Ex machina

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Introduction

The goal of this text is to understand the present state of the factory by exploring its origins, historic evolution and the fundamental principles that have remained unchanged since its inception. Originally called a “mill” it is a recent typology, born in the early 18th century as a direct consequence of the use of machines into the production process, indeed the Oxford dictionary defines the factory as “A building or group of buildings where goods are manufactured or assembled chiefly by machine.” The evolution of the factory and of the machine are intimately linked. The third component of the machine/factory equation is the worker, as since its inception the work of the machine has been done concurrently with that of the worker, a symbiotic relationship, that Marx would describe in slightly less glowing terms would evolve throughout the 19th and 20th centuries between these three actors, exerting mutual influences on one another.
Interdependent relationships however do not mean a balance of power however, and as we shall see, the principle innovations were pushed by the machine, which determined how the other two actors would react, then industrial architecture had to contend with the limits imposed by man in conjunction with those imposed by the machine, finally architecture found an appropriate form to answer such constraints.
As we shall see, the three industrial revolutions, that of the late 18th century which gave birth to the factory but also to the steam engine and the foundations of mass production, late 19th century which would eventually give birth to the car, electricity, steel and concrete and mid 20th century which would start the process of automatisation each created the catalyst for major changes in the factory, as such this shall be a chronological study, based on thematic research.
The research is informed by Paolo Virno’s reading of Karl Marx’s Fragment on Machines, the text written between 1857 and 1858 in a collection of notes for his other books. In it he explains how capital replaces workers as fixed capital (machines), with less labour required from the worker, his unused labour potential is not wasted, instead he can concentrate on knowledge, the knowledge which itself was the original stimulus behind his being replaced by the machine, Virno writes “abstract knowledge — scientific knowledge, first and foremost, but not only that — moves towards becoming nothing less than the principal productive force, relegating parcelled and repetitive labour to a residual position.”[1] It is this process that will be attempted to be explained by the interaction of machine, labour and architecture.

Accompanying the text is a booklet holding the plans and sections of a selection of industrial buildings, from Lombe's Mill to contemporary factories, in an attempt to give architectural expression to the subject discussed in this text.
This will be the foundation for a project in the second semester that will attempt to use the subjects elucidated in this text.
Towards which form do the forces push architecture? And what is the future of the factory, place of production par excellence, as some commentators hold that we are in the midst of the fourth industrial revolution?

1 Virno, Paolo. A Grammar of the Multitude: for an Analysis of Contemporary Forms of Life. Semiotext (e), 2010. p.100

Genesis

Proto-typical factory 14

Proto-typical factory

The genesis of the factory was in 1721 on the banks of the River Derwent in Derbyshire, England. Lombe's Mill, the building that has been defined as the earliest fully fledged factory was to define the typology as it evolved through the 18th Century. The break between Lombe's Mill and previous buildings devoted to production was the machine as we have seen. This allowed goods to be produced in large amounts and changes in labour organisation were to have fundamental consequences on the architecture of these buildings, and the make up of the surrounding areas.

Though previously the different elements making up the factory had been present, they had never been combined. Medieval paper mills in Islamic Spain had been producing paper thanks to hydraulically powered machinery, but production was on an artisanal scale. In Venice, the Arsenale had been producing ships on a proto-industrial scale and at its height in the 16th century it was producing more ships than any other workshop in Europe, employing up to 16'000 workers. Scale was accompanied by a way of organising work that wouldn't be seen again until the end of the 19th century. The ship's construction began with the hull, which was necessary as the ship was to be towed to each remaining step in the production line, meaning that each section of the building was dedicated to a different aspect of production and as each step of the process was separated, there was a division of labour and a specialisation in tasks, bringing about improvements in productivity, it was not a question of the worker moving to the product, but the product moving to the worker.[1]

Lombe's Mill was the first building to successfully combine production on a large scale using machines. In 1702, Thomas

Image: Painting of the Cordiera of the Venice Arsenale

1 Roser, Christoph. *"Faster, Better, Cheaper" in the History of Manufacturing from the Stone Age to Lean Manufacturing and Beyond*. Taylor Francis Inc., 2017. p.88-91

Crotchett had attempted to build a water powered silk mill in Derby using Dutch machinery, however due to their poor quality the threads they produced were of poor quality, but at the turn of the 18th century, the first prototype of the factory had been created. John Lombe went on an exploratory mission to Northern Italy where the best quality silk was produced using the best hand powered machines. While there, he worked in a silk mill, operating the silk weaving machines during the day and draw them each night to be sent to his brother in England. This was an illegal activity and after escaping Italy, where industrial espionage was punishable by death, he made his way back to England in 1715 and built a factory in Derby, next to Thomas Crotchett's abortive effort. This was a five storey building where up to three hundred workers were employed spinning silk on dozens of machines copied and improved upon by Thomas Lombe, John Lombe's half brother, from the Italian models. These were driven by a 23-foot diameter water wheel placed in the River Derwent. The scale of the factory becomes more evident from the telling of Daniel Defoe's visit to the factory, where he described how the machinery "contains 26'586 Wheels and 97'746 Movements, which work 73'726 yards of Silk-thread, every time the Water-wheel goes round, which is three times in One Minute, and 318'504'960 Yards in One Day and Night."[2]

All the machinery fit in a factory building which was a 100 by 39 foot rectangle pierced by 15 window bays on each floor, below which water flowed through arches. The structure of the building was made using timber columns and beams. Lombe's Mill, with its rectangular form, regular window openings and undecorated exterior and interior would become the model for factories throughout the 18th and 19th centuries. Throughout the 18th century the factory changed very little formally, and a comparison between Lombe's Mill built in 1721 and William Strutt's calico mill built in 1792 shows barely any external differences, though it is longer and wider and has six storeys to the Derby mill's five. However, its innovations are not found on the outside. It was the first mill to use cast-iron as a structural material. As with the 1721 building, the external load bearing walls are built using masonry, but inside iron columns were used to support brick vaulted floors with timber beams lined with metal and then plastered. The impetus for these innovations was the danger of mills catching fire and collapsing; Albion Mill in London was gutted by fire in 1791, having been completed in 1786. It was a huge event happening not in far away northern provincial towns, but the capital opposite St Pauls. This was the era of incremental innovations.

In 1797, Benyon Marshall and Bage built a flax mill at Shrewsbury, for the first time using a structure made entirely of cast-iron

2 Freeman, Joshua Benjamin. *Behemoth: a History of the Factory and the Making of the Modern World*. W.W. Norton & Company., 2018. p.16

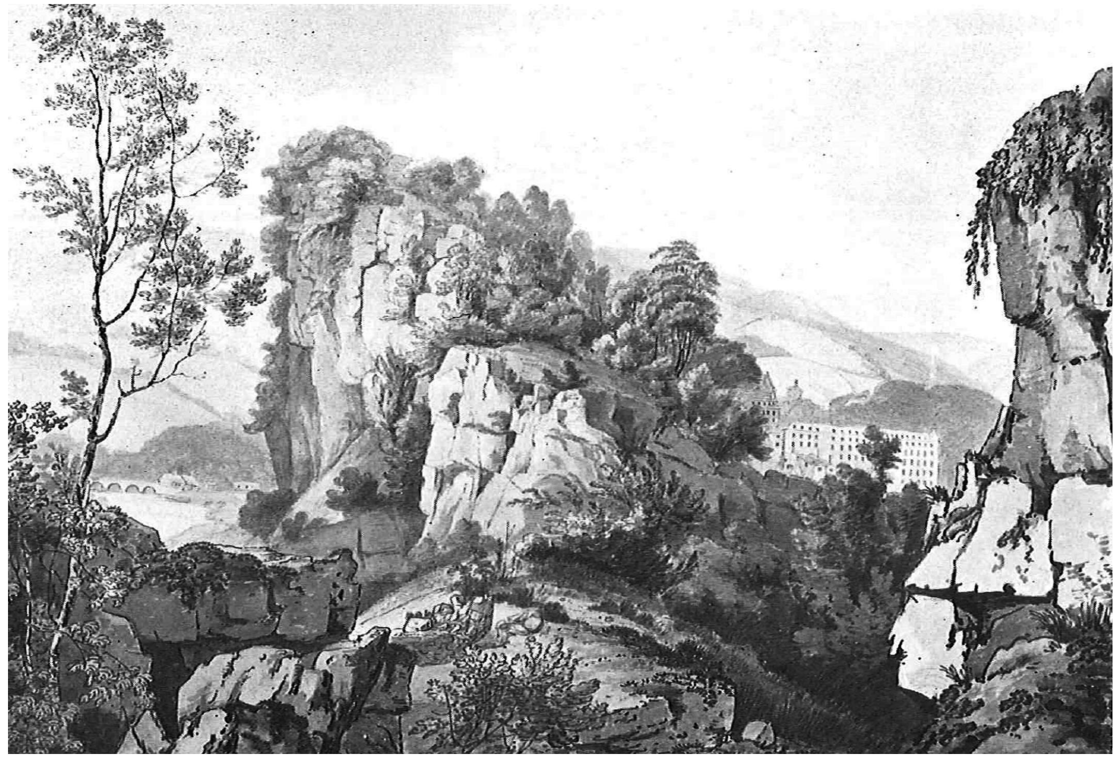


Image: Romantic painting of Cromford Mill seen through 1765

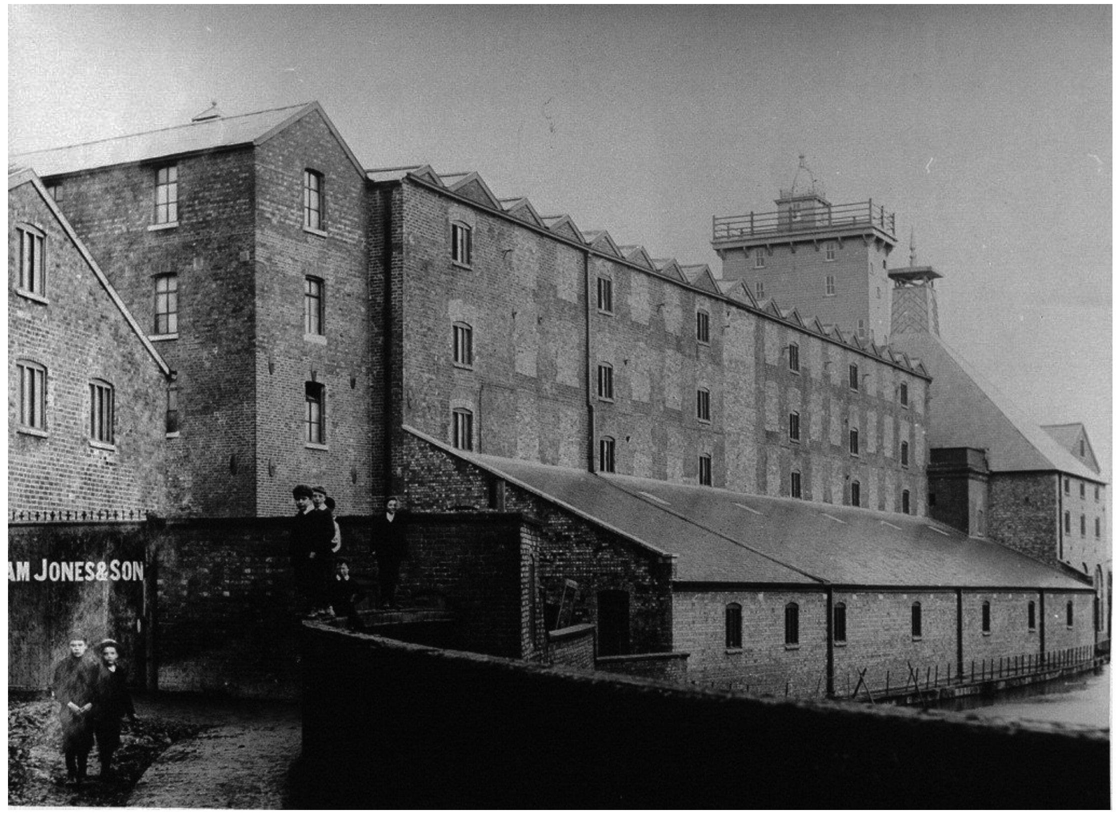
3 Ackermann, Kurt, et al. *Building for Industry*. Watermark, 1991. p.18

4 Biggs, Lindy. *The Rational Factory: Architecture, Technology, and Work in America's Age of Mass Production*. Johns Hopkins University Press, 2003. p. 18-19

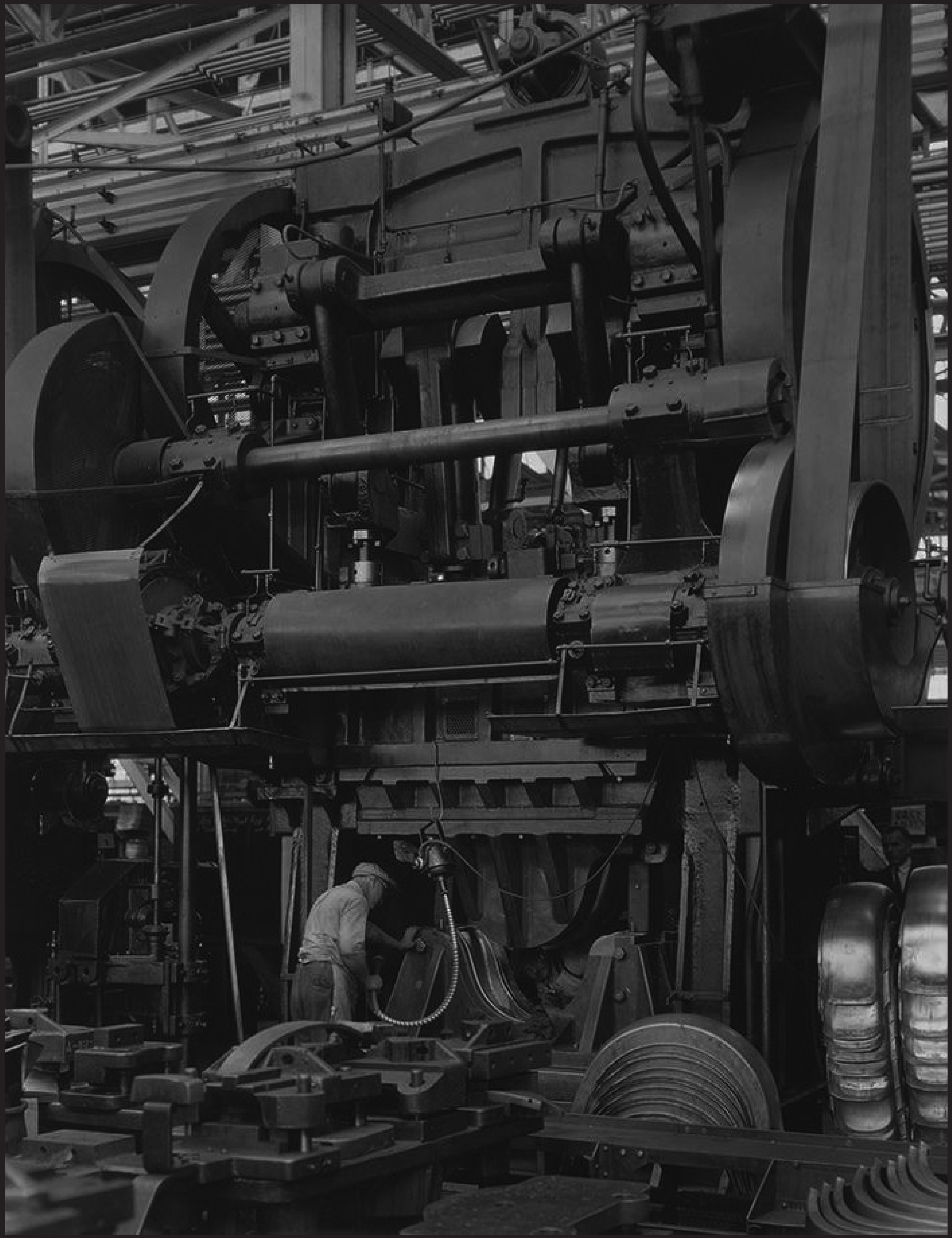
where "brick vaulted floors were laid across cast-iron girders, each supported by three cruciform cast-iron columns."[3] These innovations had parallel aims, the first being to guarantee a measure of fire protection, the second a pragmatic business problem: "As productivity increased in textile mills, owners found that the old mill buildings could not accommodate the growing numbers of machines and workers. [...] The growth in production demanded a shift from the relatively small and inconspicuous mills of the early nineteenth-century to large industrial complexes that dominated the economic and social life of small towns."[4]

The steam loom was the machine that allowed these changes. It allowed greater freedom in locating the factory, more flexibility in the organisations and more power for the other machines, enabling the factory to grow to never before seen dimensions. In 1836 Shaddon Mill was built in Carlisle, it was the largest factory then, at 224 by 58 feet and 83 feet in height (69.5x17.5x25.3m). Shaddon Mill was not fundamentally larger than the Shrewsbury flax mill of 1797, which was 177 by 40 feet and 55 feet high (54x12x16.5m) but what did change was the height. The improvements in the production of metals saw higher quality, permitting structures to stand more weight and the buildings to grow to new heights. Throughout the 19th century, the trend toward larger factories aided by incremental innovations in structural materials, glass on one hand and power generating and productive machines on the other would continue unabated, without any major changes, until the turn of the 20th century when two new technologies made their appearance in industrial architecture: concrete and electricity.

Image: Shrewsbury flax mill
Photograph 1908



Machine



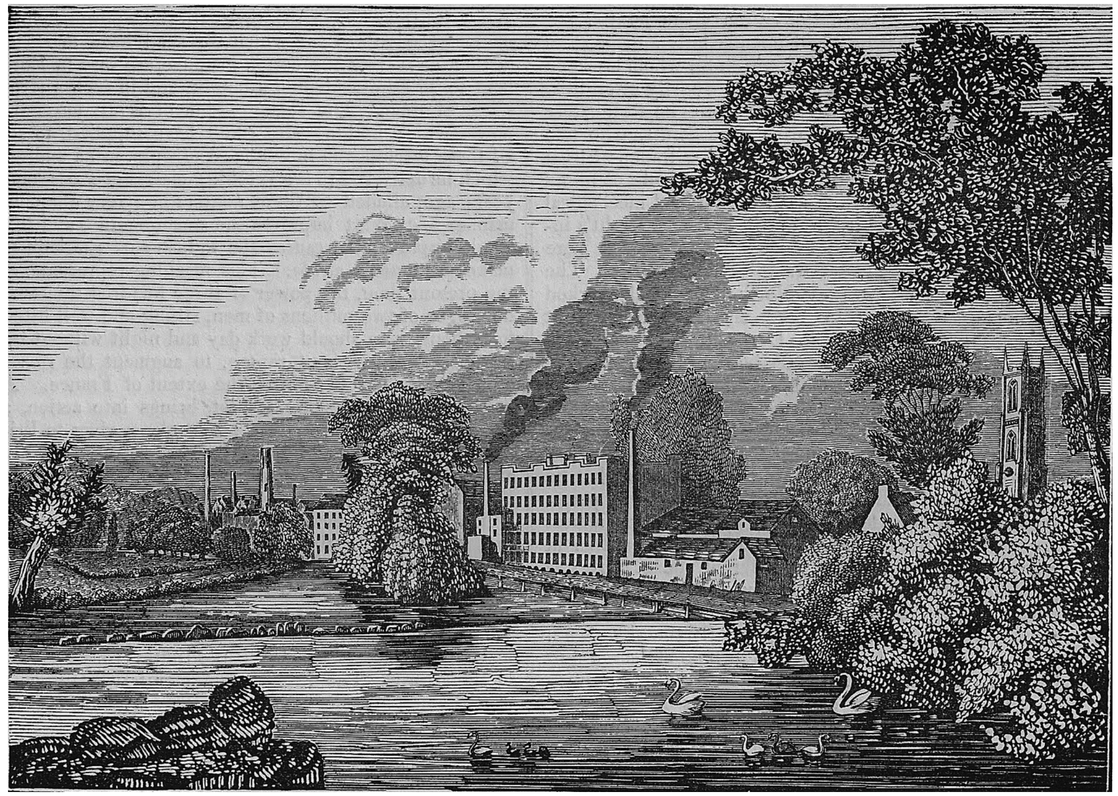
Logistical location

Previous page: Ford Plant — Stamping Press
By Charles Sheeler 1927
The Lane Collection, Image Courtesy Museum of Fine Arts, Boston

1 Freeman, Joshua Benjamin. *Behemoth: a History of the Factory and the Making of the Modern World*. W.W. Norton & Company., 2018. p.16

Image: View of Lombe's Mill over the River Derwent (1847)

"In early textile factories, complex arrangements of shafts and gears distributed power from waterwheels to individual machines. Water power was cheap and efficient, as long as there was a steady flow of water. That meant that mills had to be sited on rivers with substantial, steady flows, like the Derwent."[1]
Both Cromford and Lombe's Mills, alongside a number of other early factories, were located on the banks of River Derwent in Derbyshire. The presence of machines in the factory now required a source of energy to make them run and thus the most important factor in locating the factory building became access to a cheap and available source of power.
When David Dale (1739–1806) chose to build New Lanark Mill in Scotland in 1785, the nearest village was over two kilometers away meaning the site was chosen despite the lack of local workers or the infrastructure necessary to house them. The choice of the location was predicated by the presence of running water flowing out of an old mine and which was diverted to the factory turbines by digging a hundred meter long tunnel through solid stone. The cost of creating housing for the workers -- which equaled that of the factory building itself - and the difficulty of digging the tunnel were offset by the advantages provided by cheap and constant power.
These ideal conditions for hydraulic power, a controllable, constant flow of water, were not available in many locations meaning that early industries tended to congregate in the same locations, and when a single factory took advantage of the power possibilities, it tended to grow to an extremely large scale. At the end of the 18th century New Lanark was the largest factory in the country and despite its isolation, was able to outproduce and grow larger than other factories due to easy access to power.



The advent of steam power, which could be harnessed regardless of location, liberated the factory from the stricture of having to be located next to a river, though hydraulic power remained efficient. New Lanark was a successful factory well into the 20th century and being located near the waterfront still held logistical advantages. The new requirements of the factory were not for powering the machines inside, but of the factory as the centre of a logistical network where location was key.
Alfred Weber (1868–1958) developed the “Model of Industrial Location”, where he determined the ideal location for a factory by considering the input and output factors; the weighted cost of sourcing the different raw materials needed for production — which includes coal for powering the steam engine —and the cost of transporting the finished goods to the marketplace. By triangulating these rational constraints, the location of the factory becomes simple to determine. From the latter part of the 19th century until the mid 20th century, the main means of transporting goods was by railroad.
The railroad came to have a large influence on the construction of the factory, when discussing the daylight factory, Reyner Banham makes an analogy with the dockhouses of Nyhaven in Copenhagen where he describes their great height as resulting from the “competitive pressure on expensive land at the water’s edge”[2] due to the advantage of moving goods over water rather than land. Such pressures also applied to factories located near railroads and the related benefits, Albert Kahn’s Highland Park factory for Ford built in 1910, the main factory building — Building A — was four stories high, the entire logistical organisation of the factory was dependent on rail transport; a track ran next to the plant, linked the logistical organisation within the factory to that of the wider logistical organisation of the railways, raw materials entered the factory via the railroad, were transformed into a finished products in the factory which then left the factory on the railway tracks. The factory was located just outside of the city limits, as the railroad allowed fast transport without the need to be located within the city.

2 Banham, Reyner. *A Concrete Atlantis: U.S. Industrial Building and European Modern Architecture*. MIT Press, 1989. p.40

Just as the railway allowed for the construction of multi-storey factories and their suburbanisation, the advent of the truck ended the domination of the daylight factory and bought about new changes in configuration and location. Reyner Banham notes how “in an era of improved horizontal transportation [...] would kill off the multi-storey type with its cranes and hoisting doors [...] and replace it with the single-storey workshed, where everything moved horizontally from truck dock to truck dock.”[3]
The shift from the locomotive to the truck revolutionised the form

3 ibid, p.41

Image: Loading Ford Model T Parts into a Boxcar at the Highland Park Plant, Detroit, Michigan, 1915
From the Collections of The Henry Ford

of the factory. Rational considerations — the price of land and the simplified horizontal layout of the factory — asked only that the building be located near a motorway interchange, liberating the factory even more from the constraints of location “the trend has been for industry to leave the city, in Europe as in the USA.”[4]

4 Darley, Gillian. *Factory*. Reaktion Books, 2003. p.198

This trend was strongest after the second world war and the massive infrastructural investments that followed it. The form of the factory in the latter part of the 20th century in Western countries has been that of the single-storey shed located in the periphery of smaller cities or in the countryside.

The low cost of the land and the horizontal nature of the factory increases its modularity, as the acquisition of empty adjacent plots of land is easier than building upon an already existing structure and the cost of land is cheaper outside of the city than in it. As the factory is no longer an ensemble of floors stacked upon one another, but extended over a single floor, it takes on a new aspect, no longer an element rising above its surroundings, but rather as an element to be included in the landcape. The factory becomes territorial.

Kevin Roche’s sub-assembly plant for Cummins in 1975 is exemplary of this new scale. Laid out over 5 hectares of Indiana countryside, it attempts to camouflage its huge size by hiding the volume of the building under a large car park on the roof of the building. Which is itself sunk half a level below the level of the earth, hiding the building as a part of the landscape.

Image: Aerial view of Kevin Roche’s Cummins Engine Company sub-assembly plant 1975

Building as machine
Machine as building

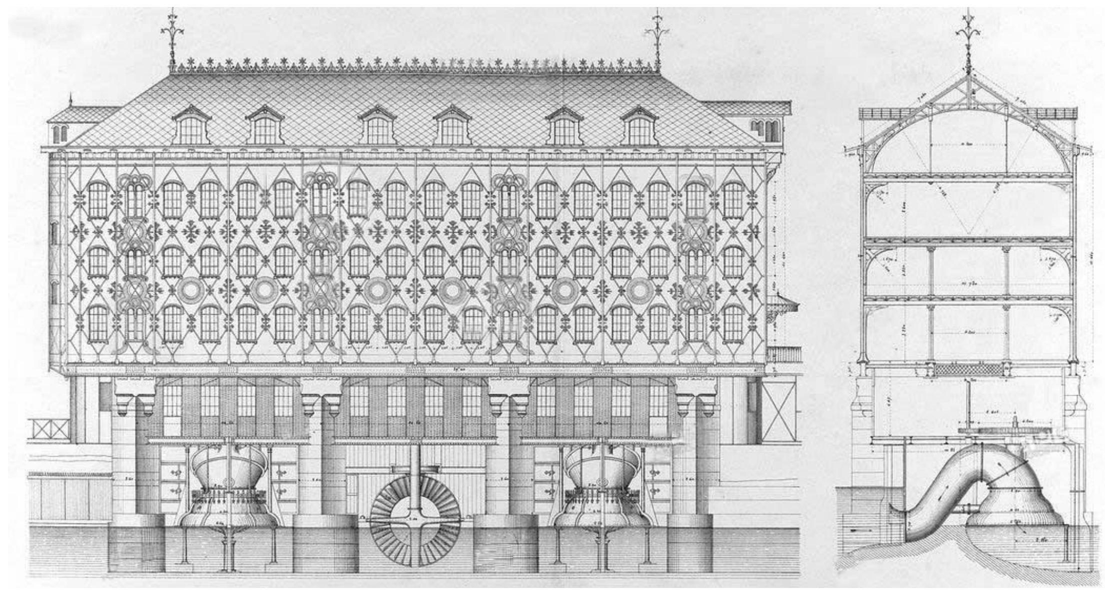
Machine and architecture are considered as two separate elements, the first is infrastructure — transient — and the other, structure — fixed — the solid, if vanishing, frame surrounding an ever changing landscape of production. However as we shall see, the limit between the two has never been clear cut and with the ever more technological character of architecture, exemplified by "high-tech", the gap between architecture and machine keeps closing.

Power generation was such an important aspect of the factory in its initial stages that it could become as important as the building. The Meunier Chocolate factory built in 1830, in Noisiel outside of Paris, was built directly above the Seine in order to harness the energy of the water passing below. It does so via two large tubes extending out from below the factory, reaching into the water, which then flows through a large turbine below the central section of the factory. The floor directly above the turbine houses machines that transform the power generated by the water to the machines inside the factory. Here machine and architecture are expressed through the same formal means. The turbines and the tubes become an element of the composition of the façade of the building and are expressed as architecture.

Other times it is the architecture that becomes machine; Marco Zanuso's factory for Olivetti, which reached its definitive form in 1959 in Merlo, Argentina used the structure of the building to house and distribute machines that would regulate the conditions within the factory. For him buildings "were enlarged machines which integrated the building-as-machine with the machines it housed"[5] The ceiling structure was made up of a hollow concrete

Image: View and section of the Menier Chocolate Co. 1872 Jules Saulnier

5 Rappaport, Nina. *Vertical Urban Factory*. Actar Publishers, 2016. p.180



girder with two functions, the first — structural — to support the weight of the roof, the second to be a conduit for air ventilation, as well as serving to anchor the piping and cables running through the building. The juxtaposition of the girders and the roof panels was used to let light into the building, bringing in a diffuse light like that produced by shed roofing.
The actual machines — the air conditioners — are located at the end of the girders, transforming them into an architectural element. Defining the end on the girders, they are as we saw from the previous example a compositive element. For Reyner Banham, this shows “the difference between the structure, which is supposed to be permanent, and the services, which are hoped to be transient, and to see the difference made expressive.”[6] A play is made between what is permanent and what is transient, just as an architect can use solids and voids in order to compose the façade of a building.

6 Banham, Reyner. *A Concrete Atlantis: U.S. Industrial Building and European Modern Architecture*. MIT Press, 1989.p.196

Ventilation is an aspect of building that takes on mechanic characteristics. By taking advantage of the natural flows of air the architect can place openings in order to control the temperature and amount of fresh air within a building. The industrial pioneer Albert Kahn designed the Packard Forge Shop in order to optimise the flow of air through the factory. There is no division between what is considered architecture and what is considered machine, it is at the same time fixed and flexible. The section of the factory is determined by the three fold requirement of structure, light and ventilation, here it is the architecture that manages the energy created by the air in order to control the temperature within the building, adapting dynamically to the changes via the opening and closing of windows and whose form is conceived to facilitate the airflows.

The high-tech architecture of Richard Rogers intends to meld machine and architecture. His influences for non-industrial architecture are industrial and the technological systems that create the artificial environment of the factory he was also involved in the construction of a large number of industrial buildings, among which are the Lynn Products, Quimper Fleetguard and Inmos Processor factories. The last of which we will now concentrate on. The building is made up of three elements, on one side there are the administrative and social blocks which are separated from the production halls on the other by a walkway that cuts the building in two parts. The walkway, entirely devoid of any separations or obstacles was conceived as an element to separate the “clean” production areas from the “dirty” administrative side, allowing movement between the two

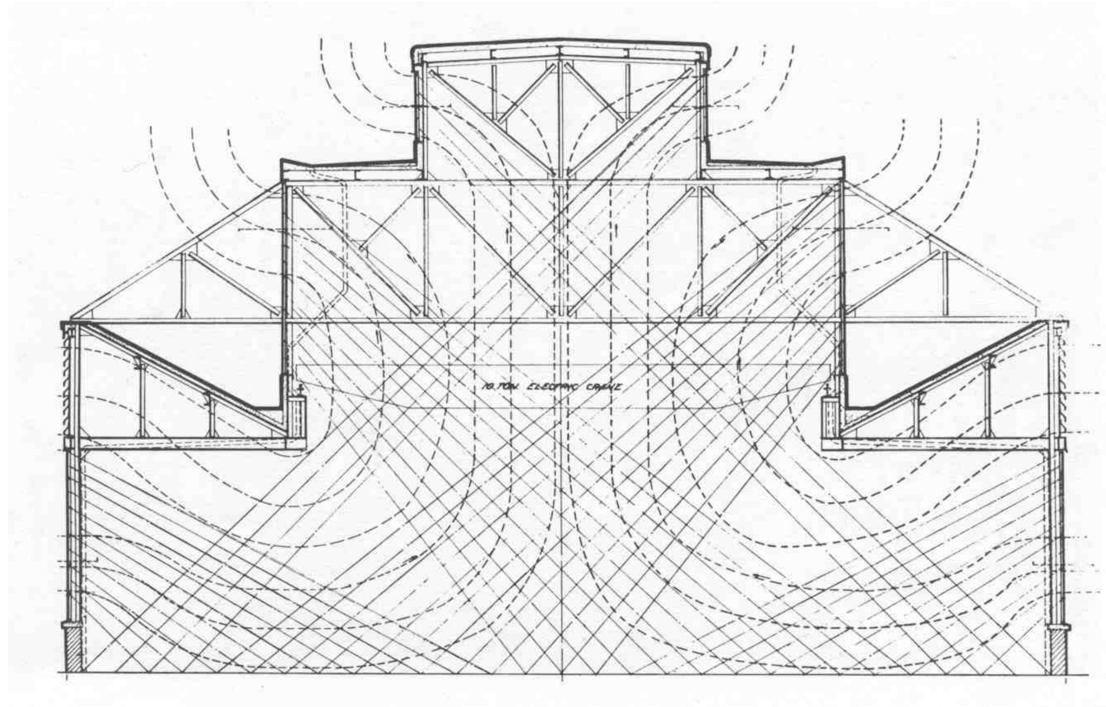


Image: Packard Forge Shop; section showing structure with paths of light and air circulation indicated.
American Architect and Building News.

blocks and workers from both sides to mingle. The clear and totally open corridor contrasts strongly with what lies above. The upper part of of the building hosts all the technical elements that allow the factory to function. The turn from Fordist to post-Fordist factory brought about a total enclosure and closure of the factory building and this entirely artificial environment is supported by air conditioning units, power boxes, wires, cables and ducts.
The roof is also houses the structure of the building where cables are attached to large masts which rise out of the building, connecting them to the extremities of the roof which is held up by steel cables. The two systems, structural and environmental are combined above the central distributive corridor, their juxtaposition brings them together, they are both signs for the factory, expressing its mechanistic character and dissolving the limit between structure and infrastructure, the forms and materiality of the two being near identical. The divide between machine and architecture is hard to see, as the building, with its artificial environment works as a large scale machine and the few elements that define the building are technologised to the extent that they become analogous to the machine.

Image: Laboratory spaces of the Inmos microprocessor factory, where the technical elements form a large part of the space.
Ken Kirkwood

Form as process

When designing the factory the engineer/architect's goal is to allow the most freedom to the programme. The production that takes place within the factory should not be constrained by the requirements of the architecture. However, the opposite is often the case; that industrial architecture will take its form and organisation from the requirements of the factory; the constraints of the programme determining the form of the architecture or more recognisably "form follows function" as Louis Sullivan, the great architect of the Chicago office building, said. For Koolhaas, the factory — a typically functional building — by its nature already has a basic form: "Typical Plan is an architecture of the rectangle; any other shape makes it atypical — even the square. [...] At its best, it acquires a Platonic neutrality; it represents the point where pragmatism, through sheer rationality and efficiency, assumes an almost mythical status."[7]
The rationality of the rectangle can be adapted to the specific programme of the factory, while retaining it's indeterminacy.

7 Koolhaas, Rem, and Bruce Mau. *S, M, L, XL*. Monacelli Press, 1998. p.338

The case of the Van Nelle factory by Brinkman and Van der Vlugt, finished in 1931 is exemplary; three raw materials were transformed in the factory: tobacco, coffee and tea. Each was given its own factory building achieved by dividing the single long block with vertical circulation spaces that created a wedge between the different parts. The height of each factory was determined by the steps needed in the transformation of each good. The vertical nature of the building being a consequence of using gravity to transfer the product to the next floor using gravity chutes, meaning that the first stage of production, irrespective of the raw material, would take place on the top floor of the building.[8]

8 Molenaar, Joris, et al. *Brinkman & Van Der Vlugt Architects: Rotterdams City-Ideal in International Style*. nai010 Publishers, 2012.

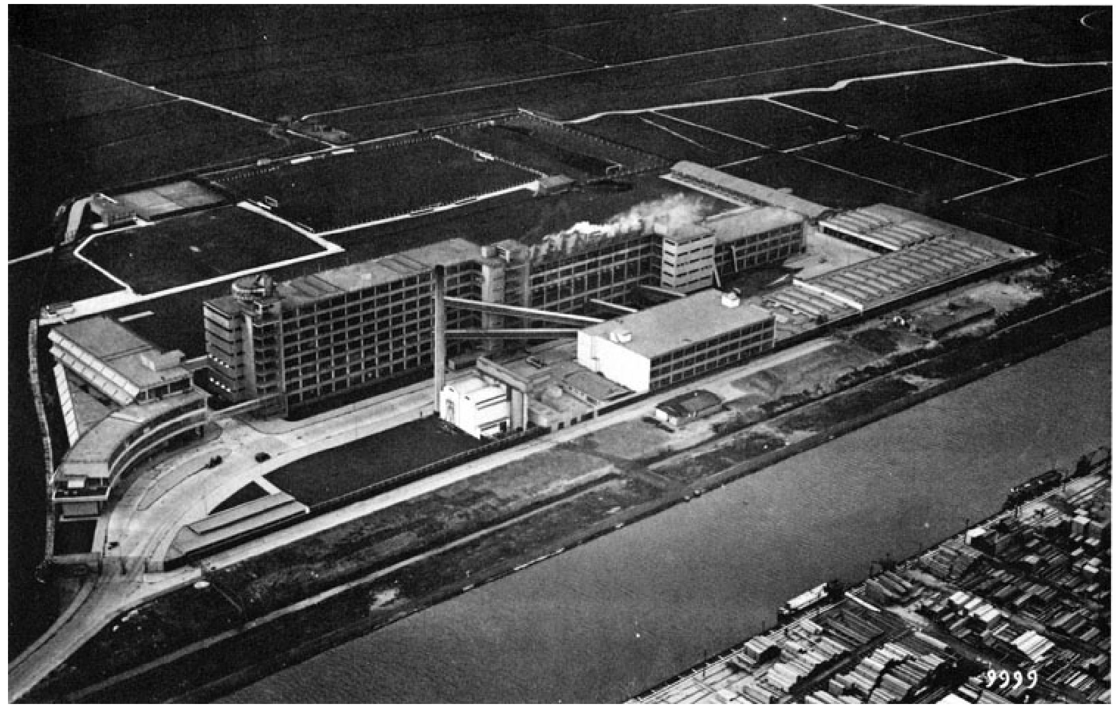


Image: Aerial view of the Van Nelle factory, with the office space on the left, the tobacco, coffee and tea factories from left to right and the storage buildings facing them.

The tobacco factory is the tallest of the three at eight stories high, here the tobacco leaves were unloaded on the first floor where they were dried before being sent to the seventh floor for fermentation. They then travelled back down to the first floor, drying on their way down, where, once dry, they were transported back up to the third and fourth floors, where workers wrapped them into cigarettes.
Next to the tobacco factory was the six-storied coffee building. As with the tobacco factory, the raw material was delivered to the ground floor, before again being sent to the top floor, which due to the presence of skylights had the best lighting conditions for examining and sorting the raw beans by colour. They were then sent down two stories into a double height space where they were roasted, supervised by workers located on a mezzanine. They were then sent to the ground floor where they were packed and shipped.
Finally, the third and smallest factory was where the tea was processed. This factory was only three stories high due to the handling speed required to maintain a fresh product. The ground floor was for logistics, the first floor for the arrival of raw materials and shipping of finished product. The tea was placed on lifts to the second floor where the leaves were separated, cleaned and blended before being poured down onto the first floor for tasting before being packaged and shipped out.
As we have seen, in the case of the Van Nelle factory the elevation of the building is determined by production needs and while the section of the building is variable, the plan is not. It is that of the traditional factory, an optimised space, where structure is reduced to a minimum and set in a free floor plan, the enclosures that there are limited to the dividing vertical volumes.
The width of the building was determined by the philosophical principles of the architects and the owners which stipulated that a well lit and clean space was necessary for the workers.[9]

In a similar manner, the FIAT Lingotto building reflects the production process, in this case, in an exalted manner. The Lingotto, designed by Matté Trucco, finished construction in 1923. The organisation of the building is fairly traditional; two parallel blocks with connecting elements between the two creating courtyards, allowing light into the volume. The production going through a series of stacked floors, the cars manufacture advancing with every level. However, the major change was the direction of production; most factories followed the Van Nelle model, where raw materials would arrive on the ground floor, but the production per se would begin on the top floors before the final product was completed on the lower floors and sent out from

9 Rappaport, Nina. *Vertical Urban Factory*. Actar Publishers, 2016.

Image: Test track on the roof of the Lingotto in use, with rear of Fiat sign in the background.
1925
Fiat Historical Archive

the ground level.
In the Lingotto factory, it was inversed. Raw materials entered the ground floor and headed up as the cars production progressed until it arrived on a racetrack on the roof of the building. The triumph of production is expressed through the racetrack which from its prominent position on top of the factory is visible throughout the city and explicitly shows the production that goes on in the factory and in doing so, transforms the factory from building to icon.[10]

10 Pozzetto, Marco. *La Fiat-Lingotto Un'architettura Torinese D'avanguardia ; Note Sulla Funzionalita e Sulla Produzione*. Centro Studi Piemontesi, 1975.

The link between production and form weakened post Second World War. As we have seen, the daylight factory of the first thirty years of the 20th century is a decidedly vertical building, and the organisation of the building influenced by the specificities of the type of production that took place inside. The single storey factory decoupled the link between form and function and instead the factory was to express an infinite field of possibilities that would permit any program to take place in the building.
The River Rouge complex built by Henry Ford and his ever present architect Albert Kahn, is one of the buildings that illustrates the transition between the daylight factory and the single storey shed. As a hybrid it retains characteristics from both types. The three storey Building B, was originally built in 1917 to manufacture submarine chaser ships for the US Navy. The three storeys were not built for the production of the ships, the full height of the building was left open, creating the volume necessary to allow ships to pass through. Production, using the innovative new assembly line process pioneered by Ford, was broken up into small tasks managed by individual workers. A single worker, from his place on the assembly line, would receive the product from the previous worker and complete his task before the conveyor belt carried the piece to the next worker in line.
The linear character of the assembly line gives Building B its form. It was the longest factory in the world at the time of construction, 100 meters wide and 500 meters long, the vast interior and top lighting announcing the future form of the factory.[11]

11 Biggs, Lindy. *The Rational Factory: Architecture, Technology, and Work in America's Age of Mass Production*. Johns Hopkins University Press, 2003.

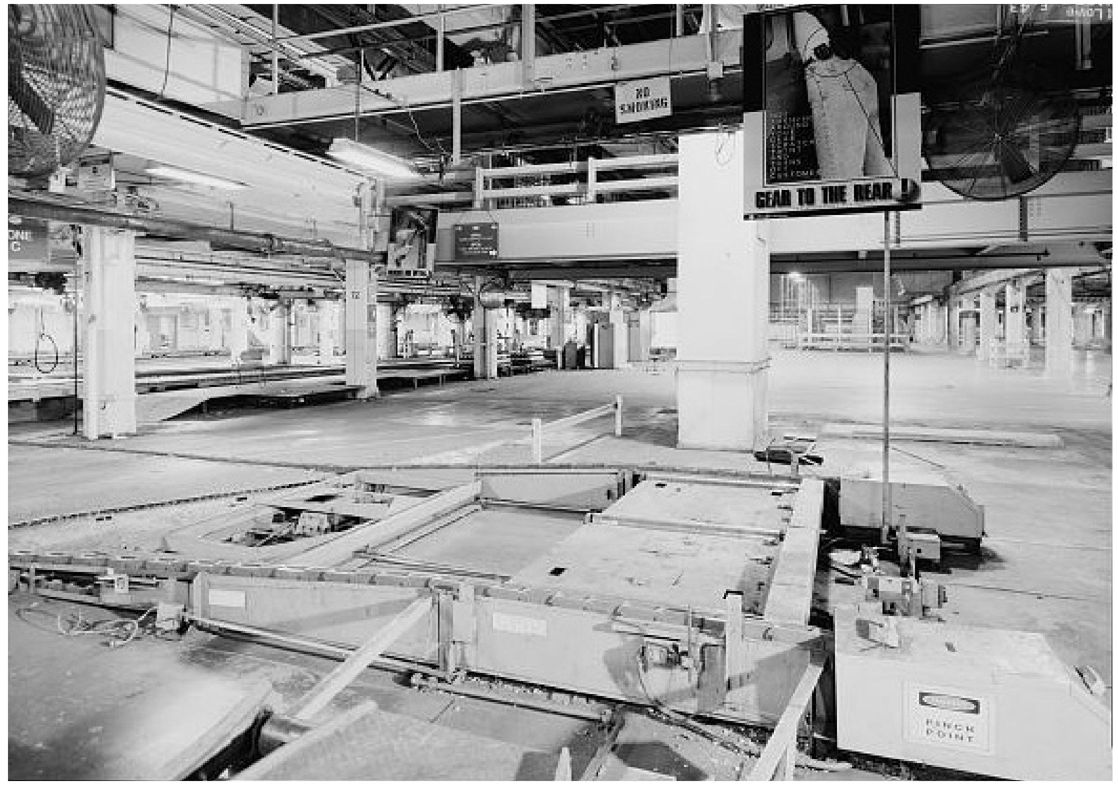


Image: Looking south in River Rouge Building B.

Labour

From physical to intellectual labour

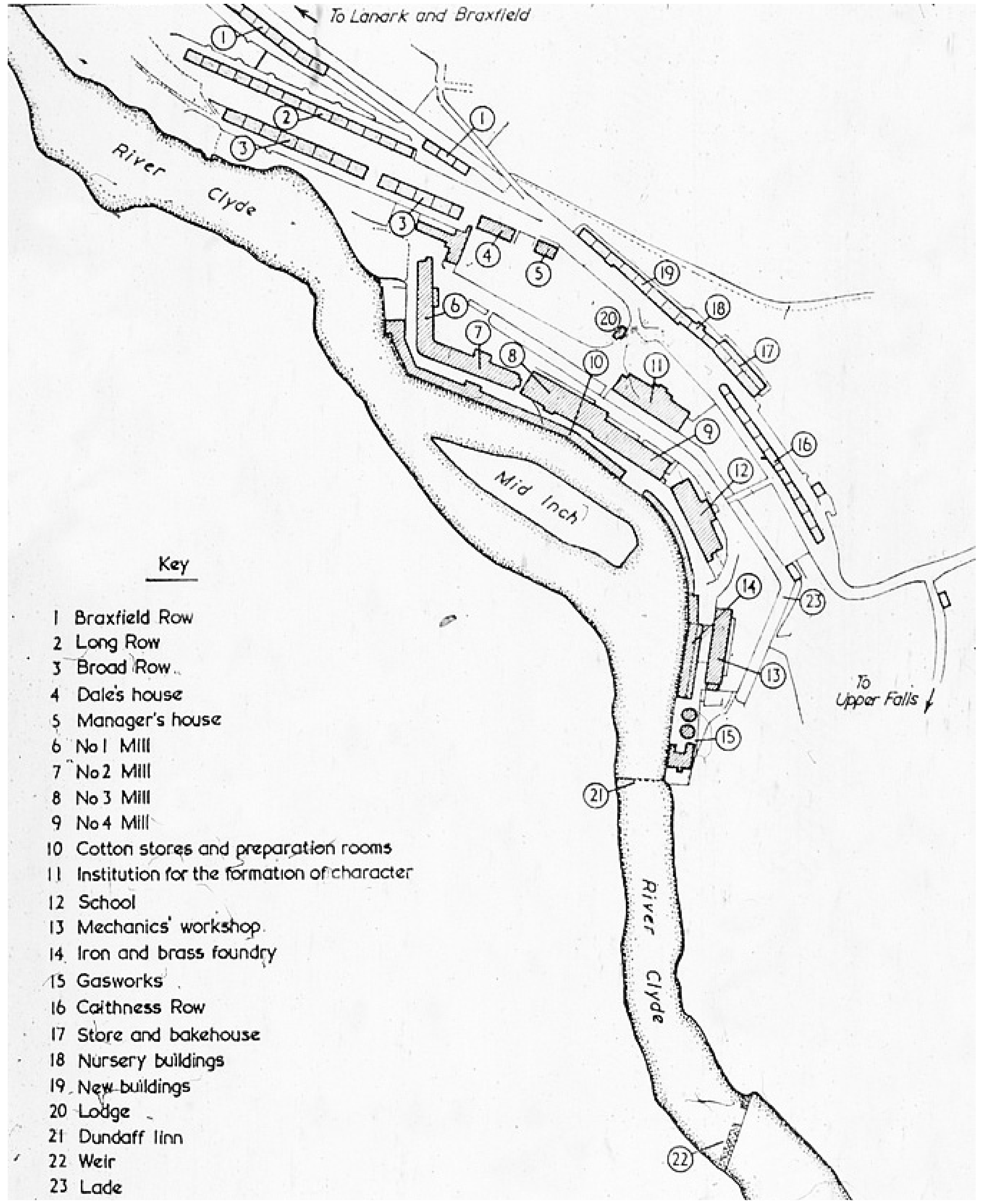
Previous page: Nha Trang 2004
Andreas Gursky

As we have seen, the earliest factories were often located in isolated areas near rivers, due to their need for a constant supply of running water and with no existing infrastructure, the town needed to be built ex nihilo. This situation was often exploited by factory owners to swindle their workers out of their salaries; overcharging for food and keeping a large share of the workers wage as rent payment. There were however enlightened owners who — through the profits generated by the factory — made a project of trying new types of utopia, one where the workers shared in the benefits of the factory, and a way for the — often paternalist — owners to apply and test their political ideologies.

The first such experiment took place when Robert Owen took over the cotton mill from his father-in-law David Dale in 1799. Robert Owen was a committed socialist, who participated in improving factory conditions in the United Kingdom, playing a part in passing the Factory Act of 1833 aimed at improving working conditions in cotton mills throughout the country.[1]
When he took ownership of New Lanark, a community had been established in order to accommodate the new mill and housing for the workers who had been brought in to work in factory. Here the community that had built up around the factory was used to apply his ideas regarding social relations and the importance of education.
Other than the mill buildings, of which there would eventually be four, the most important was the Institute for the Formation of Character completed in 1816. The three storey building was similar in appearance to the housing and mills, but with a slightly grander countenance with the addition of columns differentiating it from the plainer façades of the other buildings. It housed a library

1 Darley, Gillian. *Factory*. Reaktion Books, 2003. p.57

Image: Plan of New Lanark



with reading and recreation rooms for the workers to use outside of their working hours for education and advancement. With the same goal in mind, a school was built in the village in 1817 in keeping with the plain aesthetic of the buildings in the mill town.[2] These buildings give form to Robert Owen's focus in improving conditions for the workers. He made a rule that children under the age of ten were banned from working in the factory — at the time it was common for young children to work in the factory, so though it may be shocking to the contemporary reader, at the time it was considered quite progressive — and required them to attend school until they began work in the factory. They were also encouraged to continue attending school after finishing their work day, which was shortened to allow the workers to devote more time to education, an ultimately successful endeavor.
The presence of the school and the Institute for the Formation of Character are the physical manifestation of Owen's social preoccupations. The necessary physical nature of industrial work is complemented by cerebral activities which enriches the worker. Owen criticised the machine for the dependency and alienation is causes the workers, who are forced to work according to its never ending rhythm, Owen's philosophy was much much more humanist.

2 Edgar Jones, Industrial Architecture in Britain 1750-1939 (B.T. Batsford Ltd, London) 1985, p.28

A Century later, the Olivetti corporation, founded by Camillo Olivetti in Ivrea in 1908 was to take over the mantle of progressive planning for the factory town. The driving force behind this reformist push was his son, Adriano Olivetti, who took over the management of the company from his father in 1933. He quickly began expanding the companies production and putting into practice his ideas on improving conditions for his workforce.
To realise his ideas he collaborated with two young Milanese architects — Luigi Figini and Gino Pollini — who would go on to build a large number of buildings for Olivetti.
The first of these to be built was the nursery school, between 1939 and 1941. Hidden behind a park, it is located opposite the main factory building on Via Jervis, the main street of the industrial complex, it would prove to be the only vernacular building of the company complex. Adhering to the autarchic requirements of the fascist government of the time which required buildings to use local materials and construction techniques, the building is made of stone, lending it a radically different expression to that of the surrounding industrial buildings. The plan of the nursery school alternates between closed classrooms and open courtyards full of plants. With the incorporation of recreation areas for the children, it is a light and airy building despite the heaviness of the materials used in construction.[3]

3 Bonifazio, Patrizia, and Paolo Scrivano. *Olivetti Builds: Modern Architecture in Ivrea: Guide to the Open Air Museum*. Skira, 2001. p.28

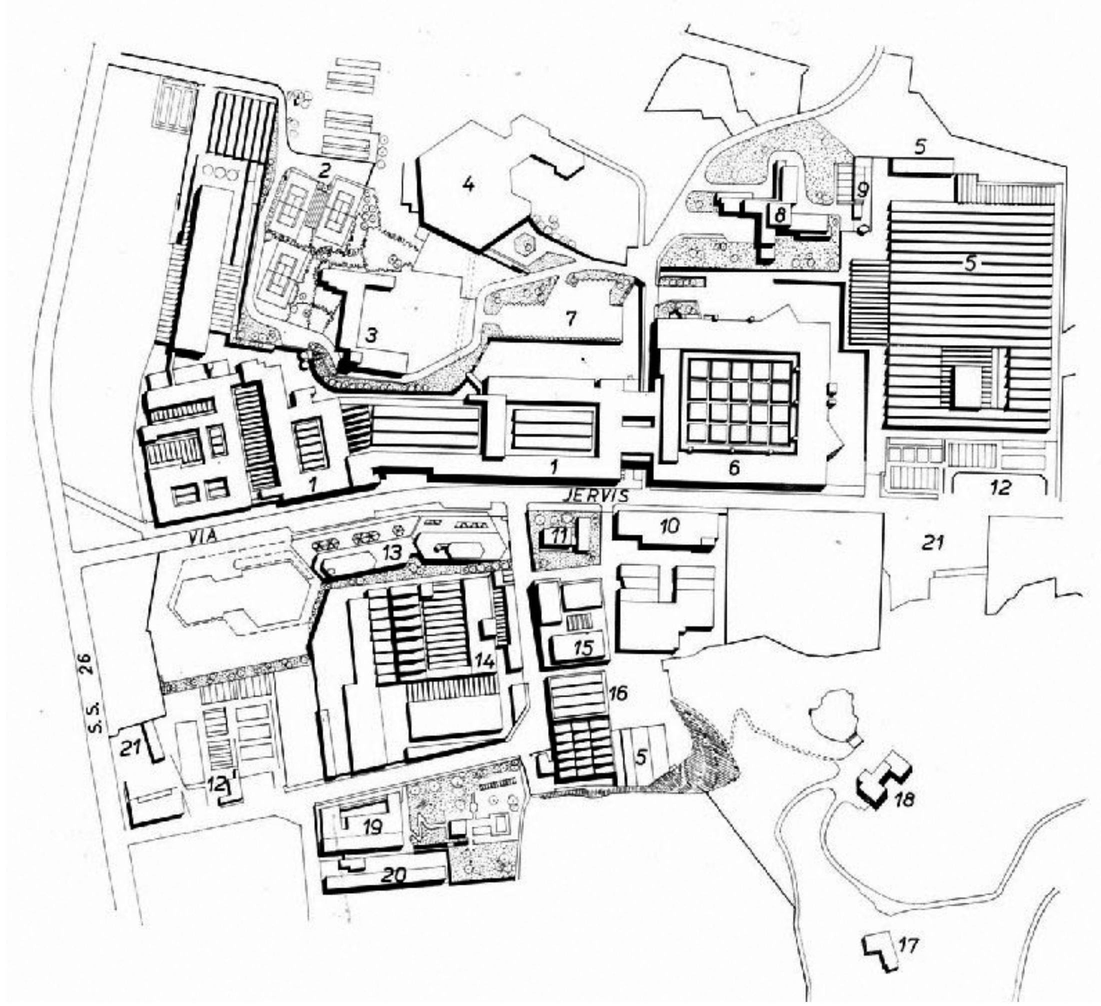


Image: Plan of Olivetti buildings near Via Jervis in Ivrea.
1: Old factory
4: Workers cafeteria
6: New factory
13: Instituto Servizi Sociali
19: Kindergarten

Another social space, more closely linked to the activity of the factory is the canteen, designed and built between 1953 and 1959 by another Milanese architect, Ignazio Gardella.
Located behind the main factory complex, it was built as the town was expanding and the workers could no longer return home for lunch. The hexagonal canteen was built on two floors from concrete with glazed façades. An annex space was appended to the main space where workers could find rest and reading spaces. Adriano Olivetti believed that the workers should use their long lunch breaks not only to eat, but also to read and inform themselves and the canteen underlines another means by which the factory can be used to educate the workers and not constrain them solely to their physical activity.[4]
Adriano Olivetti's theory was that workers would be able to achieve higher status through culture and as such devoted a large amount of energy to building facilities that would provide his workers with access to movies and books as well as conferences given by the most brilliant cultural figures in Italy.

4 ibid, p. 32

The last building dedicated to improving the cultural condition of the workers, built before Adriano Olivetti's death in 1960, was prominently positioned directly in front of the main factory building. The Social Service Centre built by Figini & Pollini between 1955 and 1959, housed the administrative offices for the cultural activities organised by the company, as well as a library and an infirmary. The Social Service Center is a composition of jutting and retracting volumes that strongly contrasts with the factory box. The variety of materials used it's opacity is in direct opposition with the solid concrete and steel of the factory with it's predominantly glass façade.The Social Service Centre was conceived as two symmetrical volumes facing the street however after revising the plan only one of the volumes remained. The ground floor comprises a retracted volume surrounded by a portico, the second floor fills the space above the volume and the portico and finally the third storey retracts allowing a terrace to surround the building. All of the floors are accessible via stairs at the rear of the building with the outdoor areas intentionally accessible to the public.[5]

5 ibid, p. 37

These three buildings exemplify the shift from manual labour to intellectual activity that Olivetti was convinced was the way forward for his company as well as the one that would benefit his workers the most.

This line of thought was also developed by Ivan Leonidov in his

Image: Olivetti nursery in Ivrea around 1950

1927 student project for a “Club of a New Social Type” which was to contain a library, meeting areas, study spaces for political education, social and public affairs, tourism, sports facilities, physical and chemical laboratories, cinema and radio transmission and a botanical garden.[6]

The building was intended for the emerging class of factory workers, a class that was steadily growing in the Soviet Union as a result of its rapid industrialisation. It would be focused on “enhancing cultural education, political awareness and Soviet organization”[7], it was a building dedicated to cultural activities just as the buildings in New Lanark and Ivrea were, though the political addition is a consequence of the exuberance of post revolutionary Russia. The fundamental concept behind the building is that there is no “absolute rest” but only “relative rest”; where the worker is not concentrated on his explicit factory work but cultural work, which here is linked to politicization, but remains close to the previous conceptions. The cultural buildings are not there for rest but for a new type of work. These can be seen as prototypes for post-Fordist labour, where the distinction between work and leisure is ever shrinking and where it is difficult to distinguish between a work space and a leisure space. As Francesco Marullo notes: “the club for Leonidov was not just another element of the city, but the indispensable collective infrastructure that linked the assembly line of the factory to the household domain.”[8]

6 A. Gozak, Andrei Leonidov, Catherine Cooke, and Igor Palmin, *Ivan Leonidov: The Complete Works.* (Academy Editions,London), 1988 p.60

7 Marullo, F. (2013). *Pure Programme and Almost No Form: Notes on the Typical Plan and Ivan Leonidov.* San Rocco, (7) p. 65.

8 ibidem

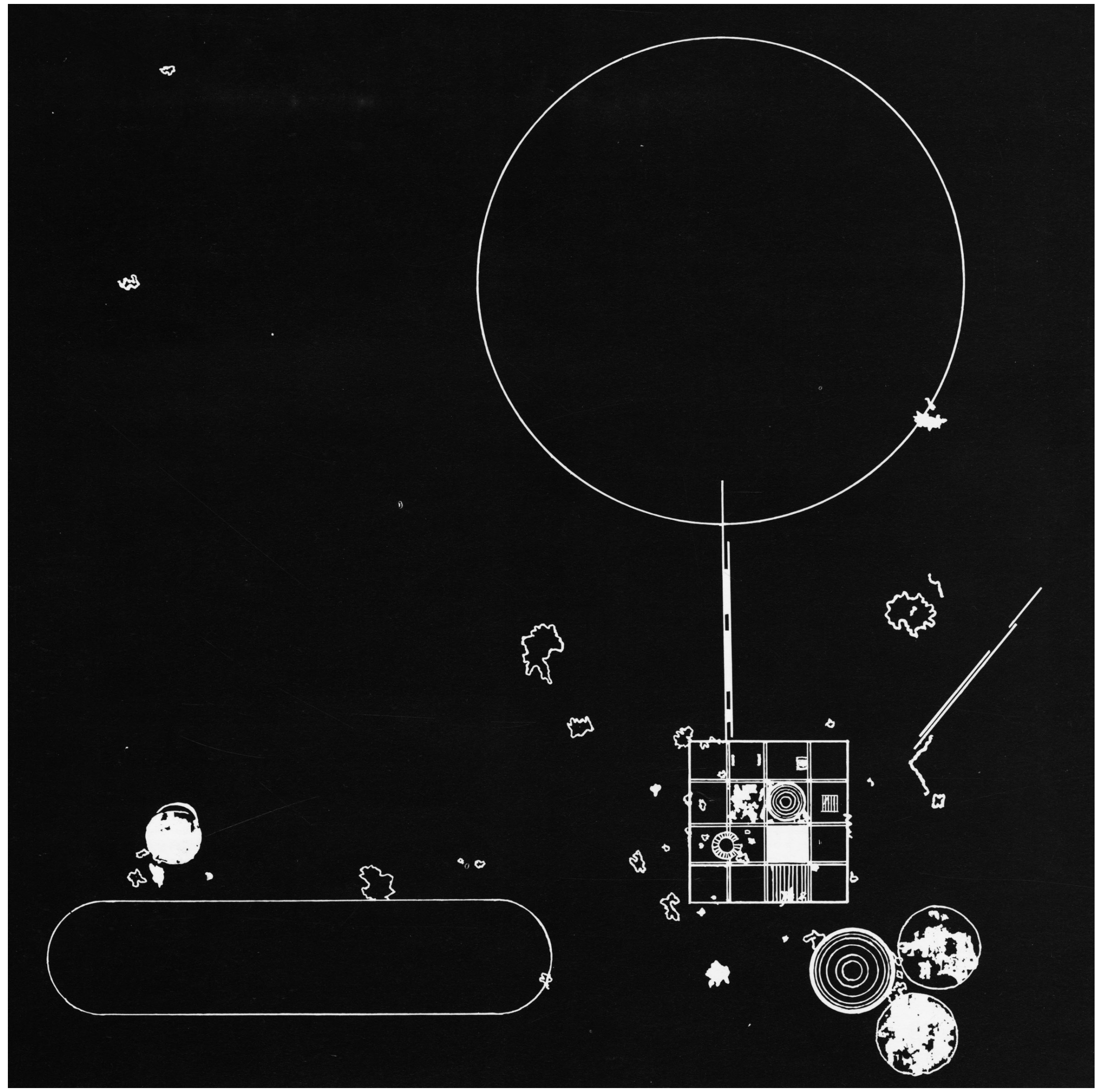


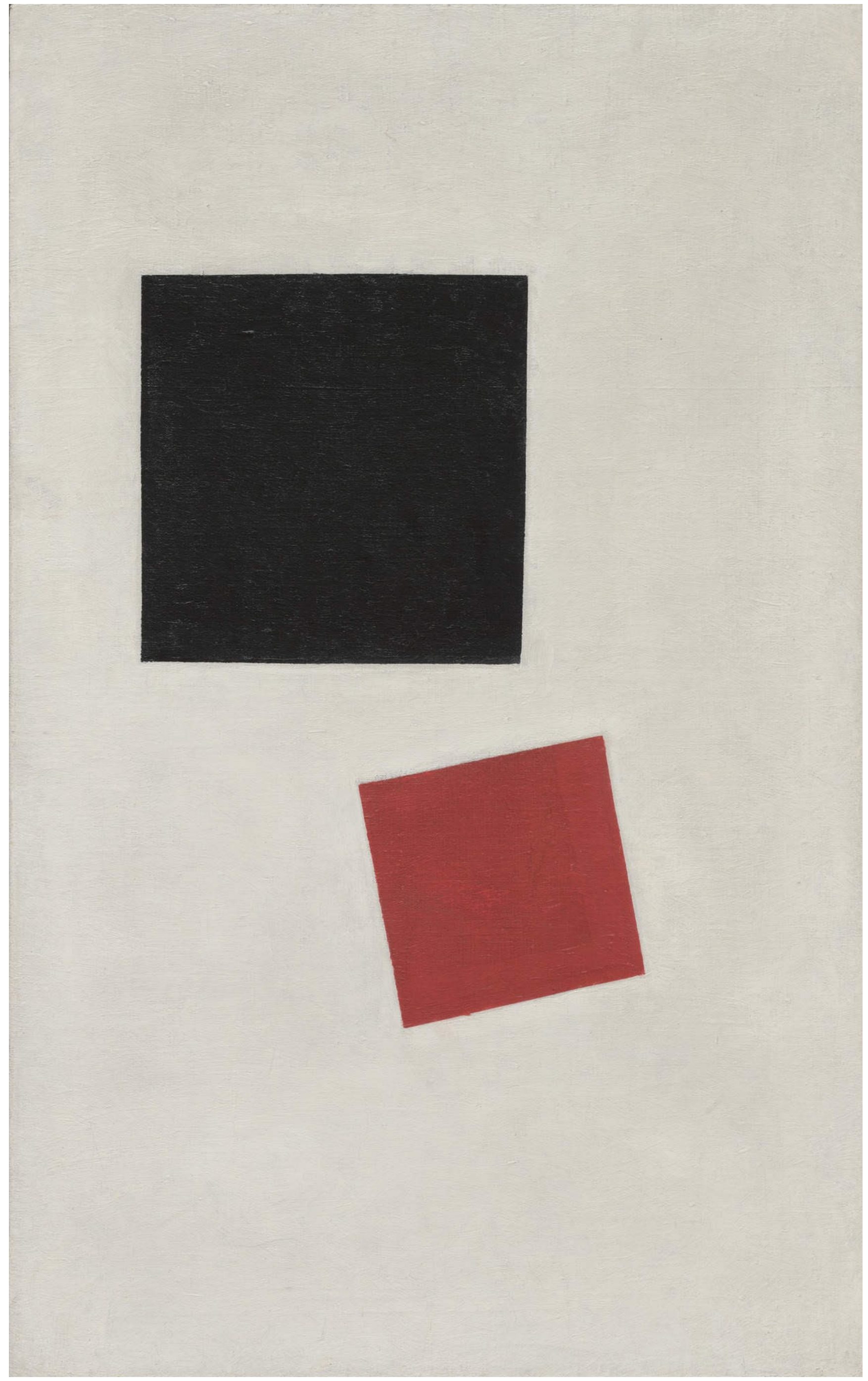
Image: Ivan Leonidov, design for a club of the new social type, variant A (1928)

Spaces for workers

The rationalised expanse of the factory, contains elements of a smaller scale. If the space of the machine is rational, immense and as devoid of limits as allowable, there are interventions that have a human scale within the free plan of the factory. Even in a plant with few workers, their presence is still palpable. On the shop floor, utilitarian elements are required for the workers. Toilets, stairs and changing rooms, punctuate the expanse of the Typical Plan, but they remain rational elements; placed according to calculations optimising their position allowing the workers to lose as little time as possible going to and from their workstations: “A single-storey building housing 500 mechanics, if the toilet rooms are misplaced by a distance of only 150 ft., the excess time involved in the workmen walking to and from the toilet rooms causes the manufacturer a loss of $5’200 ($75’000 in 2018) annually.”[9] Despite being considered rationally these “buildings within a building” are present for the only element of the factory that has not been rationally conceived: the worker. Albert Kahn’s General Motors Motor Division Building from 1938 has toilet blocks pressed against the edge of the building, their presence in the plan, as well as that of stairs negates the abstraction and scalelessness of the plan as a whole, introducing a human scale to it. Additionally, there is the element in the centre of the plan which is inserted between structural modules, falling in between the pillars, coming as close to “chaos” as the rational factory planner could allow.
Also interesting to note is the element on the left of the plan where the offices associated with the factory are located. The expression of the building changes completely with the presence of walls distinguishing it from the rest of the factory. The structural rhythm of the main factory is discarded when a half

9 Kahn, Albert, and George Nelson. *Industrial Architecture of Albert Kahn, Inc.* Architectural Book, 1939. p. 174

Image: Black Square and Red Square 1915
Kazimir Malevich



module is introduced coinciding with the centre of the office block, disrupting the regularity of the pillars, a factor not present on every module, it must find a balance with the walls that define the edges of the space. It is also interesting to note that the exterior expression of the buildings change. As can be seen in the image, the two volumes are expressed very differently. The office space is slightly higher than the factory space and while the façade of the production area is entirely glazed, the office module has two rows of windows and is much more opaque, showing the presence of two floors versus the single floored factory space.

In the Van Nelle factory, the office building and the production spaces are separate, introducing tension between the two volumes. The curved façade of the office block with its triangular shape contrasts with the rectangular regularity of the factory building setting up a human/poetic machine/rational dichotomy. In the factory building, the elements explicitly catering to the workers are pushed out from the bounds of the factory; they are glazed boxes attached to the main building with different styles of glazing used for the different parts of the façade. The relationship between the rational factory and human elements present between the factory and office buildings is replicated on the façade of the factory.
The architects also included a last minute request by the clients to add a tea-room above the tobacco factory building. The inclusion of this "irrational" programme onto the factory provoked Mart Stam — who was working on the project as a junior architect — to resign in protest, considering the purity of the factory compromised by such an inclusion. The tea room was only one such inclusion, as beyond the walls of the factory building itself a cinema, cafeteria and sports field were part of the complex.[10]

When the office and the industrial typologies are combined, it is the rationality and flexibility of the factory that lends its character to the whole. Team 4 (Su Brumwell, Wendy Cheesman, Norman Foster and Richard Rogers) combined the two in their building for Reliance Controls in Swindon in 1966: "In the 1960s there was still a strong tradition in industrial architecture of the segregated management box and workers' shed with their overtones of 'us and them', 'clean and dirty', 'back and front'. At the Reliance Controls Factory, Team 4 sought to introduce a radical new approach. The result was a democratic pavilion where management and employees shared a single entrance and a single restaurant, a practice unheard of at the time. With the electronics industry then in its infancy, the building was regarded as a light-industrial prototype, it's organisation and design

Image: Concert Hall project (Interior perspective) 1942 Mies van der Rohe

10 Joris Molenaar, Brinkman & van der Vlugt architects : Rotterdams city-ideal in international style(nai010 publishers, Rotterdam) 2012, p.57

11 Oswald W. Grube, Industrial Buildings and Factories (Verlag Arthur Niggli, Teufen, Switzerland), 1971, p.36

implying new democratic standards in the workplace."[11] The client required that a maximum flexibility for expansion and internal change was available. As mentioned the barriers between white and blue collar workers had to be reduced as much as possible. The movable partitions dividing the research, production and administration areas of the factory were fully transparent, with solid partitions separating the lavatories, storerooms, kitchens, plant areas and managerial offices. The building's social character was fundamental. All workers used the same entrances and there was a cafeteria that all workers could use. The breakdown of limits between physical and intellectual labour in the architecture mirror those of the workplace. The high-tech production taking place inside no longer needed the low skilled workers that Fordism had relied upon for the assembly line. Factory workers were now required to have technical knowledge and were just as much informational workers as those in the office.

Another characteristic of post-Fordist work is evident in the lifespan of the factory; it had to be constructed quickly, the time available for production was limited to ten and half months, and the building was demolished in 1991, just 25 years after completion. Buildings were not intended for longevity, but for quick construction and a short life.

Image: Reliance Controls office space 1966
Rogers Stirk Harbour + Partners

Automated worker

Image: 1938 BBC Television produce R.U.R as a tv play, here we see the robots surrounding a worker.

From the 19th century on, there was an effort to rationalise the worker within the factory. From the beginning, the introduction of the machine had an effect on the production speed imposed on the worker. It was the speed of the machine that determined that of the worker. This was the watchword of modernity, transforming Man into something as rational and perfect as the machine. The worker was at the vanguard of a movement that intended to drag Man into the modern world, to perfect him, to make him work better, more efficiently, to measure and calculate his movements. The worker was to be made into a robot, the etymology of the word robot coming from Karel Čapek's 1920 play R.U.R (Rossum's Universal Robots), where the robots were the automatised workers in the factory. The word itself comes from the Czech robota which means serf or forced labour. These robots are the perfect employees, executing tasks seamlessly, considered better than human workers in every aspect, that is until an engineer decides to give the robots a heart. "Young Rossum invented a worker with the minimum amount of requirements. He had to simplify him. He rejected everything that did not contribute directly to the progress of work — everything that makes man more expensive. In fact he rejected man and made the robot."[12] Labour changes introduced in the early 20th century intended to remove "everything that makes man more expensive" and rationalise the worker.

12 Rappaport, Nina. *Vertical Urban Factory*. Actar Publishers, 2016. p. 40

The turn of the 20th century was the moment that the organisation of work began to be seen as a science, as important as the design of factories or the engineering of machines. From the late 19th century, Frederick W. Taylor had been developing methods to make work more efficient. Calling it a

scientific management of labour, his aim was to rationalise work, to remove unnecessary steps taken by the workers that reduced efficiency. Taylor came from a wealthy New England family and was destined to follow his fathers path and study Law at Harvard until poor eyesight derailed those plans. After completing an apprenticeship he worked as a machine-shop labourer at Midvale Steel Works where he was quickly promoted to chief engineer of the works. He noticed that the workers were soldiering — working more slowly than their full potential in order to keep the price they were paid for each piece high and hence forcing factory owners to employ more people to produce the same amount of goods.[13]
To counter the soldiering he studied the process that the workers went through when completing their tasks and rationalised them. Each part of the process was analysed and the steps the worker took while gathering parts was reduced to a minimum. Any unnecessary movements in the process were removed and the remaining actions were optimised. The worker is comparable to a piece of machinery, his movements analysed, calculated and optimised, the pressure of time is brought to bear upon his work, which in turn brought about the "tyranny of the clock" that would be so vehemently criticised by the workers, who were alienated by new organisation of labour, which removed all decision making from them and transferred it to management. The workers resisted the changes brought about by Taylor, to the extent that factory owners were reluctant to employ him as his reputation tended to precede him and before even arriving tensions between workers and management would increase. The freedom given to the workers was reduced and decisions were taken in a more centralised manner. The supervision regime was reinforced.

13 Roser, Christoph. *"Faster, Better, Cheaper" in the History of Manufacturing from the Stone Age to Lean Manufacturing and Beyond*. Taylor Francis Inc., 2017. p.226

Further developing the idea of time studies were the husband and wife team of Frank and Lillian Gilbreth, who developed a series of motion studies called therbligs, a play on their surname. Their focus was not only on increasing the productivity of the workers, but also to improve their wellbeing. As opposed to Taylor, their methods were intended to improve the lives of the workers as much as improving productivity. The first step in their studies was to use chronocyclographs, double exposure photographs; the first exposure was of a white grid on a black background and the second a long exposure of a worker wearing a light on their hands and head while performing the required task in an efficient manner predetermined by the Gilbreth's. These photographs would then be used to train the other workers in the fastest way to accomplish their task, following the movements shown in the photographs.[14]

14 Rappaport, Nina. *Vertical Urban Factory*. Actar Publishers, 2016. p. 48

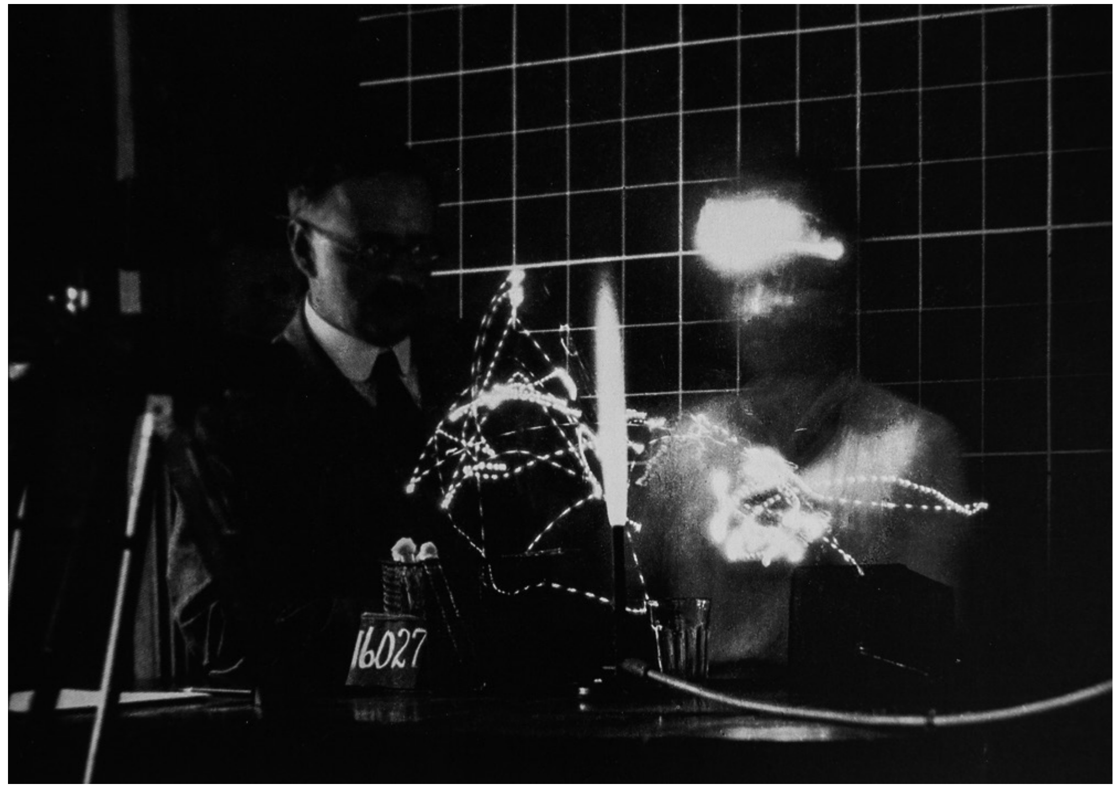


Image: Chronocyclograph of a worker being instructed as to how to most efficiently perform a task, with the light grid behind him
Frank & Lilian Gilbreth

The biggest change arguably came with the development of the assembly line, which built on previous innovations in labour management. This time it came not from consultants, but from Henry Ford. When he first set up his Ford Motor company, production was the same as it was in other factories, each worker would be specialised in building a specific part of the car, and would work on it until he had completed his task, he then moved to the next car and repeated the process. However as the worker needed to wait for the previous worker to finish, this created bottlenecks resulting in significant lost time and demonstrating the clear need for improvement. Ford opened the Highland Park plant in 1911 when increases in production had rendered his previous factory too small. It was here that he started using assembly lines; it is said that his inspiration came from slaughterhouses, where the carcass of the animal was hung from a hook and moved along the "disassembly" line where each worker would perform a specific task. Regardless of its origin, it was a revolutionary idea and one that brought about massive productivity improvements with the total amount of time to produce a car going from 12.5 hours to 93 minutes,[15] meaning that fewer workers were required. Machines took on a larger share of the production and the workers now kept to fixed positions along the assembly line. The piece to work on would arrive from the previous station via the conveyor belt, the worker would complete his task, repeating the same movement up to 810 times during his shift. The piece would then be sent onto the next post, continuing until the car was finished. Now the worker was subject to the tyranny of the machine, completing his tasks in an automated manner. The job he was given being intentionally de-skilled, labour was made into a generic entity, just as mass production introduced interchangeable parts for the machines, it introduced interchangeable workers as well, a labour sans phrase.

15 Roser, Christoph. *"Faster, Better, Cheaper" in the History of Manufacturing from the Stone Age to Lean Manufacturing and Beyond*. Taylor Francis Inc., 2017. p.238

From the third industrial revolution, labour relations became less fixed, as we have seen in the Reliance Controls building, the limits between different types of workers and layers of management was changed, with the introduction of automated processes within the factory, the worker became ever less a tool to be used on par with the machine, but was now supervising the production process himself, this required a higher level of knowledge than was previously the case in the assembly line. As production was becoming more flexible, the worker was required to do the same, being able to jump from task to task and to work in an autonomous manner.

Architecture

Plan

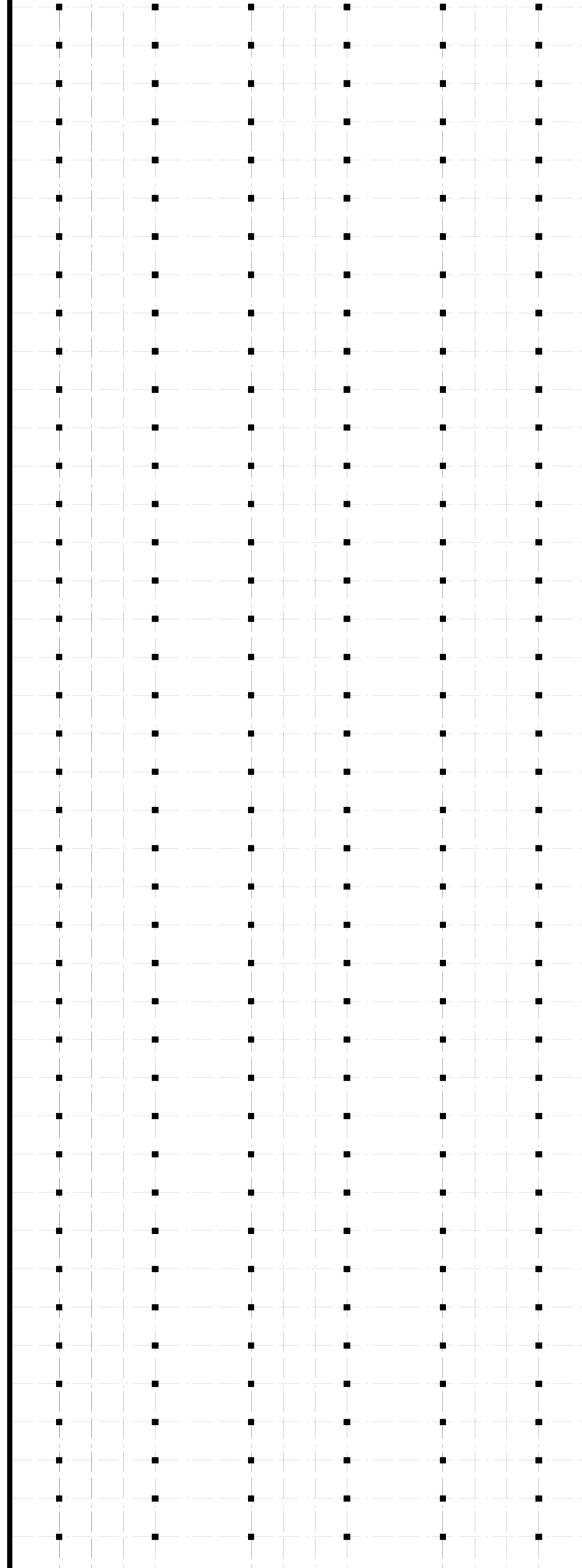
Previous page: Criss-Crossed Conveyors, River Rouge Plant, Ford Motor Company
By Charles Sheeler 1927
Ford Motor Company Collection

Image: Part of the floor plan of Building B at the Ford River Rouge Plant
Redrawn 1:1000

The modern factory is characterised by the huge extent of its plan; a flat plane upon which any activity can take place, punctuated by columns and technical infrastructures permitting these activites to take place and surrounded by an enclosure which defines the inside and the outside. Its character coalesced around the daylight factory at the turn of the 20th century. Prior to that, factories could have a large scale and empty floor plans, however they had no independent form; modeled on previous typologies rather than a pure factory and due to material constraints they were not pure expressions of production. Columns were densely packed within the building, presenting constraints and though they had larger windows than residential buildings, the language was still the same. What Rem Koolhaas described as architecture for business architecture where "the ambition [...] is to create new territories for the smooth unfolding of new processes, in this case, ideal accommodation for business. But what is business? Supposedly the most circumscribed program, it is actually the most formless. Business makes no demands. The architects of Typical Plan understood the secret of business: the office building represents the first totally abstract programme -- it does not demand a particular architecture, its only function is to let its occupants exist. Business can invade any architecture. Out of this indeterminacy Typical Plan generates character."[1]

1 Koolhaas, Rem, and Bruce Mau. *S, M, L, XL*. Monacelli Press, 1998. p.337

Though he is referring to the architecture of offices and skyscrapers, the principles were first developed in 20th century industrial architecture. For Francesco Marullo, "financial capitalism drove the typical plan towards its basic form, it was modern American industry that established its political



2 Aureli, Pier Vittorio, and Francesco Marullo. *"Architecture and Revolution The Typical Plan as Index of Generic."* The City as a Project, Ruby Press, 2013, pp. 216–260.

3 Biggs, Lindy. *The Rational Factory: Architecture, Technology, and Work in America's Age of Mass Production*. Johns Hopkins University Press, 2003. p.1

Image: Daylight factory used as office space, note the high ceilings and mushroom columns

4 Koolhaas, Rem, and Bruce Mau. *S, M, L, XL*. Monacelli Press, 1998. p.337

and economic foundation, the dialectical relation between architecture and production, typical plan and forms of life."[2] Just as life is ever evolving and changing, so too does the program of the factory and for this the architecture needs to be indeterminate. The rigidity of the factory allows few architectural interventions, which gives the activity inside more freedom. The paradox is that despite reducing the importance of architectural elements in the factory, they remain decisive in allowing the activities within to unfold such that "the object of the factory builder should... be fitness for purpose at minimum cost in a combination with complete flexibility for replanning and alteration."[3]

The form of the factory found its original expression in the architecture of Daylight Factories, in which innovations in the world of construction and work were happening simultaneously. As labour was being rationalised and was coming further under the control of management, becoming an "an abstract and generic entity, so too was industrial architecture. The factory was built in such a way as to allow the program to unveil itself to its maximum potential, allowed by horizontal expanse punctuated by isotropic condition throughout the building. The building must respond to the principle aim that it shares with the program, which is a business, in the sense that Koolhaas meant, as a place of work, but also an investment. The flexibility of the factory means that it is ever adaptable to the changing conditions of business and can readily accommodate these changes when they come.
The program fills the space vacated by architecture within the building. Rem Koolhaas compares the architecture of Typical Plan to the main protagonist of Robert Musil's The Man Without Qualities where Ulrich is a young man, unsure of his ambitions and who adapts to the social situations he finds himself in, but always on the basis of rational thought.[4]

Just as Ulrich, Typical Plan uses rational planning to create a rigid framework which negates architecture by defining it as a set of rules. This framework is represented by the remaining element of architecture, the vertical support, the most eminently rational element of architecture and often the domain of the engineer who shares the work of building the factory with the architect. As efforts to measure and quantify production and transform labour went ahead, industrial space was quantified. The basic unit of the factory is the module, which defines the grid that gives the factory its shape. It's chief quality is that of providing a fixed measure, every modular element is the same within the factory,

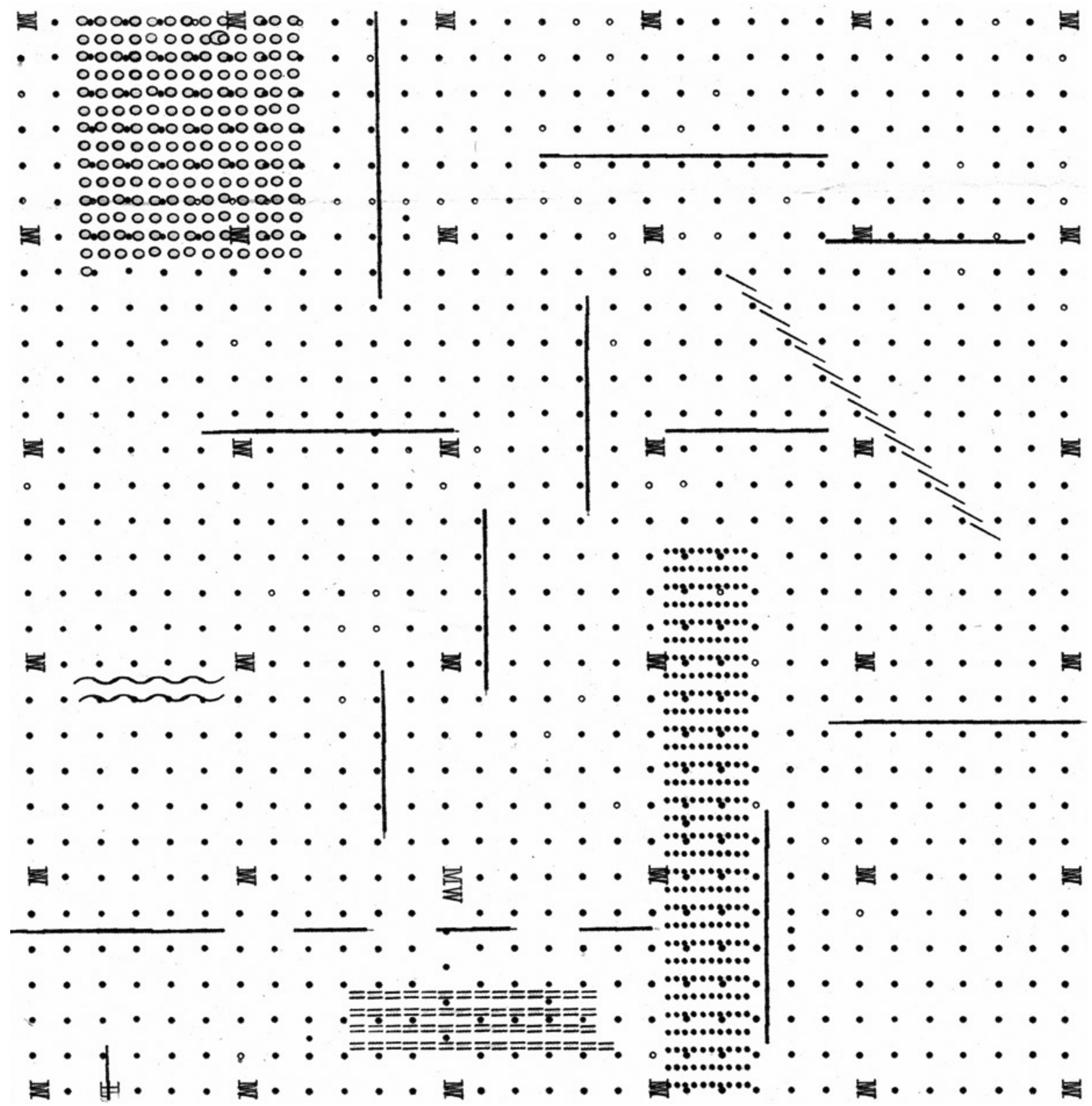
it is defined by measurable characteristics and the strength of the material defines the maximum span the structure can cover. It does this on an x, y axis, introducing the principle of the grid, the ultimate mathematical plane, which removes forms of hierarchy and as mentioned previously, this renders the floor an undifferentiated plane, neutralising difference by having the same conditions which apply to every point in the grid. It is an artificial environment, which uses artificial means of control to control the conditions within the factory.

Image: No-Stop city 1969
Archizoom Andrea Branzi

The grid, a supposedly fixed and rigid element also adds flexibility to the organisation of the factory, which can be extended according the the requirements of production. The lack of a defined character implies that the grid can be modified without changing its organisation or underlying principles, as architecturally each module can be conceived as independent from the whole. Because of its lack of expression, the grid of the factory can be reproduced anywhere, it does not respond to its context but to the requirements of the activity inside and in that regard it is autonomous, just as the Cartesian grid it is self-contained and refers only to its rational system of reference. The grid is the basis for Archizooms No-Stop City, where a 5x5m structural system determines the rhythm of a city that can extend infinitely, based on the structural closed systems of the factories, it becomes a field of possibilities, the liberating potential of the plan is here underlined, it is extended ad infinitum, with the isonomic character of the grid allowing for any activity to take place inside, a space for living, working and play.

One element remains outside of rational control, the part of the program that responds to the human needs of the workers. The presence of stairs, toilets, refectories and changing rooms, are irrational elements within the rational plan and express the inherent irrationality of the workers. Indeed, often these programs are included in the design of the factory, but set outside, disconnected from the main volume, or when set inside going against the perfection of Typical Plan by the insertion of blobs into the perfectly rational and rigid plan.

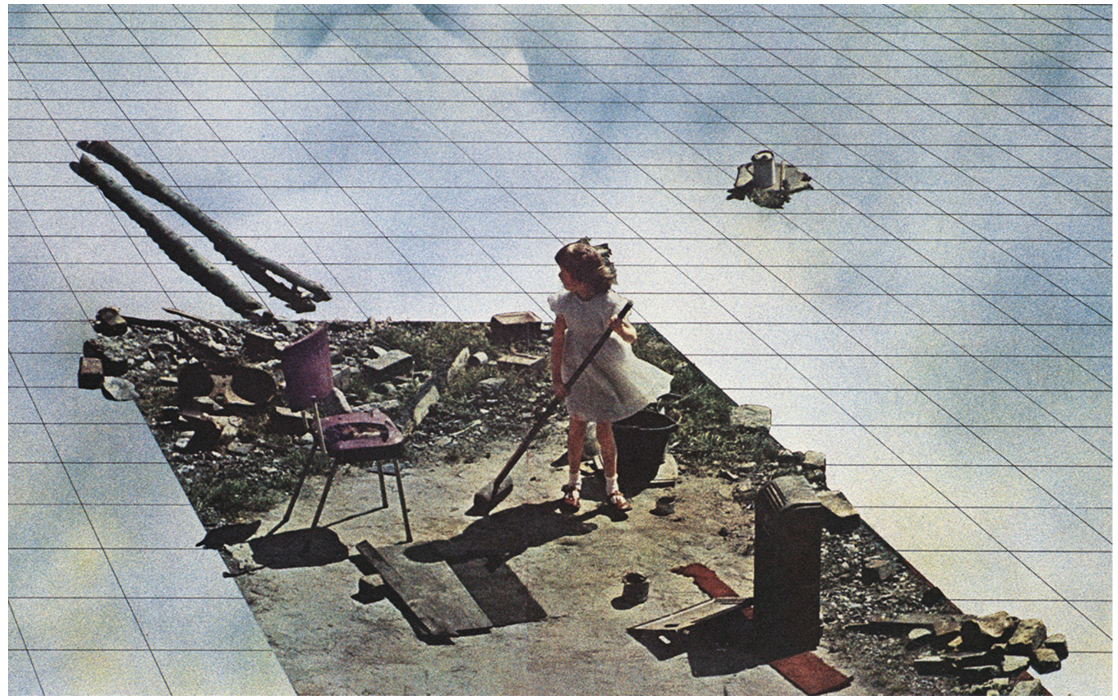
The factory's floors can be stacked upon one another, in which case they keep the same character on each floor, simply repeating the same elements on every level. By stacking the same floors upon one another, the floor of the factory takes up a special importance, as it is in the floor, or the ceiling that the technical flows of the architecture circulate. On the surface they are flat slabs, but inside they are the most technologically developed



element of architecture, with power cables, ventilation ducts, structural elements traversing the flat floor/ceiling. It is thanks to these elements that the autonomy of the factory can be expressed as a totally artificial environment.

The conception of architecture as a dissolution of itself is pushed to an extreme in Superstudios Supersurface, where architecture is rendered as its most basic element and representation, the plan. It is an architecture of the plan and nothing else, there is a gridded floor that extends indefinitely, but more than a floor it is a field of possibilities; just as the factories indeterminacy creates freedom, so does that of the Supersurface, and just as in the factory the technological aspect helps the slab reach its liberating potential. The Supersurface is traversed with a network of infrastructures that respond directly to the individual who is above and provides all that is necessary to support life: shelter and means of communication.
The isonomic character of the Supersurface deems that it is a plane that works without hierarchy, seemingly unplanned, as it extends throughout the whole world, indiscriminately leaving room for free expression. But the gridded slab tells another story; that of rational planning and technological progress. The analogy with the factory is even more pertinent here, as the degree of freedom the plan permits is directly proportional to its rigidity and rational planning.

Image: Supersurface
Superstudio 1971-1973



Box

Image: Cromford Mill façade with a regular grid of windows and a solid brick wall, no difference with regular housing, other than scale.

The edge of the factory is defined by a solid border which marks the limit between the inside, where production happens and the outside, where production is reciprocated by consumption. The border marks the the beginning of a controlled and rational space. The physical manifestation of this edge defines how the interior is organised: if it is transparent or opaque, hermetic or open to the outside. These choices, just as all others within the factory, are made with two considerations in mind; optimisation of processes on the one hand and maximisation of flexibility on the other.
As the element that defines what the factory expresses to the outside, it is the envelope that mediates between the strict productive activities of the factory and the general public.
The form the factory takes is a rational one, that of the box, the ultimate generic expression of form and the form of the box, the rectangle, gives the factory its volumetric shape. The roof of the building is where changes to the box happen with the necessity of providing light in the factory changing its aspect, most notably in the case of the single storey factory, where ceiling lighting is most important.

When considering the façade, choices are made based on rational cost calculations and the ratio between the capital and labour costs of the building come into consideration. “Architecture is 90 per cent business and 10% art”[5] as Albert Kahn said. Consequently, in his factory design he must base his calculations rationally on optimising the building’s efficiency, rather than the usual architectural considerations of light, proportion and mass. We can see the reasoning behind the opening of the façade in the daylight factory here, where Kahn speaks about the hypothetical design of a factory in Detroit; what is interesting to note in

5 Kahn, Albert, and George Nelson. *Industrial Architecture of Albert Kahn, Inc.* Architectural Book, 1939. p.17

passing is the rare influence that location has on the architectural decisions relating to the factory.
“It is erroneous to assume that large areas of glass in the outer walls of a factory building increase operating costs on account of the heat loss in the winter season. In a locality, say in the neighbourhood of Detroit, the heat loss through 1000 sq. ft. of ordinary glass requires $46.80 worth of coal per season, when coal costs $4.00 per ton. In a factory employing 500 men, the total area of the external walls will be approximately 33000 sq. ft. If the entire wall area were glazed, the heat loss would require $1544 worth of fuel per annum. If large expanses of glass increase the efficiency of the workmen by only one per cent, the annual saving in labor cost would be about $5200. This demonstrates, so far as production costs are concerned, that it would be advisable to have glass in the entire area of the walls if this were practical.”[6]

Image: Nighttime image of the Van Nelle factory, the extreme transparency of the building is highlighted by the lights streaming through the windows. 1950

6 ibid. p.175

From the outset of the factory typology, the conundrum of lighting the interior of the building was one of the most pressing issues. Indeed, as illustrated by Kahn in the previous quote, how can workers be efficient if they cannot see what they are doing? The question of providing adequate lighting also determined the form of the factory, which could only expand in length as their multiple stories constrained them to side lighting, hence, the depth of the building was limited by the amount of light that could enter the workspace.
Until the 20th century, the factory was a typically solid building with a masonry façade punctuated by a regular grid of windows, which grew in dimension in time as material innovations reduced the importance of the load bearing façade. But the basic arrangement of walls and windows remained unchanged.

The major change came with Julius Kahn’s Trussed Concrete Steel Company, or Truscon founded in 1903, which developed a new reinforced concrete system which was applied to factory buildings by his brother, the prolific Albert Kahn.
The first major industrial building built using this new construction method was the Packard Plant 10 built in 1910, where the façade is no longer punctuated by windows, but by columns. The bulk of the façade is filled with glass interspersed at regular intervals by structural concrete columns, a system that allowed greater spans within the factory, but more importantly marks an inversion between dominant solid and secondary transparent elements and a new openness and marks the moment when the ratios began to change.

A year earlier, the Steiff Factory in Germany had experimented

7 Rappaport, Nina. *Vertical Urban Factory*. Actar Publishers, 2016. p.123

with an entirely glass façade though on a much smaller scale. Built using techniques that had previously been applied to greenhouses, a steel and glass façade was held up by a steel structure and an x bracing system. But the glass box had been introduced, not by architects, but by builders.[7]

The Boots Wets factory competed by Owen Williams in 1932 is an exemplary daylight factory following in Kahn's footsteps. Commissioned by the company's American owners who were further ahead in factory design than their British counterparts, it was one of the first major buildings to have almost continuous glazing over the entire façade. What is additionally important to note is that no distinction was made between the production areas and the administrative block, unlike the treatment other factory buildings received, where the administrative block was treated differently to the production side, even in the case of a precursor building such as the Van Nelle factory. The entire building being glazed combined with the mushroom column structure entailing flat floor slabs means that interior lighting conditions are optimised and the factory truely lives up to the daylight factory moniker.

As the glass and concrete factory reached its most exalted form in Europe a transformation was happening on the other side of the Atlantic. American factories were transitioning to a single storey top lit model. Abandoning the old model, which developed linearly with openings on the sides, the new factories were too deep to be follow this model. The roof was now the main source of light and had the consequence of closing the edges of the factory, making it into a closed box. The only expression of its function now given by the ubiquitous shed lighting system which although extant in previous incarnations of the factory, became a universally recognisable feature of the shed factory, a signifier for the activities happening inside.

The exterior of the factory was often used as a prop. In the 19th Century the style of the factory construction was intended to express the values of the owners and the company. The facades followed the same trends as did the rest of the architectural world, moving through Greek revival, classicist, Gothic and Italianate throughout the century in Great Britain.
As ever, the main change came in the 20th century where the expression of the factory was homogenised and with the move to concrete, glass and steel, the material expression of the factory became independent of the wider world of architecture and took on its own symbolism, which was thoroughly appropriated

Image: The printing presses at Nicholas Grimshaws FT printworks, the façade in front is entirely glazed, which shows passersby the machinery on the inside. 1988 Grimshaw

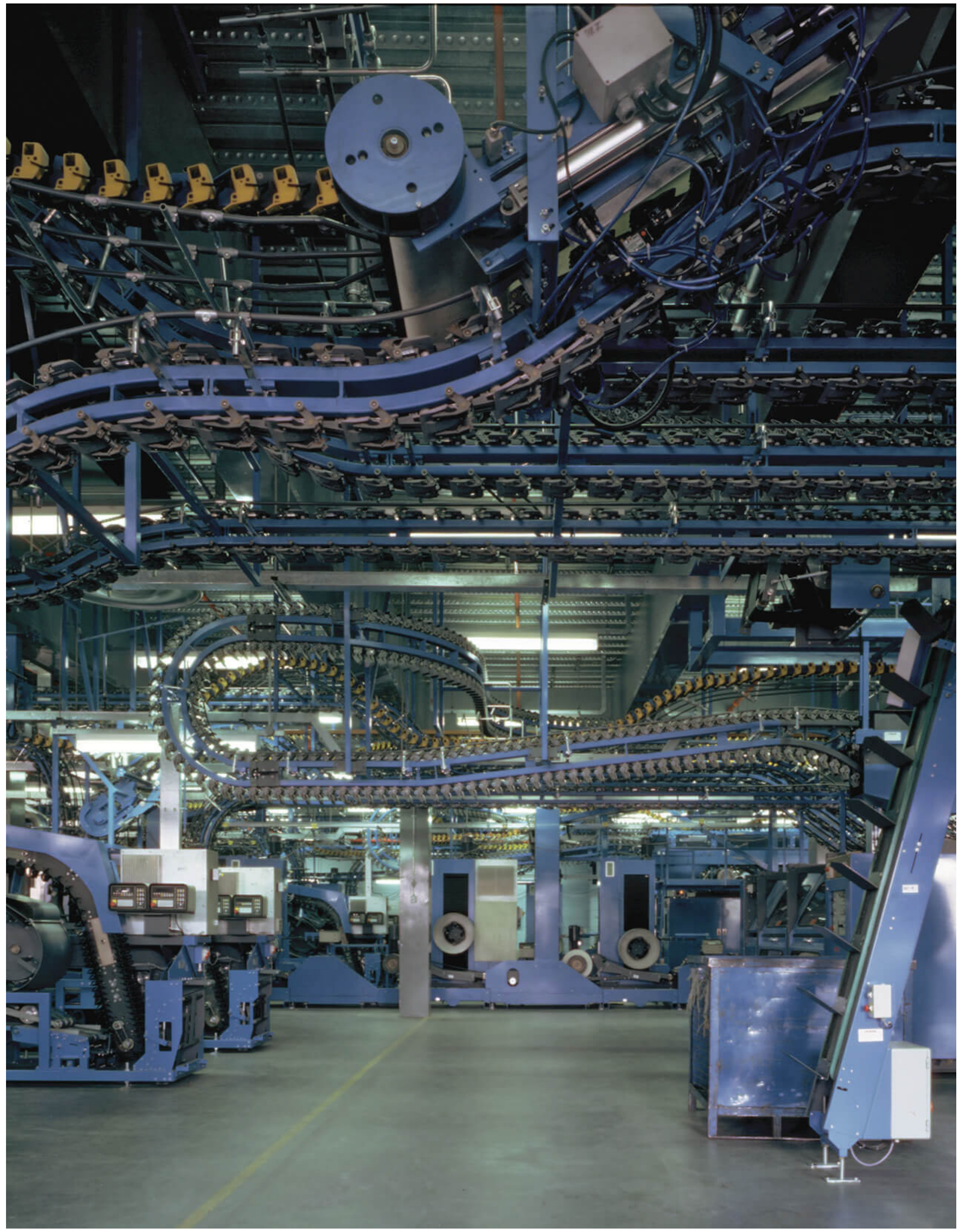
by modern architects. Technical innovations such as Julius Kahn's new concrete structural system and innovations in the production of steel allowed fully glazed façades, which beyond their functional advantages, also held symbolic meaning. Yevgeny Zamyatin describes the homes in his dystopic novel We as having façades totally open to the outside, entirely made of glass. This is a futuristic world, where reason and industry are both worshiped. Glass here stands in for industry signifying progress and "the sanity of science reason and order"[8] the crystaline façades of industrial buildings representing the future.

8 Yeomans, David T. *Owen Williams*. Thomas Telford, 2001. p.87

The factory was often considered a decorated shed, a box — but a box with a message. At Highland Park, Henry Ford had three extra chimneys built above the powerplant in order to accommodate a F-O-R-D sign on the roof of the building, effectively acting as a billboard all passersby could see. Ford was aware that the juxtaposition of the brand and the symbol of industry that was the powerhouse, with its large windows through which people could see the large machines at work inside, would link the two together in the minds of the people who saw it and build upon the perception of the factory as the future. Of Ford as the future. The verticality of the chimney stacks is reminiscent of the spires of Gothic cathedrals, which would tower over a city, expressing the domination of the church over its surroundings.[9]

9 Biggs, Lindy. *The Rational Factory: Architecture, Technology, and Work in America's Age of Mass Production*. Johns Hopkins University Press, 2003. p.104

Richard Rogers uses the roof of the Inmos microprocessor factory to express the technologies used in production and to compensate for a totally opaque façade. The technical elements that allow the production to take place: ventilation, lighting, structure, are positioned onto the roof of the building, almost as a technical sculpture standing in for the production itself. The whole is suggested by its components, isolated in the air once again, visible from far away.
Nicholas Grimshaw, in the era of closed high-tech factories opens a side of his FT Printworks from 1988 to frame the printing presses; the gigantic machine that fills the entire space and through which the famous pink pages of the Financial Times pass. Here the architecture and the contents of the factory are combined to make the factory into an image of the production, architecture disappears. All that remains is production.



Structure

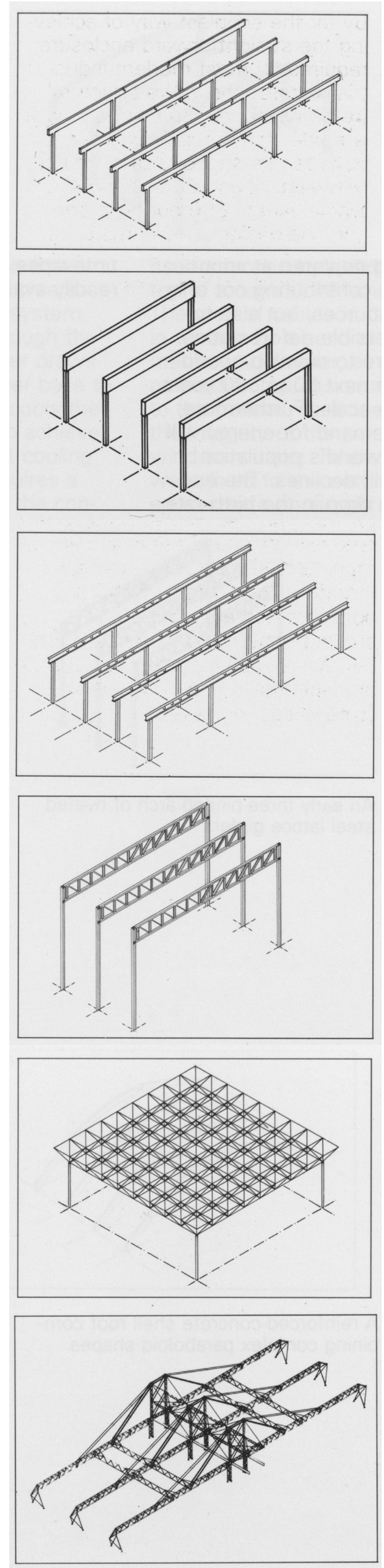


Image: Structural evolution of the factory.

Wood post and beam structure

Concrete post and beam structure

Steel beam structure

Steel truss beam structure

Steel space frame structure

Cantilevered prismatic trusses with cable support

Drawings by Fritz-Ulrich Buchmann “Frames for Industrial Construction

The most architecturally present and important element in the factory is the structure, for it is the column that unleashes the potential of the plan. The structure is the regulating element of the factory, everything else is measured and determined according to it and it creates the link between the other elements. The box is joined to the floor via the structure, the floors are linked to one another by the structure and it can be hollow to allow the technical infrastructure — of which it is also part — of the factory to pass through. Indeed the structure is a hybrid element, bridging the gap between technique and architecture. It is the element that links the engineer and the architect, since it is the sole architectural element that remains on the factory floor. Once the factory lost its load bearing walls, all that was left was the column, the beam and the truss. The structure determines the future form of the architecture and as it is a modular structure, the factory when and if it expands, will do so according to a set of rules determined at the moment the structure was conceived. The structure of the building is the element most subject to technological change, with developments in materials and technology in this domain having a wide impact on the form of the factory, more so than any other constructive aspect. The structure of the building is its central element, that which allows the frame to envelop the Typical Plan upon which the users adapt their activities around the possibilities granted by the structure. It interacts with the production process and machines and men are organised according to its consistent rhythm. It is the hinge upon which the system rests, as it determines the size of the building as well as how present, or absent, the architecture is.

The history of industrial architecture mirrors that of the structure.

The first factories used a conventional wooden beam and column structure, rendering the building vulnerable to fire.
Once innovations were made, whilst the underlying structure remained the same, the materials changed. At first cast iron was introduced to reinforce the wood, but due to the increasing rarity of strong timber beams and their intrinsic vulnerability to fire, these were replaced in the 1790's by structures made up entirely of cast iron This had the advantage of being more more resistant than wood, allowing the sections to be smaller and the span larger and was cheaper to find than wooden beams of the required dimensions. Combined with brick arches, the introduction of cast iron further guaranteed fire resistant buildings. From the 1850's wrought iron was introduced, with little change apart from increased tensile resistance.

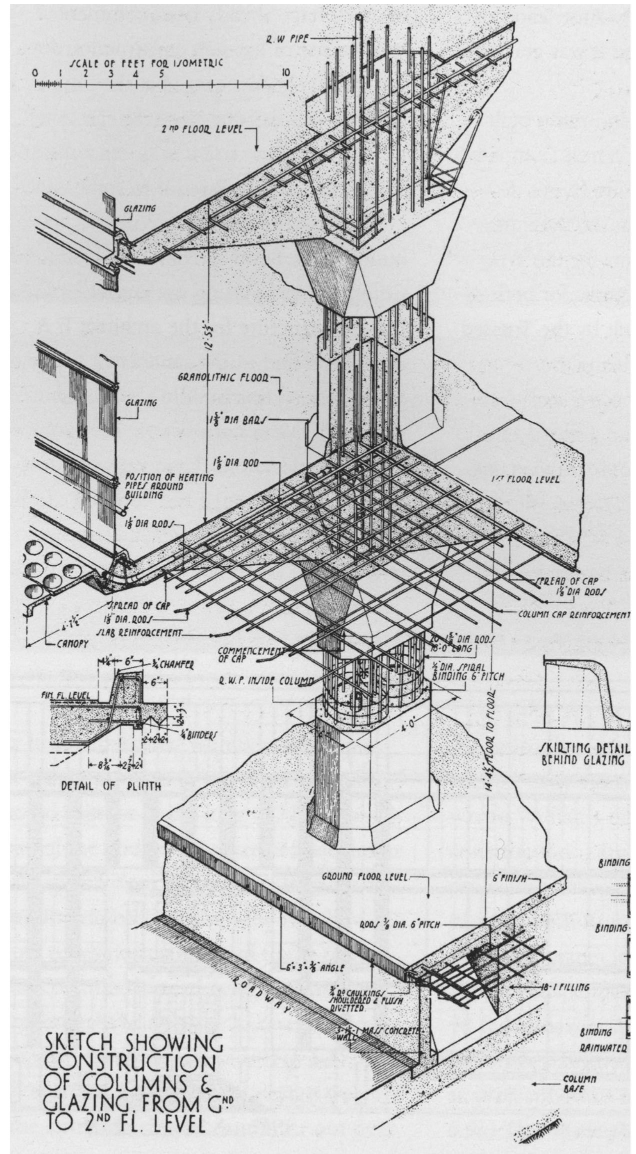
Image: Drawing of the "mushroom" construction at the Wets building 1932 Building

The radical change came at the turn of the 20th century with innovations in the world of concrete. New structural systems started to be introduced, the most famous of which are the Hennebique and Truscon post and beam systems, whose structural organisation was analogous to the wood and cast iron structures that came before but with a distinct advantage it was a monolithic material. It held a fourfold advantage; "it reduced floor vibration from machines, making multiple floors more feasible; it required fewer interior columns than older mill construction, opening up space on the shop floor; the strength of the outer walls meant both that the window areas could be much larger, opening the way for the window-walls of the daylight factor, and the building could be made much larger than the mill building".[10] The consequences of this structural innovation were clear, wider working spaces and more light for the workers and a building capable of hosting more and larger machines.

10 Biggs, Lindy. *The Rational Factory: Architecture, Technology, and Work in America's Age of Mass Production*. Johns Hopkins University Press, 2003., p.82

There were incremental improvements in concrete construction and the mushroom column would be the one to leave the strongest association to the factory in popular imagination. In this system, the slab is included within the structural system, and steel reinforcements located in the floor transfer shear forces directly to the beam via diagonal steel elements added to the head of the column. This has the advantage of producing a flat slab as the function of the beam in previous systems is directly included in its thickness. The main advantage: "for factories are that it simplifies the shuttering of the concrete and makes the installation of service runs and machine shafting very much simpler (emphasis added). Also the absence of beams, especially edge beams, can improve daylight conditions within the building".[11]

11 Yeomans, David T. *Owen Williams*. Thomas Telford, 2001. p.87



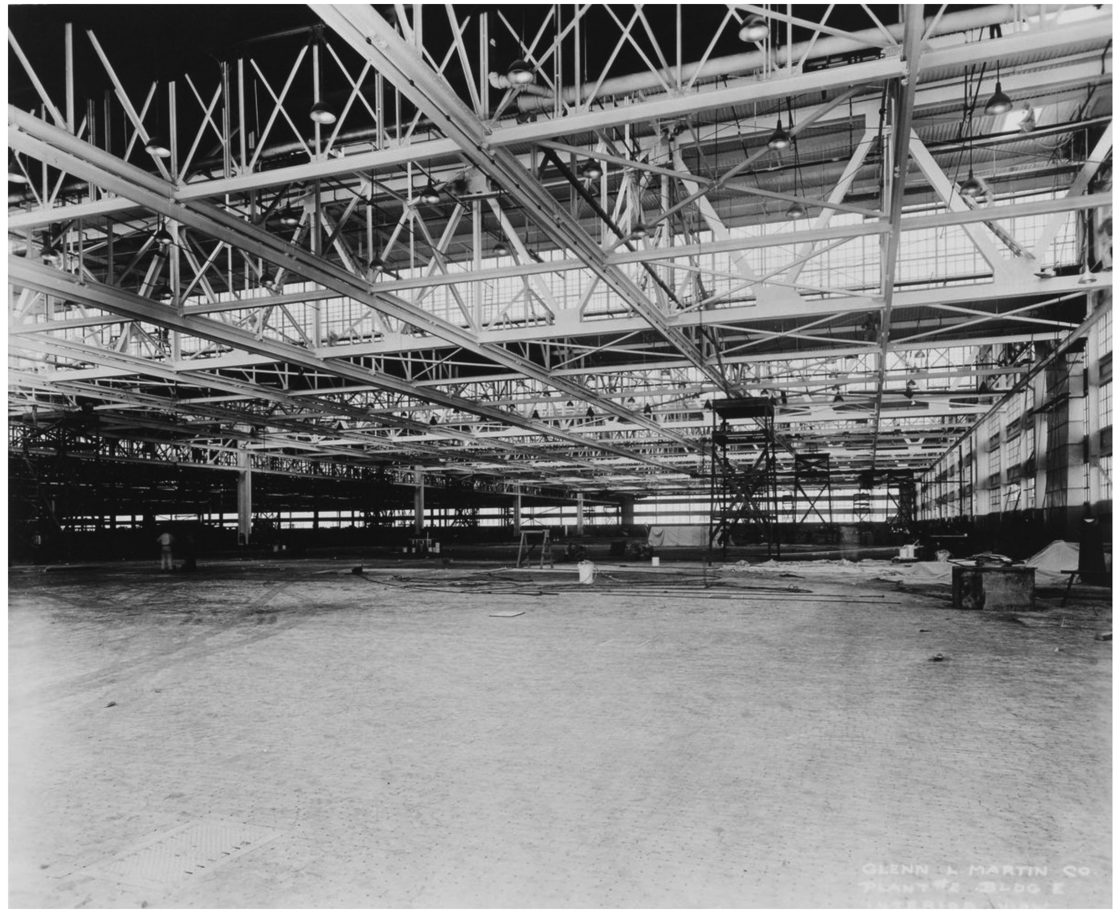
The Van Nelle factory takes full advantage of this system to allow unobstructed light to enter the workspaces, which was especially advantageous for multi-storey buildings, that as we have seen, received their light from the edges of the building.

Image: Interior view of the Assembly Building (also known as Building E) under construction, Glenn L. Martin Company Navy Assembly Plant No. 2, Middle River, Maryland 1941
Forster Studio

The single-storey shed made its apparition just as steel was beginning to exploit the industrial system of mass production. Introducing lower prices and increased standardisation, steel construction is also the most industrialised system of construction. Prefabricated and assembled on site, steel had a clear advantage over wood, concrete and cast iron, all of which required a greater or lesser degree of in situ construction. The availability of prefabricated elements needing to be assembled together reduced costs and increased the speed of construction. The relative lightness of the material, compared to its strength made possible spans much larger and the Glenn R. Martin built by Albert Kahn and completed in 1939 clearly shows the advantages of building with steel. The factory, which was made to build airplanes, demanded a huge 300 x 450 ft (91.44 x 137.16m) space for construction and thanks to an efficient steel construction borrowed from bridge building, supported by ten columns, the colossal space was achieved. As the quality of steel improved, the size of the spans increased and the cost of construction decreased.

High tech architecture of the latter part of the century used steel for its industrial and high-performance qualities. The immense spans of Richard Rogers Inmos microprocessor factory were allowed thanks to the use of high-grade steel in cantilevered prismatic trusses used under tension. This allows the space below to be unconstrained by beams and results in a totally open and reorganisable space.[12]

12 Ackermann, Kurt, et al. *Building for Industry*. Watermark, 1991. p.172



Present Future

Present factory

In the West, the share of the economy controlled by the manufacturing sector has declined steadily since the 1970's, due to a combination of factors, notably the growth of the tertiary sector and the advent of globalisation. In the UK, manufacturing as a share of GDP decreased from over 32% of GDP in 1970 to 10% in 2017, however these numbers can be misleading as in the same time span, manufacturing output increased by 40%, simply put industrial production grew, but not as much as other sectors of the economy.

This is a consequence of two factors, first, an the increased importance of services of the economy, second, the outsourcing of labour intensive industries to countries with a cheap labour force, which was made economically feasible by the decrease in transport costs, the same factor that meant that industries moved out of the cities into the countryside and the development of the single storey shed. This led to the explosion of the factory, where the productive and the cognitive functions of the factory are separated. High added value production remained in the West which changed the traditional aspect of the factory from a place of production only to a more hybridised space where machines, production, intellectual labour and leisure mix. In buildings devoted only to production, the climate became ever more artificial, adapted to the needs of the machines, not needing nature light, nor ventilation. The jobs in these new factories were different to the Fordist model, indeed in the new Post-Fordist world, the characteristics of labour changed. The focus of labour went from physical to intellectual, the worker on the production line, according to Toyotist principles was asked to have an input in the production process, no longer just a drone on the assembly site, hierarchy is flattened, the distinction between white and

Image: Ocado's Robot Warehouse
Greg White Photographer

blue collar workers breaking down, just as we have seen with the organisation of Team Four's Reliance Controls building, where the limits between all the work spaces are transparent, in an effort to diminish the distinctions between the different categories of workers, with the symbolic step of creating the same entrance for all workers. Where the spaces had to be separated, such as in Richard Rogers Inmos microprocessor factory, an intermediate space was created to encourage mixing, the later inclusion of leisure spaces within the work spaces dilutes the distinction that existed between life outside of the workspace and work.
The borders that Hannah Arendt defined between the three different spheres of life, Labour, (political) Action and the Intellect have become blurred, for Paolo Virno, the distinction between Labour and Action has crumbled, what used to belong purely to the world of Labour has now been inflected with the values of Action, political Action that is, which for Virno means that labour is now an act of virtuosity, no longer a repetition of a task ad infinitum as it may have been during the Fordist era. The virtuosity of labour means that it copies the language of performance art, that every act is different from the last based on the activity of the speaker, whose speech is public and varying between each occasion, which links it to Guy Debord and his Société du Spectacle in which "it is not just the the relationship to commodities is now plain to see — commodities are now all that there is to see; the world we see is the world of the commodity."[1] The factory is the place where the production process and its logistics are materialised, where raw goods enter, finished products leave, but it is the result of a system of connections that extend beyond the factory and into society, which it mirrors as it is its the materialisation of capitalist flows, it is the location of commodity, the location of production. Architecturally the model of the closed box prevails, the flexible one storey shed remains the most utilised form for industrial architecture, accompanied by moves toward showcasing the factory, the building becomes representative as we have seen of the values of the company, the production process is no longer hidden away, rather it assumes a prominent position by exhibiting itself.
A new type of architecture for cognitive activities uses the model of the factory, taking its constituent parts, a repetitive structure and an indeterminate floor plan, and modify its components. Junya Ishigami's KAIT workshop in Kanazawa appropriates the structural column of Typical Plan in a baroque manner, using them not to clear the space, but to fill it, here architecture is reintroduced into the cognitive building in order to create new obstacles, which intend to reintroduce architecture as an active element in the life of the building which pushed it to become an

Debord, Guy. The Society of Spectacle. Black & Red, 1970. p. 47

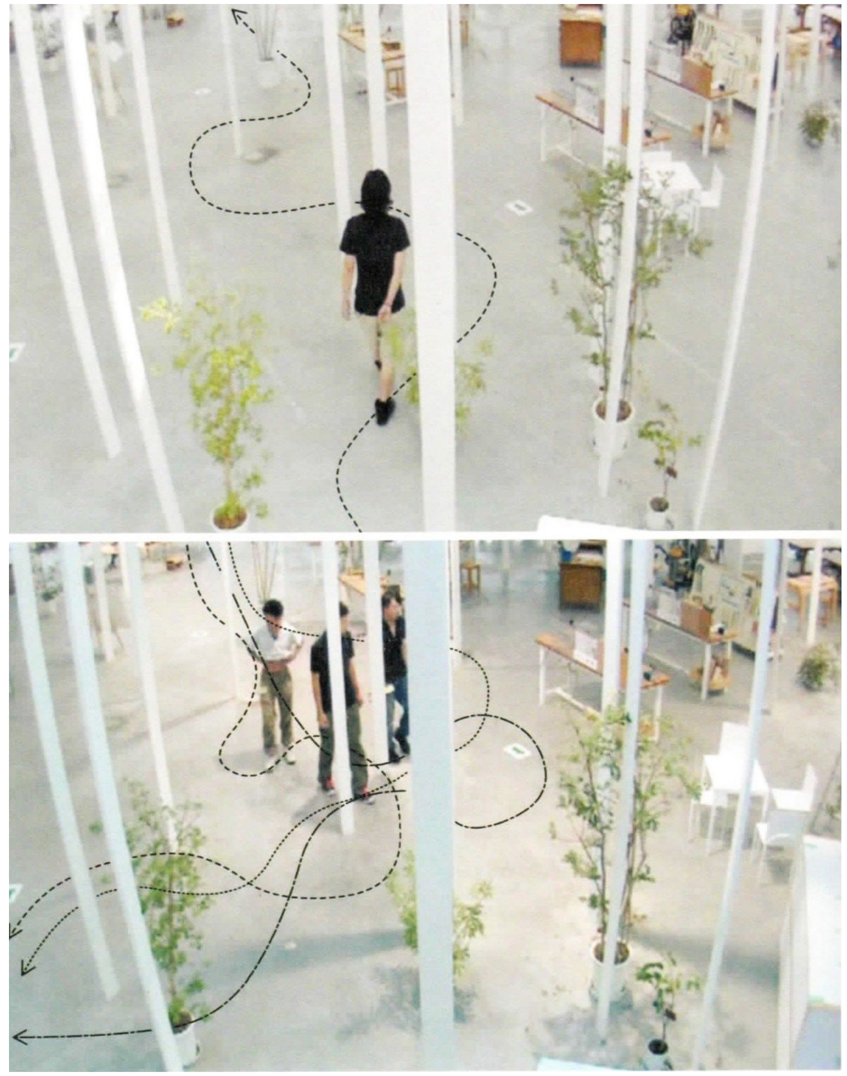
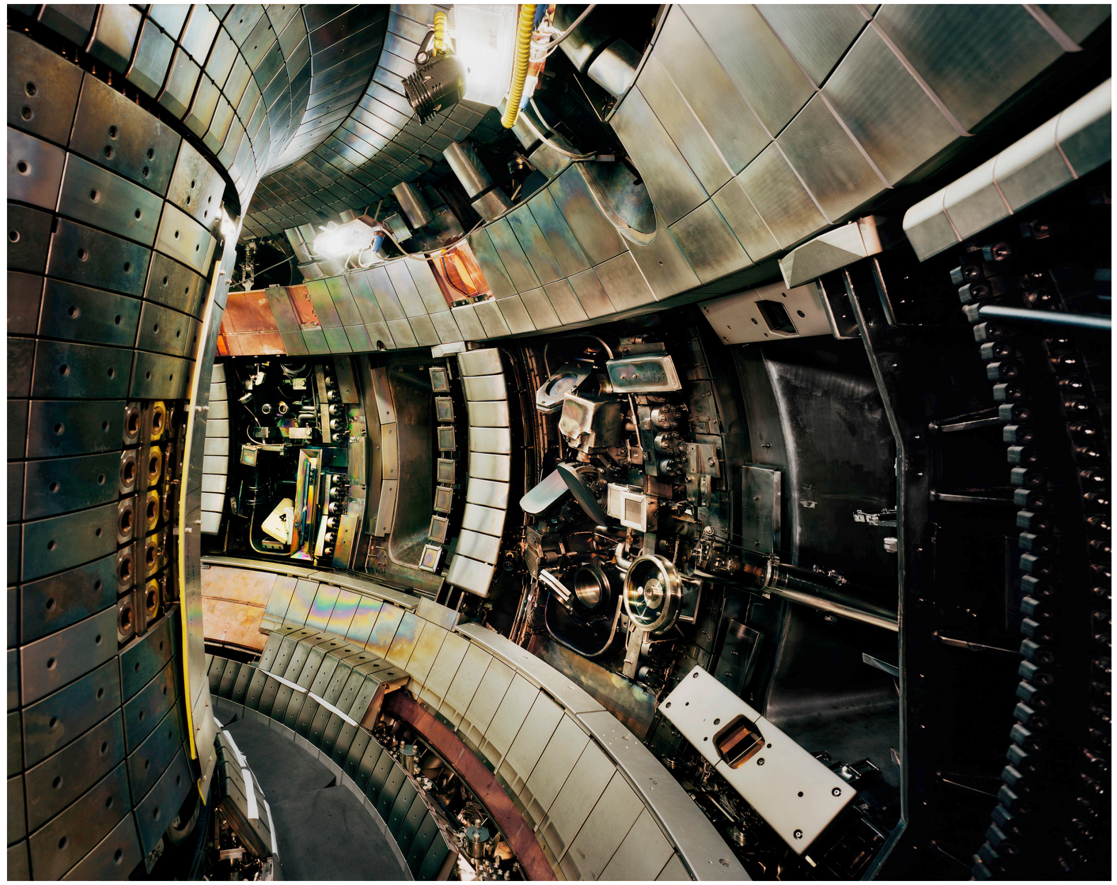


Image: Kanagawa Institute of Technology, showing the different paths available to people in the factory
Junya Ishigami

irrational factory, where the architecture challenges the user to by making him interact with his surroundings in a new manner. The structure is organised according to rational principles by which the pilars are divided by function, some are used to hold the roof, other are used for bracing, the combination of the two systems creates a seeming randomness in the floor plan.
Another such building is the Rolex Learning Centre by SANAA, here Typical Plan is transformed into a landscaped floor, when the plan is seen, it seems like a homogeneous floor plan with few pillars holding the structure up, punctuated by courtyards, however the section tells another story, the floor is raised in parts creating a hill like environment inside, here the legibility and rationality of the plan are replaced by a changing condition which is meant to create new relations within the factory.
These example use the lexicon of rational architecture and modify twist it to the extent that it loses its meaning, no longer catering to rational flexibility, it rather caters to a form of irrational flexibility, the spaces remain indeterminate, but architecture no longer clears the field for other types of activities, rather it fills them with a new type of indeterminacy, here the machine is taken out of the equation and it is man that uses the building.

Image: CERN large hydron collider, laboratory and architecture at the same time, it generates space.
Nature & Politics
Thomas Struth



Conclusion

The fourth industrial revolution is that of the internet, of interconnected communication, dematerialised. As we have seen, each successive industrial revolution has pared back the architectural elements of the factory, as the façade became transparent and then anonymous and the structure ever lighter. In the contemporary factory there have been two parallel developments, in the factories that remain in the West, the manual side of labour has been reduced and the cognitive side increased, accompanied by a separation of machines and labour. The research side of production is done in laboratories where machines support the research role of the workers; and in production halls where machines are supervised and aided by the workers. Production has become more flexible, as have the workers and on a smaller scale.
The worker remains central in a production process that has become flexible and that depends on the adaptive capacities of the worker, in A Grammar of the Multitude, Paolo Virno says that "while the material production of objects is delegated to an automated system of machines, the services rendered by living labor, instead, resemble linguistic-virtuosic services more and more.... Within the culture industry, even in its archaic incarnation examined by Benjamin and Adorno, one can grasp early signs of a mode of production which later, in the post-fordist era, becomes generalized and elevated to the rank of canon."[1]
The factory is a building based on rational principles, adaptive and flexible, the model of the factory is now the model pot the post-fordist worker, the seriality of factory construction however is at odds with the new role of the worker, who as Virno states works in an environment in which he states that their work consists in linguistic-virtuosic activities. These already existed in the fordist factory as the elements for human workers, elements that challenged the ordered rationality within the factory, left its grid and acted according to a different set of rules, both however located in close proximity, their contradictions creating a creative tension. The bubbles of human spaces were not designed in opposition to the plan of the factory, but their inclusion changed its nature, even if the activities that took place in these additions were self contained, within what remains a space of production.
We can ask what the role of these spaces can become in the factory of the 21st century, where the role of the worker and that of the machine are ever more separate, but their symbiotic relation remains.

1 Rappaport, Nina. Vertical Urban Factory. Actar Publishers, 2016.
2 Virno, Paolo. A Grammar of the Multitude: for an Analysis of Contemporary Forms of Life. Semiotext (e), 2010.

Bibliography

Ackermann, Kurt, et al. *Building for Industry*. Watermark, 1991.

Aloi, Giampiero, and Carlo Bassi. *Architetture Industriali Contemporanee: Testo e Didascalie in Italiano e Inglese*. Hoepli, 1966.

Amery, Colin. *Architecture, Industry, and Innovation: the Early Work of Nicholas Grimshaw & Partners*. Phaidon Press, 1995.

Banham, Reyner. *A Concrete Atlantis: U.S. Industrial Building and European Modern Architecture*. MIT Press, 1989.

Bianciardi, Luciano. *La Vita Agra*. Biblioteca Universale Rizzoli, 1974.

Biggs, Lindy. *The Rational Factory: Architecture, Technology, and Work in America's Age of Mass Production*. Johns Hopkins University Press, 2003.

Bonifazio, Patrizia, and Paolo Scrivano. *Olivetti Builds: Modern Architecture in Ivrea: Guide to the Open Air Museum*. Skira, 2001.

Darley, Gillian. *Factory*. Reaktion Books, 2003.

Debord, Guy. The Society of Spectacle. Black & Red, 1970.

Freeman, Joshua Benjamin. *Behemoth: a History of the Factory and the Making of the Modern World*. W.W. Norton & Company., 2018.

Gertner, Jon. *Idea Factory - Bell Labs and the Great Age of American Innovation*. Penguin Books Ltd, 2013.

Grube, Oswald W. *Industriebauten-International*. Arthur Niggli, 1971.

Hardt, Michael, and Antonio Negri. *Multitude: War and Democracy in the Age of Empire*. The Penguin Press, 2009.

Hildebrand, Grant. *Designing for Industry: the Architecture of Albert Kahn*. The MIT Press, 1974.

Jones, Edgar. *Industrial Architecture in Britain: 1750-1939*. Facts On File, 1986.

Kahn, Albert, and George Nelson. *Industrial Architecture of Albert Kahn, Inc*. Architectural Book, 1939.

Koolhaas, Rem, and Bruce Mau. *S, M, L, XL*. Monacelli Press, 1998.

Marullo, Francesco. "Typical Plan: Architecture of Labour and the Space of Production." *The City as a Project, by Pier Vittorio*. Aureli, Ruby Press, 2013.

Marx, Karl. *Grundrisse: Foundations of the Critque of Political Economy (Rough Draft)*. 1974.

Molenaar, Joris, et al. *Brinkman & Van Der Vlugt Architects: Rotterdams City-Ideal in International Style*. nai010 Publishers, 2012.

Mostaedi, Arian, et al. *Factories Office Buildings*. Carles Broto, 2003.

Pozzetto, Marco. *La Fiat-Lingotto Un'architettura Torinese D'avanguardia ; Note Sulla Funzionalita e Sulla Produzione*. Centro Studi Piemontesi, 1975.

Rappaport, Nina. *Vertical Urban Factory*. Actar Publishers, 2016.

Roser, Christoph. *"Faster, Better, Cheaper" in the History of Manufacturing from the Stone Age to Lean Manufacturing and Beyond*. Taylor Francis Inc., 2017.

Srnicek, Nick, and Alex Williams. *Inventing the Future: Postcapitalism and a World without Work*. Verso, 2016.

Virno, Paolo. *A Grammar of the Multitude: for an Analysis of Contemporary Forms of Life*. Semiotext (e), 2010.

Yeomans, David T. *Owen Williams*. Thomas Telford, 2001.