Unlearning Architecture: Environmental History of Production Spaces from Mill Buildings to Machine Landscapes

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Anthropocene is the present geological epoch in which human-built infrastructures dominate the resources of the world and the highest level of human intrusion to the ecosystems have been accumulated since the Industrial Revolution. Utilization of the steam engine initiated change in energy sources and extraction of raw materials that altered the existent means of production and led to the hegemony of industrial activities. The spread and growth of industry prevailed onto the practice of architecture to construct rapidly developing bases of production, storage, and distribution. Therefrom, physical embodiments of these bases as an overall system enable to relate energy, labor, and technology as fundamental elements of industry with the discourse of architecture. Hence, this study examines three architectural typologies -mill buildings, daylight factories, machine landscapes- for the evolution of production as a historical overview and analyzing the typologies with an emphasis on environmental history uncovers the intricate relations in between these elements and architecture in the exigency of climate change. Cases from different industrial periods reflect the altering nature of energy, labor, and technology regarding means of production, construction techniques, and materials. Acting as design parameters through the spatial transformation from mill buildings to daylight factories, and now to the machine landscapes, these relations indicate the interdependency between architecture and industry, and allow to formulate further spatial entities for production that are more climate-conscious within the curricula of architectural pedagogy.[1]

INDUSTRY MEETS ARCHITECTURE: PRODUCTION SPACES

Industry, as a means of production, employment of labor, and fundamental source of elevation for energy altered many disciplines since the Industrial Revolution. In the eighteenth century, before mechanization, products of agriculture, textile, mining, and metal manufacturing were produced in small scales, as needed, and based on regions. There were limited sources of power and industries relied on water wheels, windmills, and horsepower to sustain their energy requisites. However, in the second half of the century, James Watt revolutionized a prior model for a steam engine designed by Thomas Newcomen in 1712 and initiated a new era in power generation. Industry had been transformed from the level of craftsmanship to mechanization, and the Industrial Revolution changed communication technologies, methods of mobility, quantity and diversity of production with the inclusion of new energy sources.

In the beginning of the twenty-first century, an atmospheric chemist, Paul J. Crutzen introduced a new geological epoch called the Anthropocene and raised awareness to the shift from Holocene to Anthropocene as a result of continual industrial activities. He defines the Anthropocene as an epoch in which humans dominate the biological, chemical, and geological processes on Earth through land use changes, deforestation, and high dependency on non-renewable energy sources such as fossil fuels and nuclear energy since the invention of the steam engine. Therefore, Anthropocene is the present geological epoch in which human-built infrastructures dominate the resources of the world and the highest level of human intrusion to the ecosystems have been accumulated since the Industrial Revolution. In accordance with the spread and growth of industry, it prevailed onto the practice of architecture to construct rapidly developing bases of production, storage, and distribution. Physical embodiments of these bases as an overall system with an emphasis on environmental history and theory enables to associate architecture with histories of energy, production, infrastructure, and labor in a nodal point, the production spaces. Thence, this study examines three architectural typologies -mill buildings, daylight factories, machine landscapes- for the evolution of production as a historical overview and cases from different industrial periods reflect the altering nature of energy, labor, and technology. Acting as design parameters through the spatial transformation from mill buildings to daylight factories, and now to the machine landscapes, these relations indicate the interdependency between architecture and industry, and allow to formulate further spatial entities for production that are more climate-conscious within the curricula of architectural pedagogy.

MILL BUILDINGS

In the process of advancing industries, be acquainted of new materials and techniques, there arose the necessity of assembling all machines under the same roof, in a factory.

Figure 1. Photograph of Old Woolen Mill (1812) on the grounds of the duPont Powder Works. It represents the general typology of mill buildings with its masonry facade, narrowness, and numbers of windows. The building now accommodates the Hagley Museum in Greenville, Delaware. Courtesy of the Hagley Museum and Library.[6]

Therefrom, nineteenth century mill building typology in architecture started to appear. The nineteenth century industrial landscapes were mainly dominated with mill buildings; long, narrow, multi-story buildings constructed with masonry or wood, and powered by a water wheel early in the century, then steam engine until the twentieth century.[7] Three main concerns came into existence for the organization and design of mill buildings: power distribution, construction, and lighting since industry required central power system to generate energy for machines, workers to operate them, enough light for workers to assess the quality of products, and above all a building to fit every part in. In the first half of the nineteenth century, one of the most restrictive part was the power transmission technology; how to supply power for either one or more floors of the building and to plan a network of gears and shafts for the process of carrying power from the source to each machinery.[8] Power transmission and distribution process and planning of it led to the segregation of operations by floor and arrangement of machines in rows. In addition to power issues, concern of lighting projected itself as another layer on the work environment and planning of construction. By the absence of electricity, mill buildings depended mostly on natural light and gas lamps as supplementary. In nineteenth century, buildings were constructed out of wood and masonry, thence, design of mill buildings prioritized the amount of sunlight they can capture on the shop floor in consideration of the thickness of load-bearing walls and illumination radius and competence. Gradually decreasing thickness measurements of masonry walls and sizes and placements of windows allowed to surpass the limitations of construction. Furthermore, high dependence on natural light minimized the width dimension of mill buildings to avoid the dark center section and typology of long and narrow structures for production spaces arose.

In progress of time, as productivity increased, former mill buildings started to become inadequate. Augmentation of production volumes and growth of necessary spaces for increased numbers of machines and workers initiated industrial and architectural conversion to meet with the demand. Intricate coordination within factory floors changed the relatively small and obtrusive mills of the nineteenth century to large factories and even industrial complexes that dominated economic and social life of its surrounding settlements.

By the end of the nineteenth century, individuals concerned with advancements of industry, introduction of new technology and materials, and growth of industrial complexes and production volumes realized that the most important concern was the planning of operations.

> Special-purpose machines were already helping to build guns, sewing machines, bicycles, and other goods, and handling technologies were revolutionizing the processing industries. In many industries a new kind of engineer also knew that mechanization had to go farther than special-purpose machines, beyond individual operations.[9]

As Lindy Biggs expresses by the end of the century, industrialists figured machineries fell short and the key to success of their production depended on the ways to organize the shop floor, coordination of processes, and the plan of turning raw materials into products. The plan of manufacturing and production mirrored itself on the architectural floor plan in the twentieth century after the Second Industrial Revolution in the form of daylight factories.

DAYLIGHT FACTORIES

In the ends of the nineteenth century, the effects of new inventions such as telephone and telegraph, utilization of electricity for lighting, heating, and power, and improvements in transportation with the emergence of cars and planes guided industry to the Second Industrial Revolution. Determinative of this revolution was electrification, mass production enabled by new inventions and transportation advancements, and thus, necessitated assembly line.[10] All three determinants were correlative to each other and transformed the architecture of factories.

Under the influence of the Second Industrial Revolution or Industry 2.0, in the twentieth century, industrial complexes that morphed from relatively small and obtrusive mill buildings, excessively multiplied. With every advancement of technology, energy sources such as electrical unit drive, and new materials and techniques in construction, new factories were built. As a result, industries again congregated with a new architectural model, daylight factories.

The daylight factory constituted the rhetoric of light, order and hygiene with its open plan, big windows, electrified systems of ventilation, lighting, cranes and lifts to carry heavy loads, and power to operate each machine autonomously on the hierarchical configuration of the assembly line.[11] The emergence and development of the daylight factory became possible not only with the introduction of reinforced concrete but also, the wide range of electrification in the instruments of labor to ease the process. The progress of industry and correlatively the architecture of production spaces were interdependent developments. For instance, electrification and the disappearance of the mechanical power transmission systems enabled the use of electrical travelling crane, and new configuration of transportation and materials handling tools. Furthermore, the inexistence of mechanical power transmission equipment allowed natural light to enter through large glazing surfaces and roof lights onto machineries without hard shadows. Therefore, prior advancements regarding technology and energy acted as agencies in the construction of production spaces, and in the case of the daylight factory, it was the accumulation of many alterations and movements. Multi-story platform and a three-dimensional concrete frame organized the entire production process under one roof and altered the multi-story buildings of production into a single story, modular and horizontal production spaces in the twentieth century. (For the transition from mill buildings to daylight factories and cases of daylight factories, AEG Turbine Factory designed by Peter Behrens and industrial complexes such as Highland Park Plant and River Rouge Plant of Ford Motor Company designed by Albert Kahn can be examined respectively.)

The gaze of an architect simplifies and regulates the intricate state of production spaces with the technological and construction advancements. For instance, daylight factories elevated the state of production spaces in terms of working conditions, openness, and foremost, brightness. Through progressing construction techniques and utilization of new materials, it altered the dark and congested interior environment of mill buildings into well-lit and open daylight factories. However, under the hegemony of industry and immoral strategies concretized in production, architects' contribution remains incapable to transform the balance between the base and superstructure. Nevertheless, the presence of architecture as a discourse in industry matter to comprehend with the changes in industry, energy, and labor movements through a spatial perspective. Therefore, following the historical overview of industry and the architecture of production enables to perceive machine landscapes of Industry 4.0 within the discourse of architecture.

MACHINE LANDSCAPES

In the later twentieth century, industry transformed again with the invention of computer, Internet, and automated machineries. In the Industry 3.0, machineries in production spaces substituted with semi-automated machines that required the assistance of workers to operate, yet largely being automated on their own during production processes.[12] Following the prior technological advancements, Industry 4.0 distinguishes itself by targeted full autonomy of machineries, Internet of Things (IoT), and to change singular entities of production, transportation, energy, and agriculture into vast lateral networks.[13] The main focus of Industry 4.0 concentrates on the degree of autonomation in many peculiar territories ranging from fulfilment centers, cryptocurrency mines, data centers, and to unmanned logistical spaces. Continuously advancing industries that relied on fossil fuels and nuclear energy sources laid foundation for a transition process toward machine landscapes, where instead of the human scale, machines define the parameters of the architecture of the production spaces.

Figure 2. Interior of the Amazon Fulfilment Center, Rugeley, UK. Courtesy of Ben Roberts.

> We once understood our world through systems that positioned ourselves, human scale, vision and patterns of occupation at the centre of the structures that we design. In the age of the network, however, the body is no longer the dominant measure of space; instead it is the machines that occupy the spaces that now define the parameters of the architecture that contains them.[14]

FULFILMENT CENTERS

Fulfilment centers represent the concretized form of production and consumption rush of individuals rooted from mass production strategies of the twentieth century.[15] They are vast machine landscapes comprised of production, storage, and distribution of goods and capital, in other words, all stages of sustaining the habits of consumption and demands of the market are covered in one architectural meta. They are indicative for the continuation of industry and the development of altering architectural language for production spaces merging with the necessities of automation. Thus, new design parameters to overcome operational and logistical issues emerged from the spatial greatness empower the architectural transition from daylight factories to fulfilment centers as part of machine landscapes. Fulfilment centers of Amazon without

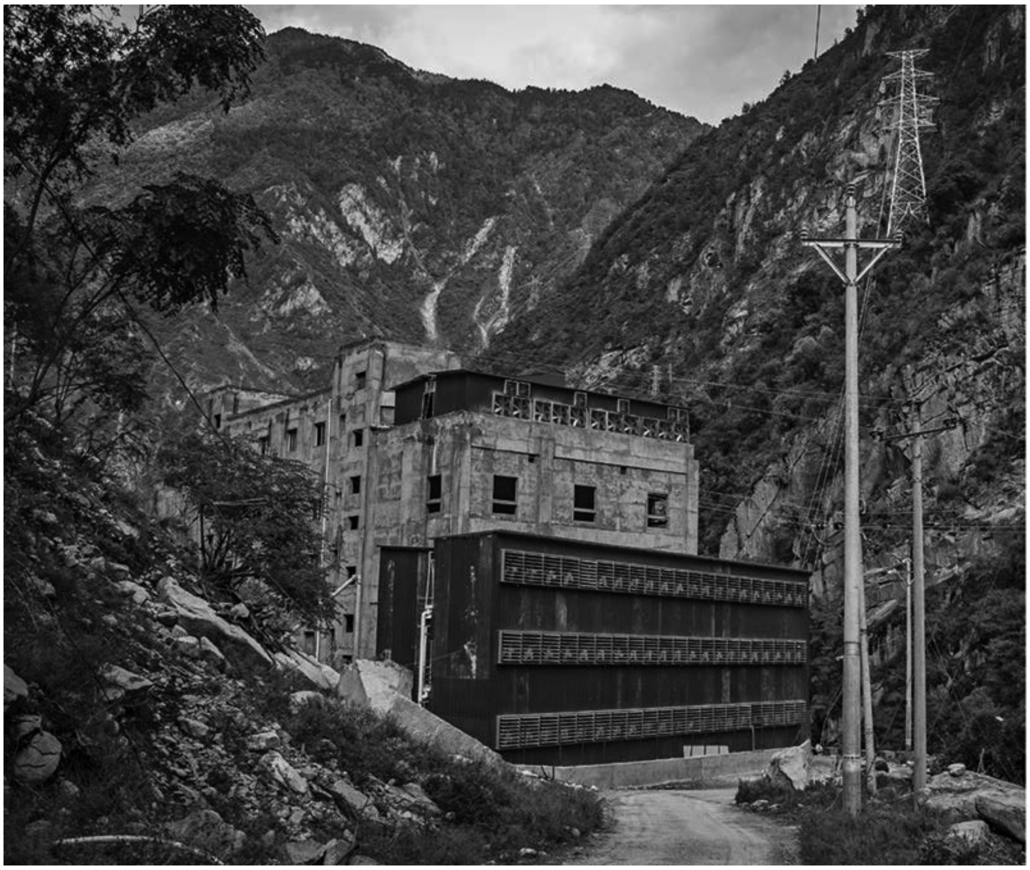

Figure 3. Exterior of the Bitcoin Mine. Courtesy of John Wiley and Sons and Copyright Clearance Center.

any segregation depending on the level of automation or the location of the site, display changes in production spaces in terms of lighting, layout, kind of machineries, and adopted technologies for architecture, construction, and industry. As human scale and orientation started to fade from machine landscapes, design parameters of the floor plan alter. The need for natural lighting and ventilation supported with artificial lighting and HVAC systems declines since automated machineries and robotic systems' requirements are not the same with humans. Therefore, fulfilment centers enable the development of new architectural parameters for machine landscapes and strengthen the collaboration between human and robotic work force through trials of ameliorated conditions.

BITCOIN MINES

In the reality of Industry 4.0 and the twenty first century with artificial intelligence, cyber physical systems, and Internet of Things, the economic equivalent of the developing industry has evolved into a new technology, that is cryptography and cryptocurrency. Thus, another cases of machine landscapes are Bitcoin mines. The densest population of bitcoin miners and company owners inhabit in remote mountain villages in Sichuan province of China because the fundamental need for electricity is supplied with hydropower through the utilization of mountain streams for the lowest cost.[16] In one of the bitcoin mines in Sichuan, there are 550 microprocessors mining 24 hours a day which require control and maintenance of seven employees working in shifts. This structure prioritizes necessary working conditions for its microprocessors without altering the generic layout of the building. For instance, stocked walls of cooling fans provide optimal temperature for microprocessors to run continuously and keeping human scale eases the reach of human workers to machines and shortens the duration of control and maintenance.

PEARL RIVER DELTA REGION

In China, Sichuan is not the only region to accommodate leading technological and industrial advancements, but Pearl River Delta Region is also considered as pioneering.[17] Diversifying from Hacker Robot Laboratories in Huizhou to battery factories for electric car companies, e-commerce villages, production spaces for machines to actualize data farming and harvesting, and many more machine landscapes generate and develop in the Pearl River Delta region with the technological initiatives and easy access to outputs of various manufacturing processes. The most unequivocal aspect of this region arises with the interaction and co-existence of humans and robots in manufacturing establishments. In other words, production spaces territorialized around the Pearl River Delta internalize the necessity and flexibility humans can offer with their labor and redefined structure to consolidate their relationship with robots and automation. It contributes to spatial concerns of production spaces and reformalising architectural discourse in relation to industry and technology. To exemplify, Rapoo Technology, an electronics manufacturer, employed robots in the easy to automate repetitive tasks that human workers actualized on the assembly line in daylight factories and appointed humans to control and maintenance. With the gradual transition from manual labor to fully automated workstations of robots, collaboration between agents enable a modular design for layout with segregated stations and lay foundation for an entirely machine landscape.

CONCLUDING REMARKS

As industry advances itself from steam engine to electricity, from electrical systems to digitalization and Internet, and last but not least, from semi to full automation, technological and industrial developments transformed production spaces since the emergence of mill buildings to machine landscapes. During the spatial conversion of architectural typologies, impacts of industry and energy has reflected on both means and relations of production. While tools evolved, craftsmanship passed to mechanized labor, then deskilled labor, and at the current state, it nearly left production spaces to automated machineries. To conclude, analyzing the spatial formation and transformation of the production spaces with an emphasis on environmental history can uncover the intricate relations between architecture, energy, production and labor and their resultant impact on climate. Environmental historic reading of constant technological and industrial developments allows to expand the field of architecture through the pedagogy of production spaces and define its position in the vast network of relations. It can reveal the structuring of Anthropocene that exceeding levels of human intrusion evoked through exponentially growing industrial activity from water wheels and steam turbines as power sources to the invention of electricity. Consequently, the subtle linkage between former and latter advancements through industrial periods demonstrates commonalities to follow regarding energy sources, instruments of labor, and production to prepare for more sustainable and green economies.

ENDNOTES

1. This study has been developed from the master thesis titled "An Inquiry on the Architecture of Production Spaces: From Mills to Machine Landscapes" written by Ilayda Guler under the supervision of Assist. Prof. Dr. Esin Komez Daglioglu for the M.Arch degree fulfilment in Middle East Technical University (METU) in Ankara, Turkey in 2021.
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