Merve Pekdemir Başeğmez

Ph.D. Thesis

AGU 2024

ARCHITECTURE FOR MACHINES; PRODUCTION SPACES IN TRANSITION

A THESIS
SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
AND THE GRADUATE SCHOOL OF ENGINEERING AND SCIENCE OF
ABDULLAH GUL UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

By
Merve Pekdemir Başeğmez
January 2024

ARCHITECTURE FOR MACHINES; PRODUCTION SPACES IN TRANSITION

A THESIS
SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
AND THE GRADUATE SCHOOL OF ENGINEERING AND SCIENCE OF
ABDULLAH GUL UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

By
Merve Pekdemir Başeğmez
January 2024

SCIENTIFIC ETHICS COMPLIANCE

I hereby declare that all information in this document has been obtained in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

Merve Pekdemir Başeğmez

REGULATORY COMPLIANCE

Ph.D. thesis titled Architecture for Machines; Production Spaces in Transition has been prepared in accordance with the Thesis Writing Guidelines of the Abdullah Gül University, Graduate School of Engineering & Science.

Prepared By	Advisor
Merve Pekdemir Başeğmez	Prof. Burak Asiliskender

Head of the Architecture Program

Assist. Prof. Buket Metin

ACCEPTANCE AND APPROVAL

Ph.D. thesis titled Architecture for Machines; Production Spaces in Transition and prepared by Merve Pekdemir Başeğmez has been accepted by the jury in the Architecture Graduate Program at Abdullah Gül University, Graduate School of Engineering & Science.

17 / 01 / 2024

JURY:

Advisor : Prof. Burak ASİLİSKENDER……………………….………….

Member : Assoc. Prof. Ahmet Erdem TOZOĞLU……………..………….

Member : Assist. Prof. Sema SERİM………..…………………………….

Member : Assist. Prof. Sinan AKYÜZ …………………………………….

Member : Assist. Prof. Can BOYACIOĞLU……………………………….

APPROVAL:

The acceptance of this Ph.D. thesis has been approved by the decision of the Abdullah Gül University, Graduate School of Engineering & Science, Executive Board dated ….. /….. / ……….. and numbered ………….……. .

……….. /……….. / ………..

(Date)

Graduate School Dean
Prof. İrfan ALAN

ABSTRACT

ARCHITECTURE FOR MACHINES; PRODUCTION SPACES IN TRANSITION

Merve PEKDEMİR BAŞEĞMEZ
Ph.D. in Architecture
Advisor: Prof. Burak ASİLİSKENDER
January 2024

The industry has experienced a new revolution. In this revolution defined as Industry 4.0, smart systems have started to be used in production. Thanks to smart production technologies, a new method has been created in which production can continue non-stop, and workers can monitor the entire process remotely with the help of smart robots and machines. Production spaces designed following this technology are defined as smart factories. While machine spaces where unmanned production methods are applied are being designed in the revolution, on the other hand, humans and production are trying to come together again.

This study first investigates how human and machine cooperation changes space. The technologies that have caused revolutions in production since the first invention of the revolution, the steam engine, and the factories transformed by these technologies have been examined. Then, the first smart factories and production spaces in which smart production was carried out in the last revolution of the industry were analysed. With the help of references from the past of production in the context of human, space, and city, the present and future are discussed, and new concepts and codes are produced. Finally, "*Plug-in production*" proposal is developed for the factory architecture and production environment.

Keywords: Factory, Production Space, Industry 4.0, Production and Architecture, Plug-in Production

ÖZET

MAKİNALAR İÇİN MİMARLIK; DEĞİŞİM İÇİNDEKİ ÜRETİM MEKÂNLARI

Merve PEKDEMİR BAŞEĞMEZ
Mimarlık Anabilim Dalı Doktora
Tez Danışmanı: Prof. Dr. Burak ASİLİSKENDER
Ocak 2024

Endüstri yeni devrimini yaşamaktadır. Endüstri 4.0 olarak tanımlanan bu devrimde üretiminde akıllı sistemler kullanılmaya başlanmıştır. Akıllı üretim teknolojileri sayesinde, üretimin durmadan devam edebildiği ve çalışanların akıllı robotlar ve makinalar yardımıyla tüm süreci uzaktan takip edebildiği bir model inşa edilmektedir. Bu teknolojiye uygun olarak tasarlanacak üretim mekânları da akıllı fabrikalar olarak tanımlanmaktadır. Devrimde insansız üretim yöntemlerinin uygulandığı makine mekânları tasarlanırken, diğer taraftan insanla üretim yeniden bir araya gelme çabasındadır.

Bu çalışmada ilk olarak insan ve makine işbirliğinin mekânda neleri nasıl değiştirdiği araştırılmıştır. Devrimin ilk icadı buhar makinasından bu yana üretimde devrimlere sebep olan teknolojiler ve bu teknolojilerle dönüşen üretim yapıları incelenmiştir. Daha sonra endüstrinin son devrimindeki ilk akıllı fabrikalar ve akıllı üretim yapılan üretim mekânları analiz edilmiştir. İnsan, mekân ve kent bağlamında üretimin geçmişinden alınan referanslar yardımıyla bugünü ve geleceği tartışılmış, yeni kavramlar ve kodlar üretilmiştir. Son olarak fabrika mimarlığı ve üretim çevresi için "*Plug-in üretim*" önerisi geliştirilmiştir.

Anahtar kelimeler: Fabrika, Üretim Mekanı, Endüstri 4.0, Üretim ve Mimarlık, Plug-in Üretim

Acknowledgements

First, I would like to express my sincere gratitude to my thesis advisor, Prof. Burak Asiliskender, for his great support and for believing in me throughout my Ph.D journey. His experiences, methods, and enjoyable thesis discussions shed light on my path, and his positive and exciting approach has been one of my greatest motivations.

Since the first day I started my undergraduate education, architecture has been a power for me to understand myself and my environment. I am very grateful to Assist. Prof. Sema Serim for making me believe in this power. I always feel lucky to be her student.

I would like to thank Assoc. Prof. Ahmet Erdem Tozoğlu for his inspirational ideas, constructive criticism, and, most importantly, his endless support throughout my thesis meetings. As a researcher, his academic discipline, rigor, and patience have always been an example to me.

I would like to thank the members of the thesis defence committee Assist. Prof. Sinan Akyüz and Assist. Prof. Can Boyacıoğlu for their comments and contributions. I would also like to thank the architects and my friends for helping me in this adventure.

This thesis was supported by '*TÜBİTAK 2211- Yurtiçi Doktora Programı'*. I would like to thank TÜBİTAK for their financial and moral support during this process. In addition, the thesis was supported by '*YÖK 100/2000 Doktora Programı'*.

I must express my gratitude to my family for their help. My dear brother, my beloved mother, who always loves me endlessly always, my soulmate, with whom I enjoy talking about and visiting factories together… I couldn't have done it without them. I am so grateful to my lovely daughter İdil, because I have learned so much from her!

Finally, my dear father, who worked in a factory all his working life, I undoubtedly learned how to labour and produce from him. He is the real inspiration for this thesis.

TABLE OF CONTENTS

1. INTRODUCTION 1

1.1 RESEARCH SCOPE AND LITERATURE REVIEW 2

1.2 RESEARCH METHODOLOGY 6

2. REVOLUTION: DESIGN OF PRODUCTION 9

2.1 FIRST INDUSTRIAL REVOLUTION: INNOVATOR FACTORY 12

2.2 SECOND INDUSTRIAL REVOLUTION: PIONEER FACTORY 20

2.3 THIRD INDUSTRIAL REVOLUTION: ICON FACTORY 30

2.4 RE-CODING PRODUCTION SPACE 38

3. DIGITALISATION: FUTURE OF PRODUCTION 41

3.1 PRODUCTION WITHOUT HUMAN 43

3.2 FORTH INDUSTRIAL REVOLUTION:SMART FACTORY 47

3.3 DE-CODING SMART PRODUCTION SPACE 53

4. TRANSITION: CONSUMPTION OF PRODUCTION 56

4.1 HUMAN FROM LABORER TO PROSUMER 58

4.2 SPACE FOR HUMAN AND MACHINE 65

4.3 CITY AS PRODUCED AND CONSUMED 75

4.4 DE-CODING PROSUMER SPACE 90

5. PROPOSITION: PLUG-IN PRODUCTION 93

5.1 RE-VISITING OF PLUG-IN CONCEPT 94

5.2 PRODUCTION IN TRANSITION 98

5.2.1 Plug-In Labour 100

5.2.2 Plug-In Factory 104

5.2.3 Plug-In Production Network 108

5.3 PROPOSING PLUG-IN PRODUCTION SPACE 112

6. CONCLUSIONS AND FUTURE PROSPECTS... 119

6.1 CONCLUSION 119

6.2 SOCIETAL IMPACT AND CONTRIBUTION TO GLOBAL SUSTAINABILITY 122

6.3 FUTURE PROSPECTS 124

REFERENCES….. 125

LIST OF FIGURES

Figure 2.1.1 New Harmony 14

Figure 2.1.2 Phalanstère.. 15

Figure 2.1.3 Saltaire Factory and Company Town.. 16

Figure 2.1.4 Cadbury Factory and Company Town 17

Figure 2.1.5 Pullman Factory and Company Town.. 18

Figure 2.1.6 Roebling Factory and Village.. 19

Figure 2.1.7 Hershey Factory and Company Town.. 20

Figure 2.2.1 Garden City 21

Figure 2.2.2 Une Cité industrielle.. 22

Figure 2.2.3 Broadacre City.. 23

Figure 2.2.4 Albert Khan's factory organization.. 24

Figure 2.2.5 Ford Motor Company.. 25

Figure 2.2.6 AEG Turbine Factory.. 26

Figure 2.2.7 Hat Factory.. 27

Figure 2.2.8 Fagus Factory 28

Figure 2.2.9 Fiat Lingotto Factory.. 29

Figure 2.2.10 Van Nelle Factory 29

Figure 2.2.11 Usine Claude & Duval Factory 30

Figure 2.3.1 Industrial architecture map.. 32

Figure 2.3.2 Vitra Campus.. 33

Figure 2.3.3 Frank Gehry Vitra Factory 34

Figure 2.3.4 SANAA Vitra Factory.. 35

Figure 2.3.5 L'Oreal Factory.. 36

Figure 2.3.6 Funder Werk Factory 37
Figure 2.3.7 Transparent Factory 37
Figure 3.1.1 Amazon Fullfillment Centre 44
Figure 3.1.2 Facebook Prineville Data Centre 45
Figure 3.1.3 Bitcoin Mine 45
Figure 3.2.1 Wittenstein Innovation Factory 48
Figure 3.2.2 Arena36 49
Figure 3.2.3 Trumpf Smart Factory 50
Figure 3.2.4 The Plus Factory 51
Figure 3.2.5 Future Stitch Smart Factory 52
Figure 3.2.6 Zhejiang Factory 53
Figure 4.1.1 Human and production 61
Figure 4.1.2 The future of work 64
Figure 4.1.3 Human in revolutions 65
Figure 4.2.1 Hallmark of the American manufacturing system 66
Figure 4.2.2 Human in production 68
Figure 4.2.3 Work organization scenario 69
Figure 4.2.4 Trumpf Smart Factory Digital Workspaces 70
Figure 4.2.5 Experience Factory 71
Figure 4.2.6 Looop, the Machine in a Shopping 72
Figure 4.2.7 Ankara and Kayseri Model Factories 73
Figure 4.2.8 Strathcona Village 73
Figure 4.2.9 Xiaomi Smart (Dark) Factory 74
Figure 4.2.10 Production models in revolutions 75
Figure 4.3.1 Science Technology Engineering Arts and Mathematics Centre 78

Figure 4.3.2 New Lab 79
Figure 4.3.3 Vertical Urban Factory 80
Figure 4.3.4 Hybrid Factory 81
Figure 4.3.5 2007 Skyscraper Competition 81
Figure 4.3.6 2007 Skyscraper Competition Proposal 82
Figure 4.3.7 BioCity, Local Digital Production 83
Figure 4.3.8 Industrial Urbanism 84
Figure 4.3.9 Integrated City 85
Figure 4.3.10 Prototypes of industrial spaces 86
Figure 4.3.11 BMW FIZ Future 87
Figure 4.3.12 Toyota Woven City 88
Figure 4.3.13 Future Science and Technology City 88
Figure 4.3.14 Oxagon 89
Figure 4.3.15 City in revolutions 90
Figure 5.1.1 Plug-in City, Archigram 95
Figure 5.1.2 Plug-in City, Computer City 95
Figure 5.1.3 The Cloud 96
Figure 5.1.4 Plug-in City, Alain Bublex 97
Figure 5.2.1.1 Wearable computers 101
Figure 5.2.1.2 Human and Plug-in Human 103
Figure 5.2.2.1 The White Collar Factory 105
Figure 5.2.2.2 Factory and Plug-in Factory 107
Figure 5.2.3.1 New City 110
Figure 5.2.3.2 Plug-in Production Network 111
Figure 5.3.2 Production Networks 117

Figure 6.2.1 United Nations Sustainability Development Goals 123

LIST OF TABLES

Table 1.1.1 Research questions, objectives, and assumptions 3

Table 1.2.1 Overview of the scope and research methodology 6

Table 2.1 Industrial revolutions and key words 11

Table 2.4.1 Industrial revolutions and morphological coding.. 39

Table 3.4.1 Industrial revolutions and morphological coding.. 54

Table 4.4.1 Actors, spaces and cities of revolutions... 92

Table 5.2.1 Production and Plug-in Production.. 101

Table 5.3.1 Factories in Plug-in Production 113

Table 6.1.1 Evaluations 121

LIST OF ABBREVIATIONS

ACATECH	German Academy of Science and Engineering
AEG	Allgemeine Elektricitäts-Gesellschaft
AGU	Abdullah Gül University
AM	Advanced Manufacturing
BMW FIZ	Bayerische Motoren Werke Forschungs und Innovationszentrum
CNC	Computer Numerical Control
FANUC	Factory Automation Numerical Control
IIoT	Industrial Internet of Things
IoT	Internet of Things
RI	Re-industrialisation
SANAA	Sejima and Nishizawa and Associates

To my daddy, 2024

Chapter 1

Introduction

Today, the fourth great technological revolution is taking place. The technologies of the new revolution, defined as Industry 4.0, are smart systems. Production spaces designed according to these smart production methods are also defined as smart factories. These factories describe a system in which machines can both produce and manage production processes, and employees can remotely monitor all production stages. Architecture, which prioritises people, is now rethinking the space for machines with this revolution.

The factory is a spatial consequence of the Industrial Revolution. Factories have been buildings that ensured the continuity of production in a specific order on specific days and hours and where raw materials were transformed into products. Many machines of different types and sizes and their operating principles, the type of energy required for the operation of the machines, the stages until the raw material becomes usable, and the needs of the employees determine the architectural design criteria of the factories. Now, the factory is renewing its relationship with one of the design criteria affecting its architecture: machines.

In this study, an updated background for the evolution of machine spaces has been created, and a proposal for future production spaces has been presented. The changing forms of the machine, the stages of flexibility in production, the reproduction of the workforce, and the adventure of the factories that house the machines are discussed. This adventure has been examined in the context of human, space, and city, and as a result, a projection has been prepared for the production spaces and environment of the future. The relationship between the evolution of the machine and space has been sought, and the possibilities of the new in the changing world of production have been discussed.

1.1 Research Scope and Literature Review

This thesis focuses on the future of production spaces. First, it deals with technology and space relations in production. Therefore, the first research question is: *What are spatial needs in mass production / digital production / smart production processes?* (Table 1.1.1) It is thought that understanding the transition of production spaces according to the industrial revolutions will be a background for the future.

The industry has experienced four technological revolutions for two centuries. The invention of the steam engine and its use in production was the beginning of the machine age and Industry 1.0. Industry 2.0 coincides with the use of electricity in production and mass production methods. The third great revolution, Industry 3.0, began with the invention of the computer and the use of automation systems in factories. Industry 4.0, as a result of all these technologies, has started a process in which production is completely digitalised.

Developments in technology undoubtedly bring new problems, research, consequently, solutions in production. In this case, the new question is: *How will new production methods affect human, space, and the city?* (Table 1.1.1) Each development also witnesses the transformation of labour, producers, consumers, factories, and cities. In this context, the thesis investigates how the machine or the stages of mechanization affect working life. The cooperation of humans with the machine ultimately gives an idea about how they uses the production space and its environment.

The digital revolution in production brings a transformation in and around production spaces. In addition to studies on the future of new production methods and human and robot or *cobot* cooperation, the place and environment of this new order are also of critical importance. In this transition, where Industry 4.0 and its technologies are introduced and experienced, a new workplace is sought for humans as producers, consumers, and her/his new colleagues, the cobots. In simpler terms, the question is: What will the production space and environment be like in the future? (Table 1.1.1) In this direction, this thesis questions the new production space from the architectural terminology. Production spaces of digital transformation, unmanned production areas defined as smart factories, and spaces designed for machines are priority research areas.

Table 1.1.1 Research questions, objectives, and assumptions

research questions	objectives	assumptions
What are spatial needs in mass production / digital production /smart production processes?	Understanding the transition of production spaces with the revolutions in the industry and exploring the smart production spaces.	Production spaces are basically designed according to production type and process. However, the biggest breaks in the transition of factories were the innovations brought about by technological revolutions, which affected both production areas and cities.
How will new production methods affect human, space and city?	Re-thinking the relation between production method, labour, space and city.	Changes in production technologies and methods have led to an increase in the use of machines in factories over time. The production organization between machine and human changed first the factories and then the cities where these factories were located.
What will the production space and environment be like in the future?	Projecting industry architecture of future and understanding smart production space.	This revolution in the industry, as in others, will cause some changes in both the production spaces and the environment.

Technological revolutions of industry do not always have such clear boundaries in the literature. Firstly, Alvin Toffler listed this historical process in the industry as the first, second, and third wave (Toffler, 1981). The first wave covers a long period in which Vitruvius's machines were used, and this period, also known as the agricultural revolution, revealed a new way of life in small settlements. When cranes, lifters, and presses turned into electromechanical machines, the second wave, the Industrial Revolution, began. Faster and more sensitive machines began to be used in factories. The Industrial Revolution changed the way of life by adding factories to towns. Textile, automobile, steel, food, and chemical factories shaped new homes, furniture, environments, and architecture.

Moreover, Alvin Toffler defines the post-era as the third wave of the industry and says that its focus is on information (Toffler, 1981). Producing information, using it, and searching for ways to access information are the most important values of this era. Toffler even says that in this information society, the truly ignorant people are not those who cannot read and write but those who do not know how to access information.

The Industrial Revolution had different results in many areas. In Eric Hobsbawm's studies, the Industrial Revolution and its aftermath are classified as The Age of Revolution 1789-1848 (1996), The Age of Capital 1848-1875 (1995), The Age of Empire 1875-1914 (1989) and The Age of Extremes 1914-1991 (1995). Hobsbawm discussed the impacts of revolutions on the social order and the city based on his research in the political and industrial context.

Since the first revolution, factories have been where the technology of the age is produced and where labour is produced. Craft production at home began to move to factories. Frederick Taylor developed a system that allowed many factory workers to produce uninterruptedly. Henri Ford designed mass production lines by defining each step of production one by one. In a very short time, factories became both a new production place and places that shaped the daily lives of many people and affect their social environment.

Furthermore, Micheal Hardt and Antonio Negri defined the labour process in production as the transformation of material labour into immaterial labour as the transition from the Fordist order to the post-Fordist order (Hardt & Negri, 2001). In other words, while labour was being produced, the temporal and spatial boundaries of the factory were being questioned, and the possibilities of non-factory production were being discussed.

Besides the effects and consequences of the industry on the social, economic and working order, Gillian Darley (2003), in her book Factory, discussed the architectural periods of the factory, unlike the others. Darley examines the factory as an image with the adjectives she gives to the factory, such as early versions, modern models, an icon, a sales tool, a laboratory, or a laboratory as a factory.

More recently, Erik Brynjolfsson and Andrew McAfee's book The Second Machine Age (Brynjolfsson & Mcafee, 2014) draws attention to the new environment and economy; social and cultural life is led by computers. After the labour-intensive period of the First Machine Age, the production period left to robots is defined as the

Second Machine Age. In this age, there is a rapid transformation under the influence of intelligence, information, and artificial intelligence.

The change in the energy used, the production method and variety, and the increase in the consumption rate have led to changes in the interior spaces of the factory, its surroundings, and even on an urban scale. With the imposition of globalization, factories spread all over the world have formed industrial zones. As a result, each innovation in the industry has created different spatial needs in factories.

Nina Rappaport criticized this age, which has been described as Industry 4.0, or The Second Machine Age, as the '*consumption of production'*. In her book Vertical Urban Factory (Rappaport, 2019), Rappaport describes the process of production that evolves with technological revolutions and the factory story. In addition, Rappaport explains ideas about reused factory buildings and their potential for mixed uses within the scope of the Hybrid Factory-Hybrid City study, which consists of her studies at the Future Urban Legacy Lab of the Politecnico di Torino. She discusses how new technologies and advanced production systems with a hybrid model will appear in cities.

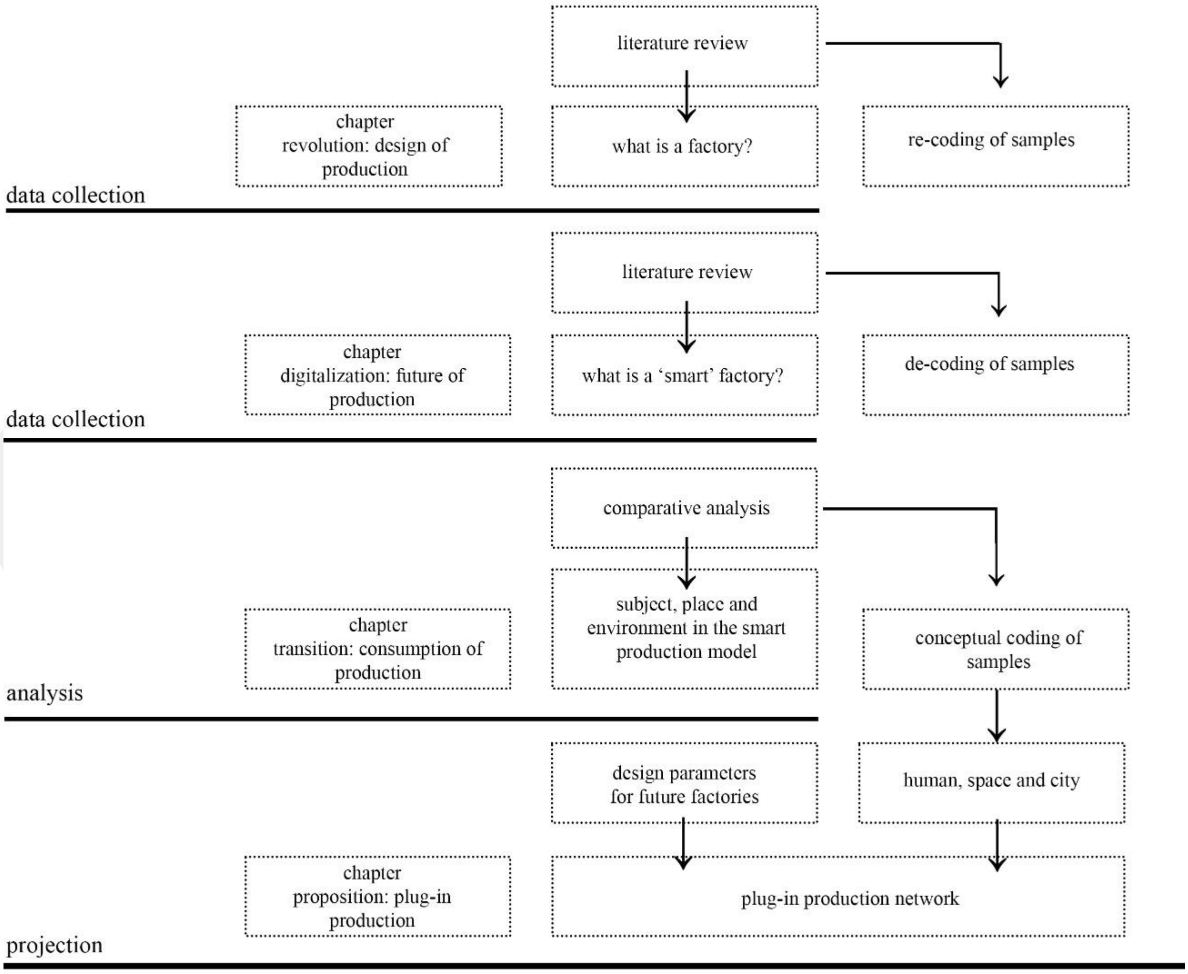
Furthermore, Tali Hatuka and Eran Ben-Joseph search for the place of new production in their book New Industrial Urbanism (Hatuka & Ben-Joseph, 2022). The factory and its relationship with the city are discussed in the research based on the four technological revolutions of the industry. Within the scope of the study, 'integrated city' is introduced as the new revolution's return to the city model.

Industry and factory studies are an interdisciplinary area. It is seen that there are more studies in the literature in the fields of engineering, technology, economics, and sociology. Studies at the intersection of architecture and industry have mostly been research aimed at the conservation of industrial heritage. As a different study, the thesis of İlayda Güler, *'An Inquiry on the Architecture of Production: From Mills to Machine Landscapes'* (2021, Middle East Technical University, MSc). In the thesis, the evolution of production was discussed through mills, daylight factories, and machine land spaces and examined by comparative analysis. All this literature forms a basis for the research method and conceptual framework of the thesis.

1.2 Research Methodology

The method of the thesis consists of the following stages: First, a literature review was conducted based on the four technological revolutions of the industry and factory examples of the period, which were examined morphologically. In the second stage, a conceptual framework was prepared under the headings human, space, and city, and a formal and conceptual basis was created for the thesis proposal. In the final stage, a proposal for new production spaces has been developed. Plug-in possibilities for shared labour, factories and networks between humans and machines were discussed. In this context, the thesis consists of four main parts: design of production, future of production, consumption of production, and plug-in production (Table 1.2).

Table 1.2.1 Overview of the scope and research methodology



The Design of Production chapter deals with the Industrial Revolution that started with the production of machines, the technological revolutions that followed, and the factory as a place of production. Developments in industry and the changing and transforming production areas with these developments are analysed. This chapter aims to seek an answer to the question *'What is a factory?'* by utilizing the spatial discussions, concepts, and design discourses of production.

The technological revolutions of the industry, namely the invention of the steam engine, the use of electrical energy in production and the transition to mass production, and the computer-aided production methods were selected as the periods of investigation, and the factory was examined morphologically in these three periods. Spatial readings of the factory buildings corresponding to each period were made on the plans. In these periods, the units of the factories were coded, and what was added or removed over time and what caused these changes were discussed. It aims to create a historical background for understanding and discussing the 21st-century factory.

In the **Future of Production** chapter, the transformation of the new production areas with innovations in the last revolution of the industry will be explained. However, after the Industry 4.0 unmanned production methods, the factory is referred to with adjectives such as "digital, smart or dark". The purpose of the chapter is to seek an answer to 'What is a smart factory?'. Although the process is very new and experimental, the innovations and proposals for a smart factory are examined through current examples and compared with the codes produced in the previous chapter. In this way, the first spatial clues of the new factories were identified, and a morphological basis has been prepared for the future.

The **Consumption of Production** chapter focuses on the actors, spaces, and cities of production. In this adventure, the role of humans in production changes as an employee, producer, and consumer. Factories, which have been hosting people as workers for many years, now accept them as visitors, and the factory is evolving into an architecture where machines and humans have different functions. In addition, humans and space are not the only results of revolutions in production; many city developments are directly or indirectly related to production. For this reason, in this part of the thesis, the transformation of humans, spaces, and cities in response to industrial revolutions has been examined through comparative analysis and the conceptual codes presented. As a result, arguments for new production spaces are determined.

Finally, **The Plug-in Production** chapter projects the production spaces for the future. This section discusses plug-in possibilities in production, inspired by the Plug-in concept Archigram produced as a utopia. Production is considered a degradable, pluggable, flexible activity in this part of the thesis. The plug-in status of the human being, the production actor, and now the machine, the factory, the place of production, and their network are discussed with the data obtained from other chapters. Then, plug-in production spaces are exemplified, from the smallest to the most comprehensive.

In summary, production forms the framework of this thesis. The technology offered by the revolutions, the searches in production spaces in response to these developments, and the current discussions of the transition indicate the scope of the thesis. The proposed *Plug-in Production* is intended to create a new discussion in the studies to be carried out in the field of industry and architecture.

Chapter 2

Revolution: Design of Production

This chapter seeks to answer the question 'What is a factory?’. Following the technological developments of the Revolution, production and the factory are discussed in three different periods. It examines the birth of the factory and the innovations that made it the pioneer of its time and later its icon. Clues from the past were sought to understand the transitional period of the factory. It is believed that the study of the spatial search of production in this historical process will also contribute to the main research question of the thesis.

The birth of the factory was based on the replacement of human power by machine power. The word "factory" appeared in Europe about a hundred years before the Revolution in the 1600s. Individually produced products took their final form in a different place, and this building where the product was assembled was defined as a factory (Marsh, 2019). In the past, individual workshops were used with traditional production methods, but over time, it was seen that these places could not respond to the changing production methods and needs.

The most remarkable invention of the Industrial Revolution, which began in England in the mid-18th century and rapidly spread to Europe and North America, and the most important source of power in production at the time was the steam engine. After the revolution, thanks to the invention of the steam engine, a systematic and planned production process was introduced and production increased rapidly with the involvement of machines. As production methods changed, the need for machinery increased over time, as did the type, weight and size of machines. For this reason, the old workshops were not sufficient for the new production. This led to the rapid construction of factories, where machines are mostly housed, workers enter and leave at specific times, raw materials are stored, products are manufactured and a considerable amount of energy is constantly consumed. 18th-century factories has been described as square brick buildings with bare walls, a monotonous form, and limited embellishment (Marsh, 2019). Although the product may differ slightly according to the sector or geography, the essential architectural elements that define the design of the factory are similar. The factories were organized around the energy source, machines, workers, and production flow in its simplest form. In these factories, the priority was not architectural aesthetics but functionality.

The factory began to change physically with each new technology in production. At the beginning of the 20th century, Henri Ford's system for the automotive industry caused a new and effective revolution. This method, called Fordism, adopted standardization as a principle at every production stage. In this system, which Ford designed to speed up the construction of the Model T, he described each step of production and divided it into eighty-four parts. Thus, he planned the whole system by assigning employees for each step. Henri Ford paved the way to give more space to machines in production with this assembly line he built. Henri Ford implemented this system using Frederick W. Taylor's management system (Freeman & Soete , 2004). Frederick Winslow Taylor defined process the management by calculating the movement and time required to perform a task and developed management style of Taylorism. Taylor took brainpower-based work from the production area and assigned it to the planning departments.

Producing information had also become a new type of production. A new staff between the manager and the workers has produced information (Kumar K. , 2010). Thanks to Fordism and Taylorism, machines began to partner with human labour in the new factories. Production was programmed with machine-human cooperation. Factories were designed according to the size and width of the assembly line required for production and the machines used. The location of factories was also determined by the procurement of raw materials and the transportation of products. In addition, the new materials used in the buildings, the construction technique, and the architectural style made the factory buildings the leading structures of the period.

In the second half of the 20th century, computer and automation technology have made production control more accessible. Unlike the previous production line, a computer could control the system. Although this was seen as a great innovation, computers were not initially fast enough to compete with humans. It was not easy for the robots to take over the factories. First, existing buildings where robots could speed up production had to comply with this new organization. Technological infrastructures like floor and wall sensor systems and visual guidance signs have developed. In addition, there was a rapid increase in consumption with the effect of globalization in this period. The factory began to spread around the world, leaving the geography in which it was born.

When the economic and technological developments in the industry are examined, it is seen that there were three major revolutions before Industry 4.0. Alan Blinder has examined these steps as an economic increase in production, development in the service sector and the information age (Blinder, 2006). Similarly, Nina Rappaport has associated all these steps with production methods and spaces. Rappaport defines the first Industrial Revolution factory as a workshop gathered under one roof and the second Industrial Revolution as conveyor belts and rails. The third industrial revolution, described as the post-industrial period, has developed with informatics and robotics (Rappaport, 2021).

In this thesis chapter, industrial revolutions have determined the topics for factory research. The first revolution corresponded to the invention of the steam engine, the second revolution corresponded to the use of electrical energy, and the third revolution corresponded to the use of computers in industry (Table 2.1). Each technology has enabled the continuous development of methods from arts and crafts production to automation. It can be said that these changes have also been decisive for the architecture of the factories and production areas.

Table 2.1 Industrial revolutions and key words

	1. industrial revolution	**2. industrial revolution**	**3. industrial revolution**
period	late 18.th / early 19. th century	late 19. th / mid 20. th century	the second half of 20. th century
technology	water power, steam power	electricity	computer and automation
production methods	mechanization	mass production	automation
place of factory	company town	city, industry park	industry zone, industry park
design criteria of factory	transportation, raw materials, technical infrastructure	production line, machines, manufacturing equipment, management, production, storage, physical strain, health/safety	process design, manufacturing method, assembly method, logistics method

In this context, the thesis examines the change and transformation of the factory, based on the impact of technological revolutions in industry. Production technology, production method, place of the factory and design criteria are the keywords of the research. In the first industrial revolution, the factory is discussed as an innovator; in the second, as a pioneer; and in the third, as an icon.

2.1 First Industrial Revolution: Innovator Factory

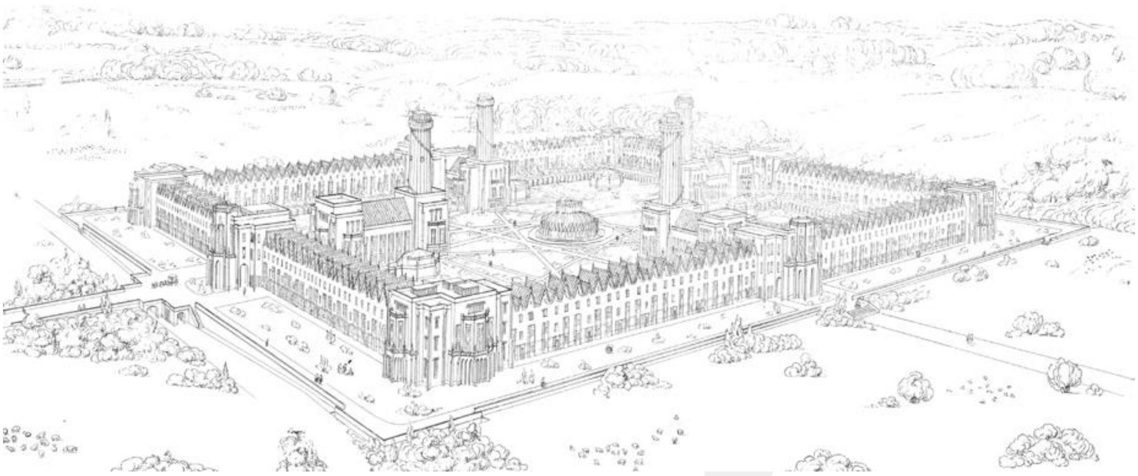
The Industrial Revolution was a breaking point for production and consumption. New inventions have replaced traditional production methods, and production and consumption have increased more than ever before. One of the most significant results of the revolution was the formation of a new working class, which moved away from agricultural activities and came from the countryside to spend most of their time in the factory. According to Eric Hobsbawm, the transformation of nobles into manufacturers and peasants into factory workers in return for wages began to change people's lifestyles and needs (Hobsbawm, 1996). Edward Thompson argues that the working class is a self-forming process in environmental and human relations. Thompson says that the end of life in the village is due to production relations in the city, the struggle to exist against the bourgeoisie, and the process of finding a place in the city (Thompson, 1966).

Another of the fundamental thing that changed with the revolution was time. In pre-modern societies, time was organised around daily work in mind; time is organized not as minutes, hours, days, or months but as sunrise and sunset, seasonal changes. Everyday life began with the sunrise and ended with the sunset; star movements, precipitation-drought times, and seasonal weather conditions have shown how to determine the time. This routine in social life forms the basis of tradition, and time is a determining factor for this cycle (Giddens, 1991). In the 18th century, changes in daily life practices and work remuneration became necessary. The use of clocks, especially in public spaces, has begun to increase. David Harvey explains that the changes in time are determined by the changes in space (Harvey, 1992). This age forced all people to live together, and new settlements began to be built. Every society or geography affected by the Industrial Revolution had to keep up with this innovation.

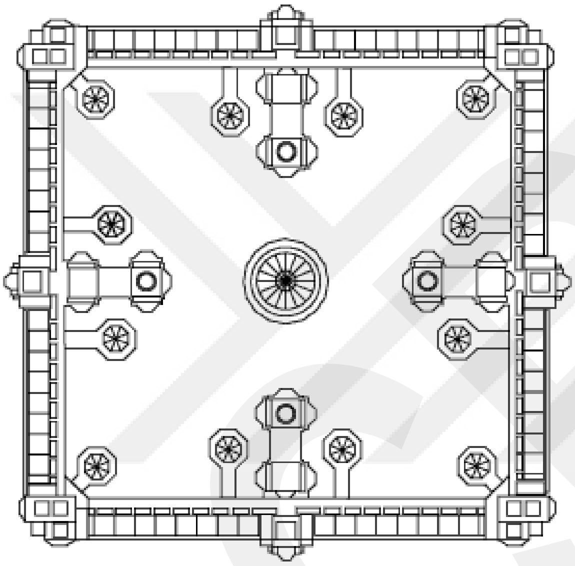
When Thomas Newcomen invented the first steam engine in 1712, this technology was used to drain coal mines. Later, James Watt developed this technology and made it an essential part of the industry. However, since steam engines are hot, noisy, and dangerous, the factories affect the whole environment in which they are located. On the one hand, while new cities were formed around the factory, on the other hand, problems began to be experienced in these cities. There was an intense migration from the countryside to the newly established cities, and the rapidly increasing population caused poor living conditions. Modern urban studies began to solve these problems in the cities. It has begun planning and building, reconsidering factory and worker housing (Benevolo, 1971). With the planning of industrial areas, healthier settlements were designed for the population migrating from rural to urban areas. While creating these settlements, the diversity of transportation, infrastructure, and social facilities has been essential to the planning.

The factory, which became an essential part of life with the revolution, was also one of the main problems of urbanization. The housing and transport of workers were essential factors for the location of the factory. As one of the essential names of the revolution, Robert Owen imaged an ideal industrial city and did some studies. With the help of architect Stedman Whitwell, he proposed an ideal society model for New Harmony with his drawing "The New Communities at Harmony in Indiana North America" (Carmony & Elliott, 1980). The communal society, designed for approximately one thousand people, is considered self-sufficient in factories and rural areas. It was a large building with factories, private residences, and dormitories for children, religious spaces, schools, kitchens, dining halls, and warehouses within this rectangular planned structure (Figure 2.1.1).

Robert Owen was a manufacturer and made machines that produced in addition to produce. When Owen was a manager, he knew that industrial production was displacing agricultural workers. For this reason, he advocated the establishment of villages where agricultural and industrial production were combined. Not only was the factory designed, but also the surrounding area. Owen's aim was to achieve social equality for all who lived here and worked for production.



(1)



(2) (3)

Figure 2.1.1 New Harmony

As a reaction to the inequalities created by capitalism after the French Revolution, Charles Fourier developed the Phalanstère utopian project (Figure 2.1.2). Fourier shared similar views with Robert Owen in his utopia. He wanted to gather many different activities in a monumental structure in the project. The goods produced in the project, based on equality and cooperation, would be distributed equally to the workers. Fourier designed this project for 1500-1600 people and was careful about the choice of location. The main criteria were water flow to the selected land, close to the hills and agricultural fields, adjacent to the forest, and not too far from the city.

The Phalanstère, which he designed like a castle or palace, was a large building that housed many parts such as dining rooms, meeting rooms, a library, a ceremonial area, religious spaces, an observatory, and a financial centre were housed. While noisy spaces such as iron and wood workshops were located on one side of the building, the other side reserved more private spaces for meetings. In this multi-story building, private residences are placed on the upper floors. All the children living here were brought together on the same floor, with the aim of giving everyone an equal life (Beecher & Bienvenu, 1971).

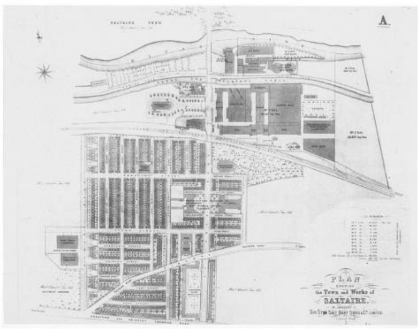
Figure 2.1.2 Phalanstère

These utopias began with the idea that a good environment would produce a good society. A direct relationship was established between the physical locations of factories, houses, and public spaces. It was quite new in those years that employers also solved the housing problem for workers. As a result of this thought, company towns emerged in 1830-1930. These towns, built quickly with significant capital, differed from other towns. In the towns initially built in America, there were houses, shops, schools, and even chapels, which was the plan of the company. The population of the towns was usually one or two thousand, and the workers who lived here often established their own culture. The company set the working hours, the daily activities, and the rules in the town to maintain the social order and expected the residents to follow the rules (Garnier, 1996).

One of the first company towns, the Saltaire Factory, was an industrial village built in England between 1851 and 1853 (Figure 2.1.3). Architects Henry Lockwood and William Mawson designed the outside of the factory and the town which included housing, schools, hospitals and religious buildings. The factory was located close to the railway and canal. It was considered comfortable for the workers, and the factory interior was well-heated and ventilated. More than three thousand people were working at different ages with different skills and different wages. The residences were separated from the factory by railway. Most of the workers lived in the newly built village. The houses were close together, and it was a very dense area (Styles, 1990). The whole factory process was carefully organized. The main divisions of the manufacture of alpaca were sorting, washing, drying, plucking, combing, drawing, roving, spinning, weaving, dyeing, pressing, finishing, and folding. The fact that all these steps were carried out in the same building made Saltaire a model. The village consisted of factories, 800 residences, 45 almshouses, institutes, baths, churches, and parks (Dewhirst, 1960).

(1)

(2)



(3)

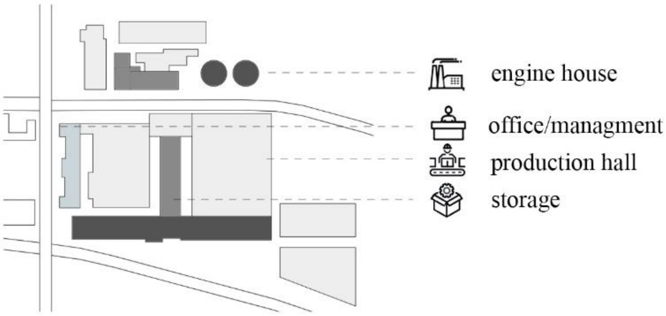


Figure 2.1.3 Saltaire Factory and Company Town

Another company town is Cadbury Town, designed by architect George H. Gadd for the Cadbury Company in Birmingham in 1879. Like Saltaire, this industrial village was considered a whole with its schools, parks, a railway station, and entertainment facilities (Zimmermann, 2013). Nearly three thousand people worked in the factory building. The aim was to create a healthy environment both inside and outside the factory. Swimming pools, football fields, and tennis courts were also built around the factory. It was considered everything for the workers to spend time outside of working hours. The factory attracted attention due to its association with green spaces (Wordsworth, 2018). The production area is built next to the water canal and railway line. The factory consists of many different buildings and is separated from the residential area by a recreation area.

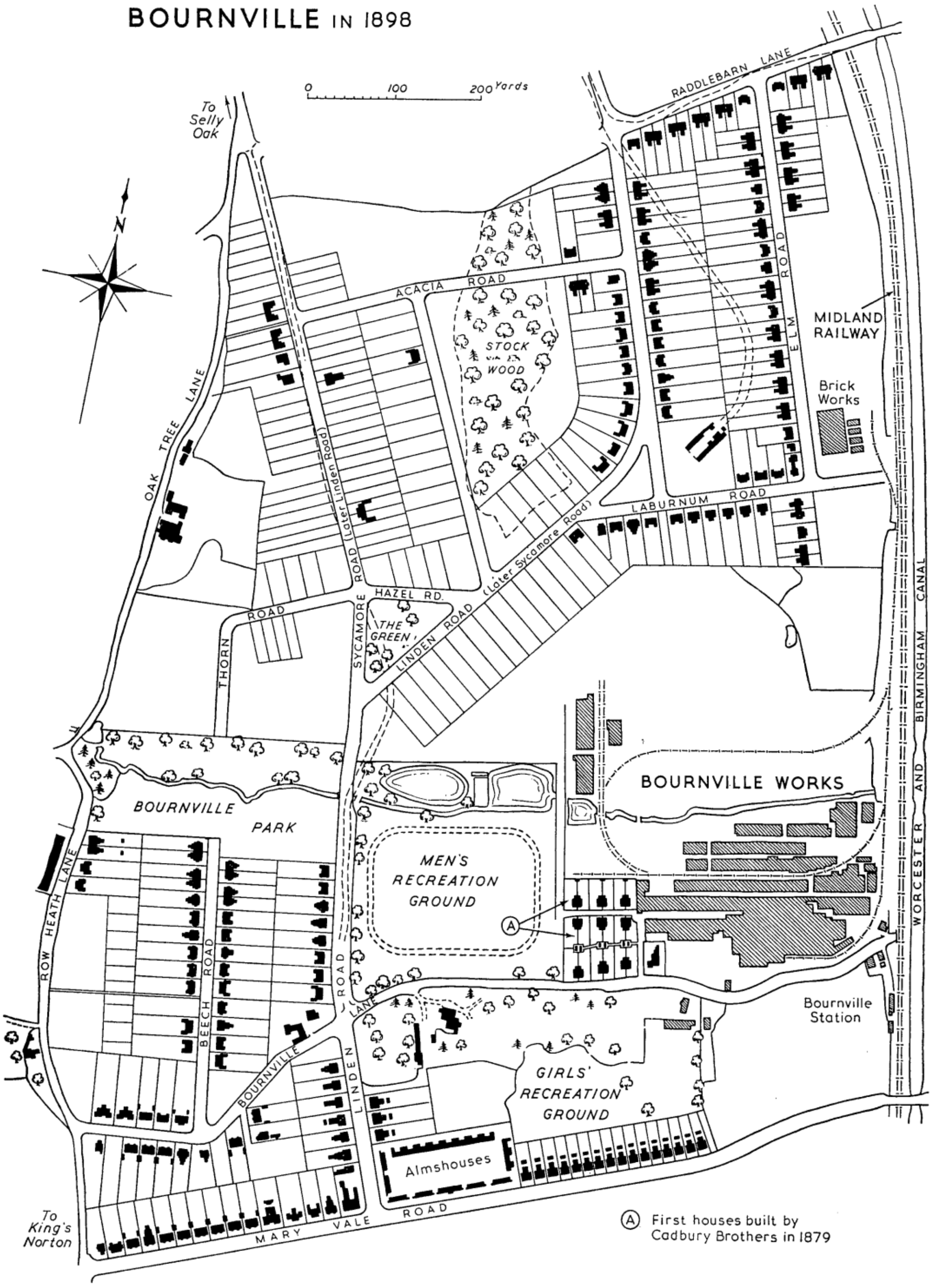


Figure2.1.4 Cadbury Factory and Company Town

In the same years, George M. Pullman worked with architect Solon Beman and landscape architect Nathaniel Barrett for the company town he was to build south of Chicago. Unlike existing company towns in the USA, Pullman wanted to create a better environment for his employees. Everyone, from managers to workers, was intended to live in this town and benefit equally from public services and planned recreation areas. It was planned to improve the unhealthy conditions in the industrial areas (Buder, 1967).

Firstly, the factory was built in the town. The administrative offices were located in front of the factory. There was a machine shop, drying rooms, a pattern shop, a blacksmith shop and a water town in addition to an engine house, production hall and offices in this area (Figure 2.1.5).

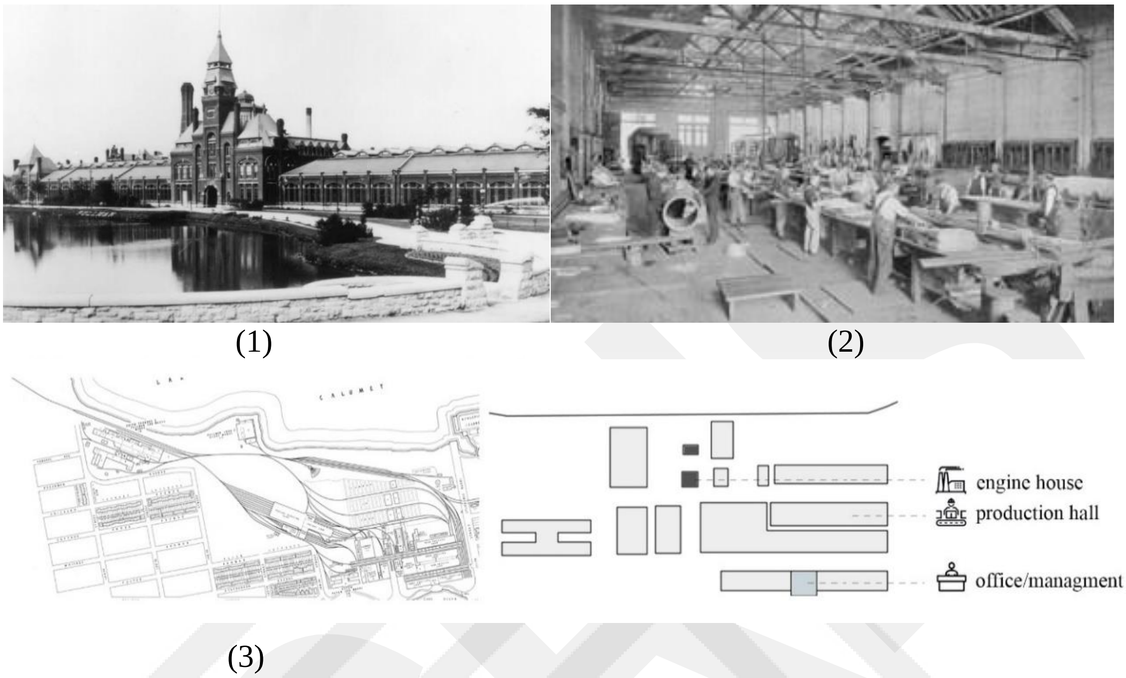
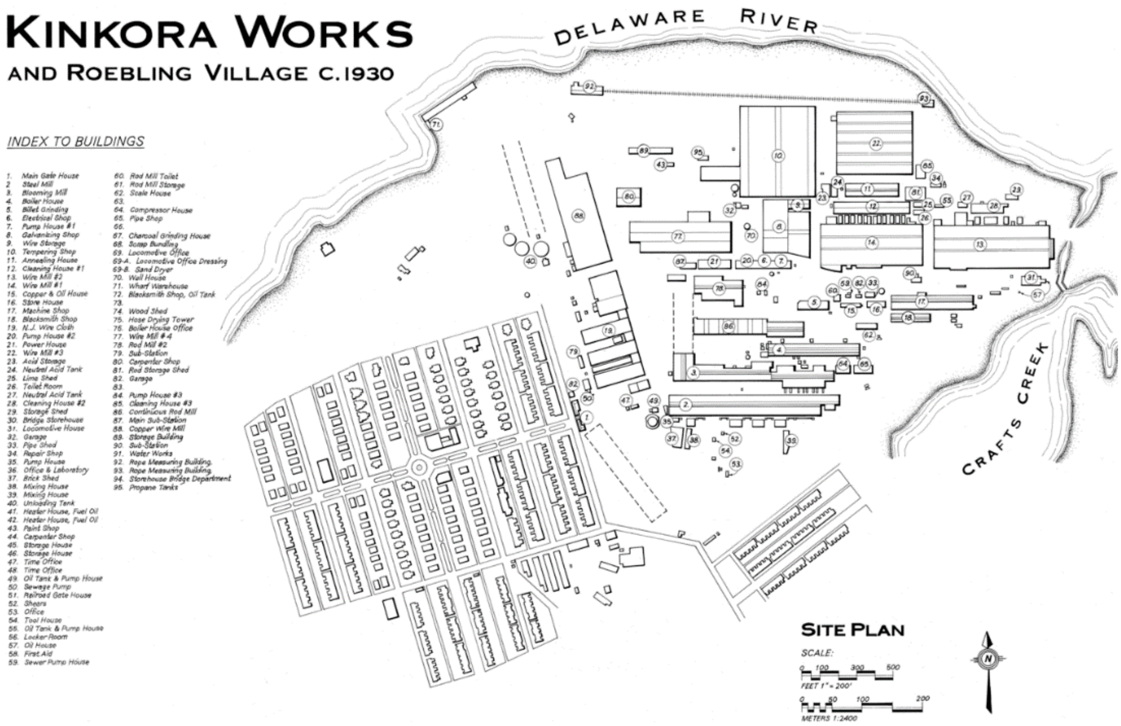


Figure 2.1.5 Pullman Factory and Company Town

Like other company towns in America, Roebling also became a significant settlement. Its founder, immigrant John Roebling, started a wire rope manufacturing business and had done remarkable works such as the Brooklyn Bridge. After his death, Roebling's sons bought farmland to build the factory and built a town around the factory with more than 750 houses, a hotel for single workers, shops, and recreation areas. The company also took care of the maintenance of the entire town. Unlike Pullman, it provided a more comfortable social environment for the workers. The company continued to take on major projects, producing materials for the Golden Gate and George Washington bridges and the Empire State Building. However, in 1947, the company sold the homes in the town to the workers and then transferred the company to its new owner (Borbi, 2018).

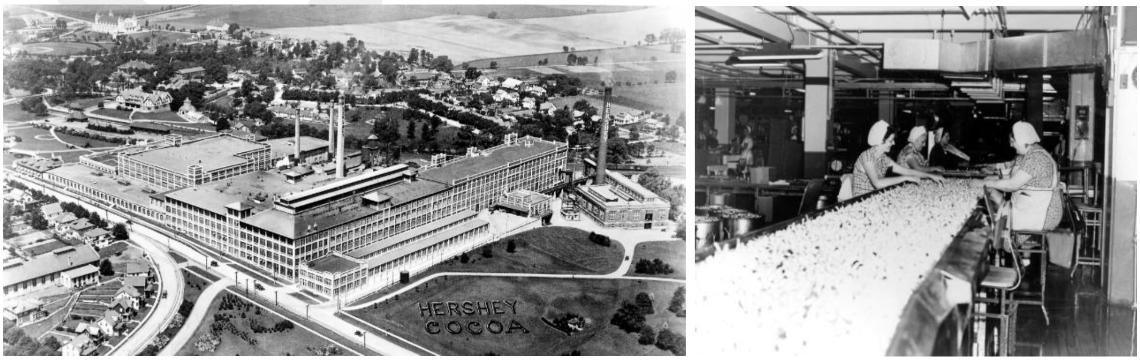
As can be seen from site plan, the village consisted of clearly separated residential and production areas (Figure 2.1.6). There were many large and small buildings in the production area. The number of production halls was increasing according to work diversity and function. The factory became a production park with warehouses, energy houses, and other buildings for other functions.



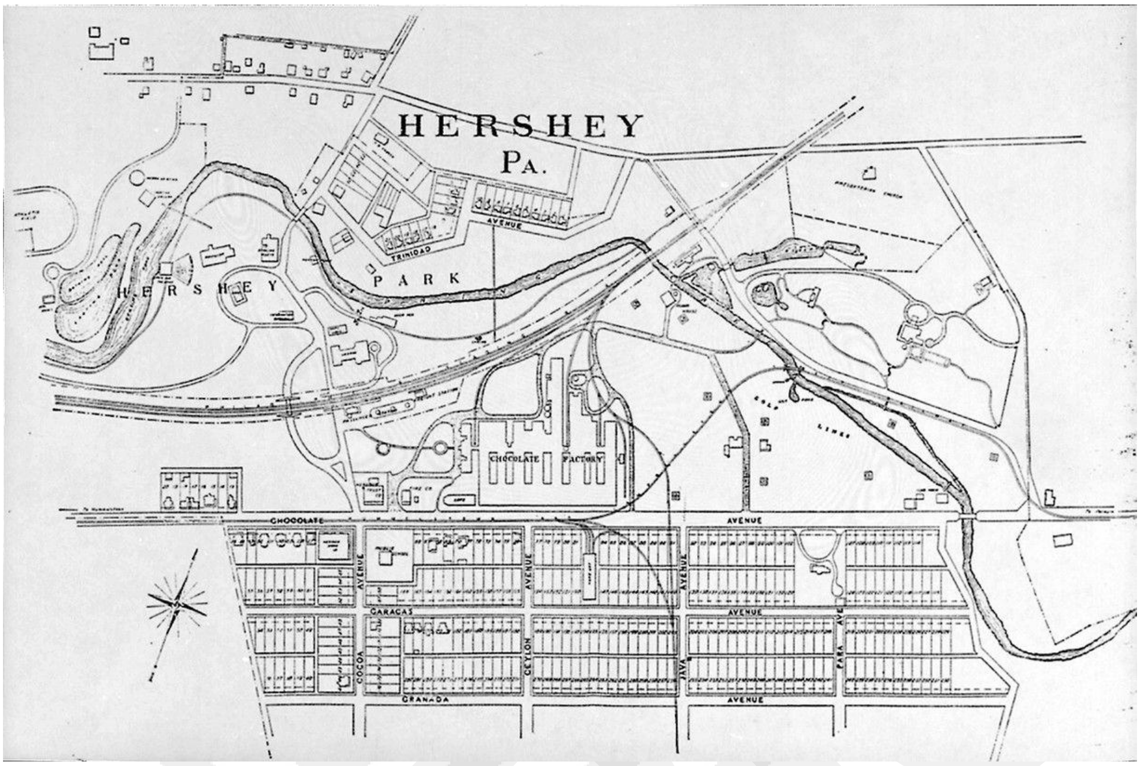
(3)

Figure 2.1.6 Roebling Factory and Village

In 1900, Milton Hershey also realized his utopia and established a facility to produce chocolate near Pennsylvania. Due to the distance of the factory, Hershey also built a town for his employees. However, the production facility still operates today (Kurie, 2018). In this town, the factory was located in the centre, and around it were built houses that employees could rent and buy, public schools, recreation areas and a zoo (Figure 2.1.7). Hotels, gyms and public buildings were later added to this model town.



(1) (2)



(3)

Figure 2.1.7 Hershey Factory and Company Town

The Industrial Revolution brought order and standardization in production thanks to mechanization. The organizational symbol of the revolution was the factory. (Stearns, 2013) Even though the first factories were small, they enabled people to work together. In these buildings, over time, the order of the machines and the cooperation of the employees were ensured. Factories grew, and more people began to work in the same factories and live around the factories. Company towns were the first examples of urbanization in this context. Production has become a part of daily life and the active force of the social order. However, the order affected by the revolution remained unchanged; it continued to develop continuously from the moment it began.

2.2 Second Industrial Revolution: Pioneer Factory

A more planned process began for production and urbanization after the first crises of the Industrial Revolution. The factory had become the centre of social and economic life in the city. It was close to transportation systems, raw materials or energy sources and gradually started creating its environment. The main reason for the birth of 20th-century urban planning was to improve bad conditions in industrial cities. In an ideal city model, the main focus was industry.

One of the initial considerations was Garden City, an ideal model for creating a cleaner environment by ultimately pushing production out of the city (Fishman, 1982). The Garden City was foreseen for groups of thirty thousand people and was arranged with clear zoning rules. Public areas are located in the core of the city, and the city is limited to agricultural areas. Unlike company towns, dwelling and industrial production areas are far apart. In this proposal, Ebenezer Howard aimed to minimize the environmental effects of production and its harm to human health and gave importance to the protection of public health.

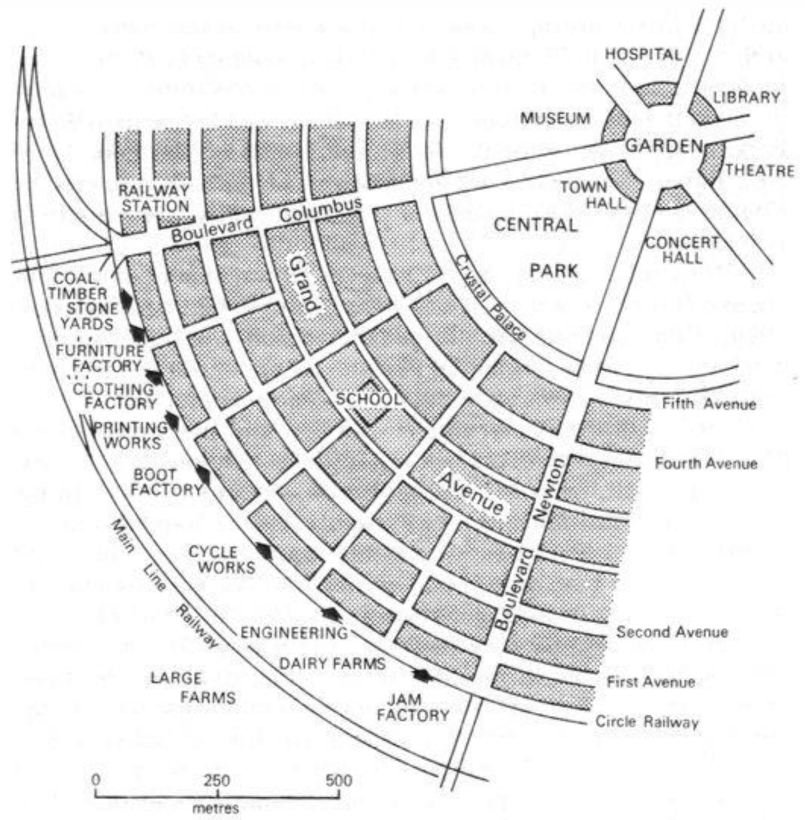


Figure 2.2.1 Garden City

At the same time, Tony Garnier proposed an industrial city for France with a population of thirty-five thousand (Figure 2.2.2). Functions in the city were defined as work, housing, health and leisure. The industrial city was organized as a residential, transportation, and industrial zone. The railway station was located in the middle of the house and factory areas, and the living and working areas were separated (Garnier, 1996). Factories were for metallurgy in this city and contained blast furnaces, steelworks, shops for large presses and hammers, shops for assembly and fitting, and a shipyard for launching ships and their repair.

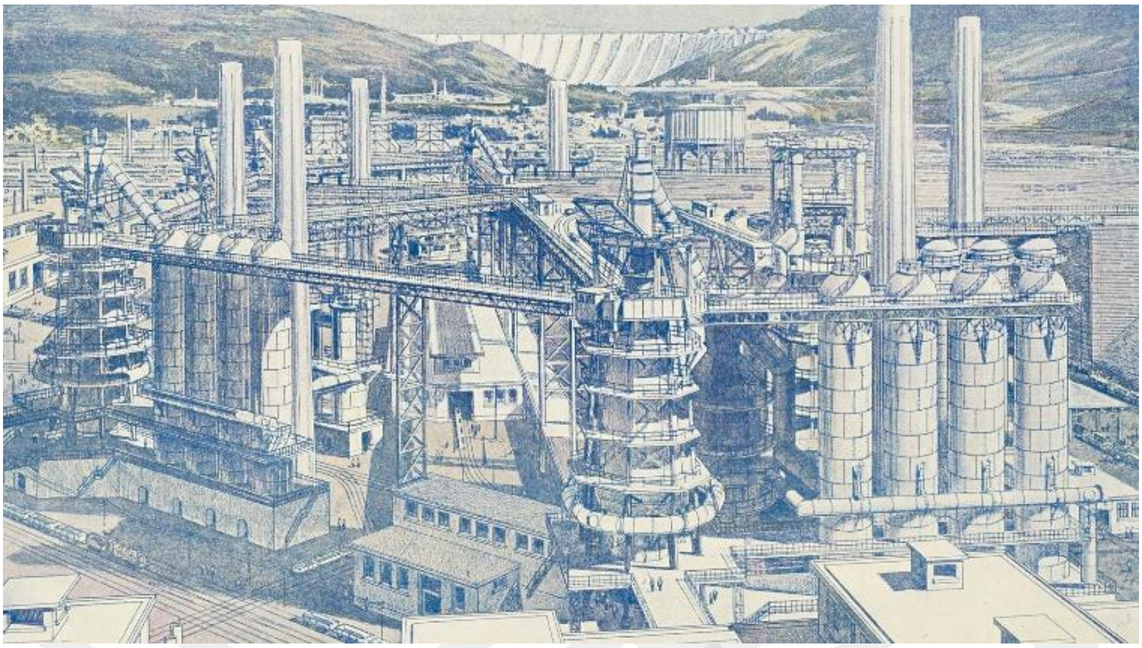


Figure 2.2.2 Une Cité industrielle

Frank Lloyd Wright's Broadacre City utopia was an innovative approach in its period. Wright defined it as '*The new city will be nowhere, yet everywhere'*. This city model has no distinction between rural and urban and has no factory areas or a city centre (Fishman, 1982). Wright described Broadacre City as the result of the automobile age, arguing that the transport and communication technologies of the 20th century allowed time and space to be controlled differently and distances to be reduced. Therefore, Broadacre City allowed for a new city form (Figure 2.2.3). Production activities in the city were minimized and were distributed homogeneously within the city. Wright says;

"All common interests take place in a simple coordination wherein all are employed: little farms, little homes for industry, little factories, little schools, a little university, little laboratories…" (Hannan, 2020).

Wright proposed an order in which people could produce food and be involved in production. He thought that social activities could be increased by using machines more humanely and reducing people's working hours. Broadacre envisioned a less stressful life by reducing commuting. Wright emphasised the sufficiency of technology for this innovation, believing that the telephone and radio were sufficient for communication and arguing that there was no need to live together.

Figure 2.2.3 Broadacre City

The second industrial revolution developed especially with mass production and assembly lines. Henri Ford set up the assembly line in 1913, and in a short time, like a year, all assembly was done on a moving line and opened the factory doors to everyone to show this work to the whole world (Pollard, 1995). After this work, the industrial areas in Detroit, designed by Albert Kahn, Julius Kahn, and Earnest Wilby, set the standards of Fordist production for the whole world. Ford's most significant change for industrial buildings was planning single-story production facilities instead of multi-storey ones. Iconic buildings were designed with light steel and glass materials.

Industrial architecture transferred from Europe to America also commonly featured a multi-storey interior, confined workshops, heavy load-bearing walls, and small windows. It was poor in daylight and ventilation. Firstly, Albert Kahn's production model is critical in developing factories in America. According to this model, the building should serve the production process and assembly line arrangement. (Zimmerman, 2017). Kahn proposed larger interior spaces for the industry by developing the reinforced concrete and steel structure framework. It has grouped the tasks in the facility to meet the production process requirements. He organized the leading workshop, welding workshop, assembly workshop and body shop based on function and designed the façades of large workshops with large windows to receive daylight. Kahn's designs were known as the most significant industrial parks of his time.

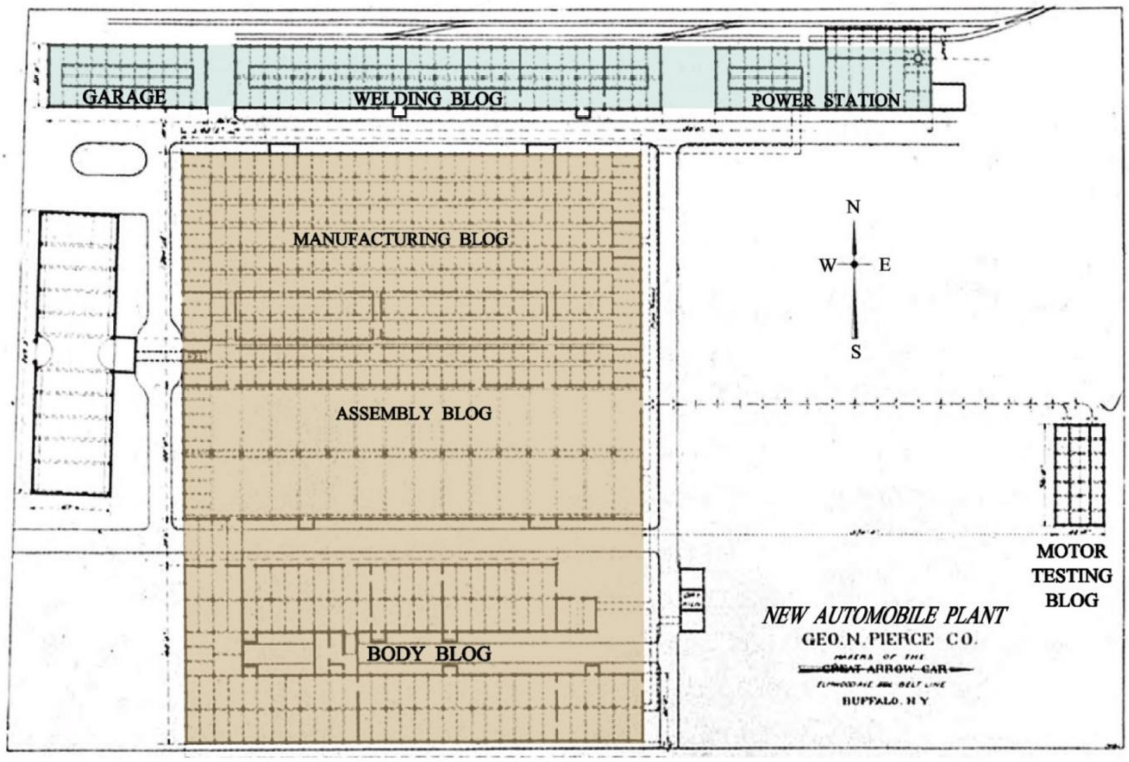
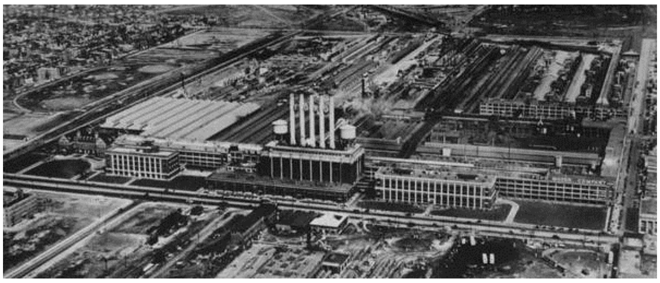


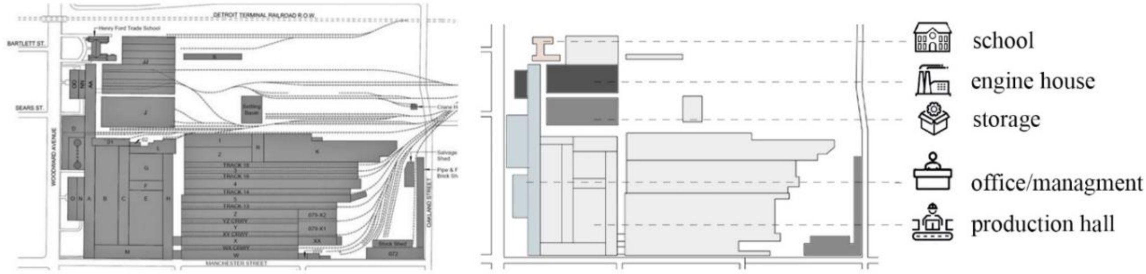
Figure 2.2.4 Albert Kahn’s factory organization

The pioneer of the assembly line, Ford needed a new factory to manufacture the Model T. For this, he worked with architect Albert Kahn for Highland Park, north of Detroit. Khan designed a four-story main building and a one-story production building. The priority was for the workers to receive natural light and modern ventilation and heating systems. He wanted to provide a clean working area. The factory was a production park with multi-piece production halls, large warehouses and energy houses. At the entrance of the area, there were multi-storey offices and even a school built later. The production hall, where many steps take place from the production of parts to the assembly of a car, and Kahn’s all-factory organization model became an example for many factories.



(1)

(2)



(3)

Figure 2.2.5 Ford Motor Company Highland Park

Similarly, Peter Behrens' AEG Turbine Factory attracted attention due to designed details for the changing needs and technologies in the industry (Figure2.2.6). Behrens designed not only the AEG factory but all the designs, from the brand's font to the product designs. Oscar Lasche, AEG's production manager, determined the spatial needs of the factory. Large spaces were needed for the huge engines at the AEG production facility (Aitchison, 2016).

The production hall was supposed to house two large cranes in height and width used to assemble the turbines. Moreover, wagons were needed to arrive at the building for transport. Side halls were designed for storage and other works. This building, designed with reinforced concrete and steel structure, became a pioneer for industrial buildings and modern architecture. The construction of a building in which many machines could operate smoothly and the design of it with an industrial aesthetics inspired the architects and architecture of the time.

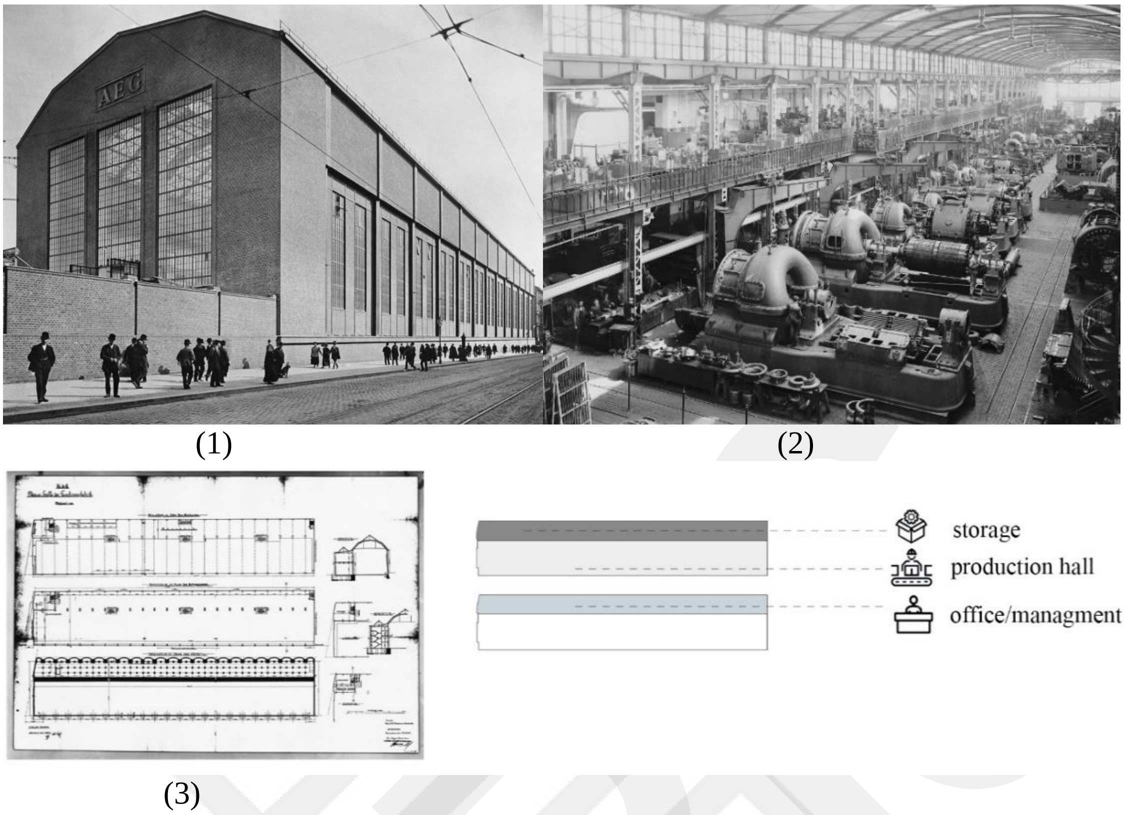


Figure 2.2.6 AEG Turbine Factory

Germany had become an essential centre in the industry in these years. Studies carried out in the industry, and materials ultimately affected the production spaces and architecture. One of the pioneering buildings of the period, the Hat Factory, designed by Erich Mendelsohn in 1923, was also notable for its design and choice of materials. The building was designed as four production halls, a boiler, a turbine, and a paint shop. (Stephan, 1999).

The use of steel, glass, concrete, and wood in the factory reflected the modern technology of the period. There are some reinforced concrete experiments which can be considered new in architecture in the roof structure and column design. The ventilation shaft for the painting hall was not only a highly functional design but also gave the building a modern look and became the company's trademark (Figure2.2.7).

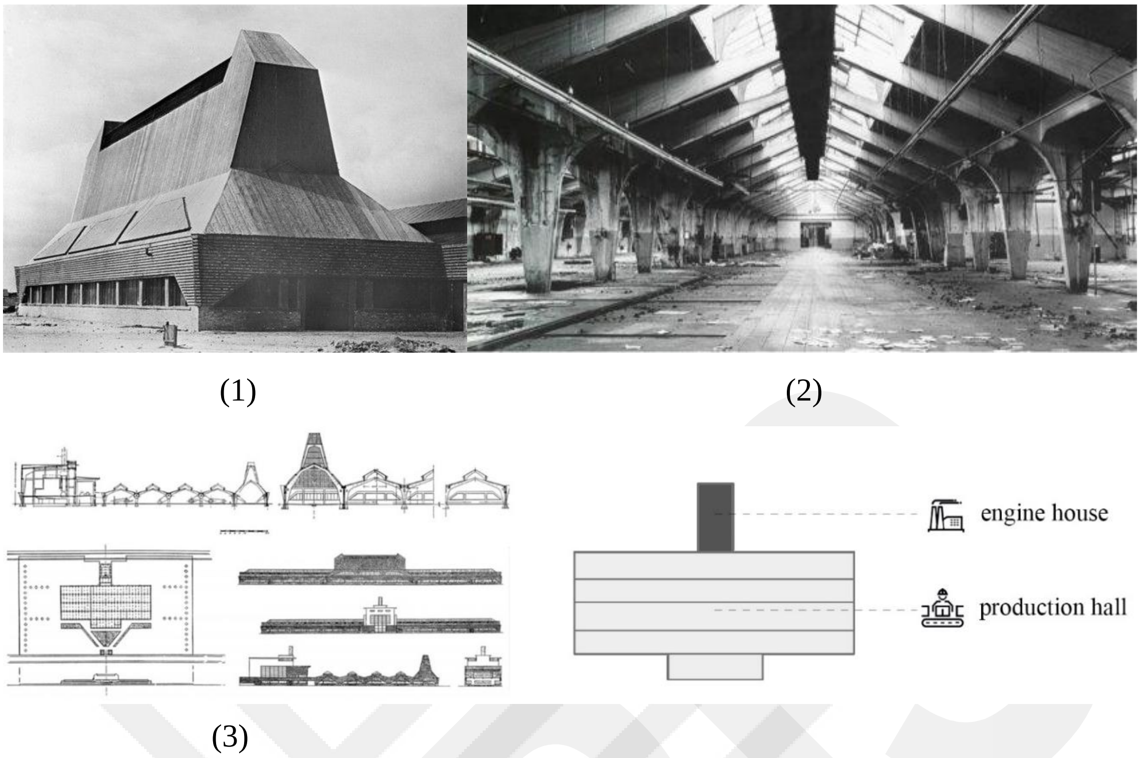
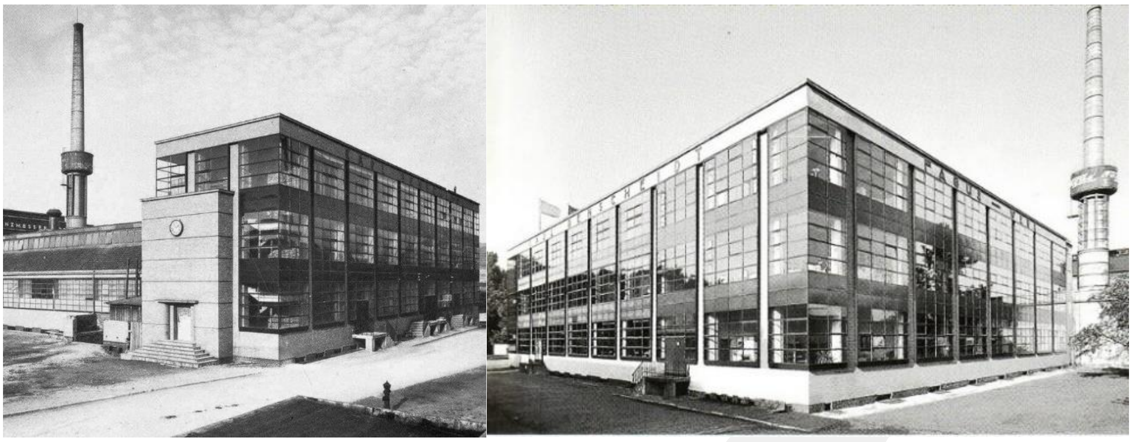


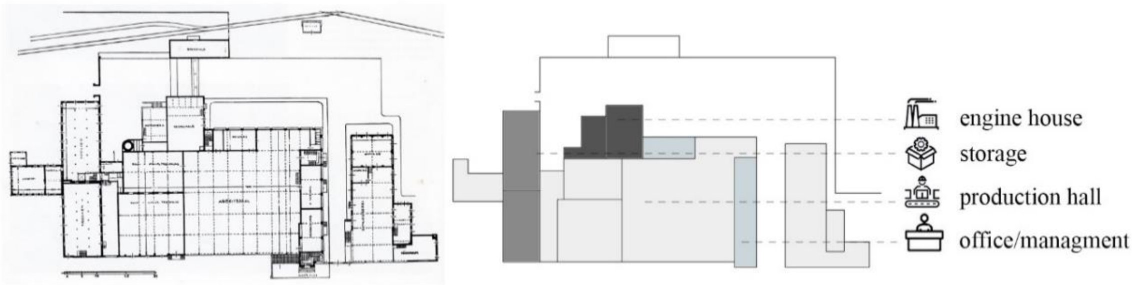
Figure 2.2.7 Hat Factory

During this period, factories in Europe were no longer part of the company towns. While urban planning continued on the one hand, factories and the volume of production were increasing on the other hand. Factories were designed and built as a single building rather than as part of a production area. Unlike their previous examples, factories became a tool for the brand value of the manufacturer and the marketing of the product. The transparent image provided by glass and steel and the display of production and work were essential to gain consumer trust.

One of the pioneering buildings of modern architecture and factories was the Fagus Factory in Alfeld (Figure 2.2.8). The factory consisted of multiple buildings that housed different functions such as production, storage, and office. Eduard Werner designed the planning of the buildings and the offices. Later, Walter Gropius and Adolf Meyer were commissioned to enlarge the main building and renovate its facades. The most significant contribution of the architects was the design they made for the office building. The building was described as a new union of art and technology. The design soon became the new face of international style (Darley, 2003).



(1) (2)

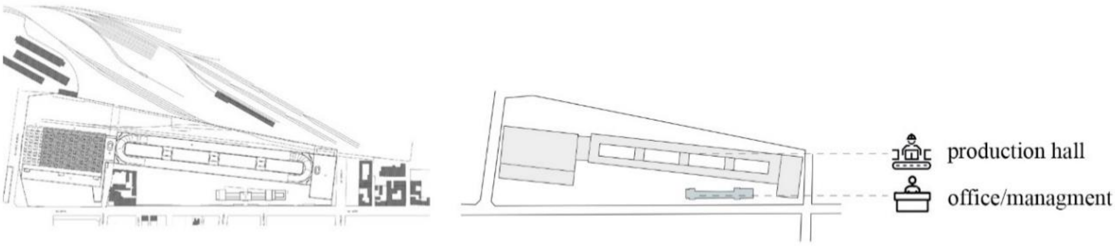


(3)

Figure 2.2.8 Fagus Factory

Fiat Factory, designed in Italy in the same years, was a modern interpretation of Ford's mass-production model (Figure 2.2.9). In the factory, which was designed as five floors, raw materials were entered from the ground and included in production on each floor. There was a test track in the attic for the cars that were out of production. It was the largest automobile factory in its period, and production has continued for many years (Cook, 2015).

(1) (2)



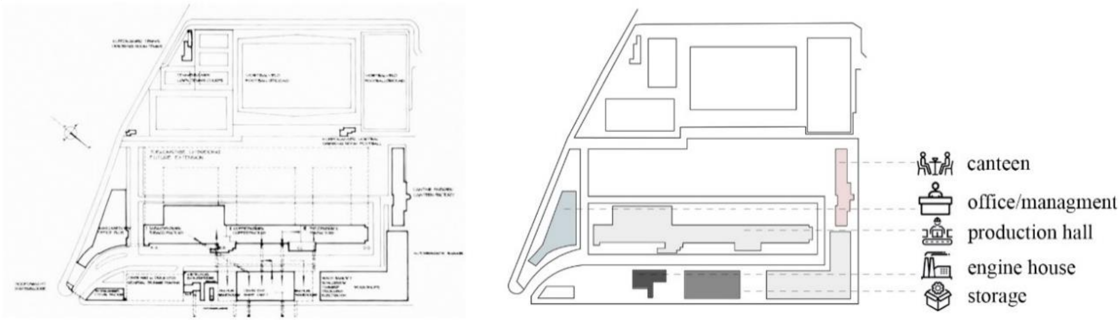
(3)

Figure 2.2.9 Fiat Lingotto Factory

The Van Nelle Factory, opened in Rotterdam in 1923 to package foodstuffs such as tea, cocoa, and coffee, was also built as a storeyed factory. The work and production steps in the factory determined the design of the building. The building, consisting of a curved administration building and an eight-story production building, had a modern look with curtain walls, cross conveyor belts, concrete floors, white ceramic tiled walls in the interior, and stainless-steel handrails. In addition, it was planned to make an open production to the outside with its transparent facade. It was also desired to create a healthy environment for employees (Darley, 2003).

(1)

(2)



(3)

Figure 2.2.10 Van Nelle Factory

The modern factory allowed horizontal and vertical production as a spatial reflection of the Fordist order. This inspiration was also noticeable in Le Corbusier's Usine Claude & Duval factory (Figure 2.2.11). Corbusier had created an area for workers' bicycles on the ground by using pilotis in the factory designed to integrate with the landscape. In the factory, which was raised from the ground, the raw material went to the top floor, was processed, reached the ground and shipped. It was a vertical factory developed with a modular system, including an elevator.

(1) (2)

Figure 2.2.11 Usine Claude & Duval Factory

The second industrial revolution was a process in which the factory gained its identity. The factory, the symbol of the revolution, also became the symbol of modern architecture. Factories, structures in which new building materials produced by the revolution were used, new construction techniques were applied, and new space typologies emerged, began to attract attention in the architectural literature.

2.3 Third Industrial Revolution: Icon Factory

The industry has undergone many changes since the first revolution. Many specific industries, such as service, research, and logistics, have developed from primary industries, such as agriculture, mining, and manufacturing. Thanks to advances in globalization, technology, and transportation, the impacts of the industry have changed dramatically. The first reflection of this is seen in the built environment.

In the second half of the last century, the speed of production technology led to the emergence of a new consumption culture over time and dragged humanity to new orders in daily life. Consumption has overtaken production over time. With this change, Fordist production left its place in post-Fordist production. David Harvey says that this transition lacks flexibility in production (Harvey, 1992). The idea of flexibility and the search for new life have become popular and have determined the new steps of capitalism. While this transformation was designing new production systems, it did not finish industrial production; moreover, it caused it to grow with more significant percentages.

Europe, the birthplace of industrial civilization, exported this the technology to the United States. Thus, industrial architecture and construction technology gradually matured in America. In the early modern era, the Soviet Union was again influenced by this formation and studied the Western industry, and by the 1950s, it had become a powerful, modern, and industrial country. Later, these innovations were carried to China, and modern industrial standards were gradually established (Pieczara, 2020). With these developments, industrial tourism began to develop around the world. The Asian countries, rich in raw materials, began to become new industrial centres where production is intensive. The number of factories increased and became industrial zones or parks.

The main need of industry was raw materials. Some regions in Africa and Asia were rich in raw materials and offered attractive new locations for production. The West had a new resource in cheap labour and low-cost industries. However, the Second World War hampered industrial progress. Both Europe and Japan suffered huge losses. The negative effects of the war on the economy led to stagnation in industry. Then Western Europe revived economically with its industrial culture and new industrial planning.

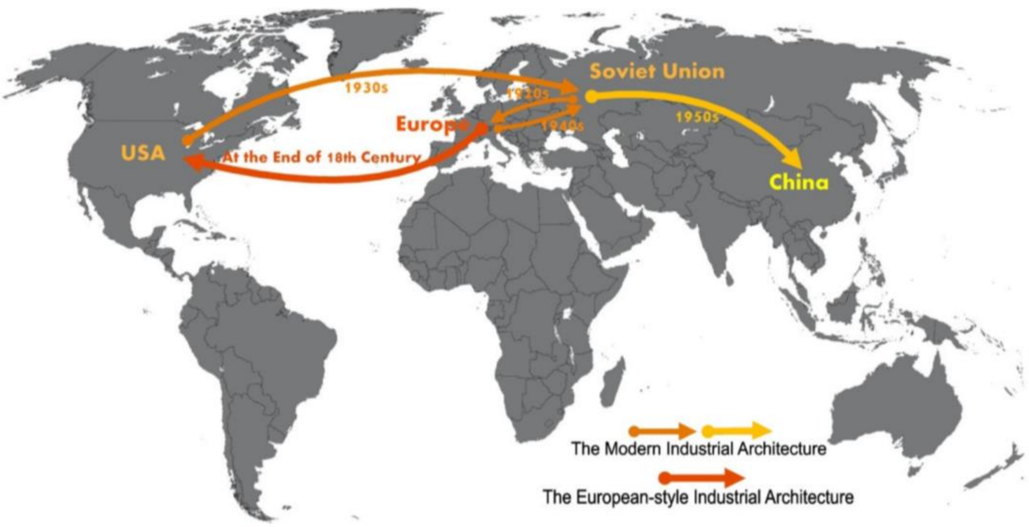


Figure 2.3.1 Industrial architecture map

Similarly, Japan has devoted all its energies to industrial development. Economic and trade links international industrialisation policies gave rise to 'globalization' (Stearns, 2013). Industrialisation went beyond borders and created a new social order worldwide. High-speed air travel, satellite communications, the Internet, and computers led to the creation of multinational companies. Although the industry does not create the same economic impact and efficiency everywhere, it has become a global experience.

In an increasingly globalised world, the main goal of business has been to reach the consumer. The supply-demand cycle became directly linked to the factory and sales relationship. This has shown that central control points are no longer critical. Many companies have created a new production network with less manpower and lower costs by outsourcing their production to local companies. The digital display and feedback logic of production began to be applied to consumption. Thanks to barcodes on products, manufacturers were immediately informed of what was sold or preferred, and the product and consumer-oriented production process was accelerated. While the storage areas of the factories became smaller, the circulation areas, which facilitate logistics, began to increase.

As global production and consumption preferences increased the number of industry parks or zones, factor architecture was also influenced by this global power. Since marketing came to the fore in the third industrial revolution, the industrial appearance and factory aesthetics began to be considered. It is considered that the convergence of the factories and the creation of a campus or a region positively affects the exhibition and marketing of the products and the logistics benefits.

As a production campus, the Vitra Campus, located in Weil am Rhein, Germany, is a remarkable example, thanks to its design (Figure 2.3.2). When the old site of the Vitra factory burned down in 1981, the company wanted to design a brand-new campus. First, Nicolas Grimshaw designed two factories. Later, the campus was enriched with the designs of names such as Zaha Hadid, Tadao Ando, Frank Gehry, Herzog & de Meuron, SANAA, Alvaro Siza, and Kean Prouvé. It has become a place where Vitra's designs and buildings are exhibited.

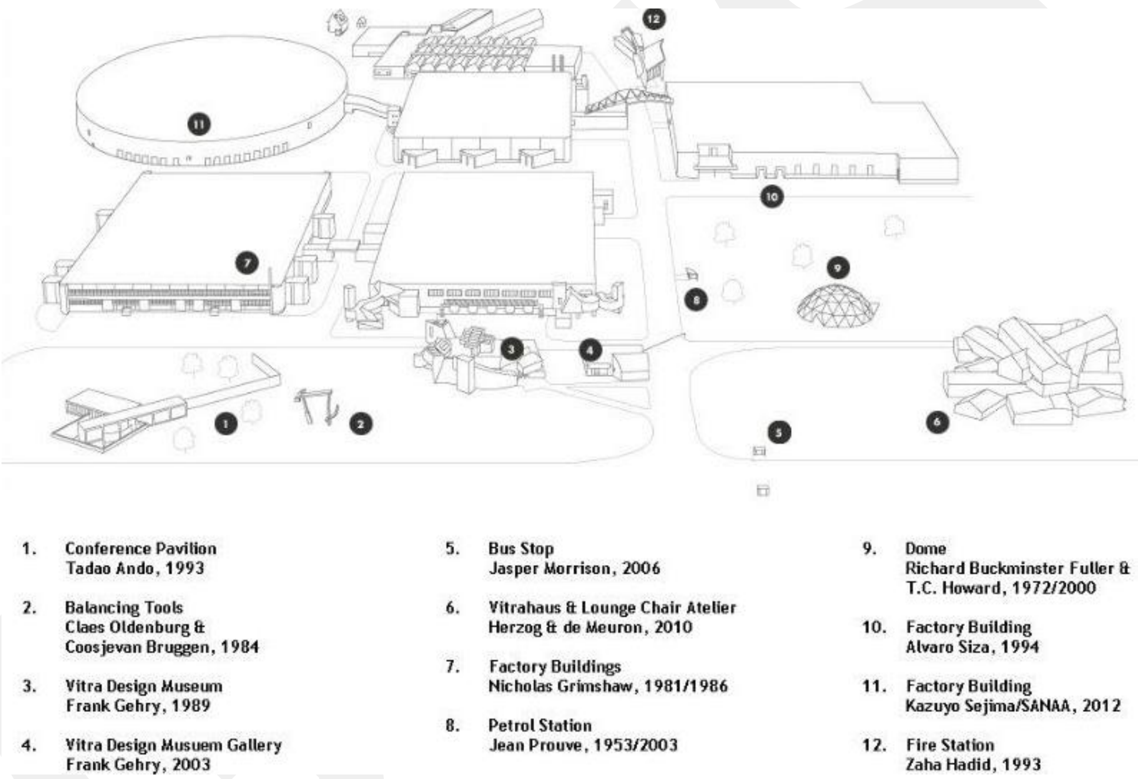


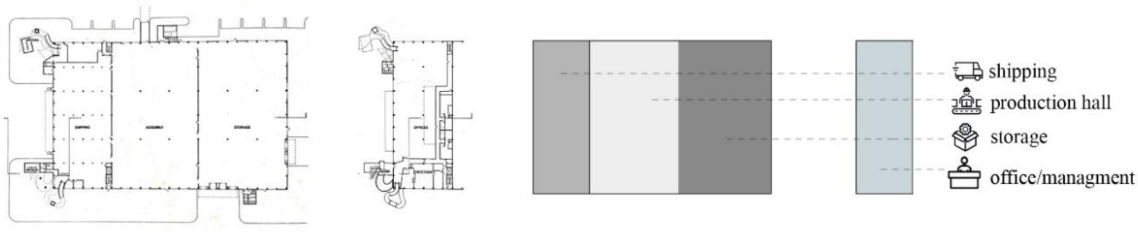
Figure 2.3.2 Vitra Campus

In the recent past, factories were often buildings that followed the Albert Kahn model of assembly line organisation. This model was quite economical in terms of efficiency and operability. For many years, the most common factory model consisted of a steel-framed machine room and a small office block. The aesthetics of the factory was something that investors rarely cared about when it came to building an image. The factories on the Vitra Campus became innovative examples in this context.

The Vitra Campus was not just a place where factories were located. A conference hall, museums and a Vitrahaus, where products were exhibited, were built on this area. As a result of the idea of exhibiting products, the production campus turned into a museum where factories are also exhibited. One of the factories located on campus was a Frank Gehry design. The building entrance door is similar to the Frank Gehry Design Museum, which is located next to the factory. The factory includes production halls, exhibition space, test rooms, and offices. The windows of the factory are designed to allow visitors to see the production process (Vitra Campus, 2021).

(1)

(2)

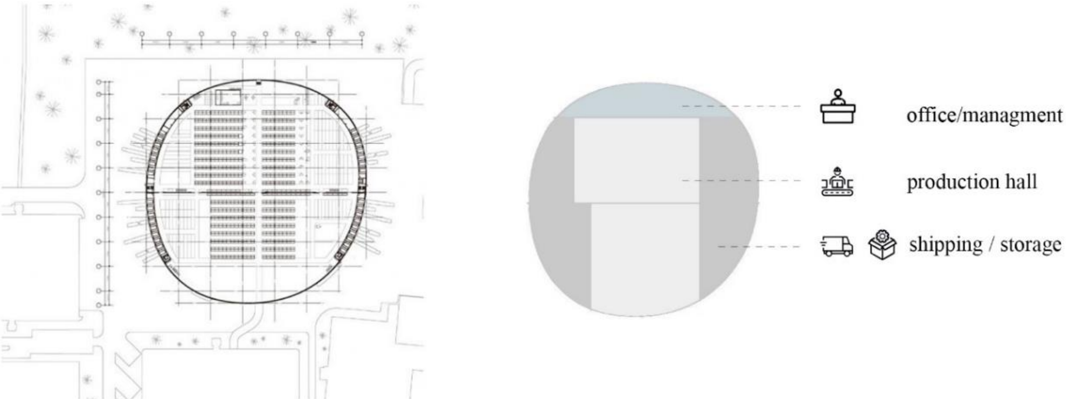


(3)

Figure 2.3.3 Frank Gehry Vitra Factory

The last production building of the Vitra Campus was designed by SANAA (Figure 2.3.4). It was aimed to use a flexible and accessible space for the factory building, which has a larger area than all the buildings on the campus. The central assembly works of the building were designed in a geometric form close to the flat, and its walls were reserved for the storage and shipping area. The high-bay storage system is set to be removable and rebuildable. The loading area is arranged around the building. Offices within the factory cover a tiny area and can be relocated thanks to the flexible spatial design. (Factory Building on the Vitra Campus SANAA, 2022).

(1) (2)

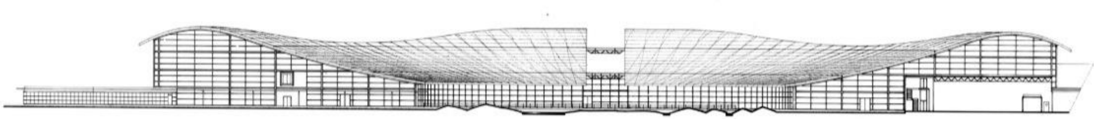


(3)

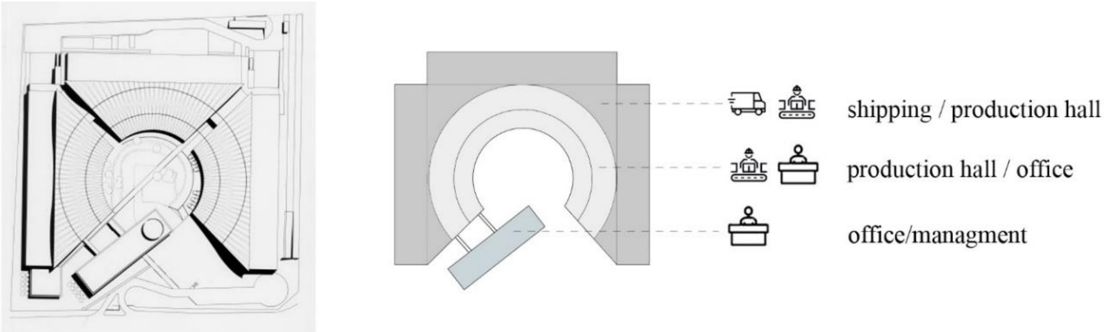
Figure 2.3.4 SANAA Vitra Factory

The remarkable detail in the L'Oréal factory is that the entire production and working hall can be displayed. The factory was inspired by a three-leaf orchid. A green courtyard was created, and production units were placed around this courtyard. Workshops, warehouses and logistics units are lined up from the courtyard to the outside. Bridges between the workshops were designed, thus ensuring the circulation of people without interfering with the production on the ground. A rectangular office building, completely separate from the production part, has been added to the factory (Usine L'ORÉAL / Aulnay-Sous-Bois, 2022).

(1) (2)



(3)



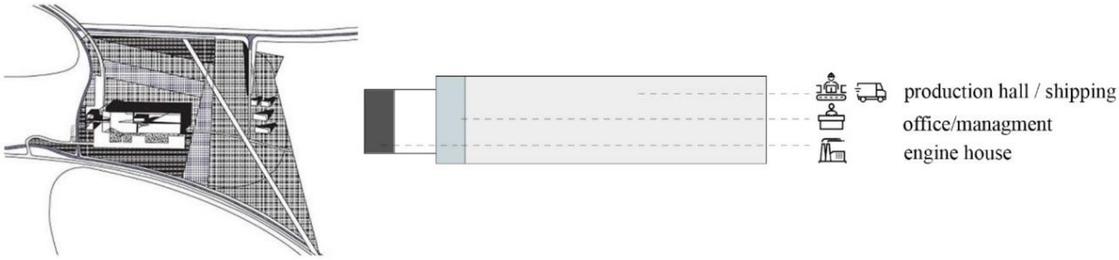
(4)

Figure 2.3.5 L'Oreal Factory

While the factories were designed, the type and size of the production were the priority, but it pioneered the architecture of many factory periods. Coop-Himmelblau argues that industry is a culture and that this can emerge with a multidimensional design, even with economic and functional constraints. The Funder Werk Factory building, designed by Coop-Himmelblau in Austria, has entirely different details for a factory. The production section is designed as a head-body with offices and laboratories. On the facade of the building, which is a paper-coating factory, chimneys, transparent roof detail, and red facade elements increase the visibility of the building aesthetically as well as their static functions (Funder Werk, 2021).

(1)

(2)



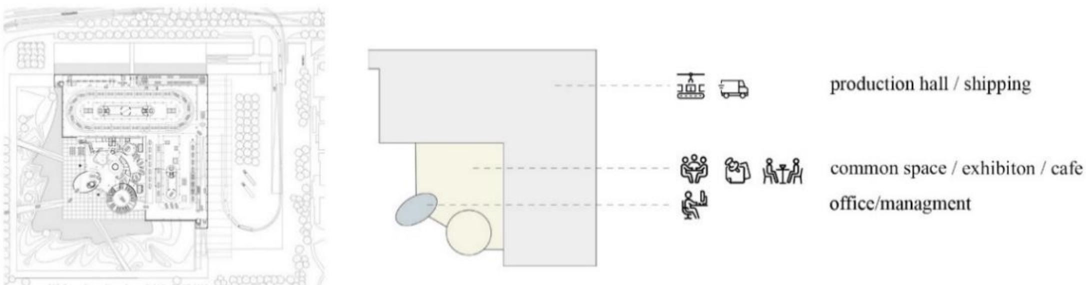
(3)

Figure 2.3.6 Funder Werk Factory

The fact that the factories are visible or noticeable is also effective in marketing the products produced. Henn Architecture has produced exhibits with the transparent factory designed in Dresden. The main goal of the automobile manufacturing company is to show customers and visitors how the automobile is produced. To achieve this, the factory building was designed to be completely transparent. Production steps can be followed on every floor of the building, and the product can be tested in the same building. In addition to production, this factory has also been used for events such as exhibitions and concerts (Glaserne Manufaktur, 2021).

(1)

(2)



(3)

Figure 2.3.7 Transparent Factory

The third industrial revolution was a period in which the world was industrialised to a large extent. Production, marketing, trade and, therefore, competition on a global scale had increased. In this case, the factory entered a new transformation process to provide its manufacturer with a brand identity and become an icon in addition to its modern identity. New functions such as exhibiting, displaying and making the production transparent were discussed. The factory began to become a more accessible place.

2.4 Re-Coding Production Space

The morphological coding of the factory title contains a brief discussion about production organization. The evolution of the factory throughout the process is examined, and what each period adds to the factory and how the factory is affected by these revolutions are deciphered. The plans of the factories have been coded morphologically. Ultimately, this discussion will form a background before moving on to new production spaces, which is the main aim of the thesis.

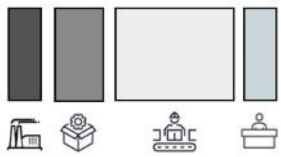
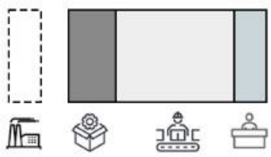
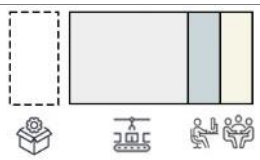
Factory: architectural symbol of the revolution. When small workshops became insufficient for production, factories with larger machines began to be built. In factories, raw materials are processed, turned into products, and shipped. Therefore, in these building, the transportation of raw materials and products and the requirements of the machines used in production were the primary design problems.

Another problem of the factories was the team that would manage the production, operate the machines and employ the people in the production. Housing was the biggest problem for those who migrated from the village to work in the factory. Choosing a location for the factory and the town that would be built around it was another problem. In the early days of the revolution it was quite difficult to get used to this new order. Although the first production factories brought accommodation and housing problems, the company towns designed later were a solution for both producer and employees. The housing problem was partly solved by companies building company towns, which provided a healthier environment for workers and their families.

Factories had to be large buildings because they housed large machines. In the first examples, the production hall, the management and office section, the power house and the warehouses were built as separate buildings. For this reason, the first factories were industrial parks with many sections. The first examples did not show any modern influence. Similar factories were built around them, using existing building materials and techniques.

When the second revolution began, cities were built around factories and the population increased. Urban plans drawn up by the states solved the problems of education, health and housing. The potential for production and consumption increased, and more factories and businesses were established. During this period, factories became singular. The daily life and after-work life of the workers was left aside and the focus was on the scale of the factory itself. Factories also symbolised the new in this period. New products were being made that did not exist or had not been made before and, unlike the first revolution, new techniques were being tried and applied. Materials and techniques were applied in the same way in architecture. This is why factories became landmarks of the revolution. From being an industrial park, the factory evolved into modern structures that combined production, management and other support functions.

Table 2.4.1 Industrial revolutions and morphological coding

period	**morphological coding**	**framework**
1.industrial revolution		production+ engine house storage production hall offices
2.industrial revolution		production+ engine house storage production hall offices
3.industrial revolution		production+ storage production hall offices common space

The modern factory was both the production location and the brand of the manufacturer. Iconic examples of these structures, which are highly functional and have planned and regular users, continued to be designed. The third revolution made computerized systems available in production, now providing flexibility in production and space. Just-in-time production methods were added to mass production technology. Thus, production spaces began to be used more economically and effectively. The factory was cleared of warehouses, engine houses and other helper units. All these units have become small enough to be added to the main production hall.

In summary, the production halls were characterised by the stages in the transformation of raw materials into products. The machines, energy sources and installations used determined the size and physical structure of the spaces. The production preparation process, the post-production stages, the type of product and even the brand and marketing values became the design criteria for factory architecture. The ideal production order and environment for all technological revolutions was and is sought in the factory.

Chapter 3

Digitalisation: Future of Production

This chapter discusses the future possibilities of production. With digitalisation, the industry and the factory have entered a new era. While this term is experienced on the one hand, on the other hand, its future state is imagined, and its development and results are wondered. For this reason, in this chapter, the concepts that led to the revolution are examined, and how these concepts are perceived in new production spaces is investigated. After all, this section aims to understand the present and the future.

The First Machine Age began when James Watt discovered the steam engine. II. Machine Age began with software, robotics, and artificial intelligence technology, and these developments soon gave rise to new technologies and a new industrial transformation for humanity. Now, Industry 4.0 was first introduced by the German National Academy of Sciences and Engineering (ACATECH) at the Hannover Fair in 2011. The concept describes a smart manufacturing model that is digitalised and customised according to customer demands, enabling simultaneous communication and connection between people, machines and products. Industry 4.0 is known as “Factories of the Future” in Europe, “Industrial Internet” in the USA and “Internet +” in China (Wang, Wan, Li, & Zhang, 2016).

Industry 4.0 is considered to be a driving force that will not only influence German industry, but also international industrialisation and guide production in the future. For this reason, knowledge-based factories will be built to significantly increase efficiency and competitiveness (Zhou & Taigang Liu, 2016). In order to progress in this regard, Germany, academia, industry, and government jointly organize forums and support academic studies on the subject. In the USA, the Advanced Manufacturing National Program Office in the National Technology and Standards Institute develops standards on the topic in collaboration with industry. The United States works with the terms Industrial Internet of Things (IIoT), Advanced Manufacturing (AM), Re-industrialization

(RI), and Internet of Things (IoT). Japan's Industrial Intelligence concept draws attention to machine-to-machine communication and autonomously controlled machines (Ernst & Frische, 2015). The Japanese e-Factory concept aims to use advanced industrial internet and make the factory visible, measurable, and manageable. Undoubtedly, one of the countries that quickly adapted to the process, China improves product innovation ability, gains quick market response-ability, and enhances automatic, intelligent, flexible and highly efficient production processes and approaches across national manufacturing industries. This initiative focuses on a modern production model. Similar studies are being followed in Korea, and efforts are being made to spread smart production and smart factories. Trainings are planned to encourage digital transformation in production and support innovations (Kang H. S., et al., 2016).

The determinants of the new mode of production in Europe are social urbanization, access to information, class conflict, education, technological research and development, new materials, customization, urban manufacturing and big data; in economic terms, it is listed as human capital, new production services, cooperation and competition, new markets and competitors (Flynn, McCaffrey, & Sejal, 2013). However, although the new industrial revolution defines these production technologies and steps, the existing knowledge is insufficient for a consistent smart factory definition (Strozzi, Colicchia, Creazza, & Noè, 2017).

Smart products, smart production, smart factories and smart cities are the leading concepts of this revolution (Roblek, MešKo, & Krapež, 2016). These concepts give clues about where and how production will operate. In addition to the definition of smart factory, definitions such as U- Factory (ubiquitous factory), the factory of things, the factory in the real-time frame and the intelligent factory of the future are also used in the literature (Hozdić, 2015). In these factories, production information and communication systems become more efficient, safer, and more environmentally thanks to data integration, making production with the Internet of Things (IoT) technologies. Sensors and artificial intelligence drive production and maintenance; mobile and augmented reality devices provide information processing and productivity to employees; Cloud computing systems enable data sharing and storage. On the other hand, cyber-physical systems help decision-making processes by enabling human-machine cooperation. Increasing the controllability of the smart factory production process based on digital and automated systems aims to reduce manual intervention. Decisions are made entirely in a virtual environment. The foundation of the smart factory is built on interconnection, collaboration and execution (Chen, et al., 2017). Key technologies are essential in transitioning from a modern factory to a smart factory.

Klaus Schwab attributes the existence of the Fourth Industrial Revolution to velocity, breadth and depth, and system impact. Unlike other revolutions, this revolution is not linear but results from capable technologies of exponential speed. In addition to the questions of 'what' and 'how', it is also changing the question of 'who'. Ultimately, it triggers the holistic transformation of systems across sectors, companies and states (Schwab, 2016). It directs production, consumption, people and societies to change. Because this change also exists in a virtual network, it is progressing rapidly compared to other revolutions.

The most intriguing innovation of the revolution is unmanned production technology. In this chapter, unmanned production and unmanned production methods are first discussed. In the transition from traditional production methods to smart production methods, the characteristics of factories are also changing. Smart factories, defined as the production space of the fourth industrial revolution, are the focus of this section. However, since it is a term that is still being experienced, other types of production spaces between traditional factories and smart factories also attract attention. Factories whose primary function is to produce and where smart production systems are used are discussed in this section. As in Chapter 2, the new production spaces corresponding to this period are examined morphologically. Finally, this new state of the factory is discussed.

3.1 Production without Human

Unmanned production began with unmanned consumption. Digital shopping brought people together with the object in an interface, and virtual connections and agreements began to be created between the consumer and the producer. Behind online consumption was a preparation process that started with humans and then transferred to robots. Large warehouses were built where many products, such as books, textiles and food, were stored. Despite all their products being together, a sales order/algorithm was created for the process to progress fast and smooth. An unfamiliar typology emerged with warehouse-production areas designed for similar shopping sites, such as the Amazon warehouse, which was designed as large as nine football fields (Young, 2019).

Figure 3.1.1 Amazon Fulfilment Centre

The Internet has been a supporting force in the spread of production and consumption. While it took about 120 years for spinning machines, the symbol of the first revolution, to spread outside Europe, the internet spread in less than ten years. (Schwab, 2016). The digital revolution is spreading in direct proportion to the speed of the internet. The internet provides an easier, more quickly accessible environment for producers and consumers. However, the data that allows this virtual environment to form and grow is stored in non-virtual spaces. Data Centres are unmanned spaces consisting of machines and energy systems that allow information to be stored and processed in a single place.

(1) (2)

Figure 3.1.2 Facebook Prineville Data Centre

Digital consumption brought digital payment options and a new technology industry: Coin mines. A digital coin whose value is calculated by hydroelectric power is produced in China. For this, a location close to the power plants of the region is chosen, and a factory is built where money-generating machines are housed. There are only machines here, not people. The workers can follow the machines on their mobile phones.

Figure 3.1.3 Bitcoin Mine

Smart production is also defined as dark production, as it is a process led by machines without the need for any human being in the production process, and for this reason, new production spaces are also called *dark factories*. The dark factory was first mentioned in Philip K. Dick's story 'Autofac', published in 1955. A factory that can operate entirely autonomously is depicted. Moreover, in Kurt Vonnegut's book Player Piano, published in the same years, unmanned factories are also described (Vonnegut, 1999). In the book, the entire political and economic operation of society is also controlled by computers. Vonnegut describes a society experiencing the third industrial revolution in his novel Player Piano: the first industrial revolution devalued muscle power, and the second industrial revolution devalued routine mental work. The third industrial revolution gave birth to the process of devaluing human thinking and real brain power (Vonnegut, 1969). As a result, the machine does the management, and society gradually thinks that their qualifications and knowledge are becoming worthless.

Nowadays, in the Fanuc factory in Japan, established in 2001, one of the most well-known examples of dark factories, production can be carried out for a month without any intervention. This dark factory was not only a factory but also a production facility. The industrial park owned by FANUC consists of 22 factories and is used by robots. Robots can produce another robot without human intervention and do it nonstop (Hunt, 2017). According to the research conducted by McKinsey & Company in 2017, the number of workers required to supervise robots in Japan has been reduced to four and more robots have been started to be employed in the Fanuc factory, which produces robots (Tilley, 2017).

Similarly, Siemens Amberg Factory has created an efficient and error-free production ecosystem (Digital transformation: Leading by Example, 2022). Thanks to the digital twin created, the factory can be viewed online, and the systems can be viewed remotely. In the report prepared for the factory, a reliability rate of 99 per cent was determined, and only 15 defective transactions per million were recorded. This small percentage is also expected to decrease with the system's ability to learn from errors.

In 2017, the Adidas Speed Factory produced 50,000 shoes a year with 160 employees and robots. In the Netherlands, the Philips Dark Factory employs 128 robots and nine people. Factories have also become a place to experience human-robot collaboration. New job descriptions have been defined for humans and robots working together. While robots work non-stop, human working hours have decreased.

Changes in the relationship between humans and workplaces are also expected in future factories. In the context of Industry 4.0, human comfort, environmental problems, and industrial sustainability are among the most researched topics (Kumar, Narkhede, & Jain, 2018). While many people can participate in various tasks in all areas of production before smart production, it is thought that fewer employees will be needed for process-based tasks in these factories. In general, this is mentioned as focusing on humans in manufacturing. In this case, the role and needs of employees should be reconsidered by applying technological methods (Gorecky, Schmitt, Loskyll, & Zühlke, 2014). The unmanned production of the factories began to bring along a series of innovations in space. In a factory that produces without light, the conditions that will ensure the comfort of people in the space are eliminated.

3.2 Fourth Industrial Revolution: Smart Factory

The production space for the smart systems of Industry 4.0 is also defined as the smart factory. The smart factory technically ensures that all machines, robots, sensors, and production lines work interconnected and automatically. In addition, smart editing detects and prevents machine problems that exchange information for the entire system and manage the whole process (Gabriel & Pessl, 2016). In factories that produce remote solutions to all the complexity in production, direct communication is provided between humans and machines. Unlike the mass production model in smart factories, a flexible production model is being adopted instead of a single product or production line. For this reason, the production space is expected to be suitable for flexible production. Although people are isolated from the production space, it is not clear how they will relate to production and where they will be involved in the production process.

One of the first smart production spaces, Wittenstein Innovation Factory draws attention with its innovative space approach during the transition to Industry 4.0 (Figure 3.2.1). This factory combines development and production activities but is designed to be flexibly with modular expansion options. The building, development, production and shipping are designed in parallel, but the innovation division has grown significantly. Customers can access the production and project sections from the open gallery (Innovation Factory). A flexible working environment has been designed next to a flexible production space, where production occurs and as a co-working place. This is one of the first steps that differentiates the innovation factory from the traditional factory typology.

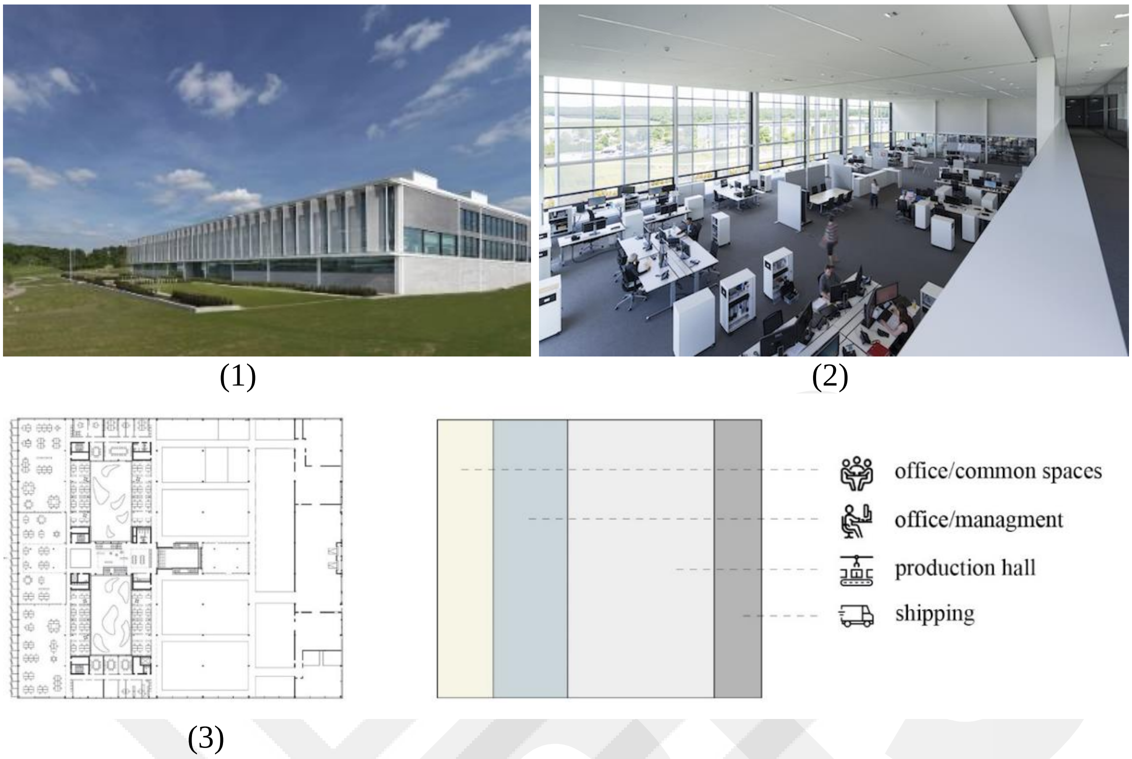


Figure 3.2.1 Wittenstein Innovation Factory

As a similar example, where the factory and innovation are combined, Arena2036 is conceived as a research centre for the next generation of cars (Figure 3.2.2). A flexible and dynamic studio is envisaged to develop and produce innovative production technologies for this centre. Arena36 aims to bring together different professional perspectives, working cultures and approaches and bring innovations produced in collaboration with other disciplines to the industry. Another aim of the formation, whose focal point is the automotive industry, is to contribute to shaping the future production style in the digitalisation process (Arena 2036). In this context, Arena 36 also adds the possibility of co-production to its co-working standards. A simulation of future production and the ability to produce together has occurred there.

The building has a large production hall, offices and a warehouse, similar to a factory. However, unlike the old factories, the production hall is designed to provide flexibility and variability, can be adapted to the combination of humans and machines, accommodates various test equipment, and has mobile offices.

(1)

(2)

(3)

Figure 3.2.2 Arena36

Trumpf Smart Factory is one of the first factories designed with smart factory functions (Figure 3.2.3). An abandoned production park with a shopping mall, church, school, and one-story houses was purchased for the factory building. The factory, designed in two large volumes, was built in a green area. The transparency of the factory and its symbiotic relationship with the environment has been compared to Le Corbusier's idea of the Green Factory (Barkow, 2021). The factory is designed with Industry 4.0 technology, from product design to production and delivery.

A digitally interconnected, controllable, and non-stop production model has also become an exhibitable space for visitors (Trumpf Smart Factory Chicago). The designers set up these two completely different functions, such as production and exhibition, in the same building, enabling the display of high-tech machines and production processes. One of the rectangles forming the building is planned as a production hall and the other as an office, cafe and auditorium. A special viewing area has been created for the visitors by designing a *skywalk* inside the production hall.

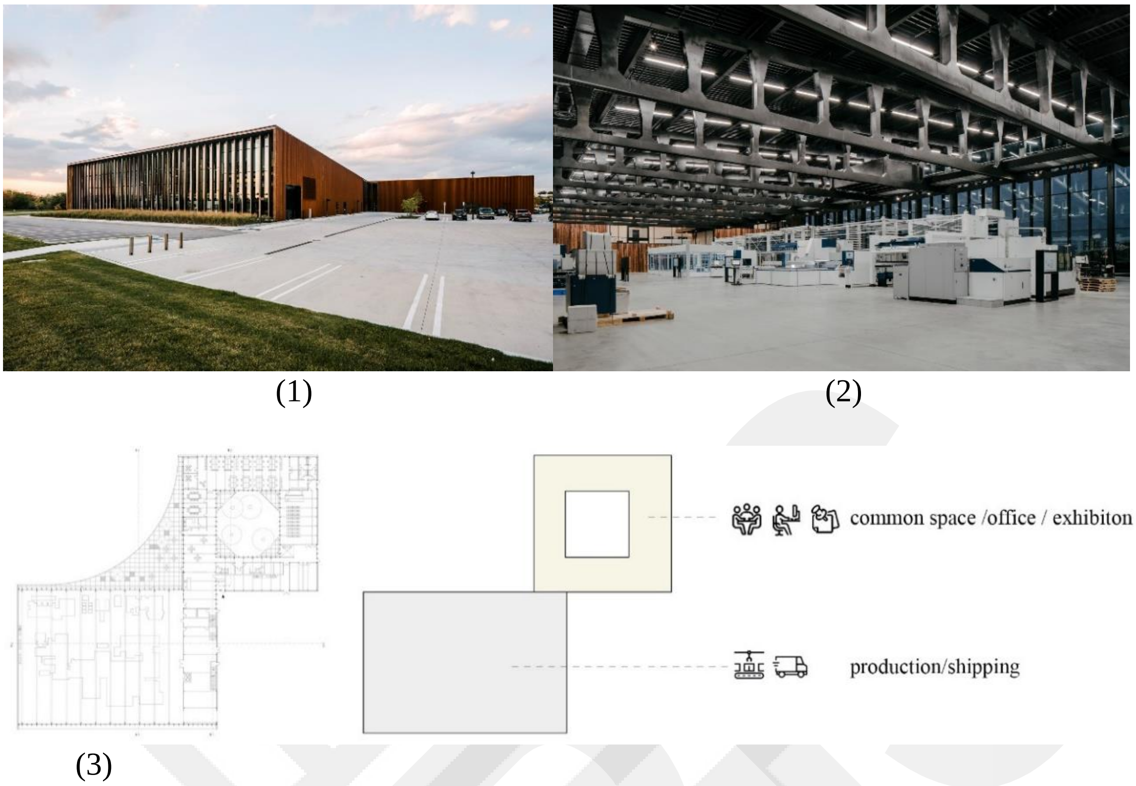


Figure 3.2.3 Trumpf Smart Factory

The Plus Factory, built in Norway, draws attention to both sustainable goals and aims to produce with new technology. The manufacturers wanted the building to be environmentally and follow the principles of renewable and clean energy by production. For the furniture production facility, the architects envisioned a small village with hiking and camping areas in addition to the factory (The Plus for Vestre / BIG). The factory becoming a part of daily life and routines is again experienced with Industry 4.0. The location chosen for the production facilities, the connections and the effort to connect them with social life positively impact the sustainability of the production.

The factory consists of four main halls connected in the centre: a warehouse, a colour workshop, a woodworking workshop, and an assembly workshop. Logistics offices and exhibitions are connected to all the halls in the centre. This area has been designed transparently and has turned into a courtyard open to all visitors, exhibiting the entire production process. In this factory where furniture will be produced, it aims to use smart robots, driverless trucks and tablet computers to manage the factory. For this, coloured sensor maps for robots are designed on the ground. In addition, these maps are considered clues to guide the visitors through the production process (Figure 3.2.4).

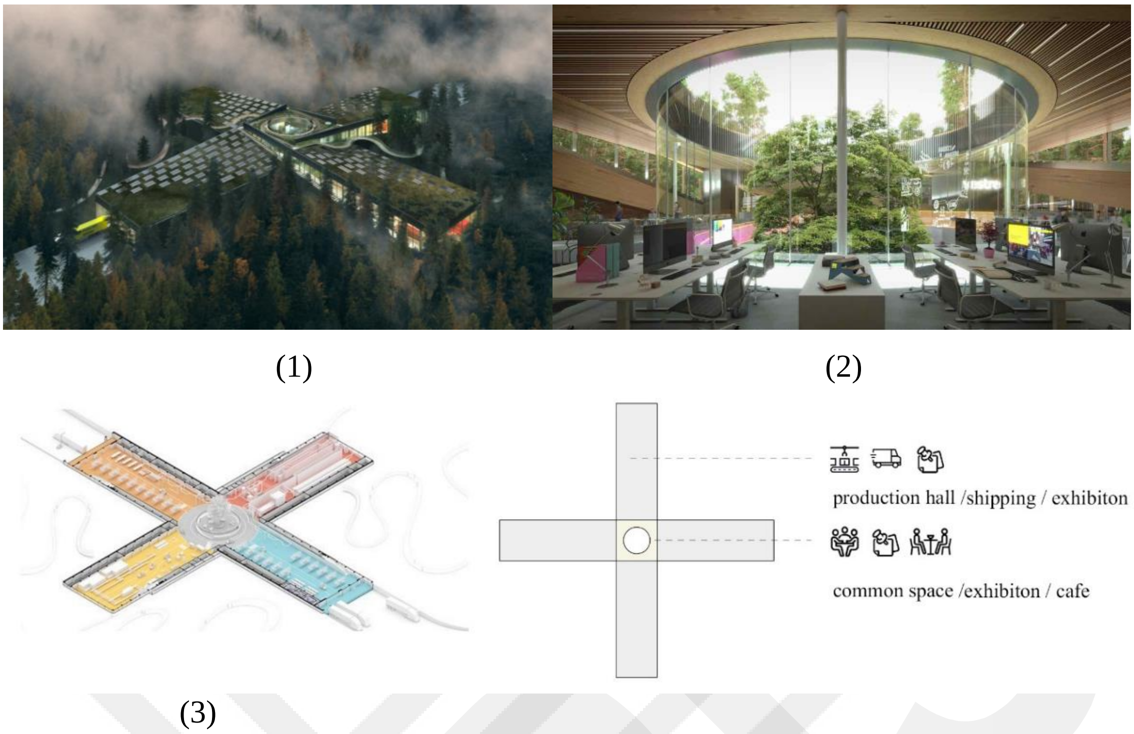


Figure 3.2.4 The Plus Factory

The number of smart production facilities is increasing in China, where smart technologies are used intensively. New factories have not been established for all smart production and trials. The first choice of manufacturers is generally to convert their existing factories for economic reasons. However, manufacturers who want to make this transformation to be more visible build new factories where production and consumption occur together. This unity also changes the user profile of the factories. The Future Stitch Smart Factory, located in the economic development zone in Haining in 2018, is one of the first examples (Figure 3.2.5). The factory, which produces socks and sports equipment, is also used for sports events and artistic activities (FUTURE STITCH Smart Factory / AZL Architects).

Stairs and corridors were designed outside the building, creating temporary open spaces for employees. For the factory, production workshops and a visiting circulation that allows the process from raw material to product to be exhibited are designed on each floor. The other part of the factory has a basketball court and a roof garden. The factory entrance door is common for administrative staff, workers and visitors. The galleries located to the east and west of the factory create an experience for the bottom-up production process and artistic activities.

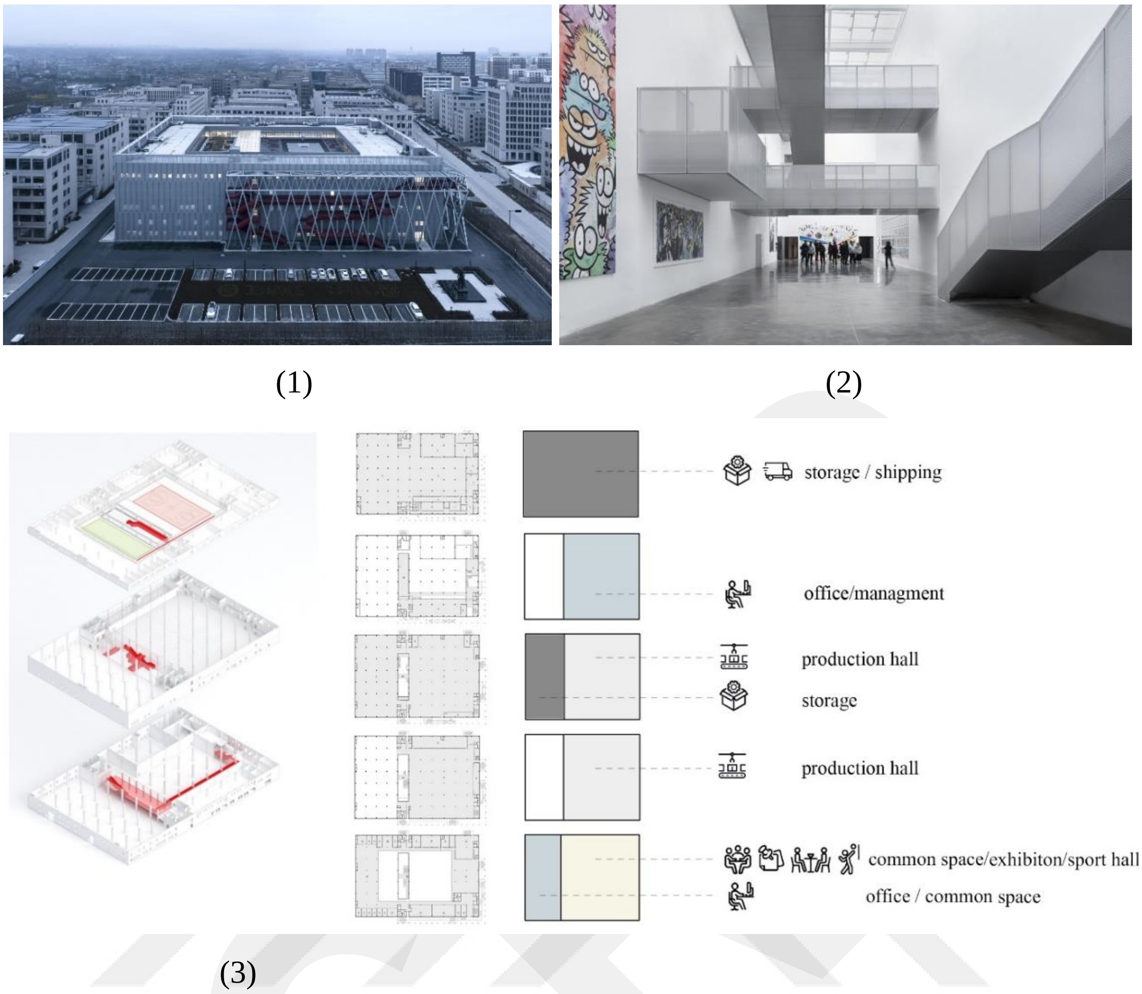


Figure 3.2.5 Future Stitch Smart Factory

The number of industrial cities has been increasing in China, guided by the traditional economic growth model. The production organization is effective for these production areas with low costs and high efficiency. In this context, Zhejiang Factory is attractive with its design approach. It creates a new order for the production area and the industrial workers who will work or even live there. This suggestion brings to mind the first design condition of the factory after the Industrial Revolution. In the new revolution, the reunion of the factory and the house suggests that the robotic production space could be a part of the house. The architect of the factory first created a courtyard to provide easy access to the space, surrounded by the production workshop, laboratories, offices, and living space. The dining hall and life service centre were designed at the centre of the site. In addition, the architect designed a stair that continues inside and outside the building to connect all the units. In addition to its primary function, the stairs are break and rest area (Zhejiang Perfect Production Factory, 2022).

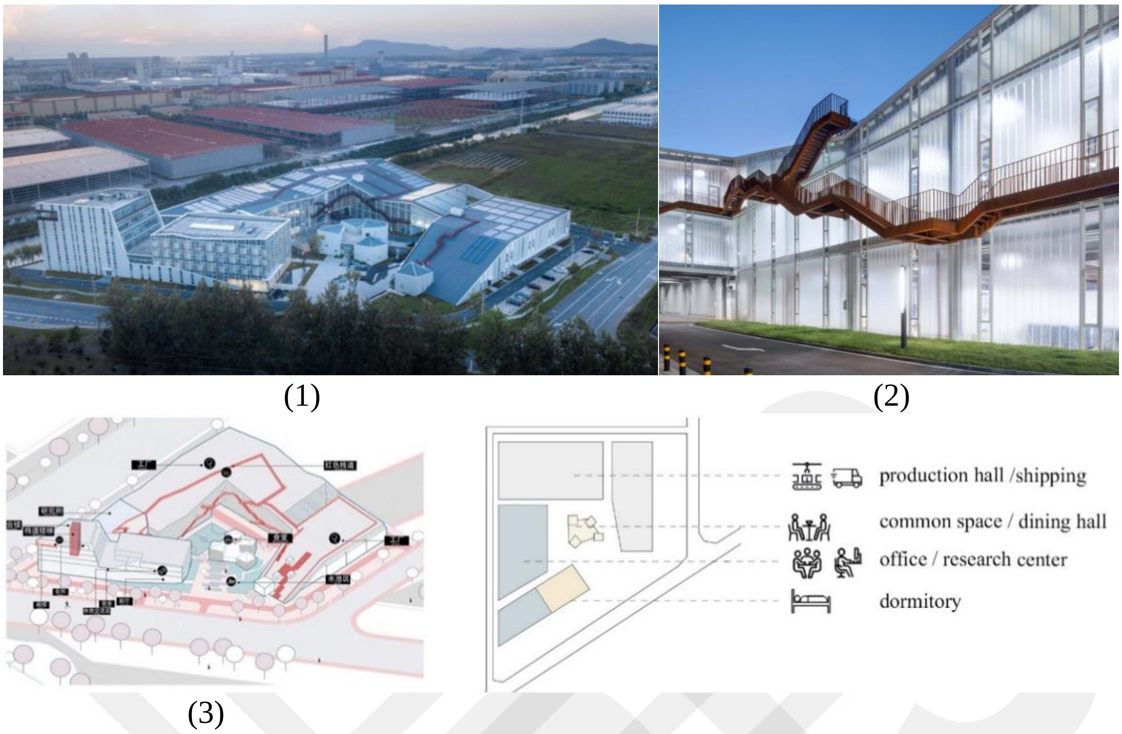


Figure 3.2.6 Zhejiang Factory

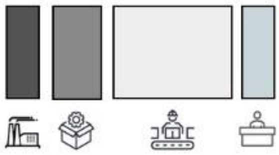
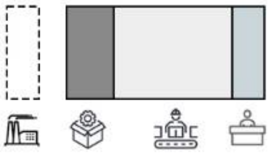
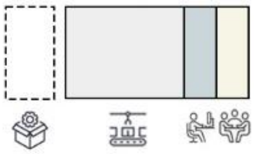
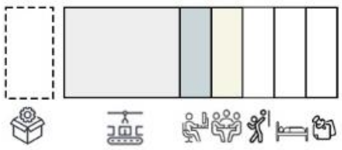
The smart production spaces of Industry 4.0 differ significantly from the space typologies of traditional factories. In addition to the theoretical definitions of smart factories, it can be said that the planned and designed factories are in a new search. The diversity provided by robotic production, remote control systems, and on-site display of the products and production has changed the standard operation of the factories.

3.3 De-Coding Smart Production Space

The discussion in this chapter complements that in Chapter 2. Innovations in the factory in the new industrial revolution are discussed in relation to previous research findings (Table 3.4.1). The information in this chapter will contribute to the description of future factories or future production spaces.

In its simplest form, the factory consisted of an energy house, storage, production and management units. The reduction of these units or the addition of different units varied according to the production energy, method and technology. The use of electricity allowed power houses and storage units to be added to the production hall as smaller units over time. As machines began to do more work, workplaces were created for workers to control production. As the number of machines in the production hall increased, the number of workers decreased and common areas were created for employees and other factory stakeholders.

Table 3.4.1 Industrial revolutions and morphological coding

period	morphological coding	framework
1.industrial revolution		production+ engine house storage production hall offices
2. industrial revolution		production+ engine house storage production hall offices
3. industrial revolution		production+ storage production hall offices common space
4. industrial revolution		production+ storage production hall offices common space exhibition sport hall research centre dormitory

Units such as energy houses and storage, which were no longer needed in the factory, were not units that people used directly. The shrinking or non-construction of these sections or annexes over time allowed the factory to simplify. Machines became small, and robots entered the space. The production hall also became a place of both production and experience. New suggestions such as research, exhibition, sports and housing have been added to this experience, and it seems that they will continue to be added. The factory of the digital revolution is becoming a multifunctional typology.

Visually, it best expresses the industrialised way of life: centralised, huge, capital-intensive factories, equipped with gigantic machines and filled with workers producing mass-produced products on assembly lines. What happens now when many people make faster and cheaper mass or individual production at home or at work, with quality control equivalent to these giant factories (Rıfkın, 2013)? Jeremy Rıfkın summarizes the entire criticism of the digital revolution with this description and the following question. This revolution has only just begun, and it has experienced changes in production, economy, working life, work order, producer, consumer, and, ultimately, factory codes.

Chapter 4

Transition: Consumption of Production

[*]The definition of 'Consumption of Production' belongs to Nina Rappaport.

This section of the thesis focuses on production dynamics during the revolutions and critiques the transition. It examines human interaction with industry and factory, the positions taken in this adventure as producer, consumer, and now prosumer. The significance of factories for both humans and machines is discussed, as is the evolutionary process of the factory as a production space. Furthermore, this chapter explores the relationship between the production and consumption processes of urban areas, highlighting the conceptual gap between traditional factories and the factories of the future.

Industry 4.0 is a revolution not only in the industry but also in the machines and factories. It involves the physical transformation of the factory, as well as changes in the labour, knowledge, and power that created it. The relationship between production, time, people, and space is being redefined. Production actors have transitioned from humans to machines, from machines to digital screens, and from digital screens to robots. The place of production has moved from workshops to factories and now to unmanned factories. This transition seeks ways to consume the production. For all that, a place of production is sought inside or outside the city.

Over time, the ways of producing and consuming have developed their own culture. Generally regarded as a production theorist, Marx argued that production and consumption are strongly linked and that raw materials, means of production, labour, and time are consumed in the production process. Likewise, Marx said that people are in alternating relations as producers and consumers. Producers needed to destroy raw materials, and consumption was a must for production (Ritzer & Jurgenson, 2010).

However, the popularity of consumption gradually increased, and it became a distinct culture. While production and consumption remained balanced, consumption took on a more prominent role.

While Karl Marx focused on production, Jean Baudrillard and Alvin Toffler focused on consumption. Baudrillard described the result of this transformation as a consumer society or consumer capitalism (Baudrillard, 1998). Alvin Toffler coined the term 'prosumption', a combination of production and consumption, to explain the changes and transformations in the new consumer society (Ritzer G. , 2015). Similarly, a 'prosumer' is a producing consumer resulting from the combination of producer and consumer. The concept is based on the transfer of work from wage workers to consumers who produce for free. The idea of the producing consumer quickly became pro-consumer (Kotler, 1986). Economies began to shift towards consumption activities. Just as postmodern thought criticises the modern, consumption culture also began to criticise production.

The focus of early capitalism was production, which was primarily located in factories. However, Hardt and Negri argued that production occurs across society, not just in factories (Hardt & Negri, 2001). They developed the term social factory or factory without walls. Physical labour in production has decreased because many factory jobs do not require material labour. It was thought that a product was a production process in its activities for selling and marketing as much as the production process. The service sector forced the consumer to produce. This is evident in the rise of self-service options in restaurants and shopping malls, which have given birth to the concept of the 'prosumer'.

Factories were initially created solely for production purposes, but as they produced, they also gave rise to cities and specialised to meet consumer demand. According to Nina Rappaport interprets factories as the key to unravelling the spatial logic of society, defines the factory as predictive rather than prescriptive, and relates modern factories to production and contemporaries to consumption. Rappaport also describes this period as consumption of production (Rappaport, 2021). A factory is no longer solely a place of production; it has evolved into a space where production is showcased and time and space are consumed alongside the products. The process of transforming raw materials into finished products is now presented as a live exhibition, led by robots, departing from the rigid structure of mass production.

Cities also began to be consumed like products were consumed. Firstly, the producers moved their factories from the city to the suburbs for better consumption in the city. Low costs outside the city were attractive to producers. Although it was thought that moving the production away from the city would solve many environmental problems, this caused many logistics problems. However, this caused logistical problems and increased transportation costs for workers. According to Hatuka and Ben-Joseph (2017), separating factories from urban areas created a spatial disparity between social classes and income.

Nowadays, it is discussed that production should be reintegrated into the daily activities of the city. While the factory returns to the town, it is expected that the streets will provide movement between the producer and the consumer, the open spaces will be used more effectively at different time intervals, the new buildings will support the working environments, and the factories will create an efficient space for the processes within themselves with the common open spaces (Lane & Rappaport, 2020). In addition to the economic effects of this process, the design approach and conclusion are also critical.

In this context, the transformation of production involves three main domains: human, space, and city. The human, who was once the primary actor in production, is now transitioning from a worker to a prosumer, acting as both a producer and consumer. The machine has become the new actor in production, and the factory is now the machine's workplace, rather than that of the human. This raises the question: Where will humans work? A similar question can be asked for factories when remote and placeless work creates a new culture: Where will the factory be in the city? Another question is asked for new cities: Does the city of the 21st century produce or consume? This section discusses the conceptual foundations of this transition, the actor, its space, and the environment.

4.1 Human From 'Laborer' to 'Prosumer'

The Industrial Revolution was a system alteration in many areas. Undoubtedly, the most compelling area was the relations between production and consumption. Although production and consumption coexist with humanity, they have never been so affected by any period or event. Before the Revolution, the guild system was effective in commercial relations during The Middle Ages. It was developed to control the flow of trade and to protect the interests of artisans. This system, which continued with the master-apprentice relationship, was essential to learning and developing the profession. Newcomers worked for low wages, struggling to move from apprentice to master.

The putting-out system was a significant influence on European commerce just before the Revolution. It was an industrial system that differed from the guild system. The employer assigned defined work to workers, and production was typically completed at home. Private workshops were seldom opened. This system was widespread throughout Europe, particularly in the textile industry. In 1786, one of Austria's largest wool producers had over 29,000 employees working in their own homes (Marsh, 2019). Although traditionally women were primarily responsible for this work, all members of a household could be involved. Employees were required to provide their own equipment. Traders and entrepreneurs were able to operate without capital attached to their equipment. However, due to the lack of regulation, capitalists were able to quickly exploit this system. This system was known as rising capitalism, in contrast to the Guild system. Unlike the guild system, wages paid to workers were determined based on their skills and job demands, rather than being equal for all workers. This system encouraged the expansion of production into new markets and aimed at international trade rather than just local trade. As a result, it enabled the foundation of factories to be laid.

The Revolution brought many people together in production. Before the Revolution, production was household-centred in smaller communities, while the factory allowed more people to work together. The industrialization story mainly comprised workers (Stearns, 2013). The factory system defined time as either work or break, and wages were paid based on the amount of time worked, rather than the quantity of goods produced. It was during the 1880s that managers began to use clocks to regulate the factory system. People working at home could take a break whenever they wanted, but every minute counted once they got to the factory.

Frederick Taylor designed a method that has been used for years with the system he developed. Taylor analysed jobs, prepared work descriptions, and listed them. Taylor believed that a worker's work urge was to slow down and advocated the importance of using time correctly to maximize productivity. It also completely changed the mastery system for mass production that emerged. The worker began to take part in only the defined position of production, not from the beginning to the end. The labourers were seen as part of the machines. The factory was a discipline. The planned method of work sets it apart from a workshop. A system was established in the factories, to enable more economical use of time and raw materials. On the one hand, a power source, machines, and production factory existed, while on the other hand, another control mechanism that provided all this order was operating.

The factory has been a workplace for many years, where capital, labour, and machines have continuously transformed it. While the system established by Ford and Taylor was influential in shaping working conditions globally, innovations were also sought for production in a changing world. For instance, Toyota Motor Company developed the just-in-time model to avoid waste or excess stock in its warehouses. Toyota engineers created the 'Andon Boards' digital board to monitor the production process and analyse the situation (Rappaport, 2009). This sign board enables workers to easily identify problems on the production line and develop quick solutions.

In the 1970s, computer controls and CNC machines became fully integrated into production, and workers began operating the systems that controlled them, rather than the machines themselves. This shift in responsibility altered worker activities and job descriptions. Following the linearity of the Fordist production model, various spatial organizations and modules were experimented with. These included R&D areas, 'solar system' layouts, 'mainstreet' spines to encourage personnel interaction, the 'fractal' which housed management near the workers, centralised break areas, and communal entries for both workers and management. The term 'partners' and 'team players' are now used to refer to labourers instead of 'workers' (Rappaport, 2009). Thus, new factories were re-mechanized with workstations and computers. Workstations also reduced the indoor mobility of the workers. Similarly, computers work on modelling, quality control, problems, solutions, and production capacity. This way, workers could work with robots and manage many jobs remotely.

As a result of innovations in the industry, the use of space by production actors has also changed over time (Figure 4.1.1). In the craft production model, the human is active in the design, management, and production, and the process is planned in itself as it is both the worker and the manager of the production. The means of production are individual, and often, the product is expensive, as production is slow. The same quality is not expected from every product in craft production.

Mass production has found solutions to all the negativities of craft production. Employees were assigned to every production, and the jobs were taught. Worker-machine cooperation has been essential. This shortened the duration of the work and enabled faster production. The acceleration of production has reduced costs, but the effort to produce thousands of identical products has affected product quality.

When lean production was introduced, the role of machines in worker-machine cooperation increased. Workers began to monitor the production process from the machines, resulting in a gradual decrease in the error rate. Production efficiency, speed, and quality have improved compared to the previous system, while wages have decreased. Lean production requires planning the process before, after, and even in the long term. This involves defining new tasks for workers based on the production model at the place of production and on time. During the transition from material to immaterial labour, machine movement in production increased while worker mobility decreased. This resulted in more stable and cleaner production in factories.

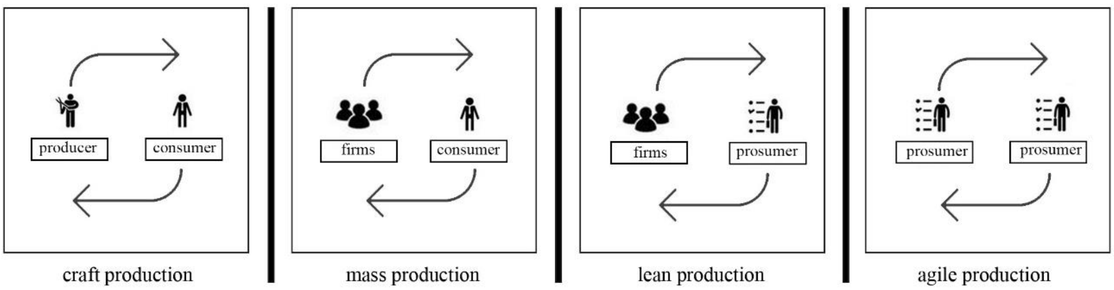


Figure 4.1.1 Human and production

Negri and Hardt describe the changes in the capitalist mode of production defined as post-industrial, post-Fordism, and knowledge economy as bio-political production. This concept focuses on the transition from object production to life and subjectivity (Hardt & Negri, 2003). Bio-political production is a result of immaterial labour. It emerged from immaterial production, such as a service or knowledge, without producing a product. Knowledge, information generation, communication, problem-solving, symbolic operations, and analytical work are all defined as immaterial labour in the service sector. Advertising, marketing, programming, software, and knowledge generation have been the purpose and means of using it.

Bio-political production refers to Foucault's bio power concept. Biopower is power over a social life, while bio-political production is a model to produce alternatives to this power (Hardt & Negri, 2011) Negri and Hardt have questioned the transition from discipline to control. Bio-political production encompasses not only mental and manual labour but also affective labour, as production is the result of both the body and the mind. Thus, bio-political production is not constrained by spatial or temporal limitations. Information and communication are inherently intertwined with life, rendering physical factories unnecessary. This blurs the line between producing and non-producing spaces, leading to the breakdown of the industrial production system that dominated the 19th and 20th centuries.

Digitisation and machines becoming new actors in production have been some of the most critical processes affecting working life. The use of computers in industry has resulted in a reduction in the number of blue-collar workers and an increase in the use of machines. This has led to a gradual decrease in the ratio of labour costs to total production costs. Additionally, changes in production costs and globalisation policies have led to a shift towards direct consumption rather than production. The Internet and telecommunications have reduced the distance between producers and consumers. According to Alvin Toffler, the third wave was characterized by the emergence of mobile phones, personal computers, and notebooks, which opened up a new era of communication for individuals (Toffler, 1981). Marketing strategies no longer focus on the product and brand but directly on consumers. While industrialization aims to replace the product with a new one, consumption has become the primary purpose of life in the post-industrial period.

Furthermore, consumption has evolved into an identity beyond its functional purpose. The relationship between the postmodern producer and consumer has become mutualistic. The term 'prosumer' was coined by Alvin Toffler to describe the producing consumer in modern societies, which he identifies as the third wave. Toffler explains that the terms producer and consumer were formed during the economic period known as the second wave. He argues that although the consumer had always existed before, it was during this period that it became the first wave. Toffler focuses more on consumption than production and suggests that production gives consumers a new quality. As a result, he defines producers as consumers who produce.

Richard Sennett claimed that the digital craftsman had replaced the craftsman (Sennett, 2008). A digital craftsman is someone who applies their knowledge of digital media. Digitalisation has made people more involved in the immaterial aspects of production. Industry 4.0 technology has enabled unmanned production through the transition from computers to robots. The development of artificial intelligence, data analysis software, and computerized process management has reduced the need for human involvement in production. Digital labour has replaced physical labour, allowing workers to monitor every step of the process. This innovation has resulted in changes to working hours, workplace, work equipment, job descriptions, and duties in working life.

This transition does not mean that people do not work. On the contrary, according to Negri and Hardt, the global debt economy and indebtedness processes constitute new forms of control and labour control (Hardt & Negri, 2012). In other words, it is necessary to borrow to carry out vital activities such as education and health and work to pay this debt. As a prosumer, humans began to manage both consumption and production processes. Due to smart production, labour needs to be reorganized when production ceases to belong to a place.

Jacob Morgan argues that the end of a traditional working method is in the future of work (Morgan, 2014). Morgan primarily draws attention to the evolution of the employee in the last ten years and claims that the system, which many companies worldwide define as agile work, will be used by many employees in the near future (Figure 4.1.2). This system begins with the elimination of the hierarchical ladder, meaning that a complex process no longer requires a step-by-step approach from the lowest to the highest rung.

In agile work, freelance employees determine their own steps, while company employees are instructed to create their own plans. Thus, the ladder of success in working life is ignored. Information is now a commodity in this system. It is important not to produce information anymore but how to reach it and use it. Learning and using knowledge is much more valuable than knowing it. Jacob Morgan also questions the existence of managers in future companies here; everyone can be a leader in their own business (Morgan, 2022). Because managers are not always leaders, and employees determine the course of the work themselves in a system where real leaders are active.

Figure 4.1.2 The future of work

Jacob Morgan describes the future of work and the employee in a more accessible and independent manner. He acknowledges the shift away from the traditional factory-imposed working hours. This is the most significant innovation brought about by Industry 4.0: the ability to work anywhere, anytime, and with any tool. Although this is considered the fourth industrial revolution, it can be argued that it represents the second major revolution in terms of innovation in working life. Although technology has changed since the Industrial Revolution, the working conditions in factories are still governed by Fordist principles.

Looking at the whole revolution, humanity has adapted to the labour-intensive work process in production. The employer-employee relationship in factories has diversified based on skills and competences depending on the intensity of work and production in the following periods. Defining a job, specializing in that job, or gaining skills have led to the emergence of different skilled employees in the production hierarchy. Qualified employees have created the service sector over time. In the fourth industrial revolution, however, workflow developed quite differently from the employee-employer relationship as in the beginning. Production is fed by human power that starts, designs, develops, organizes, and researches the jobs. Thanks to all these qualifications, humans give up the employee-employer relationship and manage their business lives (Figure 4.1.3).

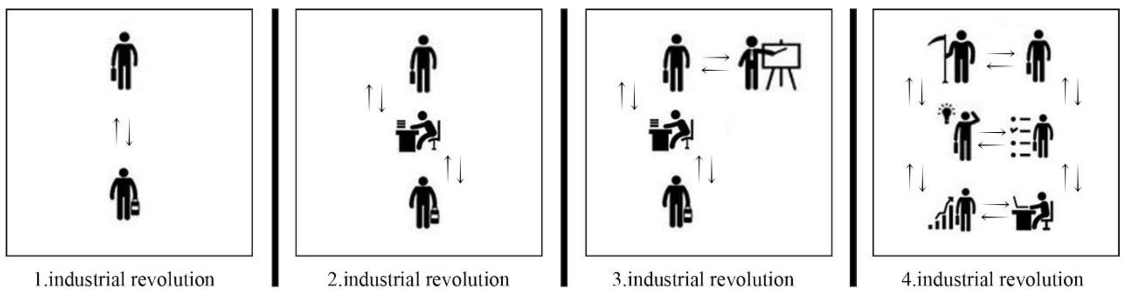


Figure 4.1.3 Human in revolutions

In the future, the focus will be on the outputs of the business rather than the inputs. It is important to consider who will be affected by the results, the extent of its influence, and the different business lines and work areas it can access for the growth of the business. Therefore, sharing information and appealing to a broad audience is valuable. Cloud systems and collaboration technologies, which allow for easy information sharing, are the new communication systems in the business world. Working life always encourages personal growth and learning.

4.2 Space for Human and Machine

Vitruvius defines the machine in his book De Architecture as follows: *a "coherent combination (coniunctio) of materials with the virtue of moving (motus) heavy loads."* (Marullo, 2014). The machine is the result of mental processes of physical works. It emerges as a set of interconnected systems. A force controls it as a simple extension of the human limb.

Simple or not, machines have been produced in many areas as tools that emerged due to necessity, accelerated the process, or made the employees less tired. The Industrial Revolution was also the revolution of the machines. Big and complex machines that could do complicated jobs were produced. Small machines started to form a system by merging with larger ones. The use of machines to divide labour resulted in new production regulations. The craftsmen were responsible for determining their own work machines, equipment, and plans. However, in the factories, workers were required to adhere to strict rules and regulations. Machinery and materials were closely monitored, and workers were held accountable for any losses or issues. To prevent any damage to the production and system, fighting, distractions, and alcohol consumption were strictly prohibited. These regulations were enforced in factories for an extended period of time.

Mechanization in the industry was relatively rapid in America, as it was in Europe. Thomas Blanchard invented a series of front-four machines for manufacturing weapons in the 1800s. These machines enabled even unskilled workers to produce a gun stock every 22 minutes (Marsh, 2019). The assignment of jobs to young men and children because of Blanchard's inventions angered the artisans, but this did not stop mechanization.

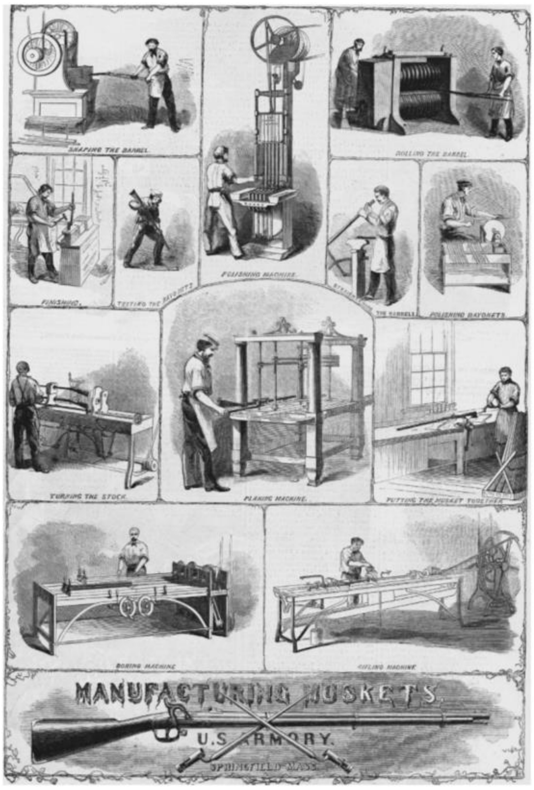


Figure 4.2.1 Hallmark of the American manufacturing system

Similarly, Henri Ford stated that 7882 different processes had to be performed to build Model T. He said that 949 of these specialized jobs could be done by compelling people and 3338 by more ordinary people (Toffler, 1981). Other jobs were demanding to be done by women or even children. Moreover, Ford said:

'Later on, we realized that 670 transactions can be performed without legs, 2637 transactions without a leg, 2 transactions without arms, 715 transactions without a single branch, and 10 transactions with the blind.'

For Ford, specialized jobs required a part of the person, not one person. He said then that man has become or will become a machine. The results of this capitalist rhetoric began to take effect worldwide.

In the second age of the machine, Peter Sloterdijk explains the relationship between machines and humans with the concept of anthropo-technology. This is a new kind of machine and human connected by information. (Dursun, 2023). The term anthropo-technical is a technical being that can shape a human. Sloterdijk also interprets the cloud systems that the specialized entity is currently exposed to as follows;

'In this respect, we should take the metaphor of the "cloud" seriously: "Clouds cover the clear sky." Covering every human area with "global information" is the maintenance of the "objective spirit" in different ways, and today, these are realized with digital tools.'

Mechanically and technologically simple production machines are turning into robots over time, and robots are now turning into autonomous robots or cobots that can communicate with internet connections, programmable and non-stop. The system is planned from the raw material purchase to the production stages, shipment, and customer returns. These robots or cobots make the given job descriptions, report the situation instantly, provide communication, report a problem to the operator and even make a decision. They can make heavy work such as transporting and assembling large parts more accessible, faster, and error-free. They do not need physical working conditions like humans and have not spatial needs such as lighting and ventilation. Cobots can work light-out, so they work in dark factories. It is not surprising in this context that the machine is the subject in space. While the physical control of humans provides every stage in craft production, when agile production started, humans are entirely isolated from this process (Figure 4.2.2).

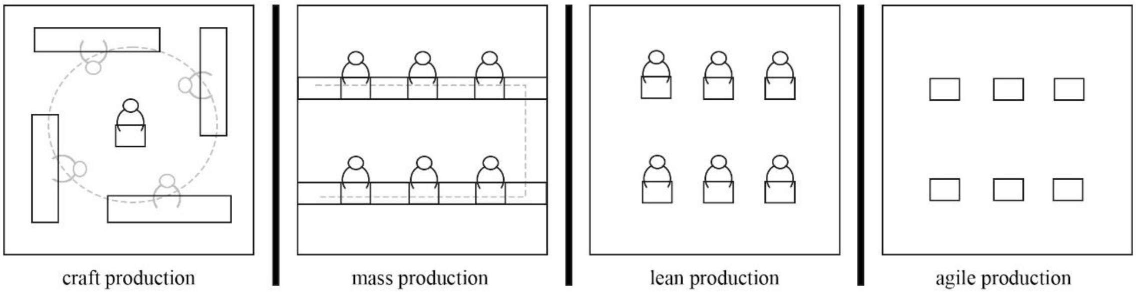


Figure 4.2.2 Human in production

The dark factory suggests that not only human will it become distant from the factory, but the factory will also get out of human life. After all, a factory where robots do the entire production process does not need to be close to humans. Unmanned production in the factory also affects the life and social life in and around the factory. The white-blue collar hierarchy disappears, and this relationship is re-established with machines and humans in a virtual environment. Here, a human does not exist by his collar colour but by his competence. Additionally, individuals are constantly evolving as they not only work as employees but also as prosumers.

In smart factories, new job roles require high qualifications, particularly in the management department. The role of human labour in the production hall of the factory is reduced or even eliminated entirely. The workflow necessitates a scenario, with human-machine interaction forming a part of this scenario. Marta Pieczera recommends three models of human-machine interaction in production: automation, specialization, and hybrid (Pieczara, 2020). Since Industry 4.0 brings together architecture and other disciplines, the question of what a new generation factory will be like will undoubtedly be discussed for a long time. The production facilities, offices, shipping, and storage areas differ according to the sector. Pieczara notes that this triple model has been scripted to meet basic needs.

The first is the automation system, which describes an automated production system in which employees are primarily managers. In this system, qualified and expert employees lead, and the factories are unmanned. This proposal suggests production halls for machines and creative workplaces for employees. Humans have been wholly removed from physical production, and the details of space design have been reduced. However, the creative workplace emphasized in the scenario is closely related to the production potential of people and diversifies with offices and showrooms.

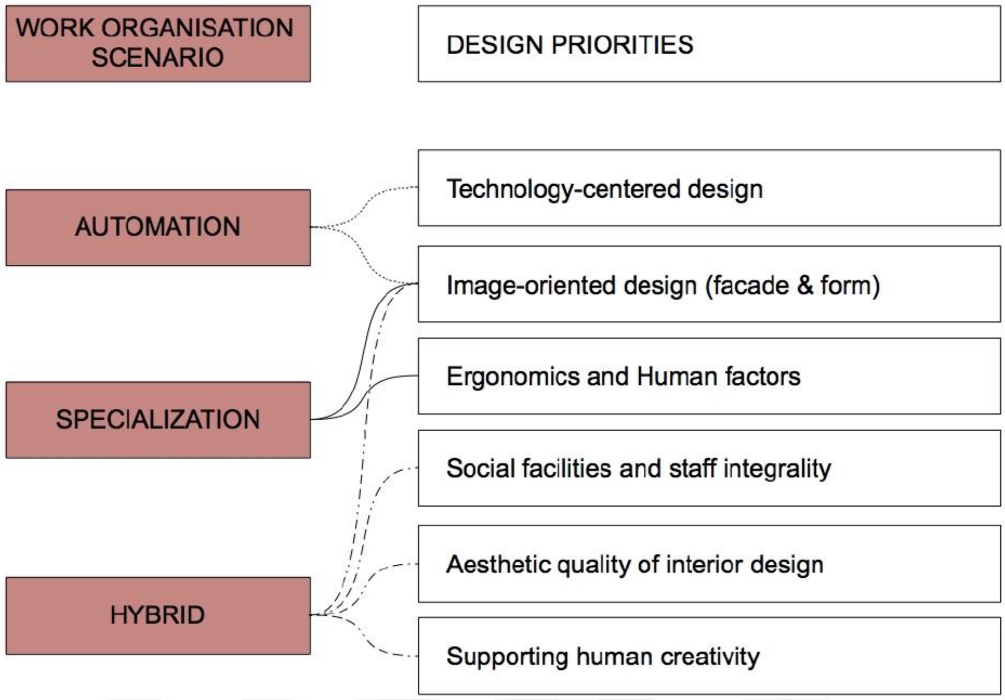


Figure 4.2.3 Work organization scenario

The specialized system is based on customization. Cyber-physical systems and computers are used, along with production; the process is designed from product concept, design, prototyping, and subsequent production stages to problem-solving, testing, marketing, and feedback analysis (Pieczara, 2020). Each employee has a defined area in this system, and the spaces consist of more determined and minor, such as design studios and laboratories. Halls or separate buildings are proposed where certain production stages are carried out. This scenario is similar to the existing production facilities. The automation system has a clear distinction between production and offices. However, roles and spaces can change and diversify functionally in a specialization scenario.

In the hybrid scenario, production processes are brought together with people. This system covers all processes, such as working, research, development, testing, and production, and the spaces are variable. Manual workshops suitable for new workplace types and places directly related or unrelated to production are suggested. To inspire human creativity, the design of the working environment is considered essential for the hybrid scenario. For this reason, it is thought that creativity will be required in multiple stages of workplace design, and functional programming will be a design problem for architects (Figure 4.2.3).

Digitalisation has been transforming business life and working environments, such as factories, for a while. Virtual participation interviews with applications such as augmented reality and holograms are now common and frequently used. Participants who are not in the same environment can conduct interviews, presentations, and discussions. Therefore, the space is expected to respond to virtual needs. Although remote work can often be done with a computer and phone, there is also a need for more flexible spaces that are planned with technological equipment and are prepared for instant and variable working conditions. The presence of wireless systems and cloud data, digital glasses that work with eye movements, digital walls, and virtual keyboards help transition to flexibility (Figure 4.2.4). Future workspaces are considered to transform into spaces open to common uses, can be personalized for a short time, and offer alternatives.

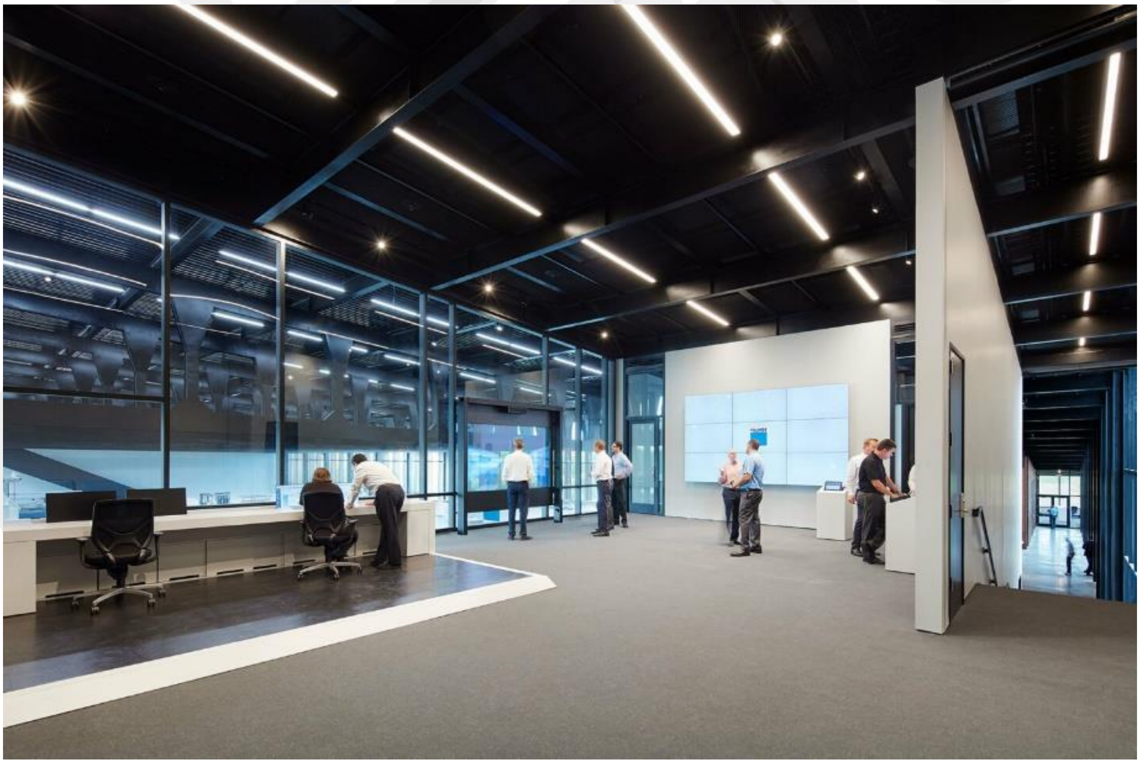


Figure 4.2.4 Trumpf Smart Factory Digital Workspace

Another innovation of smart production is the ability to customize products. In today's world, consumers find it attractive to produce and purchase products according to their personal preferences rather than the impositions of mass production. Smart production makes it possible to produce different products on the same production line by simulating the process. Producing a plan before physical production enables the detection of errors and deficiencies, ensuring problem-free production. This allows the factory to provide boutique production services to more customers and enables smart factories to connect with people in production, unlike dark factories. The experience factory is also a proposed scenario for future factories (Hüttenhain & Kübler, 2021). Until recently, only employees and managers could access factories. The factory has become a place that everyone can visit, and it is a new breath for urban production. Besides the dark factories, experience factories result from industry 4.0.

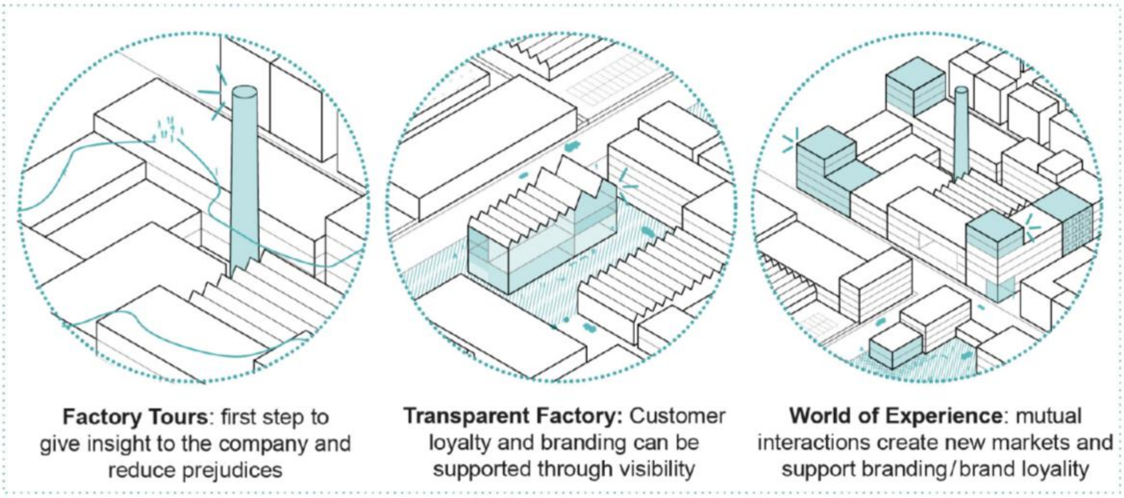


Figure 4.2.5 Experience Factory

Production has become an experienceable activity, enabling it to combine different functions. For example, production and shopping. A clothing brand in Drottninggatan stores in Stockholm has switched to factory stores with the Looop Project (From old to new with Looop, 2022). This machine, which transforms clothes into clothes, was presented to the customers in the store (Figure 4.2.6).

The machine breaks down old clothes and transforms them into new threads and fabrics. It is assembled in a factory container-sized machine with cleaning, shredding, carding, drawing, spinning, twisting, and knitting sections. Since water and chemicals are not used in the system, the problem of environmental pollution has also been resolved. The project plans to involve customers to ensure sustainable fashion awareness. Production has turned into a traceable activity thanks to the in-store factory concept.

Figure 4.2.6 Looop, the machine in a shopping

Innovations in the smart production system, training the workforce to adapt to this process, and gaining experience led to spatial diversification for the factory. Model Factory in Turkey is a project where production is planned with education. The Model Factory, prepared with the joint efforts of the government, academia, and private sectors, is based on industry and vocational education. Model Factory is defined as a competence centre for common use (UNDP , 2023). The aim is for businesses to combine theory and practice through the use of experiential learning techniques in order to gain competence. The project focuses on improving the quality of industrial education, developing a qualified workforce, and training employees with the skills required by the new production process. The training will be conducted on a sample product in the factory's training environment without any commercial activity.

The location for the model factory was chosen based on the density of industries in the cities. Model factories were either built in these cities or added to existing buildings. The Ankara Model Factory was created by converting a factory in the industrial zone, while new buildings were designed for the industrial zones in Mersin, Bursa, Konya, Gaziantep, İzmir, and Adana. The Kayseri Model Factory was established in the restored old factory building on the Abdullah Gül University campus.

(1) (2)

Figure 4.2.7 Ankara and Kayseri Model Factories

It is a fact that Model Factory is a project that tries experiential production. This factory brings together the educator and the employer, the student, and the producer. For this reason, it has found its place in industry and university. Production is part of this experience, and the factory is conceived as a co-working and experiential learning space. In general, it is usual for the factory to be built in an industrial park or zone, but designing it in a university also gives an idea about the new locations of future factories.

Smart production and smart factories can lead to the development of smart environments and smart cities. An example of this is Strathcona Village, a mixed-use project in Vancouver that combines housing and industry. The project includes production halls, offices, and a parking area, and is designed for families with young children who run residential and light industry businesses. The industrial base, which encompasses production, distribution, and repair, is composed of large blocks that directly face the main street.

(1) (2)

Figure 4.2.8 Strathcona Village

The dark factory that live machines is a virtual space for humans. It creates the representation of the digital twin, not the original of the space. While the need for machines for spatial practices continues, human perceives the space with the representation of these practices. In addition, the machine begins to produce its practices in the space. In the dark factories, technological infrastructure, access to production energy, indoor circulation, machine communication, and robot ergonomics distinguish from others.

Figure 4.2.9 Xiaomi Smart (Dark) Factory

It can be said that this factory transformation is caused by flexibility in production methods (Figure 4.2.10). It is clear that *pre-industrial* individual flexible production is being tried again. Linear production lines of mass production were divided by workstations in the third industrial revolution. The tracking and control mechanism of the production has started to be left to the machines. Getting better results from the machines paved the way for leaving the whole process to them. Nowadays, making this production only with machines will cause the space to become smaller, fragmented, and relocated. The fragmentation of production will result in a flexible structuring in space, even in the city.

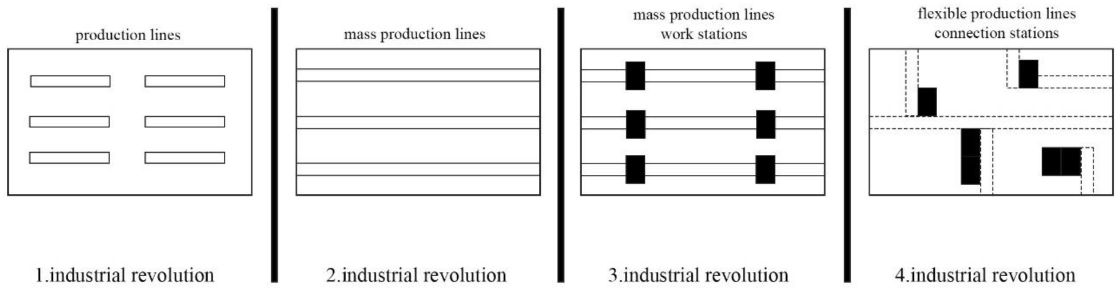


Figure 4.2.10 Production model in revolutions

The factory has transformed into a space for showcasing, with an increased focus on architectural aesthetics. In this respect, the factory looks quite different from the 20th-century Fordist image. Tatiana Mazali says that for this, *'production chains are established that look like showrooms, where even the machines become beautiful'* (Mazali, 2020). Smart production seeks ways to bring people. While the dark, light-out factory becomes the place of the machine, light-in ones become factories that can be exhibited, experienced, traced, visited, and livable. In this case, the factory is not only where production is made, or the production is no longer made in the factory. The factory has also become a place of consumption.

4.3 City as Produced and Consumed

Industrialization was a triggering force for the emergence of cities. A clear distinction was between the producer and the consumer after the Industrial Revolution. Previously, the producers produced and consumed their products. It could not be mentioned large sales or markets. It was thought that there was no need to produce more. Commerce was the occupation of very few people since it was impossible to store or sell excess products. After all, people did not have to live together.

In the early capitalism that started with the Industrial Revolution, the city became the central place of production. The cities of Lille and Manchester in the textile industry, Detroit in the automobile, and Essen in the steel changed instantly (Toffler, 1981). According to Marx, the city represents the physical space where the working class emerges (Marx, 1968). The city was a living space for the working class, a meeting place where social relations occurred. In addition, organized production was very different from agriculture; it could only be done in the city.

The Fordist model of production led to the urbanization of the 20th century and had a significant impact on society. However, the factory was eventually relocated outside of cities. The post-industrial period marked the transition from early industrial cities to modern service cities, which facilitated the emergence of globalization and the restructuring of urban areas. The post-industrial period marked the transition from early industrial cities to modern service cities, which facilitated the emergence of globalization and the restructuring of urban areas. Following the decline of heavy industry and manufacturing, the post-industrial city became a hub for the service economy.

Industrialization of the cities ended with deindustrialization. Although deindustrialization is quantitatively a decrease in industrial employment, it means deinstitutionalizing investment, place, labour relations, de-urbanization, and even loosening relations between social identity and work (Cowie & Heathcott, 2003). It was a critical process, especially for American societies. In the 1980s, when industrial production began to be abandoned, production relations began to be restructured. Advanced capitalism witnessed a new process in which the market was liberalized, the services of collective consumption were privatized, and the economy directly changed. The closure of the factories and the shrinkage of the industry were interpreted as the displacement of production. However, the closure of subsequently opened factories, advancements in technology, and wage competition resulting from globalization have led to company shrinkage and decreased employment opportunities for workers.

In addition to the economic impact of deindustrialization, there are also negative effects on work, housing, health services, local environments, crime rates, cultural resources, and the business world. Increasing job loss causes uncertainty, especially in industry-based societies. This situation has become a constant struggle in society, creating a cycle of failure. On the contrary, industrialization has given identity to many cities. When this identity is lost, there is a loss of population, the loss of faith of society decreases, and the image of institutions and communities is damaged. Deindustrialisation often leads to population decline, as workers migrate to safer areas in search of employment. Social capital refers to the relationships people have with each other and with their environment. Cities that have been abandoned due to deindustrialization are at risk of urban decay, resulting in once lively neighbourhoods becoming quiet and dangerous. The closed factory buildings remain as a reminder of the past (Russo & Linkon, 2009).

Detroit was one of the cities that experienced deindustrialisation the hardest. In the 1940s, Detroit was an industrial city where employment increased and unemployment decreased. Many African Americans migrated quickly and began working in factories. This trend continued until after the Second World War. However, after a sudden and severe deindustrialisation, many people became unemployed and homeless. This led to an increase in crime rates and a decrease in the quality of education. The city experienced riots, which led to an increase in racism and class discrimination. These events have created an uncertain and insecure environment for residents. The city is facing challenges due to neglected and old housing areas, as well as inadequate public transport services (DeRuiter-Williams, 2007).

Although it is considered a negative situation, deindustrialisation is the natural course of the process. It is a result of overgrowth in advanced industries. Adverse conditions may change depending on the increase in efficiency in the service sector. However, the service sector is unsuitable for centralization (Rowthorn & Ramaswamy, 1997). Deindustrialisation started the process of late capitalism with globalization. The city is the most important place and valuable image for capitalism in the global world. Cities have been used to ensure and maintain competition and to encourage foreign investment. Cities have been commodified with mega projects, luxury housing, and urban transformation areas.

Fordist production pioneered mass consumption as well as mass production. However, the modern city has separated the two situations. Production was moved out of the city; consumption has been renewed in the city centres. However, Frank Barkow says production in factory towns will be limited, and there is no opportunity for growth in the future (Barkow, 2021). Barkow supports the idea of bringing the factory back to the city with light manufacturing and urban agriculture and identifies the lack of financial and functional flexibility of the industry away from the city as a strong argument for return. Now, the new revolution of the industry has started new trials in post-industrial cities. The industry goes back to the city or looks for ways to return. Revolution has already implemented the technologies we use as consumers or prosumers in daily life for production. Human-machine interfaces intended for the consumer are now being designed for manufacturers, and this began to destroy the distinction between life and work again.

Industry 4.0 not only started a technological process but also started new discussions for the future of work and new relations between factories and society (Mazali, 2020). The first movements started with the reuse of old factories. In transitioning from mass production to flexible production, manufacturers prefer regions with rich facilities, not industrial suburbs. The traces of this industrial wave can be seen cities such as Boston, Brussels, and New York (Reader, 2022). After industrialisation and deindustrialisation, an old shipbuilding yard in Brooklyn Navy Yard was converted for next-generation production. It is an experience factory with a cafe and garden where employees can spend time, a showroom for customers, offices, sewing facilities, sales and product inspection areas, storage, and shipping departments. The goal of the company is to create a campus for small and medium production that seamlessly integrates with offices, production studios, restaurants, coffee shops and shops, distilleries, grocery stores, bakeries, and roof gardens full of edible greenery.

Reader (2022) claims that Mathew Putman, one of the founders, says the following about this place that reunites machines and humans; "*You would be able to eat around our machines"* (Reader, 2022). In addition, a school named *Brooklyn Science Technology Engineering Arts and Mathematics Centre* was opened on campus. It is an attempt to train qualified personnel for their facilities. Students can also spend half their day in these facilities and be involved in production. This campus is a new prototype that tries to balance production and consumption.

Figure 4.3.1 Science Technology Engineering Arts and Mathematics Centre

When the production that was moved out of the city due to globalization started to look for a place in the city again, the first designs were the old factories in the USA. The remaining unused factories in the city were converted into new production areas. In Brooklyn Navy Yard, the New Lab project was previously an 84.000 square meter workshop. Nowadays, it is used as a common workspace by 70 companies. David Belt, one of the founders of the New Lab idea, introduced this system as '*hyberlocalized manufacturing'* (Rappaport, 2021). New Lab is designed as rentable workshops and studios as co-working spaces.

(1) (2)

Figure 4.3.2 New Lab

The last industrial revolution, defined as digitalisation in production, has brought many economic and social transformations. A transition has begun around the production space and city thanks to the revolution that changed many usual production methods. One of the remarkable works in this field is Nina Rappaport's idea of a Vertical Urban Factory (Rappaport, 2019). Rappaport looks for alternative spaces in the city for new production spaces, defines the typology of the Vertical Urban Factory as a multi-story factory and says the production process can flow from the top down or the bottom up, which will happen with new financial, real estate, technological, and managerial strategies.

Moreover, Rappaport says that smart factories, where mobile workers are connected to production virtually, will provide organic, real-time production, unlike the modern assembly line. It will provide a spatial economy rather than an isolated heterotopia (Rappaport, 2009)

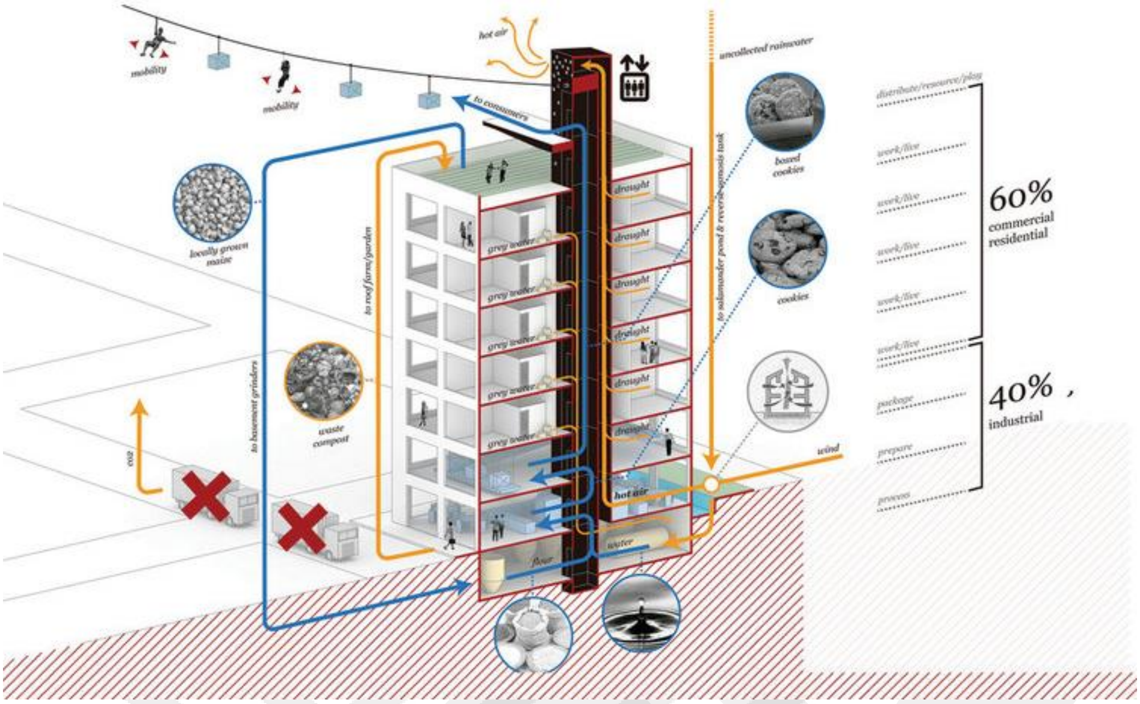


Figure 4.3.3 Vertical Urban Factory

Nina Rappaport points out that the new industrial revolution created hybrid spaces in her work. Her spatial proposal for the new industrial revolution is to place high-compact industrial zones between high-density residential blocks and create a ‘super urban symbiosis' that bridges the gap between work and life. The Vertical Urban Factory project indicates that the new industrial revolution has created hybrid spaces. It points out that common industrial areas will be formed from a factory model per company, as in previous factories (Lane & Rappaport, 2020).

In addition, Nina Rappaport also presents the Hybrid Factory/Hybrid City proposal, which is the future of flexible and innovative cities with a hybrid model of sustainable production, advanced production systems, and new technologies (Rappaport 2022). Participating researchers question mixed uses, including production, re-used factory buildings, and their potential in the near future in this study at the Future Urban Legacy Lab of the Politecnico di Torino. Final of the study, the project was presented as a hybrid trade-manufacturing, culture-manufacturing, and housing-manufacturing.

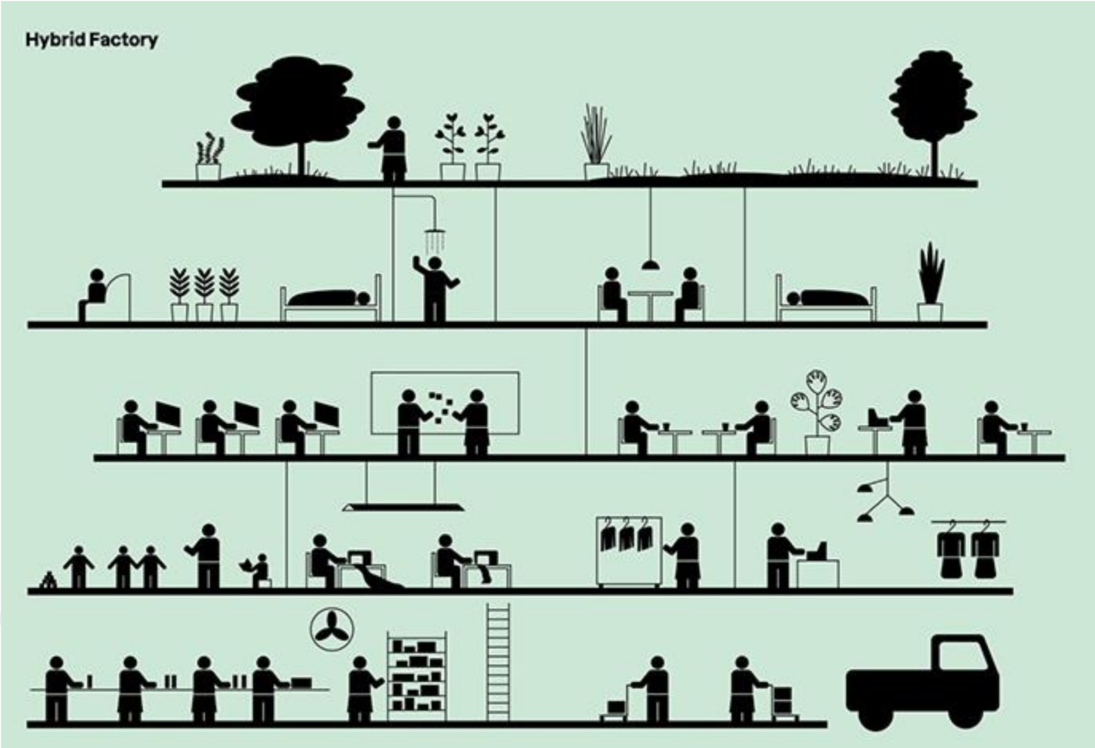


Figure 4.3.4 Hybrid Factory

The vertical production idea was also interpreted at the 2017 Skyscraper Competition. A vertical urban factory is proposed by Tianshu Liu and Linshen Xie project. The designers draw attention to the fact that the world population will live in megacities in the near future and that production areas may be closer to these cities. It is thought that the factories are now cleaner and more accessible compared to the old examples, and if they are moved to the city, a better quality of life will be provided to the employees. This proposal dismantles and distributes the horizontal factory the vertical city (Vertical Factories in Megacities, 2023).

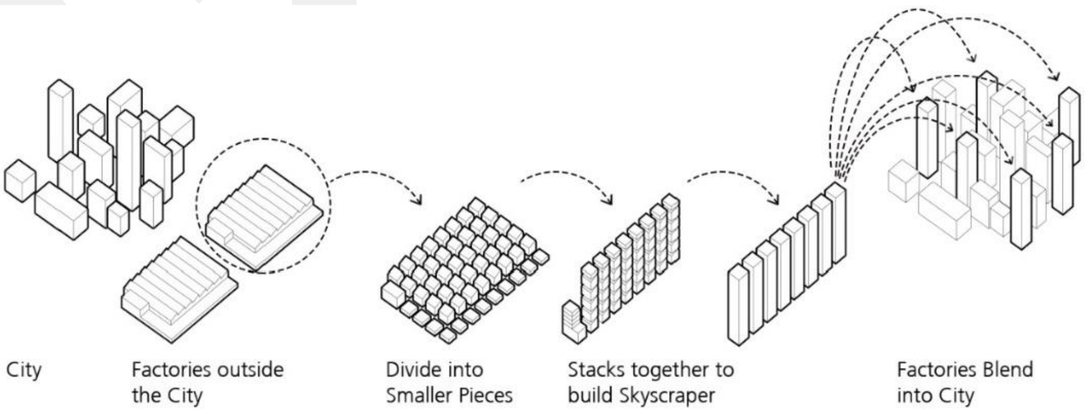


Figure 4.3.5 2017 Skyscraper Competition

This proposal was developed for Malina, Philippines. The increase in the population in the city causes more industry and production, and as a result, more waste is generated. This waste is considered the source of the vertical factory. It is suggested that the wastes are converted and used in the factory as water, fertilizer, heat, and electricity. The project aims to recapture the natural cycle between production and life.

Figure 4.3.6 2017 Skyscraper Competition Proposal

While Industry 4.0 defines a flexible production system, some things that have changed with digitalisation are business organizations, organizations of cities, and relations of people with the place where they work. Vicente Guallart emphasizes that due to the change in the traditional industry, spaces that make urban life easier with logistics and distribution dominated by robots have emerged. He defines this as *post-human architecture* (Guallart, 2021). In the first step, the digital world increased the number of freelancers, and shared working spaces began to emerge. As a result, there is a partnership in the production spaces.

In Industry 4.0 technology, the same machine can produce a bicycle and a chair and be sold in the same environment. For this reason, it is the digital age model that products are close to where they are consumed. Guallart described it as from Co-working to Co-factory. He defines the digital post-industrial city as a productive, ecologically self-sufficient *bio city*. It sees the city as a part of nature rather than growing against nature.

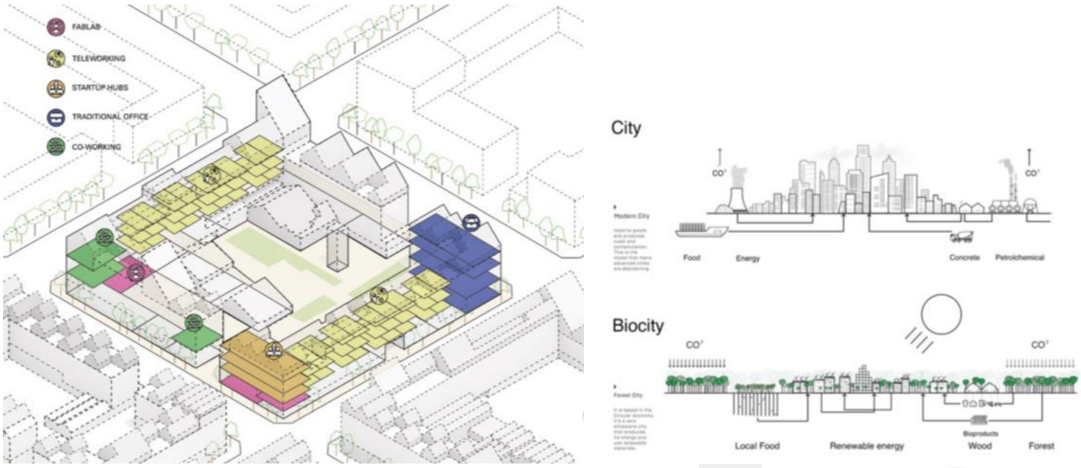


Figure 4.3.7 BioCity, Local Digital Production

Guallart's proposal, *Local Digital Production*, is also a model based on on-site and on-demand production (Guallart, 2021). Guallart criticizes the concentration of the traditional industrial model in large factories and the concentration of factories in a few regions. He describes these areas as places where labour is cheap worldwide. It has led to a commitment to a place in the world and a company for almost everything. Local Digital Production aims to restore production to cities with medium-sized factories or workshops. With the innovations brought by this digital production model, it is thought that the factory will cause less noise and environmental pollution and be more easily integrated into the city.

As an example of local production, which is not new but re-planned, the industrious city is struggling with the problems of the digital age. In recent years, global economic wars and the complexity of the global supply chain have driven producers to local markets. Social capital is another situation that is as important for producers as the economy. This intangible capital is built with trust and reputation. It is provided in the long term between local consumers and employees. In this context, the industrious city can be considered as a model in which local production is made and global connectivity is used at the same time (Aerni, 2021). Although similar to the old manorial systems, the industrious system also incorporates external skills to meet the needs. It proposes a more mobile order in which economic freedoms are provided to the manorial system's static, restricted and hierarchical attitude.

As well as the new production spaces, it is discussed where these spaces will be and how they will re-establish a relationship with cities. Tali Hatuka defines the concept of production close to the city, fed by the city-industry dynamic, as New Industrial Urbanism (Hatuka, 2021). Hatuka argues that the new technological evolution has changed the physical structure of the factory, distribution processes, innovation networks, and access needs. The new industrial urbanism is not a very new concept. During the first industrial revolution, many people worked in or near where they lived. However, mass production has led to spatial divisions. The distances between residential and working areas have increased. In contrast, Hatuka is researching new industrial cities due to these developments, not how the city will be affected by Industry 4.0; it questions how cities will embrace the new industry.

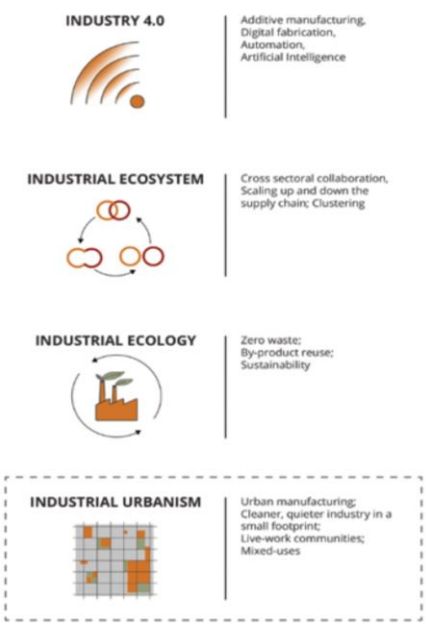


Figure 4.3.8 Industrial Urbanism

The basis of this new concept is Industry 4.0, industrial ecosystem, and industrial ecology. Industry 4.0 refers to digitalisation and innovations such as artificial intelligence, autonomous machines, biotechnology, and digitalisation between production processes and consumption. The industrial ecosystem refers to higher energy efficiency cleaner, and quieter industrial processes resulting from these innovations. It aims to encourage the innovation and growth of the region and manufacturers by placing product-oriented grouping and production at different points. The concept of industrial ecology, on the other hand, draws attention to environmental issues, sustainability, energy efficiency, and waste reduction while creating industrial zones Proximity, integration, and improved accessibility are crucial factors in developing a new industrial system.

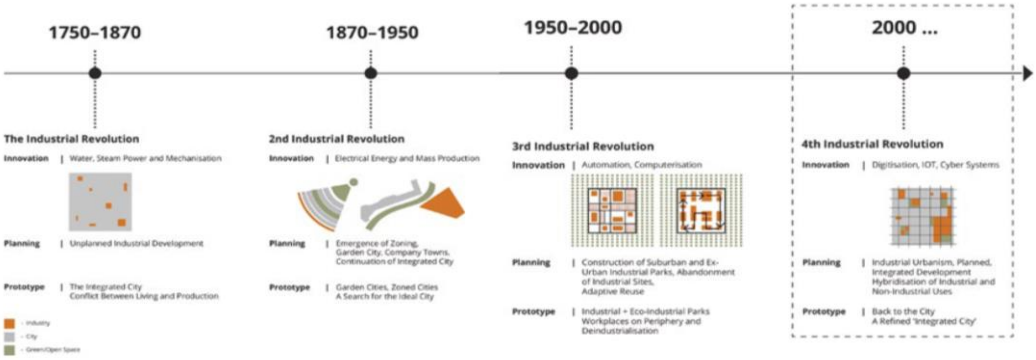


Figure 4.3.9 Integrated City

Tali Hatuka and Ben-Joseph examined three prototypes to find the ideal city of the 21st century (Hatuka & Ben-Joseph, 2017). The first, *The Integrated Industrial Space*, is described as a symbiosis between life and work. These spaces are generally residential areas. Although the proximity of the industrial zone and the city has benefits in accessing services between producers and city residents, it also causes adverse effects such as environmental pollution, noise, and traffic.

The second is *Adjacent Industrial Space*, which has developed as a model based on the separation between living and working. The city and the industrial zone are developing as two different areas. This model was considered the ideal model to overcome the problems of 20th-century industrialisation. The city and the factories are entirely separated from each other; although the industry is an autonomous area, it still depends on the municipal administration.

Third, *The Autonomous Industrial Space* describes industrial parks with large-scale uniform industrial buildings. It is pretty disconnected from the urban texture. Roads are parcelled out for large vehicles, and plots are parcelled out for significant producers. It has also been defined as private industrial areas developed as innovative and clean as the desire to create a place that is 'out of place' to the global environment.

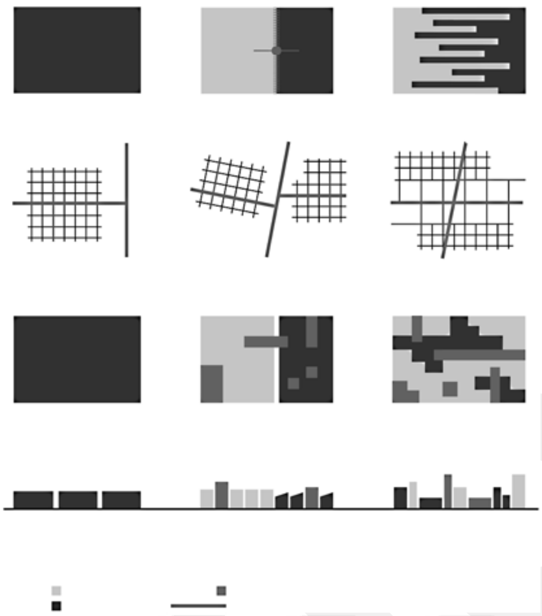


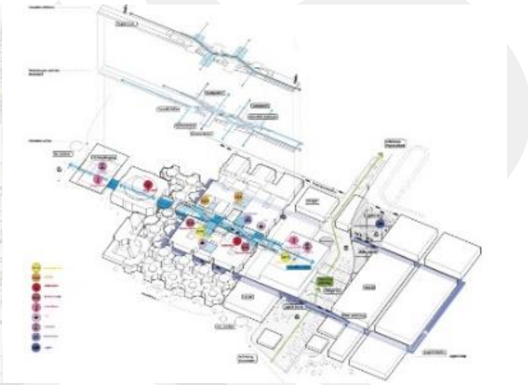
Figure 4.3.10 Prototypes of industrial spaces

The basis of these three prototypes is production. The fact that the producers moved the factories out has brought spatial incompatibility. In addition, the existence of the urban environment should not be ignored for economic growth. Hatuka and Ben-Joseph state that technology will make existing cities more livable places (Hatuka & Ben-Joseph, 2017). As a result, it can be said that the primary goal of planners, urban designers, and architects will be production for future cities.

Re-using old factories as new digital production areas and considering vertical, hybrid, green, and co-factories in cities for non-digital production indicate that production goes back to the city. The name of the factories has changed, and a new location in the cities has been sought for them. For that reason, new plans are proposed. Cities of technology and research now join cities created first by production, and then by consumption.

As an example of an integrated industrial space, the Munich BMW Industrial Park was a rural landscape when it opened in 1920 to manufacture aircraft engines. The city grew after World War II, and residential and commercial areas surrounded it. It continued to grow vertically with the opening of the Munich Olympic Stadium in 1972. Nowadays, The BMW FIZ Future project is another large-scale project. At this campus, BMW aims to bring together all the expertise in the automotive and mobility fields.

The campus, which is aimed to grow gradually over time, is a hybrid space with the physical proximity between the buildings, flexibility, and the combination of different functional areas. Around the central production axis for FIZ Future are research and development offices for various specialities, Project House North, workshops, and test bench buildings. At the centre of the project, an atrium that visually connects the floors has been designed, and 'new working places' have been created where different usage and communication styles come together. The project was developed in the east-west direction with the logistics line on the ground. This campus is also thought to contribute to the urban fabric and residential areas around it (BMW FIZ FUTURE, 2021).

(1) (2)


(3) (4)

Figure 4.3.11 BMW FIZ Future

Woven City is also different in scale from smart factory/city examples. The city designed for Toyota in Japan is an incubator aimed at developing and advancing mobility. It consists of buildings designed for housing, retail, and business for 2000 Toyota employees. This new city is planned with a new balance between vehicles produced with new industrial technologies, people, and nature. There is a main street for faster autonomous vehicles, entertainment and promenades for micro-mobility, and a traditional people-only road. Woven City is a prototype for future cities (Toyota Woven City, 2021).

Figure 4.3.12 Toyata Woven City

MVRDV's The Future Science and Technology City proposal in China proposes a network system for future settlements. The design is developed around three valleys: Knowledge, Experience and the Venture Valley. MVRDV explains this project as follows; "*by taking this parametric design approach, the result is not a fixed design but a system, which invites the input of the client and other local stakeholders. Adjusting the parameters can result in different infrastructure layouts, building heights and shapes, and more*" (Chengdu Sky Valley) . This settlement does not take reference from existing cities; it creates its unique environment. A re-network for science and technology within the rural landscape is imagined. Buildings are not gathered in a single place; on the contrary, capillary connection elements of building groups provide transportation.

Figure 4.3.13 The Future Science and Technology City

Research and development seem to be the most striking areas of new settlements. Because it is considered that new settlements can be liveable and sustainable only if these places adapt to technology. The users of settlements are not only humans but also machines who often use this system. In many stages, from production to use, the machine shares the same network with the human.

Designed for Saudi Arabia, Oxagon is an industrial campus with clear boundaries. The project, designed as a floating city on the Red Sea, consists of a research and innovation campus, energy, food and water innovation hub, villages and manufacturing (Oxagon). For Oxagon, it is projected as an island that produces and consumes independently, without context, within its borders. In other words, this island reminds us of a new company town model where production can be plugged in with its immediate surroundings.

Figure 4.3.14 Oxagon

Although the symbiotic relations between the factory and the city continue, their spatial association has weakened. While the factory was the centre of the city during its existence, it was pushed out of the city in a short time. The long, laborious, and dirty stages of production caused the factory to be left out to protect the city from these problems. Then, city-dependent factory cities began to form outside the cities. The postmodern city has become a place of consumption, not production.

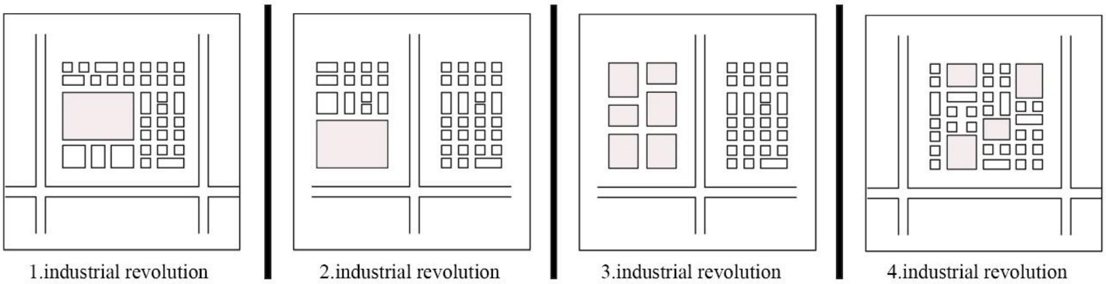


Figure 4.3.15 City in revolutions

Firstly, while the city is defined as a production environment, it has continued to grow without a factory. However, it is seen that the industrial and technological revolutions in recent years brought the city and production together again. Instead of reopening areas for production in the cities, the first examples are old factories in deindustrialised regions. Living, showing and exhibiting the production is a new excitement for the city. Production is not looking for a place with the factory as it used to be but with the minor version of the machine. In its more fragmented, small, and experiential form, it strives to establish relationships with everyone, not just producers or people directly related to production. Exhibiting the production process like everything that is produced and consuming production like products, heralding a return or re-urbanization process for cities free from factories.

4.4 De-Coding Prosumer Space

The discussion of this chapter is the conceptual codes of the factory. The factory was examined morphologically in the previous chapters, and what changed in the space from its first examples to smart factories was discussed. In addition to the evolution of the factory, this chapter focuses on how people, space, and cities have also changed. As a result, conceptual codes were written for transition.

The factory existed with the industry, leading to the birth of many new concepts, situations, and formations in the history of humanity. The factory's hierarchy of employees and employers gave birth to society's worker and capitalist class. However, in a very short time, the expectations of the employer from the employee led to the emergence of different specialities in the job hierarchy. The employer has grouped its workers as white-collar-blue-collar, skilled or unskilled. As a result, a group that organizes and designs the relations between employer and employee, product, production steps, and plans has been included in the factories. In the third industrial revolution, service was considered a different workflow and started to be included in production from outside. Those who serve the production from outside the factory have started to specialize in the given business lines. The fourth industry is also a transition period regarding innovations it provides to working conditions. Work and working life eliminate employers' limitations and diversify with the definitions of individual and expert people and specific processes. Starting, designing, organizing, producing, and selling the works are new branches of this hierarchy that are independent of each other but also connected. Moreover, it is predicted that these specialities will increase even more.

Similarly, the factory also diversifies in the spatial context. After the transition period from the workshop to the factory, where the production is more planned, gradually, the factory has preserved its identity for many years. Although the size, architectural structure, and size change in each era, the factory has been the spatial equivalent of the industry. As a production hall or site, its borders changed in the third industrial revolution, and automation and remote control methods started the transformation process of the factory. Smart production has transformed the factory into a place that produced, exhibited, shopped, studied, researched, and, most importantly, experienced.

When the Industrial Revolution began, cities gained identity with the factory. After the pre-city term, where production continued individually, and producers worked in their properties, the first attempts were company towns for people to live together and establish a new relationship between work and daily life. However, the search for regularity between the factory and life in the Second Industrial Revolution led to the emergence of the industrial city or modern cities that still exist worldwide.

In the same century, while the production-consumption relationship increased, the factory and the city gradually moved away from each other. While it was thought that this would be a solution to many environmental problems, the delivery of products to the consumer and the necessity of employees to go to the factory every day also caused other problems that could not be resolved between the city and production. Nowadays, smart production has begun to create smart cities. In this way, the cities are being rethought as hybrids and integrated with production.

Table 4.4.1 Actors, Spaces, and Cities of Revolutions

producer worker	producer designer worker	producer service provider designer skilled worker	work-starter work-designer work-organizatior work-producer work-saller
workshop factory	factory production hall	factory production hall production site	factory-produced factory-exhibited factory-shopped factory-worked factory-researched factory-experienced
pre-city company town	industry city modern city	post-modern city	city-hybrid city-integrated city-smart
1. industrial revolution	2. industrial revolution	3. industrial revolution	4. industrial revolution

In summary, in this period of industrial and technological transition, the factory is undergoing a spatial and conceptual transformation. Because the factory is not only a place of production, but has influenced people, space, time, social life, art, architecture and ultimately the city since its first revolution, it is crucial to understand how it will change.

Chapter 5

Proposition: Plug-In Production

The actors, the spaces, the environmental and social order of production, such as the method, energy and technology, are also influenced by a new revolution. Unlike others, this revolution predicts the future and presents its contents. It has been announced as Industry 4.0, its components have been introduced, and its effects on industry and other sectors have been partially planned and predicted. This is exactly the motto of its technology; the system is established and possible problems and solutions are visible from the beginning. The results and potential are also usually clear.

Smart production has brought machines and humans together in a virtual network, and production mobility has been transferred to machines. Production has become more compact with machine and robot technology, energy, and storage, and finally, the removal of factory management departments changed the scale of production. However, the new revolution of the industry has brought people and production together in different relationships. The new production spaces were defined as smart factories consisting of machines. After the smart factory, proposals for smart production spaces vary, such as an innovation factory, future factory, multi-story factory, model factory, 'lab' factory, vertical urban factory, hybrid factory, green factory, and co-factory.

In addition to all the studies in the experimental phase of the revolution, this thesis focused on the architectural reflection of production. It has produced codes at the intersection of industry and architecture for new production spaces and their environments. It has discussed the new possibilities of production in the context of humans, machines, space, and places during the industrial transition to smart systems.

As a proposal for the future of production, the *Plug-in Production* is a spatial interrogation of the changing production and consumption culture. This study seeks alternative and innovative ways to develop a hybrid daily life in collaborating with production and project a co-operative consumer-based proposition on a human scale.

Instead of re-building a factory with new functions, it could be divisions and distributions of production into daily life. Spreading and distributing production to the city like consumption, *plugging* it *in* some functions, *plugging in* to the city, and even thinking and designing 'out' versions could be an alternative proposal for the production space and indirectly for the city.

In this chapter, first, the futuristic interpretations of the Plug-in concept in the literature have been criticized to recognize the understanding behind it. It focuses on why and how these examples were designed or fitted into the built environment. Within this perspective, the possibilities of the plug-in production idea for humans and space have been examined. Transcription of the codes and keywords for plug-in labour and plug-in factories has been tried. Consequently, the possibilities of all these codes or concepts with the Plug-in Production Network have been discussed. This study intends to present virtual and real plug-in production space suggestions for the Fourth Industrial Revolution and future production areas.

5.1 Re-visiting the Plug-in Concept

In the architectural literature, *Plug-in* as a city model appears as one of many discourses, models, and drawings produced by Archigram between 1960 and 1974 years. Plug-in City, Instant City, and Walking City aimed at a mobile, flexible, impermanent architecture. The Plug-in City, designed by Peter Cook, was a portable and constantly evolving megastructure containing housing, transportation, and essential services. The criticism of the Plug-in City, a building proposal with mixed functions and unclear boundaries, was the uniformity in existing structures (Sadler, 2005). Peter Cook's proposal was for subtractive, transformative units to be added to keep cities afloat in a rapidly changing age. It was a city design that could exist with the participation of Plug-in City users (Figure 5.1.1).

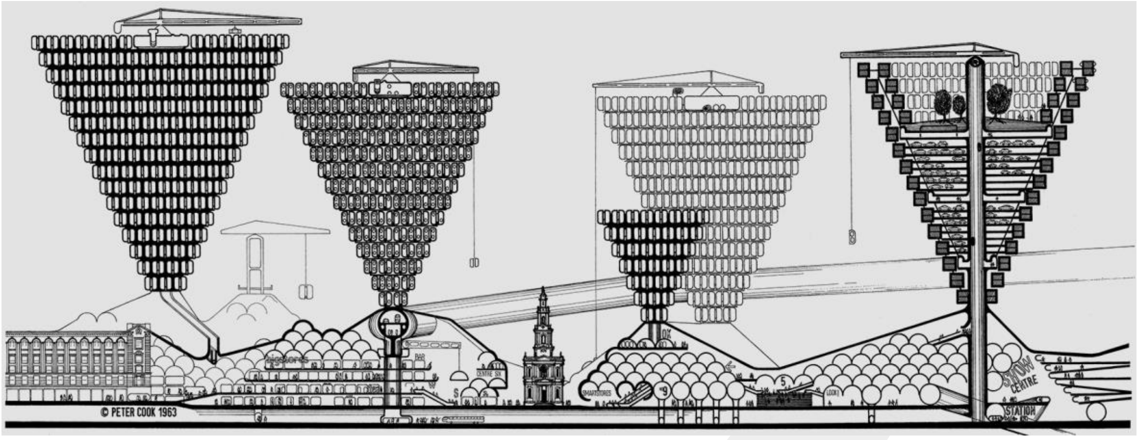


Figure 5.1.1 Plug-in City, Archigram

Peter Cook limited the components of the city to their life, like twenty-five years for a hotel core and three years for hotel rooms. The Plug-in City embraced the idea that physical labour should end with automation systems, and assembly plants or large oil refineries were not visible in the Plug-in City. Citizens of this city generally have worked in white-collar occupations. Workplaces were generally close to shops or entertainment centres. The controlled taxis, ambulance services and monitoring systems that keep Peter Cook's Plug-in City running were drawn in the Computer City diagram by Archigram member Dennis Crompton. Computer City showed the infrastructure, information, connectivity and technologies of Plug-in City. It was defined as a flow network consisting of traffic, people and more information. It is not an alternative to Plug-in City; it is a diagram of the systems prepared for its operation. The idea of a Plug-in City was developed with the help of this diagram, and it has become easier to change the location and number of units, and even to provide a new order according to needs.

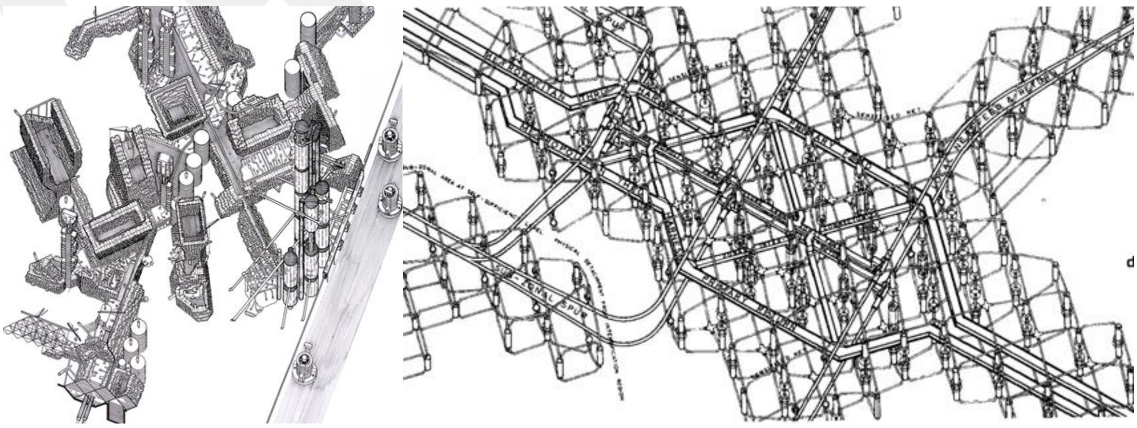


Figure5.1.2 Plug-in City, Computer City

Archigram designs have managed to create a discussion in architecture, and utopias have been designed with the idea of plug-ins for different problems in cities. As an example, Coop Himmelblau designed the living form, the Cloud, in 1968. The Cloud was also developed as a mobile, displaceable organism. The building materials were air and dynamics. It was not a new design like Plug-in City; it was directly plugged into the city. The Cloud is timeless and placeless. Its form and architectural style differ from the city silhouette and attract attention. It tries to establish a new relationship with the place where it is plugged in, or not.

Figure 5.1.3 The Cloud

Designed by Peter Cook in 1964, the Plug-in City was reinterpreted in 2009 by industrial designer Alain Bublex. He proposed a mobile organism that could be attached and detached according to the needs of society that could grow and shrink. Bublex referenced the housing crisis with these blogs, which plug directly into existing city images. In the virtual environment, this utopian approach was conceived as a solution for housing in a rapidly changing world, with an independent perspective and a self-created design, similar to the Cloud.

Figure 5.1.4 Plug-in City, Alain Bublex

Although the plug-in idea is thought of as a utopia, it is seen that these innovations occur in real life over time. *Plug-in City* and *Computer City* are now the design philosophy of smart cities. The control mechanism for managing, planning and maintaining the city with computer software in smart cities was designed with futuristic drawings fifty years ago. Similarly, it is not a coincidence that the Cloud is out of context and that super modern spaces are similar in the post-post-industrial period. Although adding the residence to the workplace or the workplace to the residence may seem exaggerated in Bublex's drawings, the concept of the home office, which combines work and daily life, became popular in this period. In addition, plug-in production to the city as ‘mass’ will soon be a common situation soon. Living with production, machines, or robots is the standard of daily life, not a utopian discourse.

This study offers the plug-in production idea as a spatial manifestation of production in the near future. In this context, the plug-in concept has been revisited in the architectural literature and its implications, both conceptual and realistic, have been examined. Utopian approaches of their time, such as Plug-in city, Computer city, or Cloud, are no longer considered utopias for the future production space but are possible projections. Moreover, the images that Bublex produces from these utopias give an idea of the urban texture of the near future. For this reason, in the search for new production codes during the transition period, the plug-in concept has been a guide in this study.

5.2 Production in Transition

Individual workshops in arts and craft production were brought together in mass production, creating a continuous workflow. Determining the entire workflow with the production line of the factories made complex work more manageable. However, the problem changed because of the increase in production. The fact that the machines started to take a more active role in the production processes caused a decrease in human-machine cooperation within the factory. The job descriptions of the workers have renewed, their movement has decreased, and even the number of workers working in production has changed.

The revolution in production technology led to the restructuring of processes and the transformation of the factory. The most important innovation is undoubtedly the flexibility in production. Contrary to mass production technology, the absence of a linear manufacturing line in smart production and the production processes on a variable and flexible line are the most fundamental variables affecting the production spaces.

The production itself is a fragmented process. In its simplest form, all the steps are defined until the material becomes the product, and these steps are plugged in to a production line. The immaterial part of the process concerns what happens before or after these steps. The factory has made this process more regular for many years. Now, as Industry 4.0 technology provides flexibility in production, it becomes possible to disassemble, distribute, and plug in.

Having a digital twin of the process ensures that production and management or other service processes can be easily separated. The production of information in the digital environment also enables it to be easily shared in digital networks. Production in virtual and augmented reality, artificial intelligence, and co-bots collaboration is an organized and sustainable process, from product ideas to customer feedback. In the smart production, the main task is to plan the whole process, to determine its stages, to assign tasks, to control, to present, and to be able to remotely intervene in the problems that may occur in the process. For this reason, material production is perhaps the simplest step of this revolution.

New codes, possibilities and arguments of smart production, unmanned production or human-r/cobot cooperation are presented as Plug-in Production in this study. The Plug-in Production is a predictable projection of a new industrial transition. It treats production not as heavy, light, or service but in a more individualised form for the producer and the consumer. For this reason, it has questioned its relationship with human and machine. It accepts every real, digital, or virtual possibility of the factory as a place of production.

Plug-in production redefines the types of production as it breaks down production and its processes. It enriches heavy and light industries, which differs from the early times of industrial history in terms of economy and scale with daily productions, special boutique productions, recycling/reuse productions, and material productions that cause environmental pollution and requires more energy use. It also distinguishes immaterial production, previously classified as information, communication and service production, which is now even more critical of material production due to data production (Table 5.2.1).

Table 5.2.1 Production and Plug-in Production

production		**plug-in production**	
material production	**immaterial production**	**material production**	**immaterial production**
heavy industry machinery industry, mining, metallurgy, energy, defense industry, and chemical industry **light industry** food industry, paper, leather/textile, electrical appliances	**informatization of material production** information, communication, and service	**daily productions** **boutique productions** **recycling/reusing material productions** **productions using more energy resources** **productions cause environmental pollution**	**production of ideas, information, data**

Material and immaterial production is an integrated and symbiotic process that complements each other. However, in the new revolution, the actors of these productions have completely separated. Humans have shared tasks with the robot, created the co-bot and managed to participate in production as a virtual producer. Plug-in production uses the digital competencies of r/co-bots in work, such as assembly, maintenance, and repair.

By gaining the ability to act flexibly, detect faults, take risks, determine routes, and act together, robots or co-bots learn to work like humans. The material part of production is taken and joined with different functions. While a place is required to plug in material production, immaterial production can be plugged in directly to humans and any place where humans are.

As a result, labour and its space are disintegrating and evolving into a new state, just like production in the transition. In the first part of the title, the re-sharing of labour in human and machine cooperation was discussed. The possibility of plugging-in production to humans and machines, and their new identities in production as plug-in human or plug-in machine, were examined. In the second title, a new place for human, machine and labour was sought in virtual, remote and immaterial production forms. The flexible and evolvable state of production supports the possibility of production spaces becoming plug-in factories. Therefore, Plug-in Factory offers a projection as a new production space.

5.2.1 Plug-in Labour

The transition from labour-intensive to capital-intensive production resulted in the pioneering of machines in physical production. The machine, whose share in physical production has been steadily increasing since the first revolution, has also begun to play a role in the planning and decision stages of the process. The fact that the machine is the new actor of immaterial and material labour has initiated a new era in human-machine cooperation in production. While the machine has been designed to do things like a human, on the other hand, a machine-like lifestyle has emerged.

Human-machine collaboration also suggests a version where the machine is plugged into the humans. The transformation of technology into a biological form began with the revolution. Machines have multiplied as organisms that imitate humans but can do faster and cleaner work. Humans and machines have been the subject of discussion for a long time among post-revolutionary designers and design theorists. The real problem is this: Technology is the biggest threat to humanity and our world. Because humans invent tools to make tools, and they have always used their creations to reinvent themselves. The concept of design was developed due to this discussion and is still a global meta (Colomina & Wigley, 2022).

Ray Kurzweil says that shortly, humans will become a cyborg. The 2.0 version of the human sees technology as the integration of the humans (Kurzweil, 2006). In its simplest example, the computer has recently emerged as a machine that produces information in large-ventilated rooms. Then, it shrank and became usable on work desks. It has become even smaller, turned into a screen, and has become portable. Kurzweil mentions that this information-generating system will soon be plugged into humans. He even says that by the 2030s, there will be more non-biological limbs than biological ones, and by the 2040s, there will be much more non-biological intelligence than biological ones. In fact, while machines become like humans, humans evolve to be like machines.

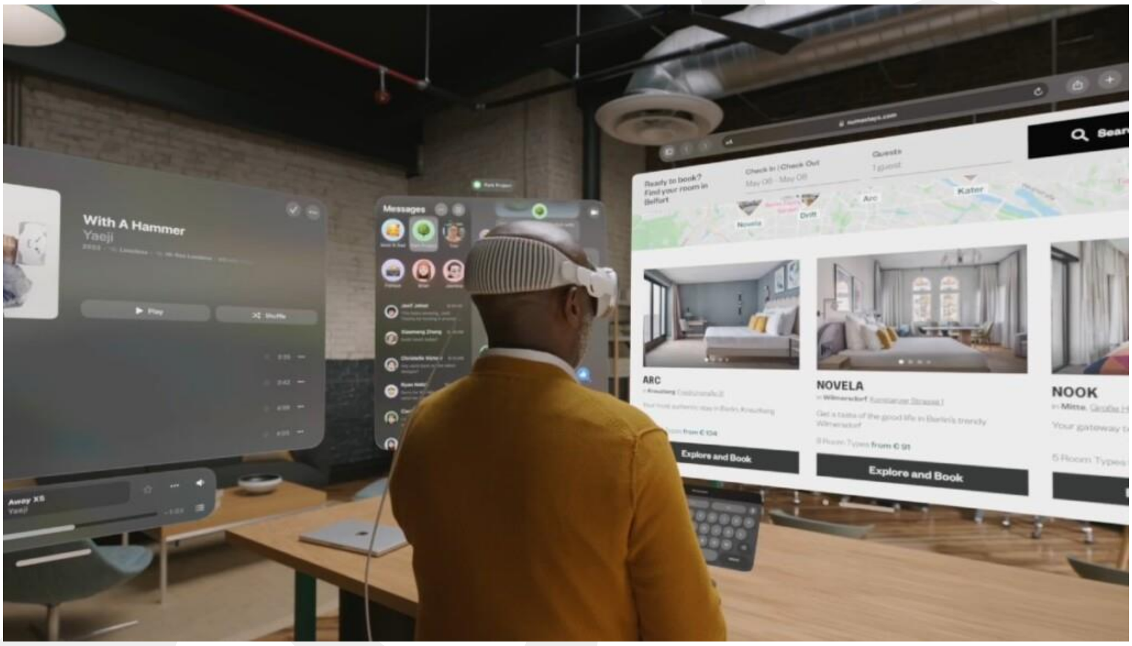


Figure5.2.1.1 Wearable computers

Computers are now turning into parts that can be worn on the body. Pluggable or wearable computers will be perhaps the most primitive state of the machine to meet the human in the digital age. In his book The Singularity Is Near, Ray Kurzweil talks about more miniature robots added to the body when describing the new machined version of man. Kurzweil tells us that billions of nanobots will circulate in our bodies and blood to correct potential system errors. He mentions that online learning will begin with nanobots that it will be possible to access new knowledge and skills online. In this context, the role of work will be to produce knowledge in all disciplines.

Daniel Bell says that the computer is the tangible symbol of change in the information society. Bell mentions that societies in the past were limited by space or time.

While the Industrial Revolution replaced the clock of nature with the clock of the machine, the information age moved with the microseconds of the computer. The computer provides a new time-space framework for modern society. Information and knowledge have replaced labour and capital (Kumar K. , 2010).

The digitalisation of production, increased mobility and the communication tools of the Fourth Industrial Revolution and its aftermath have created a new way of life. Location-independent living offers opportunities for distance learning and employment. In this way, the number of mobile people meeting global living standards is increasing. People have a digital twin and share their work, life, and digital existence with many people in the digital environment. All business meetings can take place in this environment and anywhere in the world. It gives rise to the digital mobile person (Schwab, 2016). The digital mobile human also gives birth to the digital culture.

Industry 4.0 affects the economy and societies globally, bringing innovations in many fields thanks to robotics, artificial intelligence, nanotechnology, and 3D applications. It means that many professions today did not exist a hundred years ago. However, neither the steam engine nor the many machines that were invented after it prevented people from working and producing.

The primary task of machines was to be a physical part of production. In traditional production, machines worked alone; possible technical problems were affecting all systems. In the digital age, on the contrary, machines can work together. Data can be transferred to the entire system, and the system can solve problems. Moreover, communication between material production and immaterial production is also provided by machines. The machines of the revolution are now producing *plug-in machines* that manage themselves.

The human, who previously established and managed the factory and took part in every step of the production, caused the evolution of the machine first and then of their own business life. Ultimately, this evolution gave birth to the *plug-in human*. The human to whom the machine is plugged or plugging in to the space with the machine now determines her/his own working conditions or place. After the ‘mass’ conditions of the industry, plug-in labour, plug-in machine and plug-in human offer a flexible system (Table 5.2.1.2).

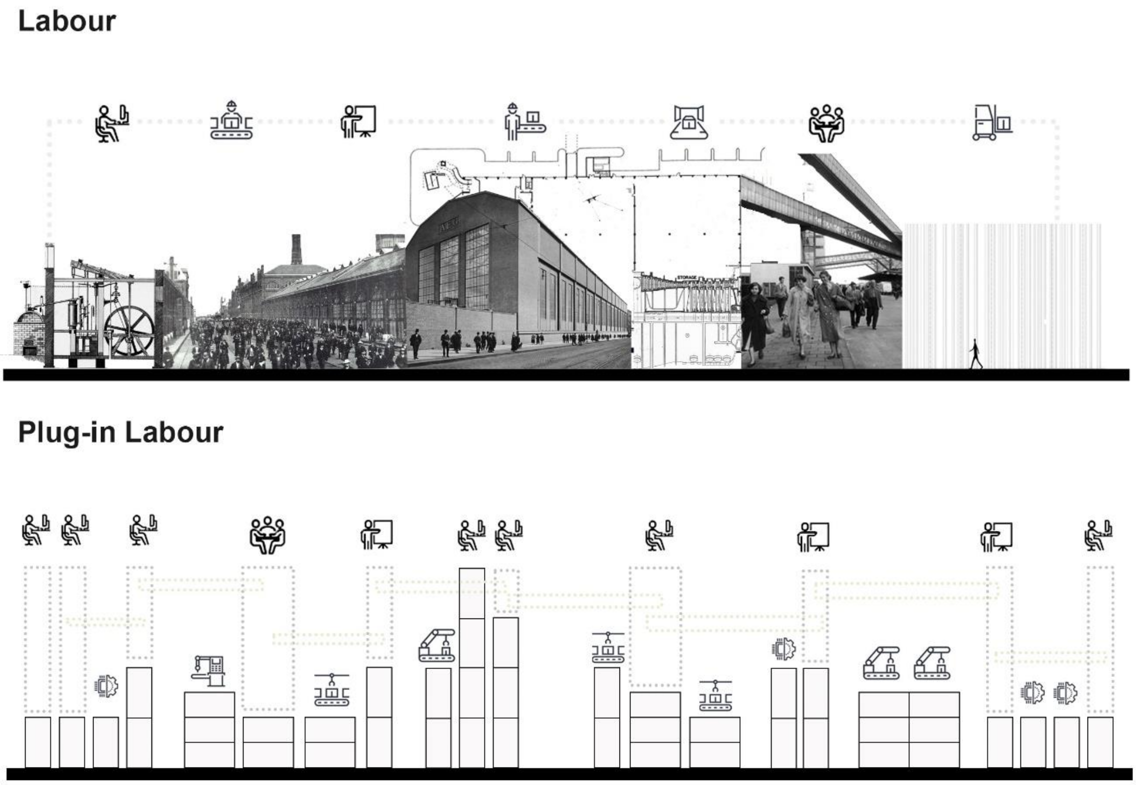


Figure 5.2.1.2 Labour and Plug-in Labour

In future factories, it can be said that production will be physically transferred to machines and robots. Thus, the heavy workload in the factory and the errors that may occur due to the workers will be eliminated. Unmanned production, especially in large-scale works that require more energy, will make production independent, and non-stop production can be planned without energy loss. Although production is unmanned, the process is under human control. In this way, humans can be involved in production in the digital twin of the factory, regardless of location. In other words, humans also plug into the system and work in a part of the system with her/his expertise. This situation is not much different from working in a mass-production factory. While space and time still require factory standards for the machine, a human, as a producer, now sets these standards herself/himself. As consumers, on the other hand, they prefer to be close to production.

Innovations brought by Industry 4.0 to automation technology show that the need for a factory workforce will decrease, and jobs will change significantly. While low-skilled activities are left entirely to robots, humans are more active in the product and production design process. It is thought that the new industry employees will be assigned tasks such as designing, planning, and problem-solving. When robots are used to improve things, as machines have done so far, there will be time and service opportunities to turn new ideas into products.

After all, humans have moved away from the factory but have not left the machine and have even started to live with the machine. However, the production space for humans and the production space for machines are becoming increasingly different, and the producing human is looking for a new place for herself/himself. Plug-in Production accepts humans as a plug-in part of the system in this balance between humans and machines. In other words, it takes the management part of the factory and installs it wherever the human is. In this version, the plug-in human is a mobile production space.

5.2.2 Plug-in Factory

Marc Auge says that technology changes the experience of time and space (Auge, 1995). The virtuality created by the telephone, television, and computer changes the perception of place. As a result, the built environment becomes meaningless. According to Auge, the place has been replaced by a non-place in the modern world. He defines non-places as empty, meaningless environments that we pass through our lives. Hans Ibelings argues that non-places are places associated with mobility and consumption, where no one feels a special attachment (Ibelings, 1998). With consumption, anything can happen anywhere. On a global scale, manufacturers can similarly take their brands and markets to all parts of the world. Supermodernism adopts neutral architecture with all the details inside. Ibelings criticises this as an independent, conceptual architecture. Ibelings defines expressionless, neutral, and minimal works in form and character as super modern. These buildings include offices, schools, banks, hotels, and shopping malls. Now, it can be said that smart or future factories are now participating in these mix-use formations.

Especially in the post-industrial era, factories were designed by investors concerned with visibility and advertising. However, the workflow and organization were still similar. Production at the factory was divided into two parts, both procedurally and spatially. The arrival of the raw material, its processing and output as a product, and the planning process of the entire business organisation took place in the same place. All this was managed in a separate part of the factory.

While the factory has tried to become an urban factory again, production has been combined with another function. It can be say that the factory, one of the buildings of modernism, is now evolving into a super-modern space where place, context, and identity lose its meaning. The inspiration of this is also technology, which evokes the smart and points to the future. Although a factory is necessary for production, it is not for digital production in smart industry. Therefore, the factory continues to exist in many forms within both digital and transforming culture.

While white-collars and even blue-collars cannot work in factories after smart production, digital working environments give birth to different types of factories. White Collar Factory is an example of a new working area of digital humans, and production, as its name suggests, is still inseparable from the factory. This office, built in a crowded environment in London, also includes living spaces, meeting rooms, work areas and project rooms. The working environment brings to mind the new generation mass digital production. Although people can work digitally from anywhere, the relationship or non-relationship of production with place has not been resolved yet. This situation shows that the conceptual qualities and identity of the factory, such as its spatial typologies, are also under the influence of this transformation.

Figure 5.2.2.1 The White Collar Factory

The most significant innovation that Industry 4.0 brings to production is flexibility. Production lines, conveyor belts, and production systems in the factory adapt quickly to changing production conditions thanks to their flexibility. Different products can be produced in the same system, or changes can be made during production. This makes it possible to respond to individual production. Smart factories are no longer places where linear mass production lines are established, but where fragmented, variable and mobile systems exist. For this reason, it is thought that in response to the flexible state of the new system, this fragmented production model will lead to spatial fragmentation, plug-ins and new factory organizations.

The flexible *plug-in production* also affects the distance between the product and the consumer. In this context, the *Close-to-Consumer* idea is a model in which the steps required for the product to reach the consumer are minimized, and the consumer is directly involved in the design phase of the product. (Barnia, Cortia, Pedrazzolia, Rovereb, & Lucisanoc, 2017). This idea also gives rise to mass individualization. Mass individualization causes the transformation of these industrial layers. It imagines the factory with people first, with places where people live, meet their basic needs, and have experiences. This is the effort of production to re-exist in daily life.

Smart production is entirely different from the traditional production organisation. First of all, this causes the interior of the space to change. The production hall is designed not for people but for machines, and in fact, it is not a space but a system suitable for workflow. Wired or wireless systems that will provide communication, mechanical installations, and surfaces that can provide flexibility in production are built, not human needs such as ventilation, lighting, and circulation. Designing a place where only machines are sheltered, removing all human needs from the design parameters, and planning the technological infrastructure, digital design, or machine comfort is relatively new to factory architecture.

Plug-in Factory, as a production space, is the transformation of systems designed for smart production into space. It is not a proposition where production is exhibited, but a production model that is close to both the producer and the consumer can be experienced when necessary or completely isolated. Research areas, common offices, fab-lab, and start-up areas are the first experiential examples of plug-in factories. Production can be plugged directly into another function and a factory. It plugs in its immaterial state to humans and solves the problem of space as spaceless.

The Plug-in Factory is plugged in somewhere between work and home. Production is unmanned, but accessible and sustainable. It is closely involved in research, development and testing. Production can also be marketed and exhibited. In the next step, the production capacity and logistical requirements determines where the plug-in production will take place. It is also expected that the plug-in factory will grow in parallel with where it is plugged in. More energy-intensive and heavy production will require more space and a more comprehensive environment. For these spaces, it may not always be necessary to expose the production, or it may be preferable to light out production because it is more economical. The dark factory is an innovative solution, especially for productions that require more energy. Because the factories that produce chemicals and have heavier and more dangerous production stages are unmanned, remote monitoring of stages and logistics works is an excellent convenience for those working in industrial zones or parks. That's why, dark factories also can be plugged in somewhere out of sight, also underground. (Figure 5.2.2.2).

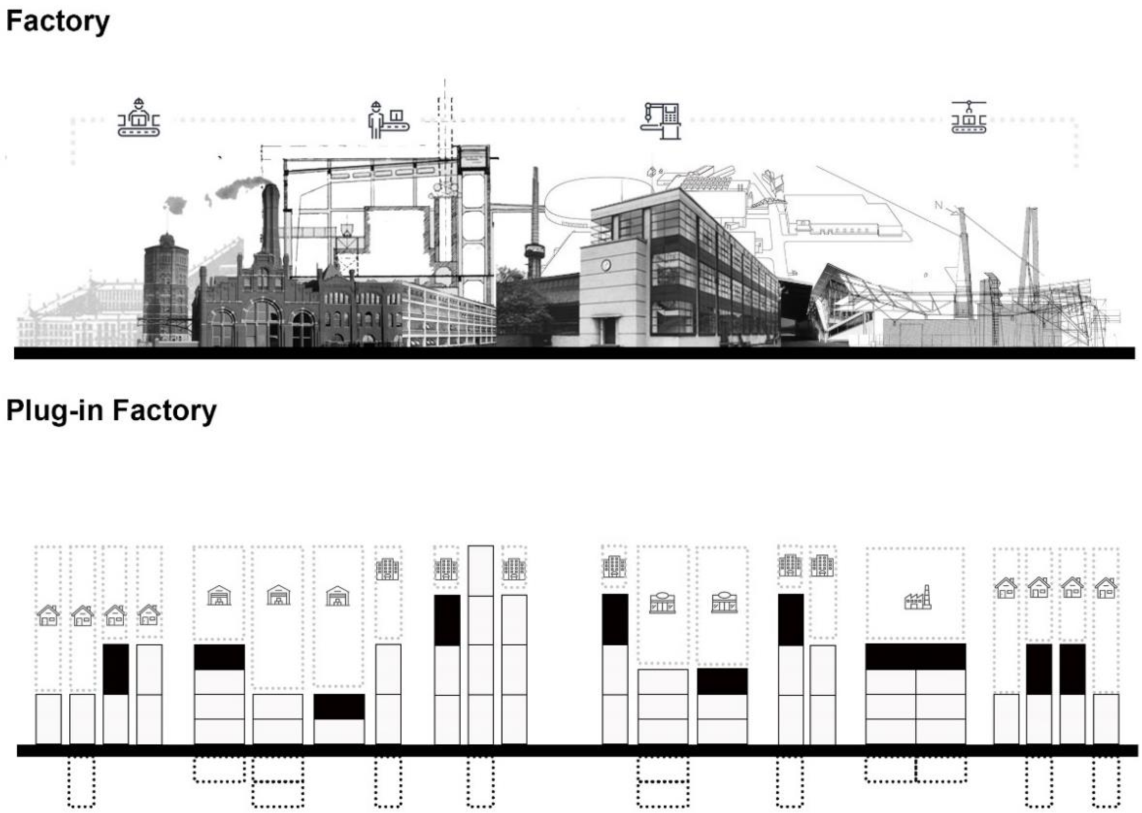


Figure 5.2.2.2 Factory and Plug-in Factory

In this industrial transition, machine and human productions, productions with and without space, and productions that are exhibited and marketed change the spatial and functional character of the factory. As a proposal, the Plug-in Factory aims to project the production environment in the near future. Although this approach is considered to dissemble and assemble production and plug these states in the factory or plug in the factory somewhere, it is the scope of the study to plug in people, space, and city and search for alternatives. The new tasks of the machine and the human in production job descriptions will give clues about the space, and these new production spaces will give clues about the new cities. Each possibility is considered a projection for the future factory or industrial environment, where production is considered together with life.

5.2.3 Plug-in Production Network

Industrialisation is still a regulating force for many societies. Production and consumption, which accelerated with mass production, became continuous with the introduction of robots. Production was separated from the city, creating more space for consumption. New production zones and factory towns began to emerge outside the city. The worker, an actor in production in the 20th century, was also the consumer of what he produced. Later, cities became places where individuals created an identity through their consumer cultures. Thanks to Industry 4.0, a revolution has begun in the relationships between production and organisation, production and people, and production and space. Today, cities seek for their new identity with the concept of "smart".

The Internet, the energy source of the digital revolution, was initially used for communication and entertainment. In a very short time, its field of application expanded. It has been used to automate home appliances, security systems and even vehicles. Many personal vehicles can be monitored by their users via a virtual network. Digital devices have created the digital environment. As energy flows, material flows and logistics services become traceable in smart cities, production data can be added to this network system (Schwab, 2016). With this network information, it will be easier for producers to provide data, set up businesses, and access and connect to market networks. Thousands of biosphere regions will be created, connected by energy, communication and transport systems in a network system that will cover continents (Rıfkın, 2013).

While the smart city concept defines an energy-efficient urban layout, it now refers to the digitalisation of public life and the development of information services through digital technologies. While Industry 4.0 is the driving force of this process, it has expanded the scope for smart houses, smart factories, smart economy, smart mobility, smart life and smart infrastructure (Safiullin, Krasnyuk, & Kapelyuk, 2019). Namely, new forms of interaction and communication, smart management and administration, smart transport technologies and logistics, and infrastructure based on intelligent systems, the Internet of Things, and other technologies of Industry 4.0 are necessary for a smart environment.

The revolution also changes habits in daily life. Although smart production brings machines and people together in a virtual network, the factory is not yet 'dark.' Working remotely is possible, but workplaces or offices have not yet been removed from the factories. In addition, new factories include functions that are not significantly related to production, apart from their primary functions. This new factory relationship with the people is a step for the industry returning to the city. It is considered that the factory will be a part of daily life again in this state. However, it is unclear how it will transform the city architecturally, as production is still based on plan and space.

While trying to re-exist in the built environment with this flexible state, production spaces differ spatially and conceptually from its previous examples. It is another discussion whether the factories will turn into a central building or where they will find a place after they turn into smart factories with virtual and unmanned technologies. The production also turns into consumable objects for cities, which are the centre of consumption in a super modern environment.

Different possibilities have been tried and are being tried. On the other hand, the new production model also builds its production environment. The Industrial Revolution created cities. The digital revolution similarly creates a new city-like texture. These settlements are neither cities nor part of existing cities. Newly built environments that have built their systems and networks have been act independently, as in proposals such as Woven City, Oxagon or The Future Science and Technology City (discussed in chapter 4).

About living with production or looking at the city with production parameters, Futurist architect Liam Young design an animation. Young has plugged a production line into the village in his Taobao Fulfillment Village work. The animated silhouette, part of the New City utopia, is a speculative urbanism proposal for the extravagant life of today. Using the exploration photographs of a mobile studio, Unknown Fields, New City combines the situation between the real and the imaginary of everyday life. In the animation, the village is wholly placed inside a production hall, and conveyors are plugged in. Living in a production has been proposed as a direct solution to fast consumption.

Figure 5.2.3.1 New City

Exhibiting the production process and product and plugging the factory in mixed-use areas is ideal for the consumer society. However, rethinking the city through production is likely to create a new everyday life. The representations of the factory before digitalisation and after Industry 4.0 technologies are quite different. The factory has different meanings for machines and humans, as well as before and after digitalisation.

Exhibiting the production process and product and also plugging the factory to mixed-use areas is ideal for the consumer society we have. However, re-planning the city with production, bringing production and consumption side by side, and including the consumer in all processes will create a new social order, economy, and, ultimately, a new cultural and architectural environment. In this context, the Plug-in Production Network projects the architectural representation of the virtual bond established by production, machine, human, and factory. This proposal questions the possibilities of plugging fragmented, disaggregated, reorganised, customised or personalised production steps into people, machines or spaces (Figure 5.3.2.2).

Plug-in Production Network is a model in which production, like consumption, is distributed heterogeneously in a city. For this reason, production, from its smallest to its largest form, looks for a place to plug in. The virtual part of the network is provided between humans and machines regardless of location. It can also be described as a dynamic, living production space. Non-virtual production will create networks according to type, size, and relational status.

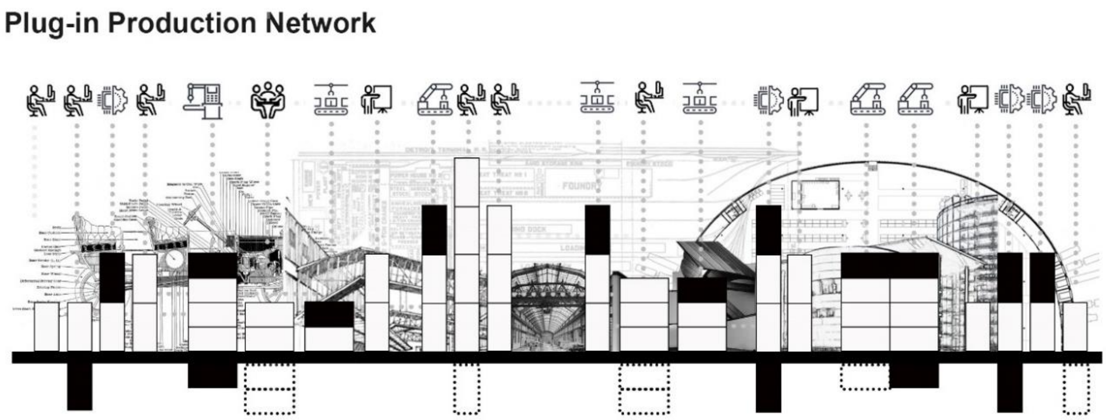


Figure 5.2.3.2 Plug-in Production Network

Since plug-in production accepts all forms of production as applicable, the possibility of plug-out is also included in this network. Light-out productions or dark factories can be considered the plug-out version of production networks. Hiding or not showing production is also advantageous in many aspects, such as economics and logistics. Thus, in the future, instead of industrial parks or zones, which are the production areas of cities, plug-in solutions that can be installed in cities' transportation and distribution networks can be developed.

The fragmentation of production and its integration into different functions and spaces will also change the texture of cities. Production first gains mobility by plugging in humans. While unmanned production is an experience, it is also a light-out process. In other words, the purpose for which production is done will determine its new location. The factory can be a landmark for the city or an underground workshop. For this reason, it is thought that the settlements formed by these networks will have a different texture than the cities of the 20th century.

After all, the Plug-in Production Network proposal, like its counterparts, adopts the idea of returning production to the city and establishing a spatial relationship with consumption. Factory is not redefined; places where production can be made are considered as factories. As a result of unmanned production, remote control, and machine collaboration, virtual and real production networks are formed. Therefore, the users and location of the factory change. This mobility in production spaces and industry prepares cities for a new planning process.

5.3 Coding of Plug-in Production Space

Production and consumption habits have changed in the transition from traditional to digital. First, the consumer has been looking for ways to produce or have the product s/he wants to buy produced. It means renewing many steps in reaching the product to the consumer. These steps now enable the development of alternatives for future production spaces. Studies have been carried out on smart production models where material and immaterial production are separated, only desktop production is carried out, or only robots and cobots work. In line with these developments, it is thought that the 21st-century factory architecture will turn into mix-use, hybrid or hi-flex production areas where workers are not included, but users change and increase in number.

Production is a part of daily life, from the most basic to the most complex model. It can be experienced, researched, developed, and also applied. In the digital age, humans can be involved in many stages of production and can even produce one of them. In the smart production model based on human and machine cooperation, the necessary conditions for humans and machines to work in this new environment are the subject of much research.

Plug-in Production offers a new discussion to other studies on back to the city. The focus is not on the new functions it brings to the factory but on new alternatives to where production can be installed. It produces a model for the spatial projection of industrial transition. It proposes an environment that defines production, humans, machines, labour, factories, and cities as new, mobile, flexible parameters in fabrication and production: Plug-in Production Network.

In this environment where production is spread throughout the city, a new order is proposed by plugging small-scale, fragmented, separated production steps into daily activities with the Plug-in Factory. Daily productions, where material and immaterial production can be done together, can be plugged into the main spaces to establish a closer relationship with the user. Houses, schools, offices, shops, museums, factories, and even cities are the new production spaces of the future.

Table 5.3.1 Factories in Plug-in Production

immaterial production	designable	digital production	human factory
immaterial / material production	experienceable	daily productions	house factory
immaterial / material production	researchable	daily productions	school factory
immaterial / material production	researchable	daily productions	office factory
material production	exhibitable	daily/ recycling/ reuse material productions	shop factory
material production	exhibitable	boutique productions	museum factory
material production	dark / lights out	productions using more energy resources	common factoy
material production	dark / lights out	productions cause environmental pollution	city factory

Human Factory: It corresponds to the mobile and placeless production. Digital production is now a non-space production activity. Production can be done, managed, and controlled wherever humans are. In this context, human can determine their working places and times. While the Taylorism eight-to-five working hours of the traditional factory are uninterrupted for machine workers, human workers determine their work schedules. The factory remains the workplace of robot workers, and the human chooses her/his workplace. On the one hand, mobile production spaces are being sought for human factories in future cities; on the other hand, factories where only machines work have been designed.

House Factory: That kind of houses are one of the smallest units where daily production occurs in response to daily consumption. However, transforming these productions into a business is not new. As an update of the pre-revolutionary putting-out system in the digital age, the house factory is the new workplace or starters. In this new version, the starter, as both employer and employee, is responsible for the production method, tools, post-product stages, and economic situations.

According to the data of a research conducted among remote workers in 2023, it was seen that 82% of the participants worked from home. This is followed by offices and co-working offices (State Of Remote Work 2023). In the same study, participants consider flexibility to be the biggest advantage of working remotely. It can be said that using the home as a production space is one of the fastest results of digital transformation. Especially in the post-pandemic period, home office working arrangements have become a quick solution for white-collar employees of companies. However, during the same period, factory workers continued to go to blue-collar jobs because factories and production methods were not yet smart enough. However, it is thought that in the near future, the flexibility provided by smart production machines will transform houses, which have been places for immaterial production for a while, into plug-in spaces where material production can also be made.

School Factory: In those, production is undoubtedly subject to intense research development and application processes. Especially in this transition where the second machine ages is experienced, a method that has not been applied in the industry until now is both researched and developed. For this reason, research and co-working spaces have not yet been separated from production in the first smart factory examples.

Moreover, production as a learned and taught activity has created *fab labs* or *research and model factories*. The school factory is considered an example of education and research plug-in of this network, where production methods are developed and machines are discussed, designed and built. Furthermore, the factory will have been as a collaborative space for entrepreneurs, producers, and researchers to engage in interdisciplinary studies.

Office Factory: They are one of the clearest results of smart production is the changes it causes in workplaces. Industry 4.0 brings together spaces flexibly with the flexible production methods it promises. Co-working offices not only allow different disciplines to work together, but also serve as alternative spaces for new and temporary projects. In the remote working model, many places are used as mobile offices. However, it could be argued that co-working spaces have the potential to facilitate the integration of immaterial and material production, and enable joint studies and experimental processes. Some may view them as plug-in offices for mobile workers. Additionally, the office factory is considered as a part of the production activity that can be plug-in to offices or production spaces where the design and testing stages can be carried out.

Shop Factory: It refers to a mixed-use usage in which production and consumption are directly related. Functional proximity is considered a priority when searching for a location in the city for a Plug-in Factory. While small and unique productions will be plugged into smaller houses, offices, or schools where production is developed, consumption spaces will be preferred for those that correspond to consumption in the ordinary flow of daily life.

It is thought that the shop factory will be the place of prosumer, the human of the digital age. Especially when the first smart factories are examined, the complete display of production, the opening of factories to everyone, not directly to customers, and the normalization of production activity as consumption is a result of the economic and sociological revolution of Industry 4.0. Plugging production spaces to consumption spaces will reveal the most striking plug-in spaces of this revolution. Producing factories will turn into consuming factories, consuming shops will turn into producing shops. After all, production plugged into consumption will create a net texture in cities parallel to space and function.

Museum Factory: It is an experiential and traceable form of production that participates in the city as an event. Leaving production to machines allows the product to be exhibited and monitored by everyone, in addition to the technological opportunities it provides for large-scale production. In this case, not only workers but also visitors can experience production. Especially nowadays, when the first results of the revolution are emerging, displaying robotic or unmanned production is considered as a kind of marketing technique.

Common factory: Although smart production designs a perfect model with robots and cobots, production is not always a process that can be monitored, experienced, or easily involved. In fact, showing and exposing may not be preferred as a method, or production may not always have something worth showing. Moreover, dark and light-out production may be advantageous for economic reasons. In addition to all these optional reasons, the absence of people in the production area, especially in high-risk production that requires more energy, will solve many problems in the industry. At the same time, the ability to perform different tasks with the same robots and to continue this non-stop enables the common use of production areas. A common factory corresponds to a situation where production is plugged into production, and the factory is plugged into the factory.

In the digital world, consumption undoubtedly has the potential to grow faster and more smoothly than production. It can spread independently of place and time, even more so, independent of language and culture. The Internet alone has become a sufficient resource for international consumption. However, it is important to acknowledge that with globalization, production concentrated in single centres may not always be sufficient to meet the needs of the digital age.

Especially in the post-pandemic period, it has become difficult to balance consumption and production, and there have been global crises due to factories not working. For this reason, it is a fact that the proximity or distance of production to consumption will form the basis of the production networks of the digital age. At this stage, plug-in production spaces will be plug-in and out alternatives to this production network as a module.

City Factory: Despite all the production technologies and systems used, production is not always clean and problem-free. Cities often contain productions that may cause environmental problems. In the fragmented, distributed, and plugged proposal of production, cities turn into reproductive settlements involved in these productions. It can be say that Wright's Broadacre City utopia became feasible nearly a century later. The fact that production in the city can be plug in different qualities and at different scales will transform the entire city into a production space instead of creating an industrial area in the cities. In other words, the city will be faced with a new production networks.

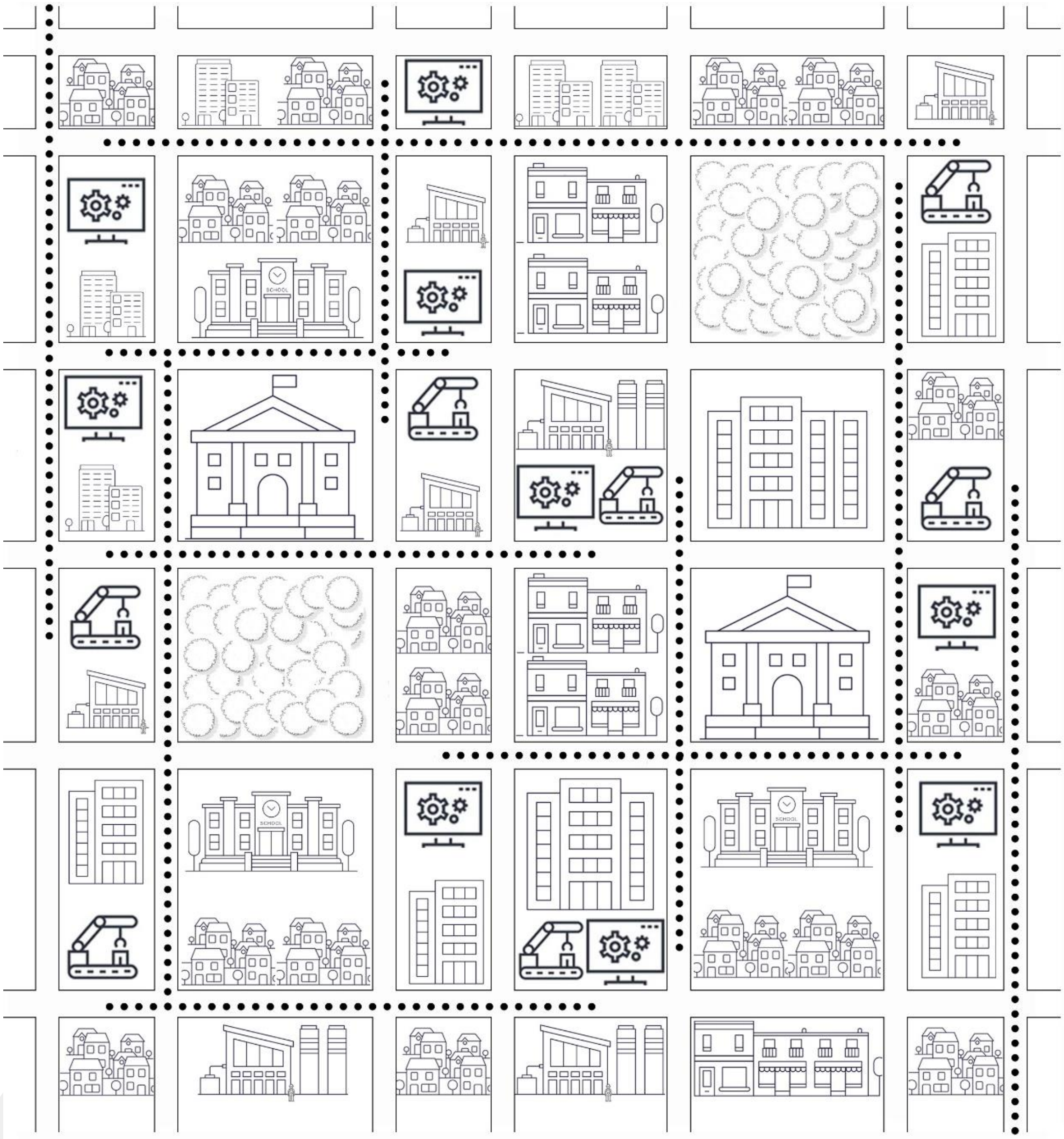


Figure 5.3.2 Production Networks

A new production-consumption balance will be seen in the environment created when production is small or large, light-in or light-out. Production networks will determine new regions of cities or become determining parameters for new cities. Thus, the location of unmanned production spaces in the city, transportation, access, and environmental relations require new urban planning. Furthermore, thanks to these new parameters in the industry and cities, it is thought that spatial and temporal limitations will gradually be eliminated in working and daily life. Because, in the human-production-city relationship, this network will be established both spatially and virtually. Therefore, new production networks bring together both the new production areas of cities and the digital environment provided by production.

In summary, the possibilities of plugging production space into the city, from the smallest production workshop to large production areas, have been reviewed as a Plug-in Production proposal. Spatial predictions of the new production model, inspired by mechanization and robotic production, are discussed. To conclude, architecture for machines is one of the most striking results of the second machine age or industry 4.0.

Chapter 6

Conclusions and Future Prospects

6.1 Conclusions

This thesis focuses on the architectural consequences of revolutions of machines and ultimately offers a proposal for future production spaces. Firstly, the spatial development processes of the factory since the Industrial Revolution and the contributions or effects of mechanisation story to this process were investigated. The research topics follow the production technologies and the historical period in which they were effective. Then, production-space, production-consumption, and city relations were examined in order to understand human-production relations. Thus, the actors of production, the space of production and the city form the conceptual basis of the discussion.

The actors of production were both influenced by technological revolutions and affected them. Simple machines were not enough for production; first, machines that produced machines were made, and then machines that managed machines were designed. Now, all production processes are left to robots, which are also machines. In each technological revolution, people have performed different tasks with different skills. Now, as prosumers, they have become consumers who are aware of the production processes.

When production moved from workshops to factories with large machines, it also carried a community of workers. At the beginning of the revolution, the factory was the centre of life. Both the environment and social life were based on the rules of the factory. Factories consisted of four main areas: management, production, storage and engine houses. The transition to electrical energy caused engine houses to become smaller. A model allowing direct entry and exit with on-time production and without storing raw materials and products was developed. Thus, there was no need for storage space. In the next revolution, management and production also separate. More compact production halls began to be exhibited by being included in mixed-use areas. Today, we are experiencing a new revolution in the industry during this transition period; existing factories are becoming museums, and production activities are turning into exhibitions.

Based on the economic and technological development of the countries, the industrial revolution was initiated simultaneously or subsequently in different geographies and affected several transformations and innovations in production and consumption as well as society and space. Production is an activity that grows, develops, transforms, increases, and spreads with technology. It is evident, especially after the Industrial Revolution that every technology produced until then is developing even more rapidly after this revolution. Each innovation in production became the key to the next, and steam engine technology ultimately turned into remote production systems. Likely, it will not remain as it is, and this technology will perhaps be updated in a much shorter time.

Industry 4.0, the second age of machines, transforms production into a more flexible, remotely controllable, experiential, and traceable activity. This new variation of the production model has initiated the evolution of factories into smart production areas. Moreover, future factory experiments such as urban, hybrid, co-factory, model, and innovation factories are envisaged, and what future production areas will be like is investigated. In addition to these studies, in this thesis, production is discussed as a plug-in and is explained with possibilities such as labour, human, machine, factory, and network.

This thesis aims to rethink the city through production with the Plug-in Production proposal. For this purpose, it has been divided into production components and rewritten in plug-in versions. Namely, plug-in labour refers to a collaboration in which humans and machines share production processes and stages. Plug-in human represents the machine-human into which production is plugged into working life and is the mobile and virtual version of production. A plug-in machine is a production tool that can be attached to humans, machines, and places, making production possible everywhere. In the smart production industry, manned or unmanned, light-in or light-out production is possible. Therefore, the Plug-in factory, as the place of new production, corresponds to the possibility of many states of the factory in different qualities and quantities. Finally, all these create new production networks.

Plug-in Production Network describes a heterogeneous environment consisting of production and its results. Factories are functional and spatial extensions of this network. The fact that production acquires designable, experiential, researchable, and traceable qualities makes it easier to transform it into a human factory, school, office, shop, or museum factory and plug it into buildings that make up the texture of the city. Moreover, the factories plug into each other and the city as buildings housing only machines.

In summary, this study aims to contribute to research on the changing production environment in response to the innovations of the industry. The research questions asked at the beginning determined the focus of the study, the research objectives formed the scope of the study, and finally, a proposal was developed (Table 6.1.1).

Table 6.1.1 Evaluations

research questions	objectives	evaluations
What are spatial needs in mass production / digital production /smart production processes?	Understanding the transition of production spaces with the revolutions in the industry and exploring the smart production spaces.	It has been determined that there are changes in factory plan organizations as a result of the revolutions in the industry.
How will new production methods affect humans, spaces, and cities?	Re-thinking the relation between production method, labour, space, and city.	In addition to the effects of production methods on human and production processes, the place of people in production and the purposes of using the production space have changed and produced cities have turned into consumed cities.
What will the production space and environment be like in the future?	Projecting industry architecture of the future and understanding smart production space.	Future factories or smart production spaces bring human and machines together in different relationships. In this context, plug-in production network constitutes a proposal.

As a result, this transition is faced with a technology in which the rules of production and labour are rewritten. In response to these developments, in this study, production technology and architectural results have been examined since the first revolution, and it has proposed an update to the production space and its environment in a changing world. The relationship between industry and architecture is significant for the planning stages of cities or networks in the future. It is believed that this study will bring a new perspective to the future factory spaces and industrial architecture.

6.2 Societal Impact and Contribution to Global Sustainability

The last industrial revolution, defined as the digitalisation of production, has brought many economic and social changes. The revolution has brought changes in the production space with innovations such as the use of cyber-physical systems and machine-human cooperation, as well as changes in many conventional production methods.

In addition, digitalisation aims to increase productivity, produce quickly and safely, and use minimum energy with the right raw materials in production with smart factories. While research focuses on the digital infrastructure of the smart factory, its spatial qualities are ignored. In this context, the study questions the architectural terminology of smart factories and aims to make a scientific contribution to the process.

Although its impact on production technology and the economy is at the forefront, digital transformation is expected to cause significant environmental and societal changes. Increased demand for skilled labour, reduced or changing working hours, new jobs and occupations, and industrial migration will require new arrangements in individual and societal life and in cities. While this study focuses on the evolution of production space, it also examines the relationship between space and human. The relationships between factories and human have been reconsidered with the information obtained.

The new industrial revolution has recently provided opportunities for new views and studies on sustainability in many areas. Based on these studies, it can be said that Industry 4.0 has stepped into creating a more sustainable industry. This thesis, which focuses on future production spaces, covers smart systems, cities and societies, innovation, and entrepreneurship among the AGU’s Research Focus Areas based on the United Nations Sustainability Development Goals. Since this thesis examines the future of production technology and spaces and the new regulations that these developments will bring to business life, it covers the eighth, ninth, and eleventh titles of the Sustainable Development Goals as it aims to investigate the new searches in industrialisation and their relations with people and the city.

Figure 6.2.1 United Nations Sustainability Development Goals

Developments in each period of the industry have had an impact on space, people, the city and society. This study deals with future working models, human-machine cooperation in transition and new professions, and therefore relates to the eighth title 'Decent Work and Economic Growth'. The thesis deals with intelligent systems from an architectural perspective and offers a new perspective. It is also related to the titles 'Industry, Innovation and Infrastructure' and 'Sustainable Cities and Communities', as it provides a projection of innovation in industry and the built environment that it affects.

Information obtained through the thesis and studies on the evolution of production spaces, their spatial fiction, and the needs of smart spaces will contribute to designing safe, accessible, and environmentally safe spaces for everyone, which will shed light on changes in urban and social life. Finally, this study aims to establish a relationship between architecture and the disciplines related to production, such as economy, industry, innovation and social life, and believes that this relationship is one of the requirements for a sustainable environment.

6.3 Future Prospects

Industry 4.0 and smart factories are being developed through the joint efforts of many disciplines. It has been thought that the new revolution would have a significant impact not only on industry, but also on architecture, as in many other fields. For this reason, the thesis aims to create new areas of study by presenting different perspectives, especially for architecture researchers. For this reason, it will achieve its primary purpose if it inspires other research.

Architecture is of crucial importance as a discipline in which changes in the industry are evaluated from many aspects and the relationship between developments and people is established. This study has attempted to support a current situation with the most up-to-date data and has sought global solutions for the near future. However, the process of researching and writing the thesis coincides with the very beginning of this transition. With each passing day, the number of studies on the subject and the diversity of opinions in the industry and other fields are increasing.

This study will start a new discussion in the literature thanks to the new codes it will produce. It is believed that each of the new concepts in the content of the study may be a different research topic. In this context, the new physical conditions of production and the smart transition of workspaces, smart consumption areas versus smart production areas, and the architecture of digital space are issues that will need to be explored through various studies in the future. In addition, more case studies will be needed for this transformation, especially in cities where industrial parks or zones are concentrated. It is predicted that all these developments in the industry will only yield positive results with a good architectural environment. For this reason, the study is intended to shed light on fabrication facilities and spaces in a transdisciplinary perspective.

References

Aerni, P. (2021). The City As An Ecosystem. H. Hosoya, & M. Schaefer *The Industrious City Urban Industry in the Digital Age* (s. 105-115). Zürich: Lars Müller Publishers.

Aitchison, M. (2016). *The Architecture of Industry: Changing Paradigms in Industrial Building and Planning.* Surrey: Ashgate Publishing Limited .

"Arena 2036". https://www.arena2036.de/en/ (Date Accessed: 20.04. 2023).

Auge, M. (1995). *Non-places: Introduction to an Anthropology of Supermodernity.* London, New York: Verso Books; New edition.

Barkow, F. (2021). A New Paradigm For The Periphery: The Case Aganist Reuniting City and Factory. *Architectural Design* , 70-77.

Barnia, A., Cortia, D., Pedrazzolia, P., Rovereb, D., & Lucisanoc, G. (2017). Mini-factories for close-to-customer manufacturing of customized furniture: from concept to real demo. *27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017*, (s. 854-862). Modena, Italy.

Baudrillard, J. (1998). *The Consumer Society Myths and Structures.* London : SAGE Publications.

Beecher, J., & Bienvenu, R. (1971). *The Utopıan Vısıon Of Charles Fourıer Selected Texts On Work, Love And Passıonate Attractıon.* Boston: Beacon Press books.

Benevolo, L. (1971). *History of Modern Architecture.* Cambridge, Massachusetts: The M.I.T. Press.

Blinder, A. S. (2006). Offshoring: The Next Industrial Revolution? *Foreign Affairs*, 3-9.

"BMW FIZ FUTURE". Henn Web Site: https://www.henn.com/en/projects/industry-urban-design/bmw-fiz-future (Date Accessed 11.11.2021).

Borbi, L. (2018). *Roebling: Company Town: Steel, Immigrants, Moonshine and Crap Tables.* BookBaby.

Brynjolfsson, E., & Mcafee, A. (2014). *The Second Machine Age Work, Progress and Prosperity in a Time of Brillant Technologies.* New York: W.W. Norton & Company.

Buder, S. (1967). The Model Town of Pullman: Town Planning and Social Control in the Gilded Age. *Journal of the American Institute of Planners*, 2-10.

Carmony, D. F., & Elliott, J. M. (1980). New Harmony, Indiana: Robert Owen's Seedbed for Utopia. *Indiana Magazine of History*, Vol. 76, No. 3 pp. 161-261.

Chen, B., Wan, J., Shu, L., Li, P., Mukherjee5, M., & Yin, B. (2017). Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges. *IEEE Access*, 6505-6519.

"Chengdu Sky Valley". MVRDV Web Site: https://www.mvrdv.com/projects/442/chengdu-sky-valley (Date Accessed:12.09.2023)

Colomina, B., & Wigley, M. (2022). *Are We Human?* Baden : Lars Müller Publishers.

Cook, J. (2015). *Lingotto Myths, Mechanisation and Automobiles.* University of Westminster.

Cowie, J., & Heathcott, J. (2003). Beyond the ruins: The Meanings of Deindustrialization. *Ithaca, NY: ILR Press. http://digitalcommons.ilr.cornell.edu/cb/33/*, 1-15.

Darley, G. (2003). *Factory.* London: Reaktion Books.

DeRuiter-Williams, D. (2007). The Critical Nexus: Deindustrialization, Racism and Urban Crisis in Post-1967 Detroit. *McNair Scholars Journal*, 22-31.

Dewhirst, R. K. (1960). Saltaire. *The Town Planning Review*, 135-144.

"Digital Transformation: Leading by Example". (2022). Siemens Web Site: https://www.siemens.com/global/en/company/stories/industry/electronics-digitalenterprise-futuretechnologies.html

Dursun, B. (2018)**.** Cins Web Site: https://www.cins.com.tr/2018/10/filozof-peter-sloterdijk-insan-ve-makine-bir-gun-tek-vucutta-birlesecek/ (Date Accessed 04.04.2021)

Ernst, F., & Frische, P. (2015). Industry 4.0 / Industrial Internet of Things - Related Technologies and Requirements for a Successful Digital Transformation: An Investigation of Manufacturing Businesses Worldwide. *SSRN Electronic Journal* .

"Factory Building on the Vitra Campus SANAA". Archdaily Web Sitesi: https://www.archdaily.com/363581/ (Date Accessed: 26.03.2021)

Fishman, R. (1982). *Urban Utopias in the Twentieth Century: Ebenezer Howard, Frank Lloyd Wright, Le Corbusier.* Cambridge: The MIT Press .

Flynn, D., McCaffrey, P., & Sejal, M. (2013). *The future of manufacturing: İnternational perspectives.* UK Government's Foresight Future of Manufacturing Project.

Freeman, C., & Soete , L. (2004). *The Economics of Industrial Innovation.* London & New York: Routledge.

"From old to new with Looop". HM Web Site: https://www2.hm.com/en_gb/life/culture/inside-h-m/meet-the-machine-turning-old-into-new.html (Date Accessed: 23.10.2023)

"Funder Werk". Coop-Himmelblau Web Sitesi: coop-himmelblau.at/architecture/projects/funder-werk-3 (Date Accessed: 09.10.2021)

"Future Stitch Smart Factory Azl Architects". Archdaily Web Site: https://www.archdaily.com/915654/future-stitch-smart-factory-azl-architects (Date Accessed: 28.10.2021)

Gabriel, M., & Pessl, E. (2016). Industry 4.0 and sustainability impacts: Critical discussion of sus- tainability aspects with a special focus on future of work and ecological consequences. *ANNALS of Faculty Engineering Hunedoara International Journal of Engineering*, 131-136.

Garnier, T. (1996). *Une Cite Industrielle.* New York: Princeton Architectural Press.

Giddens, A. (1991). *The Consequences of Modernity.* Stanford University Press.

"Glaserne Manufaktur". Henn Web Site https://www.henn.com/en/projects/industry/glaserne-manufaktur (Date Accessed: 23.10.2021)

Gorecky, D., Schmitt, M., Loskyll, M., & Zühlke, D. (2014). Human-Machine-Interaction in the Industry 4.0 Era. *Proceedings - 2014 12th IEEE International Conference on Industrial Informatics, INDIN 2014*, 289-294.

Guallart, V. (2021). The Digital Reindustrialisation of Cities. *Architectural Design*, 24-31.

Güler, İ., (2021). *An Inquiry on the Architecture of Production: From Mills to Machine Landscapes,* (Master Thesis), Middle East Technical University, Ankara.

Hannan, B. R. *Category: Wright In Wisconsın*. Write on Wright Web Site : https://writeonwright.com/index.php/category/wright-in-wisconsin/ (Date Accessed: 20.08.2021)

Hardt, M., & Negri, A. (2001). *Empire.* Cambridge: Harward Univercity Press.

Hardt, M., & Negri, A. (2011). *Ortak Zenginlik.* İstanbul: Ayrıntı Yayınları.

Hardt, M., & Negri, A. (2012). *Declaration.* Argo Navis Author Service .

Harvey, D. (1992). *The Condition of Postmodernity.* Cambridge MA & Oxford UK: Blackwell Publishers.

Hatuka, T. (2021). The New Industrial Urbanism. *Architectural Design*, 14-23.

Hatuka, T., & Ben-Joseph, E. (2017). Industrial Urbanism:Typologies, Concepts and Prospects. *Built Environment*, 10-24.

Hatuka, T., & Ben-Joseph, E. (2022). *New Industrial Urbanism: Designing Places for Production.* New York : Routledge.

Hobsbawm, E. (1995). *The Age of Extremes* . An Abacus Books.

Hobsbawm, E. (1996). *The Age of Revolution 1789-1848.* New York: Vintage Book.

Hobsbawn, E. (1989). *The Age of Empire*. New York: Vintage Books.

Hobsbawn, E. (1995). *The Age of Capital* . London : Abacus.

Hozdić, E. (2015). Smart Factory For Industry 4.0: A Revıew. *International Journal of Modern Manufacturing Technologies*, 28-35.

Hunt, J. *Businessweek: This Company's Robots Are Making Everything—and Reshaping the World*. Retrieved from Bloomberg Web Site : https://www.bloomberg.com/news/features/2017-10-18/this-company-s-robots-are-making-everything-and-reshaping-the-world#xj4y7vzkg (Date Accessed: 10.18.2017)

Hüttenhain, B., & Kübler, A. I. (2021). City and Industry: How to Cross Borders? Learning From Innovative Company Site Transformations. *Urban Planning*, 368–381.

Ibelings, H. (1998). *Supermodernism - Architecture in the Age of Globalisation.* Rotterdam : NAi Publishers.

"Innovation Factory". (n.d.). https://www.wittenstein.de/en-en/company/production-of-the-future/innovation-factory/(Date Accessed: 18.04.2023)

Kang, H. S., Lee, J. Y., Choi, S. S., Kim, H., Park, J. H., Son, J. Y., . . . Noh, S. D. (2016). Smart Manufacturing: Past Research, Present Findings, and Future Directions. *International Journal Of Precision Engineering And Manufacturing-Green Technology*, 111-128.

Kotler, P. (1986). The Prosumer Movement: A New Challenge for Marketeters. *Advances in Consumer Research*, 510-513.

Kumar, K. (2010). *Sanayi Sonrası Toplumdan Post-modern Topluma Çağdaş Dünyanın Yeni Kuramları.* İstanbul: Dost Kitapevi.

Kumar, S., Narkhede, B., & Jain, K. (2018). Industry 4.0: Literature Review and Future Research Directions. *Rotre of Industrial Engin. in Industry 4.0 Paradigm*.

Kurie, P. (2018). *In Chocolate We Trust: The Hershey Company Town Unwrapped.* Philadelphia: University of Pennsylvania Press.

Kurzweil, R. (2006). *The Singularity is Near* . Penguin Books.

Lane, R. N., & Rappaport, N. (2020). *The Design of Urban Manufacturing.* New York: Routledge.

Marsh, A. (2019). *The Factory: A Social History of Work and Technology.* California : Greenwood: Santa Barbara, California : Greenwood.

Marullo, F. (2014). *Typıcal Plan The Archıtecture Of Labor And The Space Of Productıon.* Delft: Technische Universiteit Delft.

Marx, K. (1968). *A Critique of the German Ideology (Tim Delaney and Bob Schwartz, Trans.).* Progress Publishers.

Mazali, T. *Articles: Industry 4.0: A New Relationship Between Factory and Society*. Archdaily Web Site: https://www.archdaily.com/943501/industry-a-new-relationship-between-factory-and-society (Date Accessed: 08.**10**.2020)

Morgan, J. (2014). *Articles: The Future Organization* . The Future Organization Web Site: https://thefutureorganization.com/evolution-employee/ (Date Accessed: 01.09.2022)

"Oxagon" . (n.d.). Retrieved from Neom Web Site : https://www.neom.com/en-us/regions/oxagon

Pieczara, M. (2020). Factory Building Inspired by a Product – A Seek for the Truth or a Lie? T. Kozłowski içinde, *Definıng The Archıtectural Space – The Truth And Lıe Of Archıtecture* (S. 75-88). Wrocław: Oficyna Wydawnicza Atut.

Pieczara, M. (2020). Perspectives on the Design of Creative Workplaces in Industry 4.0: A New Theme in Architects' Education. *The International Journal of Design Education*, 41-64.

Pollard, M. (1995). *Henry Ford and Ford (Great Business Stories).* Watford: Exley Publications Ltd.

Rappaport, N. (2009). Real Time / Implication for Production Spaces. *Acadia*, 186-193.

Rappaport, N. (2019). *Vertical Urban Factory.* New York: Actar Publisher.

Rappaport, N. *Factory Architecture in the Age of Industry 4.0*. Metropolismag Web Site: https://metropolismag.com/projects/factory-architecture-age-industry-4-0/(Date Accessed: 09.10.2021)

Rappaport, N. (2021). The New Industrial Commons . *Architectural Design* , 48-55.

Rappaport, N. (2022). *Hybrid Factory, Hybrid City.* New York: Actar Publishers.

Reader, R. *The manufacturing job of the future: clean, urban, and better paid*. Fast Company Web Site : https://www.fastcompany.com/90312543/the-manufacturing-job-of-the-future-clean-urban-and-better-paid (Date Accessed: 24.10.2021)

Rıfkın, J. (2013). *The Third Industrial Revolution: How Lateral Power Is Transforming Energy, the Economy, and the World.* New York: St. Martin's Griffin.

Ritzer, G. (2015). Prosumer Capitalism. *The Sociological Quarterly*, 413-445.

Ritzer, G., & Jurgenson, N. (2010). Production, Consumption, Prosumption: The nature of capitalism in the age of the digital 'prosumer'. *Journal of Consumer Culture, ,* 13-36.

Roblek, V., MešKo, M., & Krapež, A. (2016). A complex view of industry 4.0. *Sage Open*, 1-11.

Rowthorn, R., & Ramaswamy, R. (1997). *Deindustrialization– Its Causes and Implications.* Washington: International Monetary Fund, Publication Services.

Russo, J., & Linkon, S. L. (2009). The Social Costs Of Deindustrialization. *Manufacturing a Better Future for America*, 1-16.

Sadler, S. (2005). *Archigram Architecture Without Architecture.* Cambridge : MIT Press.

Safiullin, A., Krasnyuk, L., & Kapelyuk, Z. (2019). Integration of Industry 4.0 technologies for “smart cities” development. *IOP Conference Series: Materials Science and Engineering* (s. 0-8). Institute of Physics Publishing.

Schwab, K. (2016). *The Fourth Industrial Revolution.* Geneva: World Economic Forum.

Sennett. (2008). *The Craftsman.* New Haven & London: Yale University Press.

Stearns, P. N. (2013). *The Industrial Revolution in World History.* Colorado: Westview Press.

Stephan, R. (1999). *Erich Mendelsohn: Architect 1887-1953.* New York: The Monacelli Press; First American Edition.

Strozzi, F., Colicchia, C., Creazza, A., & Noè, C. (2017). Literature review on the ‘Smart Factory’ concept using bibliometric tools. *International Journal of Production Research*, 6572-6591.

Styles, J. (1990). *Industry And Vırtue:Tıtus Salt And Saltaıre.* Bradford: Salts Estates Limited.

"The Plus for Vestre / BIG". (n.d.). from https://www.archdaily.com/982957/the-plus-for-vestre-big (Date Accessed: 09.05.2023)

Thompson, E. P. (1966). *The Making of the English Working Class.* New York: Vintage Book.

Tilley, J. (2017). *Operations: Automation, robotics, and the factory of future*. McKinsey Web Site: https://www.mckinsey.com/capabilities/operations/our-insights/automation-robotics-and-the-factory-of-the-future (Date Accessed: 24.08.2023)

Toffler, A. (1981). *Üçüncü Dalga .* İstanbul: Altın Kitaplar Basımevi .

"Toyota Woven City". Archdaily Web Site: https://www.archdaily.com/931468/big-designs-toyota-woven-city-the-worlds-first-urban-incubator (Date Accessed: 29.10.2021)

"Trumpf Smart Factory". Barkow Leibinger Web Site: https://barkowleibinger.com/archive/view/trumpf_smart_factory (Date Accessed: 28.10.2021)

"UNDP". https://www.undp.org/tr/turkiye/projects/uygulamali-kobi-yetkinlik-merkezi-projesi-model-fabrika (Date Accessed: 20.03.2021)

"Usine L'ORÉAL / Aulnay-Sous-Boıs". AMC ARCHI Web Site: https://www.amc-archi.com/article/1992-usine-l-oreal-aulnay-sous-bois-93-valode-et-pistre-l-oreal.45038 (Date Accessed: 28.03.2022)

"Vertical Factories in Megacities". Evolo.us Web Site: https://www.evolo.us/vertical-factories-in-megacities/#more-35759 (Date Accessed: 24.11.2021)

"Vitra Campus". Design Museum Web Site: https://www.design-museum.de/en/information/vitra-campus.html (Date Accessed: 12.01.2021)

Vonnegut, K., (1999). *Player Piano,* Random House Publishing Group.

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing Smart Factory of Industrie 4.0: An Outlook. *Hindawi Publishing Corporation International Journal of Distributed Sensor Networks*.

Wordsworth, D. (2018). *A History of Cadbury.* Yorkshire: Pen & Sword History.

Young, L. (2019). A Place of Evertything. *Architectural Design*, 43-47.

Zhejiang Perfect Production Factory. Archdaily Web Site: https://www.archdaily.com (Date Accessed: 24.05.2022)

Zhou, K., & Taigang Liu, L. Z. (2016). Industry 4.0: Towards Future Industrial Opportunities and Challenges. *2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, 2147-2152.

Zimmerman, C. (2017). *Albert Kahn in the Second Industrial Revolution.* London : The Architectural Association.

Zimmermann, C. (2013). *Indsutrial Cities History and Future.* Frankfurt: Campus Verlag.

APPENDIX

Figure Reference List

Figure 2.1.1 New Harmony

(1) - https://www.historicurbanplans.com/product/new-harmony-indiana-1825/
(2), (3) - http://edu.saline.free.fr/01-cites/1-thema/01-newharm.html

Figure 2.1.2 Phalanstère

https://wallonica.org/blog/tag/immigration/

Figure 2.1.3 Saltaire Factory and Company Town

(1) https://saltairevillage.info/saltaire_history_0001a.html
(2) https://yorkshire.u08.eu/shipley/41553/image/6/
(3) https://www.flickr.com/photos/bradfordlibraries/8429156237

Figure 2.1.4 Cadbury Factory and Company Town

https://www.british-history.ac.uk/vch/warks/vol7/pp43-57

Figure 2.1.5 Pullman Factory and Company Town

(1) https://www.landmarks.org/preservation-programs/richard-h-driehaus-foundation-preservation-awards/2002-award-recipients/pullman-factory/
(2) https://www.loc.gov/resource/hhh.il0377.photos/?sp=1
(3) https://digital.newberry.org/scalar/pullman/media/george-pullman-interview-1897

Figure 2.1.6 Roebling Factory and Village

https://commons.wikimedia.org/wiki/File:John_A._Roebling's_Sons_Company,_Kinkora_Works,_Second_and_Hornberger_Avenues,_Roebling,_Burlington_County,_NJ_HAER_NJ,3-ROEBL,1-_(sheet_3_of_14).png

Figure 2.1.7 Hershey Factory and Company Town

(1) https://tr.pinterest.com/pin/the-original-hershey-chocolate-factory--389843530085251l5/
(2)https://www.pinterest.com.mx/pin/335799715941431306/?amp_client_id=CLIENT_ID%28_%29&mweb_unauth_id=&simplified=true
(3) https://tr.pinterest.com/pin/387380005419865115/)

Figure 2.2.1 Garden City

https://ly.redditchjobcentre.co.uk/garden-city/

Figure 2.2.2 Une Cité industrielle

https://wolfsonian.org/whats-on/exhibitions+installations/2016/08/visionary-metropolis-tony-garniers-une-cite-industrielle.html
Figure 2.2.3 Broadacre City

https://mapsontheweb.zoom-maps.com/post/135199938223/broadacre-city-by-frank-lloyd-wright-a-design-for

Figure 2.2.4 Albert Khan's Factory Organization

https://www.researchgate.net/figure/The-general-planning-of-the-Pierce-Plant-Source-8_fig2_341032818

Figure 2.2.5 Ford Motor Company

(1) https://www.meisterdrucke.ie/fine-art-prints/American-Photographer/488075/Highland-Park-Plant%2C-Ford-Motor-Company%2C-Detroit%2C-Michigan-.html
(2) https://www.macsmotorcitygarage.com/video-inside-the-ford-highland-park-plant/
(3) Tyler, I. R. (2015). Highland Park Ford Plant: Documentation and Redevelopment. *APT Bulletin*, *46*(2/3), 36–43. Retrieved from https://widgets.ebscohost.com/prod/customerspecific/ns000545/customproxy.php?url=https://search.ebscohost.com/login.aspx?direct=true&db=edo&AN=109929214&amp%0Alang=pt-pt&site=eds-live&scope=site

Figure 2.2.6 AEG Turbine Factory

(1) https://architectuul.com/architecture/aeg-turbine-factory
(2) https://www.metalocus.es/en/news/aeg-turbine-factory-milestone-industrialization-peter-behrens
(3)https://www.reddit.com/r/ModernistArchitecture/comments/w9bdh2/aeg_turbine_factory_germany_190810_by_peter/?rdt=54095

Figure 2.2.7 Hat Factory

(1)https://www.reddit.com/r/brick_expressionism/comments/u2tp5y/steinberg_herrmann_co_hat_factory_luckenwalde/
(2) https://en.wikiarquitectura.com/building/steinberg-herrmann-hat-factory/#hat-factory-2
(3) https://en.wikiarquitectura.com/building/steinberg-herrmann-hat-factory/hat-factory-alz-complejo-2/

Figure 2.2.8 Fagus Factory

(1) https://design.tel/fagus-factory/
(2) https://moonlightspostcardblog.blogspot.com/2011/11/germany-fagus-factory-in-alfeld.html

(3) https://www.archdaily.com/612249/ad-classics-fagus-factory-walter-gropius-adolf-meyer/54135e0cc07a80712f00004b-ad-classics-fagus-factory-walter-gropius-adolf-meyer-ground-floor-plan

Figure 2.2.9 Fiat Lingotto Factory

(1) https://en.wikipedia.org/wiki/Lingotto#/media/File:Fiat_Lingotto_veduta-1928.jpg
(2) http://www.turinitalyguide.com/fiat-lingotto-factory-turin/
(3) https://www.researchgate.net/figure/Figura-1-Estado-del-complejo-industrial-Fiat-Lingotto-en-el-ano-1927-1-Officine-di_fig2_274784719

Figure 2.2.10 Van Nelle Factory

(1) https://www.atlasofplaces.com/architecture/van-nellefabriek/
(2) https://tr.pinterest.com/pin/194288171401531332/
(3) https://www.atlasofplaces.com/architecture/van-nellefabriek/

Figure 2.2.11 Usine Claude & Duval Factory

(1), (2) https://www.fondationlecorbusier.fr/oeuvre-architecture/realisations-usine-claude-et-duval-saint-die-france-1946-1950/

Figure 2.3.1 Industrial Architecture Map

https://www.mdpi.com/2071-1050/12/9/3609

Figure 2.3.2 Vitra Campus

https://otrarquitecturas.blogspot.com/2014/12/vitra-campus-en-weil-am-rheinfoto.html

Figure 2.3.3 Frank Gehry Vitra Factory

(1), (2) https://www.vitra.com/en-ie/campus/architecture/architecture-factory-building-gehry

(3) https://visuallexicon.wordpress.com/2017/10/08/vitra-design-museum-1989gehry-partners/

Figure 2.3.4 SANAA Vitra Factory

(1), (2) https://www.archdaily.com/363581/factory-building-on-the-vitra-campus-sanaa

(3) https://arquitecturaviva.com/works/edficio-para-la-factoria-vitra-9

Figure 2.3.5 L'Oreal Factory

(1) https://cpp-luxury.com/loreal-invests-e15-million-in-luxury-fragrance-manufacturing-facility-outside-paris/
(2) https://monaulnay.com/2019/04/loreal-a-aulnay-sous-bois-se-tourne-vers-le-luxe.html

(3) https://www.amc-archi.com/article/1992-usine-l-oreal-aulnay-sous-bois-93-valode-et-pistre-l-oreal.45038
(4) https://patrimoine.seinesaintdenis.fr/Entreprise-L-Oreal

Figure 2.3.6 Funder Werk Factory

(1), (2) https://coop-himmelblau.at/projects/funder-werk-3/
(3) https://www10.aeccafe.com/blogs/arch-showcase/2017/01/08/funder-werk-3-in-sankt-veit-an-der-glan-austria-by-coop-himmelblau/

Figure 2.3.7 Transparent Factory

(1) https://commons.wikimedia.org/wiki/File:Dresden_Glaeserne_Manufaktur.jpg
(2) https://ibm.com/downloads/cas/1RGZLVN7
(3) https://www.henn.com/en/project/vw-transparent-factory

Figure 3.1.1 Amazon Fullfillment Centre

https://www.herepress.org/books-prints/amazon-fulfilment-centre/

Figure 3.1.2 Facebook Prineville Data Centre

(1) https://www.archdaily.com/285237/facebook-prineville-data-center-sheehan-partners/5086262d28ba0d55a50000a7-facebook-prineville-data-center-sheehan-partners-photo
(2) https://www.oregonlive.com/silicon-forest/2021/03/facebook-will-add-two-more-data-centers-at-2-billion-prineville-complex.html

Figure 3.1.3 Bitcoin Mine

https://monteverdetravel.com/environmental-impact-of-cryptocurrency/

Figure 3.2.1 Wittenstein Innovation Factory

(1) https://www.german-architects.com/en/henn-munchen/project/wittenstein-innovation-factory
(2) https://wow-webmagazine.com/wittenstein-innovation-factory-horizontal-and-vertical-movement
(3) https://www.henn.com/en/project/wittenstein-innovation-factory

Figure 3.2.2 Arena36

(1), (2) https://www.henn.com/en/project/arena2036
(3) https://anc.masilwide.com/341

Figure 3.2.3 Trumpf Smart Factory

(1), (2), (3) https://www.archdaily.com/879572/trumpf-smart-factory-chicago-barkow-leibinger

Figure 3.2.4 The Plus Factory

(1), (2), (3) https://www.floornature.com/architectural-solutions/bigas-plus-green-street-furniture-factory-vestre-15631/

Figure 3.2.5 Future Stitch Smart Factory

(1), (2), (3) https://www.archdaily.com/915654/future-stitch-smart-factory-azl-architects

Figure 3.2.6 Zhejiang Factory

(1), (2), (3) https://www.archdaily.com/925151/zhejiang-perfect-production-factory-phase1-gad-star-line-plus-studio

Figure 4.1.2 The Future of Work

https://thefutureorganization.com/evolution-employee/

Figure 4.2.1 Hallmark of the American System of Manufacturing

http://www.americaslegacylinks.com/civil_war_firearms.html

Figure 4.2.3 Work Organization Scenario

Pieczara, M. (2020). Perspectives on the Design of Creative Workplaces in Industry 4.0: A New Theme in Architects' Education. *The International Journal of Design Education*, 41-64.

Figure 4.2.4 Trumpf Smart Factory Digital Workspaces

https://www.pressbrakebuyersguide.com/news/trumpf-opens-smart-factory-in-chicago

Figure 4.2.5 Experience Factory

Hüttenhain, B., & Kübler, A. I. (2021). City and Industry: How to Cross Borders? Learning From Innovative Company Site Transformations. *Urban Planning*, 368–381.

Figure 4.2.6 Looop, the Machine in a Shopping

https://about.hm.com/news/general-news-2020/recycling-system--looop--helps-h-m-transform-unwanted-garments-i.html

Figure 4.2.7 Ankara and Kayseri Model Factories

(1) https://www.modelfabrika.org/modelfabrika-hakkinda/
(2) https://edergi.sanayi.gov.tr/File/Journal/2022/6/6_2022.pdf

Figure 4.2.8 Strathcona Village

(1), (2) https://www10.aeccafe.com/blogs/arch-showcase/2019/11/28/strathcona-village-in-vancouver-canada-by-gbl-architects/#jp-carousel-599712

Figure 4.2.9 Xiaomi Smart (Dark) Factory

https://xiaomiui.net/xiaomi-smart-factorys-growing-power-phase-two-and-innovative-manufacturing-49159/

Figure 4.3.1 Science Technology Engineering Arts and Mathematics Center

https://www.rogersarchitects.com/nanotronics-building-20/

Figure 4.3.2 New Lab

(1), (2) https://www.architecturalrecord.com/articles/14108-new-lab-at-the-brooklyn-navy-yard-by-marvel-architects

Figure 4.3.3 Vertical Urban Factory

https://urbandesignforum.org/vertical-urban-factories-nina-rappaport/

Figure 4.3.4 Hybrid Factory

https://www.copyrightbookshop.be/shop/hybrid-factory-hybrid-city/

Figure 4.3.5 2007 Skyscraper Competition

https://linshenxie.com/Vertical-Factories

Figure 4.3.6 2007 Skyscraper Competition Proposal

https://linshenxie.com/Vertical-Factories

Figure 4.3.7 BioCity, Local Digital Production

Guallart, V. (2021). The Digital Reindustrialisation of Cities. *Architectural Design*, 24 31.

Figure 4.3.8 Industrial Urbanism

https://lcud.tau.ac.il/wp-content/uploads/2022/04/THE-NEW-INDUSTRIAL-URBANISM_compressed.pdf

Figure 4.3.9 Integrated City

https://lcud.tau.ac.il/wp-content/uploads/2022/04/THE-NEW-INDUSTRIAL-URBANISM_compressed.pdf

Figure 4.3.10 Prototypes of Industrial Spaces

Hatuka, T., & Ben-Joseph, E. (2017). Industrial Urbanism:Typologies, Concepts and Prospects. *Built Environment*, 10-24.

Figure 4.3.11 BMW FIZ Future

(1), (2), (3), (4) https://www.henn.com/en/project/bmw-fiz-future

Figure 4.3.12 Toyota Woven City

https://worldlandscapearchitect.com/toyota-woven-city-bjarke-ingels-group/?v=ebe021079e5a

Figure 4.3.13 Future Science and Technology City

https://www.archdaily.com/950249/mvrdv-unveils-sky-valley-chengdu-future-science-and-technology-city-in-southwest-china

Figure 4.3.14 Oxagon

https://www.dezeen.com/2022/12/21/oxagon-floating-port-city-neom-saudi-arabia/

Figure 5.1.1 Plug-in City, Archigram

https://www.dezeen.com/2020/05/12/archigram-plug-in-city-peter-cook-dennis-crompton-video-interview-vdf/

Figure 5.1.2 Plug-in City, Computer City

https://archigram.net/portfolio.html

Figure 5.1.3 The Cloud

https://architectuul.com/architecture/the-cloud

Figure 5.1.4 Plug-in City, Alain Bublex

https://alainbublex.fr/fr/plug

Figure 5.2.1.1 Wearable Computers

https://dev.to/c0mmand3rj/apple-vision-pro-the-frontend-innovation-1o6i

Figure 5.2.2.1 The White Collar Factory

https://www.ahmm.co.uk/projects/office/white-collar-factory/

Figure 5.2.3.1 New City

https://liamyoung.org/projects/new-city

Figure 6.2.1 United Nations Sustainability Development Goals

https://sdgs.un.org/goals

PUBLICATIONS

Pekdemir Başeğmez, M., & Asiliskender, B. (2023). Evolution of Production Spaces: A Historical Review for Projecting Smart Factories. *ICONARP International Journal of Architecture and Planning*, *11*(2), 716–733. https://doi.org/10.15320/ICONARP.2023.261

Pekdemir Başeğmez, M., & Asiliskender, B. (2023). Smart Factories: New Production Spaces in Digital Transition. *Disegno Journal of Design Culture*, *VII(1)*, 66-81. https://doi.org/10.21096/disegno_2023_1mpbba