introduction of new materials such as steel, iron, concrete, and glass into a new phase.
- Larger, stronger, and more durable buildings.
- The tensile strength of iron made new design possibilities feasible, such as large train sheds at railway stations and exhibition halls.
- A reduction in construction time compared to previous periods.
- Expansion of human activities to all parts of the world.
- Increased population density.
- Effective adaptation to climatic factors.
- Changes in social structures and the emergence of new spatial needs for social interaction.

Table 8: Notable Buildings of the Second Industrial Revolution (Author)

Iconic Buildings	**Features**
Eiffel Tower	(1889) This all-steel tower, standing 330 meters tall, was the tallest structure built up to that time. It symbolized industry, new technology, and the promise of a flourishing modern era.
Machine Hall	(1889) Designed by Ferdinand Dutert, the building was constructed entirely from modern materials—glass and steel. The central span was covered with a 115-meter-long steel truss, which was an exceptional record in the building industry at that time.

Table 9: Impact of the Second Industrial Revolution on Architecture (Author)

Technological Revolution:	Architectural Changes
The Second Industrial Revolution	Development of new construction materials such as reinforced concrete and glass. Advancement of new building techniques, including skyscrapers and prefabricated homes. Emergence of new building types such as airports, highways, and

	shopping centers. Development of new architectural styles, including Art Deco and Modernism.

Many theorists argue that following the Industrial Revolution, technology (techne) began to take precedence over art, leading to a transformation in the role of the architect—from an artist to more of an engineer. This shift was largely driven by the impact of industrialization. During this period, the construction of buildings to accommodate workers became widespread, and there was also a notable increase in the development of public structures.

Third Industrial Revolution — The Digital Revolution – 1970s

The rise of digital technologies and the internet at the end of the 20th century marked the onset of the Digital Revolution. British sociologist David Harvey describes this revolution as a process of accelerating the compression of time and space, to the point where "distance" became virtually irrelevant. While the Second Industrial Revolution, with the invention of automobiles, brought time and distance closer together, the Third Industrial Revolution further collapsed them through the use of computers and the internet—ushering in an era of "real-time" experience. Beyond this spatial-temporal compression, the Third Industrial Revolution also transformed social interaction and communication patterns in modern society. Business practices evolved to transcend temporal limitations, allowing operations to continue around the clock. This period also highlighted a growing preference for machines over humans, as many traditional constraints vanished. Machines could consistently produce uniform, error-free goods in a matter of hours—an efficiency that human labor could not match.

Table 10: Chronological Sequence of Events of the Third Industrial Revolution (Author)

date	event
1950–1960	Armies, governments, and other organizations had acquired computer systems.
1960	The Whole Earth movement and the final construction of the World Wide Web.
1970	Invention of the transistor and the first personal computers.
1974–1979	More advanced digital computers.
1980	Public familiarity with computers in developed countries increased, with millions of home computers purchased.
1980	Having at least basic computer knowledge became essential for many jobs.
1989	15% of U.S. households owned a computer.
1982–1994	17 million Commodore 64 units were sold.
1992	The World Wide Web was made available to the public.
1996	The internet became a key tool for information, and most companies mentioned their websites in advertising.
1999	Nearly every country had internet access, and over half of Americans regularly used the internet.
2000	51% of U.S. households owned a computer.
2005	Internet users surpassed one billion, and by the end of the year, nearly three billion people used mobile phones.
2010	The number of internet users worldwide exceeded 2 billion.
2010	The great success of social networks, which mostly started in the 2000s (such as Facebook and Twitter).
2012	Facebook social network users surpassed one billion — cloud computing emerged.
2015	The number of people using tablets and mobile phones to access the internet surpassed those using personal computers.

Social Impacts

The digital revolution has led to numerous positive and negative impacts on society. On the positive side, it has fostered stronger connections, facilitated easier communication, and enabled the exposure of information that authoritarian regimes once easily concealed. Conversely, its negative consequences include the overwhelming volume of information and the burden it imposes, the rise of cyber predators,

the decline of the music industry's prominence, increased social withdrawal and lack of social interaction, and the saturation of media content on the internet.

Table 11: The Impact of the Third Industrial Revolution on Social Changes (Author)

Technological Revolution	**Social Changes**
Third Industrial Revolution	Emergence of the Information Age and knowledge-based economy. Growth of the service sector and decline of the manufacturing sector. Expansion of higher education and growth of the professional class. Development of new technologies such as the Internet and social media, transforming how we communicate and interact. Emergence of new social movements, such as the environmental movement and LGBTQ+ rights movement.

Impacts of the Third Industrial Revolution on Architecture and Urban Planning

The impacts of the Third Industrial Revolution on architecture and urban planning manifested in both software and structural aspects.

Advances in software systems significantly enhanced design capabilities, both conceptually and computationally, enabling the emergence of ideas involving highly transformative volumetric changes. Concepts such as cosmic leap and folding, facilitated by computer technology, allowed complex structures to be realized from an architect's vision. Indeed, computational power provided by these software tools enabled designers to create intricate and organic volumetric forms.

Simultaneously, shifts in social origins and structures prompted the creation of new spaces and physical forms tailored to emerging needs. Another important result of the Third Industrial Revolution was the adoption of digital systems to improve architectural planning and project management. The integration of computer systems into all facets of work and daily life introduced new responsibilities for designers. Enhancing the interaction between humans and existing systems led to novel approaches, including interactive, emotion-centered, and user experience-focused design.

Table 12: Impact of the Third Industrial Revolution on Architecture (Author)

Technological Revolution	Architectural Changes
Third Industrial Revolution	Development of new building materials, such as composites and nanomaterials. Advancement of new construction techniques, including 3D printing and robotics. Emergence of new types of buildings, such as sustainable buildings and smart cities. Development of new architectural styles, such as postmodernism and deconstruction.

The Fourth Industrial Revolution: Today

The most significant characteristics of the latest industrial revolution include the Internet of Things, big data, artificial intelligence, human-machine interfaces, robotics and sensor technologies, 3D printing, cyber-physical systems that integrate real and virtual technologies to enable autonomous machine communication independent of humans, blockchain, and other innovations.

In the Fourth Industrial Revolution, new operational patterns have emerged. The rapid introduction of disruptive technologies has posed a serious threat to established companies (the traditional players). This revolution is marked by the decline of large corporations, breathing new life into industrial transformation.

In today's landscape, a company's size no longer ensures its survival; instead, the ability to quickly adapt to change is crucial for success. It is not the big companies that dominate smaller ones, but rather the agile companies that outpace the slower competitors.

Table 13: Impact of the Fourth Industrial Revolution on Social Changes (Author)

Technological Revolution	Architectural Changes
The Fourth Industrial Revolution	Emergence of the gig economy and decline of traditional jobs. Increasing importance of lifelong learning and skill development. Growing gap between the rich and the poor. Rise of new social movements, such as the anti-work movement and the universal basic income movement.

Building Technologies in the Fourth Industrial Revolution

Building technology fundamentally refers to a collection of techniques focused on the use of technology within the construction industry and the potential to enhance project outcomes in this field. Key proven benefits of implementing modern technologies in construction include:

- Improving the productivity of the construction industry by 30 to 45 percent.
- Mechanization as a proven method to enhance costs, scheduling, quality, safety, and productivity.
- Electronic simulation: reduces costs and timelines, improves constructability, maintenance, operability, quality, and safety.
- Wireless and advanced technologies.

Table 14: Impact of the Fourth Industrial Revolution on Architecture (Author)

Technological Revolution	Architectural Changes
The Fourth Industrial Revolution	Advances in artificial intelligence, robotics, and biotechnology. More efficient and sustainable methods for constructing and operating buildings. Use of robotics to build structures with greater speed and precision. Application of biotechnology to develop new building materials that are stronger, lighter, and more sustainable.

Advanced New Building Technologies

1. **3D Printing**
   3D printing, also called additive manufacturing, involves creating a physical object by printing it layer by layer from a digital 3D image or pattern. Products made with 3D printers are easily customizable. In the future, 3D printers will become more widespread to the extent that they may include printing cells and body organs.
2. **Autonomous Vehicles**
   Driverless cars are headline news, but there are now many other autonomous vehicles, including trucks, drones, airplanes, and boats. With advancements in technologies like sensors and artificial intelligence, the capabilities of all these autonomous vehicles are rapidly improving.
3. **Advanced Robotics**
   Today, robots are used across many sectors and for a wide range of tasks—from precision agriculture to nursing. Rapid progress in robotics will soon make human-machine collaboration an everyday reality.
4. **New Materials**
   New materials are generally lighter, stronger, recyclable, and adaptable. Smart materials that can self-repair and self-clean, shape-memory metals that return to their original form, ceramics and crystals that convert pressure to energy, and others have now found various applications.
5. **Internet of Things (IoT)**
   One of the main connection points between physical and digital applications enabled by the Fourth Industrial Revolution. The digital revolution has created entirely new approaches that transform how individuals and institutions interact and collaborate.
6. **Biological Innovations**
   Innovations in biology, especially genetics, are astounding. Recent years have seen significant advances in reducing the cost and increasing the ease of genetic sequencing, and more recently, in gene activation or modification. Synthetic biology is considered the next step, allowing customization of organisms by rewriting DNA.

7. **Blockchain**
   A new technology in the digital world and a part of the transformation known as the Fourth Industrial Revolution. Blockchain technology can change the role or even eliminate many institutions and organizations. As an infrastructure technology, blockchain is used widely in financial and non-financial applications. By cleverly using cryptography and distributing oversight and management authorities over informational and computational resources and timestamping transactions, blockchain provides a set of security and operational benefits.
8. **Environmental Protection and Renewability**
   The convergence of the physical, digital, and biological worlds—the pillars of the Fourth Industrial Revolution—provides remarkable opportunities for the world to achieve great gains in resource use and efficiency. The World Economic Forum's "Mainstreaming Project 1" initiative has shown that not only is it hoped that individuals, organizations, and governments can have less destructive impacts on nature, but there is also significant potential to restore our natural environment through the use of technologies and intelligent system design.

Iran in the Era of Industrial Revolutions

Iran's engagement with new European countries, ideas, and technologies began in the mid-19th century, leading to profound economic, social, cultural, and spatial impacts.

One characteristic of European modernism was the uncritical and unquestioning adoption of theories, methods, techniques, and ideals derived from the experiences of advanced nations, which were embraced by intellectuals, politicians, journalists, and other thinkers. This form of semi-modernism—stemming from either European or Third World modernism—generated diverse viewpoints and reactions within Iran (Katouzian, 2004: 142).

The spread of semi-modernism in Iran involved significant contributions from the government, state institutions, and numerous journalists, writers, poets, playwrights, intellectuals, architects, urban planners, and scholars. Although many scholars mark Reza Khan's era as the start of semi-modernism or modernism's dominance, Iran's exposure to modernism actually began with the European travels of Naser al-Din Shah (and even Fath Ali Shah) and expanded further during Reza Shah's reign.

European modernists and their superficial imitators in Iran adopted a "holistic" approach to scientific matters and a "homogenizing" stance socially. Semi-modernism in Iran sought to produce superficial models that portrayed Iranian society as homogeneous with European societies.

In this context, modernism or semi-modernism primarily impacted urban society, leading to the establishment of industrial factories for domestic production, transformations in the urban fabric, the creation of new streets, and changes in building types and construction methods. Simultaneously, administrative institutions such as civil registration, municipalities, and police were established, alongside reforms in the military, education, and industries, driving rapid spatial development in urban areas.

Why have many countries that embarked on industrial planning alongside Iran surpassed its economy by such a wide margin? And is it possible for Iran to overcome this lag in parallel with the advancements of the Fourth Industrial Revolution?

The First Industrial Revolution

During this period, Iran was under the Qajar dynasty, primarily an agricultural country with minimal industrialization. However, European influence was growing through diplomatic and commercial relations, highlighting Iran's lack of modernization and creating a significant gap between Iran and the industrial Western countries (Abrahamian, 2008).

1. **Introduction of New Materials and Construction Techniques**

- **Brick and Iron:** The entry of industrial materials such as brick and iron replaced traditional mud-brick construction in Tehran. These materials led to stronger, more fire-resistant buildings. Structures such as the Masoudieh Palace (built in 1878) reflected these new construction techniques, including brickwork and metal elements that were innovative at the time.
- **Influence of European Styles:** The industrial revolution facilitated increased interaction between Iran and European countries, leading to the introduction of European architectural styles. This is

evident in buildings like Golestan Palace, where European influences blended with Iranian styles, introducing new aesthetic and structural elements (Habibi & Dehghan, 2012).

2. Urban Development and Infrastructure

Expansion of Tehran:

The technological advancements of the First Industrial Revolution also influenced urban planning in Tehran. The city began to expand, and new neighborhoods and public spaces were developed to accommodate the growing population. This period witnessed the construction of more organized streets and the introduction of public squares, marking a departure from the more organic urban layout of earlier times (Najafi, 2015).

Infrastructure Improvement:

Industrialization led to improvements in infrastructure, including roads, bridges, and better public services. The construction of Tehran's Darvazeh Dowlat (Government Gate) and other public utility works during this period reflected these changes, as they were built using modern construction methods of the First Industrial Revolution.

3. Architectural Innovation

Blending Traditional and Modern Elements:

Buildings in Tehran during this era often combined traditional Iranian architectural features with modern techniques introduced by the industrial revolution. For example, the Shams-ol-Emareh building, constructed in 1867, is a notable case that integrates traditional Iranian motifs with European-inspired innovations, such as multi-story structures and the decorative use of iron (Ashrafi, 2020).

The Second Industrial Revolution

This period coincided with Iran's Constitutional Revolution (1905–1911), which was driven by a desire for modernization and reform. Despite the growing awareness among Iranian elites of the need for technological and industrial progress, Iran's industrial development was stalled due to political instability and foreign intervention, resulting in underdevelopment (Milani, 2011).

1. Introduction of Steel and Concrete

Steel and Reinforced Concrete: The Second Industrial Revolution saw the widespread use of steel and reinforced concrete in construction, which influenced Tehran's architecture in the early 20th century. Buildings began incorporating these materials, enabling the construction of taller and more durable structures. The introduction of these materials led to a shift from traditional brick and stone buildings to more modern and resilient architectural forms. This period also marked the beginning of high-rise construction in Tehran, exemplified by buildings such as Bank Melli Iran, which featured steel frames and concrete structures.

2. Electricity and Urban Infrastructure

Electrification and Modern Facilities: The advent of electricity, a hallmark of the Second Industrial Revolution, significantly impacted Tehran's urban development. The introduction of electric lighting and modern facilities transformed the city's infrastructure, leading to the modernization of public spaces, streets, and residential areas. The development of Tehran's first electrical grid enabled the construction of buildings equipped with electric lighting, elevators, and other modern amenities, representing a departure from the more primitive and traditional urban fabric (Najafi, 2015).

Public Transportation: This period also saw the introduction of modern public transportation systems such as electric trams. These advancements reshaped the city's urban layout, encouraging the development of new neighborhoods and the expansion of city boundaries (Ashrafi, 2020).

3. Architectural Modernization

Fusion of Traditional and Modern Styles: Tehran's architecture during this era often combined traditional Iranian elements with modern and Western architectural styles. The influence of European architecture became more evident, with buildings featuring large glass windows, steel structures, and ornate façades. The Sepahsalar Mosque and School (built in 1890) is an example of this fusion, integrating traditional Iranian architectural styles with modern construction techniques introduced during the Second Industrial Revolution (Habibi & Dehghan, 2012).

Third Industrial Revolution

During the reign of Mohammad Reza Shah Pahlavi, Iran underwent the White Revolution (1963–1979), which included land reforms, infrastructure development, and industrialization efforts. Although these

initiatives modernized parts of the country, they also contributed to social unrest that culminated in the 1979 Iranian Revolution (Abrahamian, 2008).

1. Introduction of Modern Materials and Construction Techniques

Use of Glass, Steel, and Prefabricated Materials:

The Third Industrial Revolution introduced advanced building materials and techniques, including the widespread use of glass, steel, and prefabricated components. In Tehran, these materials enabled the construction of modernist buildings emphasizing simplicity, functionality, and transparency. Curtain walls, large glass façades, and minimalist designs became more common, reflecting global architectural trends of the time. A prime example of this architectural shift is the Tehran International Tower, completed in 1996, which remains one of the tallest buildings in Tehran and extensively uses glass and steel (Habibi & Dehghan, 2012).

2. Digital Technology Penetration

Computer-Aided Design and Construction: The emergence of computer-aided design (CAD) software during the Third Industrial Revolution revolutionized architectural practices in Tehran. Architects began using digital tools to design complex structures, allowing for greater precision and creativity. This technological advance also enabled the construction of more intricate and efficient buildings, highlighting the digital age's influence on architectural landscapes (Ashrafi, 2020).

Smart Buildings and Automation: The rise of digital technologies also led to the development of smart buildings in Tehran, where automation systems managed lighting, heating, and security. The integration of digital technologies into building management systems marked Tehran's adaptation to the technological advancements of the Third Industrial Revolution. A notable example is the Milad Tower, completed in 2007, which includes advanced communication and control systems, signaling Tehran's entry into the digital era (Najafi, 2015).

3. Urban Planning and Renovation

Tehran's Expansion and Modernization: The Third Industrial Revolution coincided with rapid urbanization and modernization in Tehran. The city expanded significantly, and new residential and commercial districts emerged to accommodate a growing population. Infrastructure improvements—such as the development of highways, metro systems, and airports—were heavily influenced by the technological advancements of the time. These transformations not only changed the city's architectural landscape but also altered its social and economic dynamics (Habibi & Dehghan, 2012).

Fourth Industrial Revolution

Despite facing sanctions, Iran has been striving to modernize its economy by strengthening its technology startup ecosystem—particularly in e-commerce, fintech, and software development. The establishment of science and technology parks reflects recognition of the importance of the Fourth Industrial Revolution. However, political and economic challenges continue to limit the full realization of these transformations (Golnaraghi, 2018).

1. Smart and Connected Buildings

Integration of IoT and Artificial Intelligence: A defining feature of the Fourth Industrial Revolution is the integration of the Internet of Things (IoT) and artificial intelligence (AI) in building design. In Tehran, this has led to the development of smart buildings that use sensors, automation, and AI to manage energy consumption, security, and climate control. Buildings such as the Arg Bazaar, a commercial complex in Tehran, utilize smart systems to increase energy efficiency and provide real-time data on building performance—reflecting the city's adaptation to the technological advances of the Fourth Industrial Revolution (Moradi & Hosseini, 2020).

2. Sustainable and Green Architecture

Focus on Sustainability: The emphasis on sustainability during the Fourth Industrial Revolution has led to the adoption of green building practices in Tehran. Architects are increasingly using renewable energy sources such as solar panels and wind turbines, as well as green roofs and sustainable materials. This shift toward environmentally conscious design is evident in projects like the Shamshak Eco-Lodge, which integrates sustainable design elements to minimize its environmental footprint (Ghobadian, 2018).

3. Advanced Construction Techniques

Use of 3D Printing and Modular Construction: The Fourth Industrial Revolution has also brought advances in construction techniques such as 3D printing and modular construction. These technologies are being used in Tehran to create more efficient and cost-effective buildings. For instance, the use of prefabricated modules in residential developments has reduced construction time and costs, while 3D printing is being explored for producing complex architectural components (Naderi & Zadeh, 2021).

4. Urban Regeneration and Smart Cities

Development of Smart City Initiatives: Tehran has also seen the implementation of smart city initiatives, using digital technologies to enhance infrastructure and urban services. The city's efforts to upgrade public transportation, waste management, and energy distribution through smart technologies reflect broader trends of the Fourth Industrial Revolution. Projects like the Tehran Smart City Initiative aim to create a more connected and efficient urban environment by leveraging data and technology (Tavakoli, 2019).

5. Architectural Innovation and Design

Innovative Building Designs: The Fourth Industrial Revolution has also fostered architectural innovation in Tehran, with designs focusing on flexibility, adaptability, and user-centered spaces. The use of parametric design tools has enabled architects to create buildings that dynamically respond to environmental conditions and user needs. The **Persian Gulf Complex**, with its innovative design and use of advanced materials, is a prominent example of these new technologies entering Tehran's architectural scene (Soleimani, 2020).

The Evolution of Tehran's Spatial Development (Case Study)

The first phase of Tehran's spatial development began with the decline of Rey's economic and political role and the transfer of that role to Tehran. At this point, Tehran was less significant than cities like Mashhad and Qazvin. The bazaar was thriving, and urban neighborhoods were forming around it. Shah Tahmasp, whose seat was in Qazvin, initiated the construction of towers, walls, a fortification, garden-city, mosques, bazaars, and the government house in Tehran for both religious (due to the shrine of his ancestor in Hazrat Abdul Azim) and political reasons. During this period, there was an outward-looking approach, with foreign visitors and envoys visiting Tehran. The driving forces of Tehran's spatial development in this phase were trade, geography, agricultural surplus, and strategic-military considerations**.**

The second phase occurred from the time Tehran was chosen as the capital until the reign of Reza Shah. Although Tehran's primary role during this phase was political, it also gained importance economically and commercially. During this era, Iran came under the influence of Western civilization and global capitalism. Government offices, embassies, courts, European-style neighborhoods, and political figures expanded.

The beginning of exogenous transformations due to capitalist invasion occurred during the reign of Naser al-Din Shah Qajar. However, due to the overarching influence of the political microstructure on the emergence, continuity, and expansion of cities, urban centralization has always existed in Iran (e.g., the growth of capital cities during different eras). There is a fundamental difference between the nature of centralization before and after exogenous development. When Agha Mohammad Khan declared Tehran the capital for political and military considerations, the city became a significant administrative, military, and political center, leading to commercial concentration and the formation of a consumer market. In this phase, the drive for profit and capitalist centralization spurred the foundation of nascent industries in Tehran.

The third phase of Tehran's spatial development began with Reza Shah's rule (1921 CE / 1300s SH)**.** From this point onward, urban elements gained more power within the country's political and economic system, and Tehran stood at the top of the political hierarchy. The idea of transformation and modernization, influenced by modernist thought, took hold—discarding the historical concept of the city in favor of its European meaning. In this theory, cities, under the influence of the industrial revolution, were redefined based on efficiency and productivity. These concepts, framed within modernism or pseudo-modernism, were promoted through foreign investment and its domestic agents.

In Tehran, various decisions, such as the creation of cross-shaped streets, were implemented to address issues related to the circulation of goods and capital. Corresponding laws such as the Municipality Law (1309 SH / 1930 CE) and the Street Expansion Law (1312 SH / 1933 CE**)** were enacted. By 1933, the area of Tehran reached 46 square kilometers (Abedin Dargosh, 2009: 45).

In that same year, following modernist theories and under the guidance of foreign advisors, a new plan for Tehran was developed. This plan included a grid pattern and rigid zoning**,** resulting in the placement of new functions in the historical core of the city and the construction of new buildings (e.g., Justice and Finance Ministries) over the ruins of older structures (e.g., the citadel). New administrative buildings such as the National Museum of Iran**,** Ministry of Foreign Affairs**,** Police Headquarters**,** Land Registry**,** Ministry of War, and the Post Office were also constructed.

In fact, the architectural styles of Tehran during Reza Shah's era can be summarized as follows:

1. **Glory and grandeur of Iran's past** (e.g., National Bank buildings, National Museum of Iran, Police Headquarters);
2. **German (Modernist) Style** (e.g., buildings for Finance, Justice, Railway, University of Tehran);
3. **Baroque Style** (e.g., Islamic Republic Street, Istanbul Crossroad, and Mojdaldowleh District).

Overall, three or four influential styles—nationalist, classical, and modern—shaped Tehran during this period.
The fourth phase of Tehran's spatial development began during Mohammad Reza Shah's era. Modernism (1941–1953), introduced by graduates of European schools, was employed as a new model of spatial development in residential neighborhoods such as Tehranpars, Nazi Abad, Yusef Abad, Narmak, and Manzariyeh. Simultaneously, with the First Seven-Year Development Plan (1948–1955), which relied on exogenous development, Tehran became the central hub of state and private sector activities. Following this plan, the Land Law of 1952 (1331 SH) accelerated the city's spatial expansion. Between 1941 and 1953, although the modernist model of transformation and renovation was applied in Tehran, the city never truly became a productive unit. Overall, interventions in Tehran between 1951 and 1953 were not motivated by a genuine desire for economic and social development but were rather the result of global influences and political intervention (Habibi, 2016: 160).

After 1953, Tehran expanded rapidly. With the political stabilization of the country, Tehran's position as the largest mother-city and the core of public and private investment was solidified. Between 1966 and 1976, Shahriar, Pishva, and Eshtehard joined Tehran's urban system.

From a theoretical standpoint, spatial developments during this period were influenced by Iran's full integration into the global economy, dominant capitalist growth models, structuralism, basic needs theory, and center-periphery models used in formulating and executing the five national development plans. Elements like modernism, transformation, and exogenous oil-based development were all in play. During this time, the new town developments around Tehran pushed the city's spatial expansion far beyond the limits of its original master plan.

The fifth phase can be identified with the establishment of the Islamic Republic in 1979 (1357 SH). In this period, not only did Tehran's spatial expansion not decrease, but it accelerated due to the failure of coordination and control policies between government organizations and institutions, the excessive distribution of land to the public—particularly in the first decade after the revolution—and decisions made by authorities, war-related migration (from the Iran-Iraq war), and the expansion of universities. Tehran expanded uncontrolled, and its area grew to over 1,000 square kilometers in just 21 years. The broader urban region came to include Tehran, Karaj, Varamin, Rey, Shemiranat, Savojbolagh, and Shahriar, covering about 13,000 square kilometers, which is less than one percent of Iran's total land area (Zanjani, 1989: 23).
In analyzing the decline in Tehran's population growth and urban concentration rate after the revolution, factors such as increased cost of living, especially housing, and the limited purchasing power of migrants, along with Tehran's excessive congestion, played a major role. As a result, migrants settled in urban and rural settlements on the periphery of Tehran's urban area, often using these places as dormitory towns while commuting to Tehran for work (with 21% of all national migrants settling in Tehran's metropolitan region).

From a spatial development perspective in this phase, Tehran remained dependent on the global economy, national oil surplus, and exogenous development. Theoretical and practical planning was heavily influenced by center-periphery models, and employment opportunities became even more concentrated in Tehran due to the modernist development model, capital flows, and information networks. Studies show a stepwise migration pattern, where rural populations move to small towns, then medium-sized cities, then regional metropolises, and finally to the megacity of Tehran. In contrast, innovation, manufactured goods, and advanced technical services flow in the opposite direction, down to the lowest local levels.
Tehran's problem as a dominant city is rooted in broader societal issues, national planning structures, decision-making systems, and the socio-economic framework, all influenced by the global system and transformations driven by industrial revolutions.

Discussion and Conclusion

The evolution of architecture throughout the Industrial Revolutions has been significantly influenced by technological advancements, with each revolution bringing transformative changes to both the built environment and the social fabric. This article explores the intricate relationship between architecture, technology, and social needs, focusing on how these elements have interacted and evolved from the First to the Fifth Industrial Revolution.

The world has witnessed three industrial revolutions in the past. The first occurred in 1784, when humanity succeeded in harnessing mechanical power and systematically distancing itself from reliance on animals. The development of the steam engine played a crucial role in this revolution. With the advent of mechanization, the First Industrial Revolution introduced mass production and the use of new materials such as iron and steel. Architectural design shifted from handcrafted, localized methods to standardized and modular approaches. The social impact was profound, as urbanization increased, creating a growing need for housing, factories, and affordable infrastructure to support the expanding industrial workforce. The Crystal Palace in London, with its innovative use of prefabricated materials and modular construction, stands as a testament to the technological and architectural advancements of this era.

The second revolution emerged in the late 19th and early 20th centuries with the advent of new forms of industrial product manufacturing. Driven by electricity, steel production, and advances in chemistry, the Second Industrial Revolution further transformed architecture. Skyscrapers became possible with the development of steel frames, and the concept of the modern city began to take shape. During this period, the focus on improving living conditions led to the development of better public health systems, transportation networks, and urban planning. The social needs of the time—such as safety, security, and access to basic services—were reflected in architectural responses, with buildings like the Home Insurance Building in Chicago symbolizing the technological and architectural achievements of the era.

Digital systems, modern communications, and the development of advanced computers heralded the Third Industrial Revolution, bringing us innovations such as smartphones and social media. The brilliance of this revolution coincided with the peak of information technology. The Digital Revolution, with the introduction of computers, automation, and new materials like plastic and composites, brought about significant changes in architecture. A growing awareness of environmental issues gave rise to a strong architectural focus on sustainability. Social needs during this period shifted toward sustainability, efficiency, and adaptability, leading to the development of green buildings and smart homes. The Centre Pompidou in Paris—with its advanced architecture and emphasis on flexibility and accessibility—is an example of architectural response to the social and technological changes of this era.

Each of the past industrial revolutions brought about fundamental transformations across all structures of human civilization, giving rise to new needs, values, and habits within societies. These shifts reshaped economic, political, social, and cultural relationships. Architecture, as the backdrop for all human interactions, also underwent significant changes in response to these developments—sometimes reflected in its outward forms, and other times through advancements in its operational frameworks.

From a broader perspective, it becomes clear that the countries that have achieved the best outcomes in this global competition are those that, in addition to aligning themselves with technological advancement and moving in step with global trends, have also placed importance on knowledge production rooted in historical and social foundations. These nations have progressed by carefully examining their past while planning strategically for the future, focusing on the development of their social, economic, and cultural structures.

Looking at the Fourth Industrial Revolution, it can be defined by a wide array of emerging technologies. The convergence of digital, biological, and physical technologies characterizes this revolution. Architecture in this era is marked by the integration of smart technologies, artificial intelligence, and the Internet of Things, resulting in intelligent buildings that can adapt to the needs of their occupants. The social implications of these technological advancements include increased personalization, enhanced connectivity, and a stronger focus on user experience. *The Edge* in Amsterdam—often referred to as the greenest building in the world—is a prime example of how technology can be fused with architecture to meet evolving social demands such as sustainability, energy efficiency, and occupant well-being.

The Fourth Industrial Revolution is grounded in the digital revolution, upon which new methods have been developed that allow technologies to penetrate societies, embed themselves, and even be implanted into the human body.

Advancements in robotics and automation, artificial intelligence, nanotechnology and biotechnology, quantum computing, the Internet of Things, 3D printing, autonomous vehicles, neural technologies and brain enhancers, gene editing, and existential design are among the key technologies fueling this revolution. These innovations will fundamentally transform the functioning of the modern economy and will have profound impacts on employment levels and job structures, the nature of work, business operational models, governments, nations, regions, cities, international security, society, individual identity, ethics, human communication, and the management of personal and collective information.

The effects of this transformation are already emerging as lightning bolts from the convergence of technologies. Therefore, the themes of the Fourth Industrial Revolution are not only reflected in future industries and technologies but will also leave both positive and negative effects on the nature of the

individual, the economy, and the business world.
Familiarity with the megatrends associated with this revolution, awareness of its beneficial and destructive impacts across various domains, and understanding the deep-rooted concerns it carries—such as the creation of social inequality, the fragmentation of individual and collective identity, and social isolation stemming from rapid technological growth—can help us prepare for the massive transformations that lie ahead. Ultimately, it is human insight and decision-making that will determine the success or failure of this revolution.

A brief examination of Western societies reveals that these changes have often been driven by internal economic, social, or cultural needs. Since these nations are also the birthplace of modern science and technology, their need to innovate in industries has led to the development of new methods.

The evolution of thought in these societies and the structured, sequential nature of their development demonstrates how social, economic, and cultural infrastructures have grown gradually and systematically. As a result, their architecture has responded to the needs of each industrial revolution with new expressions and forms. The ability to observe these changes over time emphasizes the continuity of development and how architectural transformation has remained responsive to societal demands.

Looking at Iran over the past century, it becomes evident that the country has lagged behind global changes and has primarily remained a consumer of technologies developed in the West. The absence of essential infrastructure to keep pace with technological, cultural, economic, and social growth has been the primary reason behind the fragmented nature of development in Iran. As a result, Iran has become a consumerist society.
This fundamental issue has caused Iranian architecture to experience tensions in social, technological, and economic dimensions. These tensions have resulted in a fragmented mindset, lacking coherence and centrality in its architectural framework.

The lack of continuity between components, the importation of ideas, and the failure to localize them have all contributed to the incoherence of the social structure and urban development—each trend pulling society in disparate directions, which is a key factor behind the disconnection of Iran's architectural system.

With the emergence of the Fourth Industrial Revolution, which promises to transform all aspects of life, it is imperative for Iran to align itself swiftly with this global framework to retain relevance in the international arena.

All of this requires strategic planning to build robust and structured systems for global engagement. In this context, understanding the key parameters of the Fourth Industrial Revolution is crucial, especially for designers and architects, as they are responsible for designing the platforms for human interaction. This understanding can equip the country to face the wave of upcoming changes with confidence.

Based on the studies conducted, and to provide a clearer understanding of industrialization and its impacts on technology, society, economy, architecture, and urban planning—all of which are interconnected components of a coherent structure—the author presents the following summary table:

Table 15: Categorization of Factors Affected by Industrial Revolutions (Author's compilation)

	Factors of Technology and Innovation	**Social Factors**	**Economic Factors**	**Architecture and Urban Planning**
First Industrial Revolution	Use of machine power instead of human labor Widespread production of iron Utilization of	Job insecurity for artisans and working-class due to the emergence of machinery Support for	Accumulation of financial reserves, leading to the growth of capitalism Expansion of	Factories during this period became one of the key urban units. Crowding of poor

	steam power Daily inventions New construction materials	private ownership Government policy of non-intervention Increase in working hours Environmental pollution Accumulation of pollution and contagious diseases Massive migration from villages to cities Urban residents have shorter lifespans than rural inhabitants Poverty and hardship in large cities	commodity sales The dominant ideology of the time is individualism and utilitarianism Increase in prices due to industrial changes and transformations	residential units around factories. Basic urban services were absent. Construction of the first iron bridges. Establishment of the first railway network and expansion of cities.
Second Industrial Revolution	Development of sciences Power plants Internal combustion engines Telephones Automobiles Airplanes Mass production Standardization Optimization New materials such as steel, iron, concrete, and glass entered a new phase	Attention to hygiene – advances in medical science Awareness of environmental pollution Social pressures to improve the urban environment Emergence of the educated middle and upper classes Repetitive work Population growth Laws for sanitation, health, and public education Social problems caused by the World Wars Emergence of labor movements following large-scale human gatherings	Economic problems caused by the world wars. High production capacity and reduction of mass production costs. Economic challenges faced by workers due to the rapid mechanization of systems.	Suburban living. The automobile changed the scale of cities, making them larger than the human scale. Construction of high-rise buildings. The emergence of highways and the increased use of automobiles. Larger, stronger, and more durable buildings. Changes in social structures and new needs for spaces to facilitate social interactions.
Third Industrial Revolution	Emergence of digital technologies and the Internet	Reduced distances thanks to digital systems.	Changes in business models Economic	New software tools assist architects by enabling

	Invention of the transistor Digital computers The World Wide Web made available to the public Augmented Reality (AR) Virtual Reality (VR)	Changes in social patterns, relationships, and communications. Widespread use of the internet and social networks. Larger and stronger connections. Easier communication. Possibility of exposing information. Social isolation. Media saturation.	models based on digital infrastructures Digital currency Changes in marketing structures	structural calculations and the creation of dynamic, parametric volumes, expanding architects' design capabilities. Systematic planning and control are enhanced through computer-based structures. New interactive spaces emerge thanks to advanced communication frameworks. The rise of cyber systems supports the monitoring and control of architectural structures. Approaches such as interactive, emotion-centered, and experience-oriented design arise through human interaction with digital spaces.
Fourth Industrial Revolution	Internet of Things (IoT) Big Data Artificial Intelligence (AI) Human-Machine Interfaces Robotics and Sensor Technology	Emergence of the gig economy and decline of traditional jobs. Increasing importance of lifelong learning and skill development. Growing gap between the rich and the poor.	Globalization and market disruption (continuous innovation to stay competitive). Enhancement of automation and productivity through	Smart, self-regulating, and self-healing structures Establishing higher-level communication between systems and humans Rapid access to reference data

	3D Printing Technology Cyber-Physical Systems Blockchain Autonomous Vehicles New Materials Biological Innovations Environmental Protection and Sustainability	Emergence of new social movements, such as the anti-work movement and universal basic income movement. Changes in workforce dynamics. Digital connectivity and social interaction. Access to information and education. Changes in consumer behavior (emphasis on convenience, personalization, instant gratification, etc.).	artificial intelligence and increased economic efficiency. Concerns over job displacement. The need for new economic models. Growing economic inequality due to faster advancement of individuals with higher technological awareness.	and software Robotic systems integrated throughout all phases (from design to execution) Ability to construct highly complex forms using agile systems Smart and nanomaterials Utilization of biological pattern structures Structures aligned with natural systems Mechanization as a proven method to improve cost, planning, quality, safety, and productivity

Policy Recommendations

An examination of architectural transformations in Tehran across the First to the Fourth Industrial Revolutions reveals critical intersections between technological advancements and evolving social needs. Moving forward, the following policy recommendations aim to guide the architectural and urban development of Tehran, ensuring alignment with technological progress and the city's socio-cultural context.

Promoting Technological Innovation in Urban Planning:

Establish a comprehensive policy framework that encourages the integration of advanced technologies into urban planning and architecture. The rapid evolution of technology necessitates that Tehran's urban development aligns with global trends, particularly in smart cities, sustainable design, and digital infrastructure.

As an actionable strategy, facilitate collaboration among government agencies, technology companies, and educational institutions to strengthen innovation. Provide incentives such as grants or tax exemptions for projects utilizing advanced technologies in architecture and urban design.

Sustainability as a Fundamental Principle:

Integrate sustainability at the core of Tehran's architectural policies, emphasizing energy efficiency, waste reduction, and the use of environmentally friendly materials as an effective approach. The global shift toward sustainability, driven by the Fourth Industrial Revolution, requires Tehran to utilize green technologies and methods to reduce environmental impacts and address the growing social demand for sustainable living environments.

Practical measures include introducing green building standards and certifications, enforcing regulations that limit carbon emissions from construction projects, and promoting the use of renewable energy sources in new and existing structures.

Cultural Preservation and Renovation:

Develop policies that balance preserving Tehran's architectural heritage with the need for modernization. As Tehran undergoes technological and architectural transformations, safeguarding its historical and cultural identity is vital to ensure that renovation efforts do not erase the city's rich

architectural legacy.
Implementation strategies include establishing protective zoning laws for historic areas, allocating funding for the restoration of culturally significant buildings, and encouraging projects that combine modern technologies with traditional architectural styles.

Inclusive and Equitable Urban Development:

Ensure that technological and architectural advancements benefit all residents of Tehran, focusing on reducing social inequality and promoting inclusive urban growth. Technological progress should not exacerbate social disparities but rather be used to create fairer urban spaces where all inhabitants can access modern infrastructure benefits.
Practical policies may include prioritizing affordable housing, strengthening public transportation, and ensuring all city areas have access to digital infrastructure and smart urban facilities.

Adaptation to Future Technological Changes:

Develop flexible urban policies capable of responding to future technological changes and their implications for architecture and social needs. The rapid pace of technological advancement, especially with the approach of the Fifth Industrial Revolution, demands that Tehran's urban planning and architecture policies be resilient, forward-looking, and adaptable to new challenges and opportunities.
Suggested measures include creating a dedicated task force to monitor emerging technologies and assess their potential impact on urban development, as well as promoting the design of flexible building structures that can easily be modified to accommodate future technological innovations.

Public Participation in Urban Development:

Increase public involvement in the planning and execution of new architectural projects to meet the social needs of Tehran's residents. Community participation in decision-making leads to urban developments that better align with the real needs and desires of the people, enhances a sense of ownership, and improves overall quality of life.
Implementation methods could involve regular public consultations, surveys, and workshops to gather resident input. Ensuring that major urban projects include public participation components and incorporate feedback into final designs can significantly enhance the effectiveness of these projects.

This proposed policy aims to guide Tehran's urban and architectural development in a way that balances technological innovation with the social and cultural needs of the city's inhabitants. By focusing on sustainability, cultural preservation, inclusivity, adaptability, and public participation, Tehran can successfully navigate the challenges of modernization while preserving its unique identity and enhancing the quality of life for its residents.

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Footnotes

Technologie
[1] Industrial revolution
[1]Architect
[1]Social factors
[1]Erik Brynjolfsson
[1] Andrew Mcafee
[1] High-tech
[1] Nanotechnology
[1] The first industrial revolution
[1] Charles John Huffam Dickens
[1] Abraham Darbi
[1] Thomas Newcomen
[1]James Hargreaves
[1] James Watt
[1] Cartwright, Edmund
[1] Eli Whitney
[1]James Nasmyth
[1]Henry Bessemer
[1]Ashton, Thomas Southcliffe
[1]Francis Bacon
[1] Isaac Newton
[11]The second industrial revolution
[1]Niels Bohr
[1]Isaac Newton
[1] Nikola Tesla
[1] Albert Einstein
[1]Karl Benz
[1] Ferdinand Duterte
[1] The third industrial revolution

[1] David Harvey
[1] The Architecture of the Jumping Universe
[1]Folding architecture
[1] Interaction Design
[1] Emotional Design
[1] The fourth industrial revolution
[1]3D printer
[1]Automatic vehicles
[1]Robotics
[1] Smart Materials
[1] Internet of things
[1]Biological innovations
[1]block chain