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TECHNICAL AND TECHNOLOGICAL FACTORS  
IN INDUSTRIAL ARCHITECTURE FORMS CREATION:  
HISTORICAL REVIEW

CZYNNIKI TECHNICZNE I TECHNOLOGICZNE  
W TWORZENIU FORM ARCHITEKTURY  
PRZEMYSŁOWEJ: PRZEGLĄD HISTORYCZNY

Abstract

This paper concerns technical and technological impacts on the process of the formation of industrial architecture. All the formational factors from the 18<sup>th</sup> to the 20<sup>th</sup> century – in the epoch of industrial architecture – are examined with special emphasis on technical and technological aspects. In the course of various historical periods, these factors changed their influence. Some of them had a dominating position while others – only a corrective status. In this way, the evolution of the impact of technical and technological factors is observed.

*Keywords: industrial architecture, impact of technical factors, impact of technological factors*

Streszczenie

Artykuł dotyczy wpływów techniki i technologii na proces tworzenia architektury przemysłowej. Wszelkie czynniki formacyjne na przestrzeni XVIII–XX wieku – w dobie architektury przemysłowej – badane są ze szczególnym uwzględnieniem aspektów technicznych i technologicznych. W różnych okresach historycznych zmieniał się wpływ tychże czynników. Niektóre z nich zajmowały pozycję dominującą, inne natomiast posiadały zaledwie status korekcyjny. W ten sposób obserwuje się ewolucję wpływu czynników technicznych i technologicznych.

*Słowa kluczowe: architektura przemysłowa, wpływ czynników technicznych, wpływ czynników technologicznych*

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As an independent type of the art of building, industrial architecture appeared relatively recently in the 18th century. It was a result of the introduction of a new production method: machine production. Historical research of the industrial architecture development process is quite justified by almost three centuries of its existence. In this connection, it becomes important to determine the dynamics of formative factors, whose continuous interaction has ensured the change of the space planning structure, emergence and transformation of different types of industrial architecture objects.

Factor determination is always relative and can rely on various approaches allowing for the characteristics of the time period and the research object itself. Assuming that the presence of two systems, the machine and the man, is peculiar to industrial architecture, the existing diversity of factors can be split into two groups. The first group comprises of the factors connected with the machine system: technical and technological factors (manufacturing process and process structure, equipment and transportation used, the sources of power and its transmission mode, materials, structures and building methods). The second group comprises of the factors conditioning the presence of the man at industrial objects: the factors of location and time of erection (natural and climatic and town-planning conditions, the speed of construction and service life, aesthetic preferences in the society) and the factors of internal environment (labor conditions and working environment structure).

In 1700–1840s, during the first development stage of industrial architecture, the influence of factors connected with the machine system was determinative. It is quite explainable because it is exactly this system that caused the emergence of industrial architecture.

Among the principle factors, the sources of power (the consecutive introduction of water and steam power) and the method of its transmission (shaft system) should be named. Water power had been used in industrial production since the 1700s. The power output depended on the strength of water stream and the design of the water-wheel, which developed from a simple wheel using the energy of a running or falling stream to a complex hydraulic turbine. The impressive size of wheels (the wheel diameter at Cyfartha plant in South Wales, England, is 50 feet, the width 6 feet and the weight is a 100 tons) and their installation on the lower floor were taken into consideration in the space planning of the building [1]. Moreover, the buildings were located on a bank of a river or a flume and they either dammed the watercourse or adjoined it.

Steam power had been used in industrial production since 1770–80s. The steam turbine was supposed to be placed in the central part of the lower floor for the most efficient distribution of power. Steam energy promoted an increase in the number of machines and their capacity, which also meant an increase in their size and weight, and therefore, initiated designing of building structures with a higher bearing capacity [2]. There was no more need to locate factories in the proximity of water, however, on the whole the transition to steam power did not change the approaches to architectural and layout design of buildings. By 1840s, both power sources (water and steam) were practically equally productive because by that time the efficiency of water-wheels reached its peak and the efficiency of steam turbines was still at the beginning of its development [3].

The biggest influence on the inner space organization of industrial buildings was that of the shaft system of power transmission patented by the Englishman Arkwright, and remained the only one till the 1860s. [1]. The system was based on the necessary connection of the power source with all the floors of the building and functioned well in a vertical direction,

which immediately predetermined the appearance in industrial architecture of many-storied buildings (5–8 floors) with multilevel structure of inner space. Substantial losses of power (from one third at the time of introduction of the shaft system to one fifth at the final stage of its use) and the impossibility to transmit power further than 100 feet, conditioned the construction of relatively narrow and short buildings. The shaft system required massive support provided by the building's bearing constructions closely aligned with the equipment used [4].

Since the 1770s, cast iron, a new construction material was used to substitute wooden structures in the inner fabric of buildings. The principal reason for its introduction was the endeavour to reduce the buildings' vulnerability to fire [5]. The new materials and the inner fabric system were innovative not only for industrial architecture, although here they were the most widely used. On the other hand, their influence was not revolutionary because the transition to these materials did not change the appearance and internal design of industrial buildings.

With regard to the factors related to man's presence, their influence was practically unnoticeable, and where it occurred, it was mediated by technological factors. Thus, the construction of first factories in rural areas on the banks of rivers and flumes made it unnecessary to take into account the town-planning situation because it was not the building that was integrated into the settlement planning pattern, but the settlement was developing around the building. To construct the first tier of the building, where water wheel installation, the natural parameters of the river were allowed for, however, they were of secondary importance because the technical requirements for water-wheel installation were more important and the watercourse of the river or the flume was adjusted to the process.

Natural and climatic factors and labor conditions related to them were not taken into account, the facilities were not heated, no premises for workers were provided ( not even bathrooms ) though the buildings themselves were many-storied and substantial in size. To a certain extent, the works building width and the story height were determined by one of the internal environment factors: the lighting, which at that time was mostly natural. However, the principal factor was the capabilities of the shaft system of power transmission and the capacity of the water-wheel.

The aesthetic preferences of the society were not reflected at all in the industrial buildings, which were purely utilitarian and only started to edge their way into being called architectural objects. However, it should be noted that by the end of the period in question, industrial buildings had substantially changed the rural landscape, particularly in England, standing out for their massive scale, enormity, ascetic and uniform interpretation of volume. In no other branch of architecture were the objects so similar to each other.

The second development stage of industrial architecture, 1840–1910s, was characterized by the extension of the list of factors related to the machine system. In the same period, for the first time the factors related to the presence of the man at the industrial objects came out.

The source of power and the method of its connection still had a significant influence on the shaping of objects. During this period, steam became the principal source of power, even though water power still had been used until the 1860s. In the USA, water powered factories had been used for a particularly long time[3]. Steam turbines had been upgraded and their position in the casing had been changed: one centralized machine, then a number of separate ones and finally, a combination of the centralized machine with dispersed smaller machines.

The increased engine capacity caused substantial growth in the size of industrial buildings and facilities.

The shaft system of power transmission was superseded by the wire-rope method, invented in Europe in the 1850s but applied industrially for the first time in the USA in the 1860s. The distinction of the system lay in the possibility to connect power both in vertical and horizontal planes over big distances of up to three miles, allowing the connection to be more flexible and customized [2]. For many-storied buildings, a mixed wire-rope and shaft system was used; to accommodate the power connection mechanisms an addition to the structure was made at the gable facade, with a gradient plane at the full height of the building. The fully wire-rope system, which did not require additional facilities to place mechanisms, entailed the appearance of single-storey buildings with large area used predominantly in the weaving industry.

The influence of a new factor in the form of lifting equipment, started to emerge. With the appearance of the crane bridge (late 1840s – England and France, 1875 in the USA), spans began forming in buildings, the crane span becoming the principal one organizing the whole plan. The crane bridge found its application in constructions with different numbers of storeys; in particular, it was widely used in single-storey buildings.

The combination of new materials (cast iron, iron, steel, reinforced concrete) with a new design-built system and full framework, which was first used exactly in industrial objects, became a crucial factor in the development in the period under review.

Full frame buildings appeared in the USA and Europe (England, France) practically at the same time: 1849 – a foundry in New-York, engineer J. Bogardus, 1840–54s – printing houses Sun Iron Building in Baltimore and Harper & Brothers in New-York, engineer J. Bogardus, architects R.G. Hatfield and J.B. Corlies, 1858–60s – a blacksmith shop Boathouse in the territory of the sea docks in Sheerness, engineer G.T. Greene, 1864–65s – warehouses St Quen Dock in Paris, 1869–72s – a chocolate factory Menier in Noisiel-sur-Marne, architect J. Saulnier [1, 5, 6].

Two tendencies could be noted in the use of full framework structures. “Cast iron facades” by American engineers J. Bogardus and D. Bagder represented a combination of the framework and prefabrication construction ideas. The whole building was assembled of prefabricated bearing and fencing elements, included decor elements [6]. Another tendency that spread predominantly in Europe was the use of brick infill for outside walls. The most striking example was the chocolate factory Menier, defined by S. Giedion as the first objectively frame building in the world [5, p. 288]. However, one can agree with it inside the boundaries of only one of the framework structure development tendencies in architecture.

The structural novelties changed not so much the layout and space organization of factory buildings as their exterior. The wall was liberated from the necessity to bear load, which caused taking the framework elements out to the facade and made it possible to increase the number of windows and their size, and made the separation wall thinner [1].

It should be noted that frame structures and the new construction technologies in Europe (England and France) related to them were introduced into large scale construction at a much slower pace than in the USA. The slow introduction of structural novelties was due to the insufficient engineering knowledge of the architects causing misunderstanding of the necessity to work jointly with engineers. In the USA, industrial engineering was becoming a field involving many specialists; in architecture, it was the first example of really synthetic

work guided by the “readiness to experiment and adopt new ideas rather than be governed by rigid traditions” [2, p. 12].

During the period under review, for the first time the influence of the factors related to the presence of man at industrial objects, came out. Thus, due to the movement of industrial establishments into cities that began in the early 19th century, they started in some cases taking into consideration the town-planning factors. It applied to luxuriant decorative elaboration of the facades of buildings located in the central districts of cities. According to the remark of H. Brockman, a researcher, some of them “looked like palaces” [7].

The paternalism movement among industrialists brought attention to the creation of an environment for the workers. Personnel facilities to serve the workers’ needs were introduced into industrial buildings (showers, bathrooms, canteens); their much larger scale and planning characteristics were changing the space arrangement of buildings. A group of buildings, not intended for the production process, but to serve the workers, was forming.

Such internal environment factor as lighting considerably influenced the formation of industrial building types. Along with the progress of gas and later, electric lighting, the design of industrial buildings allowed for less natural lighting, which was then not considered a principal factor, was now viewed equally with artificial lighting. It encouraged a practically unlimited increase in the width of the industrial building. An iron foundry works in Stanton, England, built in 1877, was the first example of complete transition to electric lighting [8].

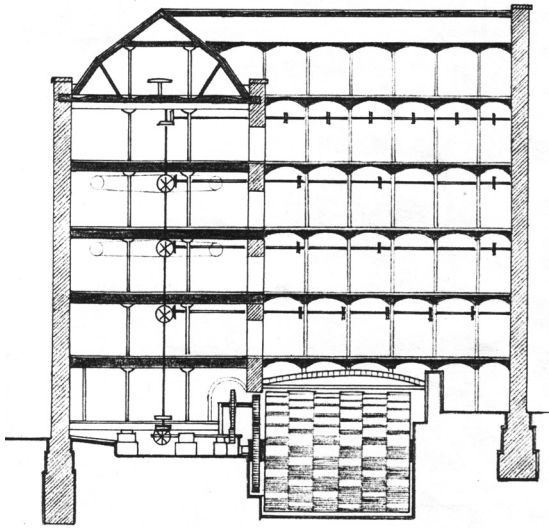
In the third period of industrial architecture development (1910–1920s – late 1970s), a sharp increase in the role of factors related to man’s presence at industrial objects was peculiar. Their influence in the process of formation of individual types was becoming determinative. At the same time, the machine system maintained its importance; however, significant changes were taking place.

In the group of technological factors, the transition to electric energy not only for lighting but for machinery work became a breakthrough (one of the first factories in England – Acme Mill, 1905) [1]. The use of electric power increased the performance by 15% and became an important incentive for production concentration. The production capacities and size of factory buildings and industrial sites, which had been increasing even earlier, started growing dramatically with the introduction of the electric motor. It became possible to concentrate the whole process under one roof and in the same space.

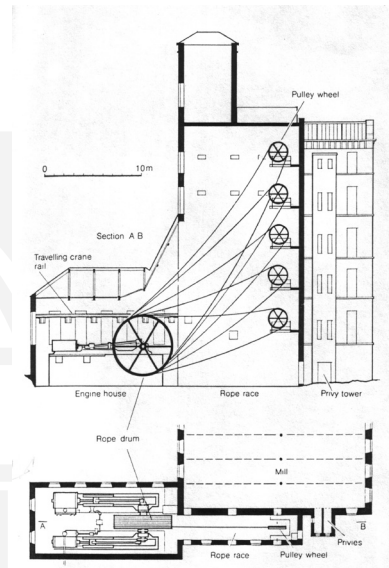
The use of the electric motor signified a new principle of power transmission – its supply going directly to the needed point. With that, the necessity to arrange power transmission systems vanished. At that point, the buildings design could freely follow the production process and not the one of power transmission. The age of the dependence of industrial object formation on the source and transmission method of power, lasting over two hundred years, came to an end.

Labor and production process organization, the factors belonging simultaneously to two groups: the machine system and the man system, were at that time the principal ones interacting closely with each other. These factors became of key importance along with the transition to large-scale production, which was characterized by splitting operations into sections and worker focused specialization. In 1913 at the G. Ford plant, a conveyor was launched, representing at that time, the most efficient organizational system, which required extensive (not less than 300 m) spaces free from supporting elements.

A new approach was formed in the creation of a “rational factory”, where the building became an instrument and an essential prerequisite for the maximal efficiency of the production process. If in earlier times the building was viewed as a space for machinery, workers and production process, from the 1920s it became “the master machine”, being a machine itself, where all elements including workers were supposed to function accurately and predictably [9]. According to such approach, the workers were viewed as a supplement to the machine or as an independent machine and the enterprise success depended not on the equipment, but on the equipment, worker arrangement and their joint work as a whole.



III. 1. Shaft system transmission of power (J. Blackner, The History of Nottingham, embracing its antiquities, trade and manufactures/J. Blackner, Nottingham: Printed by Sutton and son, 1815, 459 p.)



III. 2. Wire-rope transmission of power. (Серк, Л.А. Архитектура промышленных зданий /> Л.А. Серк., М.-Л., Гос. изд-во, 1928, 419 с.)

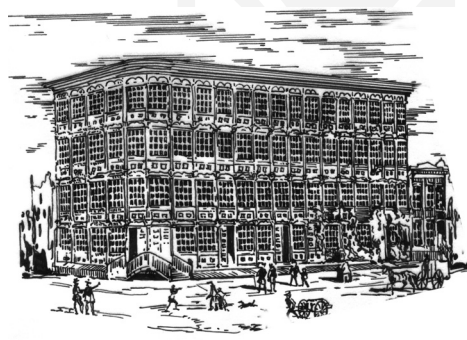
The idea of a “rational factory” originated from European theoretical thought of 18–10 centuries: the discussions of French engineers of the 1750s on “culture in science” and the works of English scientists A. Smith of the 1770s and A. Ure of the 1830s. The idea had finally formed in the USA by the 1920s and was best implemented in the plants of the Ford Motor Company, where an architect A. Kahn and a manufacturer G. Ford contributed equally into their creation. In the USA, the idea of a rational factory had incarnated by that time and returned to Europe.

Viewing the worker as a machine in the context of a rational factory urged active development of studies on the formation of a production environment. If in the 19th century the paternalist ideas of industrialists were aimed to create a worker friendly environment,

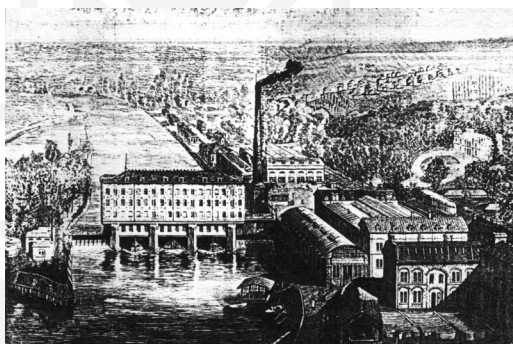
as this environment was not viewed in terms of comfort for the man, but in terms of labor efficiency. From 1910 to 1920, many enterprises had invited medical doctors and other specialists to organize an efficient working environment. In 1927, R. Dana published his book “Human Machine in Production”; industrial engineers were then trained as specialists not in “materials engineering, but human engineering” [9].

In the group of technological factors, the leading factor was reoriented. The influence of structures was overcome by the influence of new materials. Its impact was especially strong on certain building types and in particular, on the single-storey building. The introduction and further development of internal transport – crane bridge, overhead conveyor, allowed arranging various technological processes in the single-storey option, which turned out to be more cost-efficient and lead to the reassessment of the many – and single-storey buildings in favor of the single-storey.

For the first time, the influence of the artistic and world-view factor appeared. New attitude towards the machine, poetization of equipment, belief in its endless possibilities drew attention to industrial architecture. It gained the right to participate in the artistic formation of the environment.



III. 3. Foundry in New-York, USA, engineer J. Bogardus (drawing of the author)



III. 4. Chocolate factory Menier in Noisiel-sur-Marne, France, architect J. Saulnier (Серк, Л.А. Архитектура промышленных зданий /> Л.А.Серк., М.-Л.: Гос. изд-во, 1928, 419 с)

By the 1980s, the fourth contemporary development stage of industrial architecture was prepared by the technological changes signifying forward motion towards the information-oriented society. It caused the naturally determined dying out of some industry branches and downsized the number of employees, the reassessment of the production concentration principle and, as a result, the reassessment of the optimal enterprise size under the conditions of the competitive market. For the first time throughout the history of industrial architecture, the growth in size of its objects ( buildings, constructions, facilities) stopped and the advantages of small and middle-sized enterprises were admitted. The complication of production equipment caused an increase in the cost of internal systems of the building and its further operation. If at the beginning of its history the construction part of the building made three thirds of the total cost, today it makes only one fifth. In industrial architecture,

these objective processes entailed stagnation in the development of industrial building types and the use of simplified architectural and artistic solutions in large-scale construction.

A separate study shall be dedicated to the factors influencing the formation of industrial architecture objects in the modern period. However, at the moment it can be stated that their influence has been split: part of the objects are determined almost completely by the technical and technological groups of factors, the other and much larger part increasingly depends on the group of factors caused by the man presence. With that, a transition is observed from the approach where man is viewed as an appendix of the machine, to man as a man with a glance to the development of individuality and personal responsibility.

Summing up the review of the historical development of the forming factors in industrial architecture, it can be concluded that in different periods their influence was unequal. In different periods of time, dominant factors initiating the formation of certain object types can be singled out; the influence of other stabilizing factors was only correcting. With that, part of the factors could transfer from the dominant group to the stabilizing one and vice versa for example, such factors as power source and labor organization. Other factors never entered into the leading group, among which are natural and climatic or town-planning conditions; this is why their influence on the architecture of industrial objects never materialized. The tendency to shift priorities can be traced in the development of industrial architecture objects: from the complete dominance of the machine system forming factors (technical and technological) over the factors conditioning the presence of man at industrial objects to their levelling, parity and subsequent dominance of the latter.

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