Typology of canteen facilities in modern manufacturing plants

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Abstract. The aim of this paper is to investigate the potential impact that the concept of the fourth generation industry can have on the architectural design of canteen facilities in the modern manufacturing plants. The concept of Industry 4.0 initiates an important shift regarding the architectural design of industrial plants. This research paper will look in more detail at the spatial and functional features of canteen facilities in manufacturing plants of the fourth generation. More specifically, it will search to answer the question of whether the labour organisation systems that are typical for Industry 4.0 vision will have an impact on the typology of canteen facility applied to a specific architectural project. The research methods used are multiple case studies and comparative analysis, including typological and functional analysis of factory layouts, while the sources of material are designs of manufacturing plants developed by architecture master students at the Poznań University of Technology. Despite being realised by students within the framework of a design studio, the projects selected for the study are accurate and realistic works, based in each individual case on a thorough analysis of existing relevant examples as well as of the future-oriented trends in industry development. The effects of the research include observations concerning the canteen’s situation on the factory plan, its type, as well as its spatial and functional characteristics. The conclusions comprise an identification of further research directions with particular potential for development, as well as some existing trends that link canteen typology with work organisation system.

1. Introduction

The industry of the fourth generation, otherwise known as Industry 4.0, can be generally defined as a broad futuristic vision of smart manufacturing culture, in which most recent advances in communication and information technologies are employed in order to achieve an enhanced level of production efficiency. [1 p. 8] Although the popular term of Industry 4.0 was first introduced in Germany, where it was conceptualised as the name of a future oriented project presented by the German Federal Government in 2011, a few important examples of equivalent projects were developed in other countries and they are referred to as Smart Factories, Factories of the Future in the EU, or Industrial Internet in the US. The basic feature which these projects share in common is the involvement of the state-of-art achievements in computing and information technology in manufacturing processes. In other words, artificial intelligence is utilised in order to improve the production efficiency parameters as well as to facilitate its adjustment to the changing market.

The set of three fundamental concepts derived from the information technology and applied within the framework of Industry 4.0 consists of the cyber-physical system (CPS), cloud computing and the Internet of Things (IoT). [2 p. 408] In its essence, the cyber-physical production system is about integrating physical elements (machinery) with data-processing devices (computers). [3 p. 10] Such
systems are characterised by an augmented intelligence as well as by the capacity of different devices to communicate with each other. [4 p. 420] The second essential feature of Industry 4.0 is cloud computing, which is referred to as “cloud” since it comprises a set of services controlled by a third party and delivered to the industrial plant from a remote location, like for example servers and data storage. [2 p. 408] The role of this innovation is to support advanced manufacturing activities by means of providing the enabling technologies for intelligent information processing. [5 p. 1970] The third essential implementation of recent information technology within the framework of smart manufacturing is the Internet of Things, which can be defined as a web of physical elements that are equipped with electronics, software, sensors and connectivity [6 p. 1141] in order to enhance the efficiency of production. The exchange of information between the interconnected devices is reciprocal and, more importantly, human assistance is not necessary for this machine-to-machine communication process, which allows uninterrupted information flow. This fact gives the Internet of Things its essential significance for the further evolution of smart manufacturing vision. The purpose of such innovative applications of information technology achievements in the field of industrial production is to obtain maximum performance with the most economical use of resources, as well as the highest possible energy-efficiency ratio.

Although most researchers remained so far focused on the strictly technical aspects of Industry 4.0, some have recently remarked the vision’s broader impact on several areas of human life, including, among others, professional activity and environmental protection. Besides the mainstream research, related to the specific applications of information and communication technologies in the organisation and management of production processes [7], or to the issues of cyber-security [8], some of the recent papers explore new research perspectives, like for example the question how can the increased efficiency of manufacturing support the achievement of sustainable goals, both in terms of efficient use of resources and environmental protection. [2] Another important research perspective originates from Daniel Buhr’s proposition that the vision of Industry 4.0 has a potential to become a starting point of a policy of social innovation, the aim of which would be to allow the global society to benefit from the fourth industrial revolution, not the stakeholders alone. [9 p. 3] Daniel Buhr further explores the problematics related to the role of the humans in Industry 4.0, convincing that despite the ongoing automation the humans will still play a central role in smart manufacturing. However, the character of their participation is changed. Generally, the mid-level professionals are devalued in favour of highly qualified and specialised experts with high flexibility, while the low-skilled activities are largely covered by automated machinery. [9 p. 9-10] Depending on the manufacturing profile, different labour hierarchical systems can be applied, ranging from swarm to polarised organisation. [10 p. 4] Swarm organisation system is characterised by a high flexibility of staff who tend to work collectively in a loosely formulated network. The labour structure is not hierarchical, while the employees are equally active and qualified. [10] On the contrary to the swarm system, the polarised organisation is founded on the differentiation of tasks and skills. Different groups of employees have different competencies and responsibilities. In the polarised organisation system, the hierarchy can be felt within the structure of the personnel and a new range of qualifications is becoming required. This affects the employees at management level in particular, as new jobs created in smart factories require highly skilled personnel, whose competences go far beyond the current standard. Besides being specialised experts and engineers, the employees at the disposition level will be required to be more flexible and creative in order to solve upcoming problems related to the production management. [10] Swarm and polarised systems are two extreme forms of labour organisation in smart factories, while the solution that is actually applied to a specific case can be a mix of the two in different proportions. [9 p. 9]

The role of humans in Industry 4.0, widely discussed by Daniel Buhr, has important implications on the architectural design of modern factories. Firstly, the employees’ emerging new competencies require new quality of spaces. In particular, the stress on human creativity and capacity of innovative thinking initiates a considerable shift in work environment design. Considering high quality interior
design as one of the main design principles, with the intention of inspiring creativity of employees, is one of the novelty trends in the architectural design of modern factories. Besides the aesthetics, the idea of smart manufacturing has broader influences on workplace design, like for example further diversification of workplace spaces, appearance of new types of work environments, as well as further differentiation of the social facilities for employees. New trends in factory design, which develop in relationship with Industry 4.0 vision, are more egalitarian and user oriented, with the visible transfer of high quality aesthetic standards from office design to the factory interiors, with equal stress on workplace as well as on the social facilities design. The prototypes of such a design approach already exist, but they constitute unique cases so far. The trend can nonetheless be estimated to develop dynamically in relationship with the vision of Industry 4.0, becoming global.

As the new trends in factory design have been identified to put the user (employee) in the centre of interest, the aim of this research paper is to investigate how labour organisation systems typical for Industry 4.0 vision (swarm vs polarised) can potentially influence the choice of factory canteen type. Moreover, it will seek to answer the question whether the notion of Industry 4.0 can change trends in canteen typology and design, including its situation on the factory plan, its type, as well as its spatial and functional characteristics.

2. Research methodology and materials

The literature review, briefly reported in the introduction section, has allowed identifying that the changes to the work organisation system brought by the idea of Industry 4.0 can become a major driving force of changes in architectural design of factories, which need to adjust to fit the new organisational models. The research will be therefore based on empirical and academic designs of factories, which are in each case based on the existing factory models. However, with the application of anticipated modifications that are supposed be brought by the work system change resulting from the developing concept of Industry 4.0. The conceptual designs of smart factories were elaborated in recent years with architecture students at the Poznań University of Technology. The scope of the project task was to provide a conceptual design of a manufacturing plant. The specific industry branch was selected individually, along with the decision regarding the choice of its location. These fundamental decisions were in each case preceded by appropriate analyses, including, among others, the study of the site’s accessibility for a specific transport, availability of target labour and resources, and, in relation with the building’s function, the technological process of production. The analysis of the latter provides information regarding the required spaces, which can be categorised and assigned to diverse zones, the principal of which are: automated machinery park, warehouses, services and technical rooms, different types of workplaces for employees (e.g. office, laboratory, machine operation, craftwork), as well as social facilities for employees. The last of the mentioned categories of spaces consists of, among others, sanitary facilities, changing rooms, resting spaces as well as canteens, which are the focus of presented research.

The basic method used in the research is a comparative analysis of the typology of canteen facilities provided in manufacturing plants. The particular attention will be focused on their spatial and functional features in relation to the labour organisation system applied to each specific case. The basic tools used at this stage of research are descriptive and graphic analyses. The analysis of selected projects consists of three basic stages, which are related to:

− the situation of the canteen on the factory plan;
− its type;
− its spatial and functional features.

Also, it is ordered accordingly to the labour organisation system used in the manufacturing plant subjected to the study. Such a way of ordering the discussed issues shall allow investigating the potential relationship between the labour organisation system and the implemented type of canteen,
taking into consideration its design characteristics. In addition, because the labour organisation system is strongly related to the issue of the hierarchical structure of staff, a potential relationship between the hierarchy of employees and the typology of canteens might also be identified.

3. Legal basis for canteen design

Undeniably, the legal basis for canteen design constitutes an important factor that works towards standardising implemented solutions. Since most of the projects selected for the study are located in Poland, Polish legislation is generally applied to them. Besides the Polish building code [11], which regulates the general technical requirements for buildings, and the local development plans, which regulate, in a few words, the rules of land use as well as the most fundamental building restrictions (e.g. building height and/or roof type), while remaining valid independently for each site, the hygiene and sanitary conditions must also be respected, including the division of clean and dirty technological paths, which is of fundamental importance in architectural design of dining facilities. Another particularly important legal act includes occupational safety and health (OSH) regulations (pl. BHP) [12]. With regard to the discussed problematics of canteen design, the Polish occupational safety and health regulations limit the options of providing gastronomy facilities for employees in the workplace to three possibilities:

1. a canteen designated for own meals consumption (type I)
2. a canteen designated for own meals consumption provided with beverages dispensing (type II)
3. a canteen equipped with kitchen facilities, enabling delivery of full meals (type III)

Moreover, the regulations allow combining types II and III of dining facilities in workplace buildings.

Information concerning the types of dining facilities foreseen by the occupational safety and health regulations has a bearing on the analysis of selected projects presented below. Namely, it indicates the necessity to limit the choice of canteen type to one of the three described options. During the preliminary stage of the project, the students needed to rethink and identify the most appropriate dining solution for the building they were about to design. Before making a decision, it was a natural step to analyse the hierarchical structure of the personnel, striving to answer the question how many different groups of employees can be distinguished in terms of their skills and duties as well as to identify the character of work performed by each group, e.g. is this work physical or intellectual? Executive or creative? These and other similar questions remain in close relationship with the essence of the labour organisation system, therefore the appearance of similar solutions in factory projects with the same organisation system shall not be treated as accidental.

4. Results

From a number of 138 projects collected so far in the archive of the concerned design studio, 58 can be characterised as small or medium scale manufacturing plants with work organisation scheme referring to the conceptual principles of Industry 4.0. Of these, only 9 cases can be declared as using the swarm organisation system, while the majority remains based on the polarised one. The main criteria for classifying each project as falling into one of the two categories listed include staff flexibility, expressed in their ability to work in a variety of responsibilities, in which case the concerned project is considered as based on swarm model of organisation. Otherwise, if the work organisation scheme implemented in a specific project implies division of staff into defined brigades with strictly assigned competences and workplaces, the project falls into the category of the polarised system of work organisation. As the real organisation model that works for a specific plant can in the reality represent a combination placed between the two extremes, adopting simple criteria for matching each project to the appropriate category facilitates the task and makes it more reliable. In very few cases, where matching a project to a precise category turned out to be particularly complicated, the project was decided not to be taken under consideration in the presented study. In the
effect, the analysis considers 9 designs based on swarm organisation and 38 based on the polarised scheme. (Graph 1) An important finding is the fact that the industry branch does not necessarily determine the organisational scheme, as there are examples of plants which differ in terms of work organisation despite belonging to single industry branch (e.g. publishing or furniture manufacturing plants). (Graph 2 and 3)

Graph 1. Proportion of designs taken under consideration according to the work organisation system

Graph 2. Plants using swarm organisation. Breakdown by industry branch

Graph 3. Plants using polarised organisation. Breakdown by industry branch

Taking a detailed look at the layouts of the selected manufacturing plants, which are based on either swarm or polarised organisation system, two fundamental solutions regarding the dining options
provided can be identified. The first solution consists in providing a single dining area to be shared by the firm’s entire crew. The second option, which is functionally the other extreme, involves designing several gastronomies and social nodes, which are designated as spaces belonging to a limited group of employees, which gives them a more individual character. It is quite common practice to propose a large restaurant for the largest group of employees, as well as several more individualised nodes for smaller brigades. For the sake of research clarity, it was assumed that two basic options should be distinguished: either a single canteen is provided for the entire staff, or a manufacturing plant is equipped with multiple dining options. The results show that there exists a tendency which links swarm organisation system with the implementation of the single canteen model (9 of 9 cases). In the case of the polarised scheme, both single and multiple dining solutions are used. However, the multiple solutions prevail with more than a double advantage (11 single and 27 multiple out of 38 cases). (Graph 4)

![Graph 4. Typology of dining facilities in modern manufacturing plants using swarm or polarised organisation. Based on the discussed selection of designs.](image)

What can be assumed from the research results is that multiple dining solutions model is used mostly in relationship with polarised work organisation scheme, while swarm organisation scheme promotes the use of a single canteen by the entire staff. The following section discusses the results based on relevant examples.

5. Discussion

The typological and functional analyses of selected factory layouts are performed in relation to the labour organisation that applies to each manufacturing plant, stretching between the two opposite options: swarm and polarised system. The following discussion of the research-by-design results will seek to identify model relationships, if such exist, linking the type of dining facility provided in each factory with the labour organisation system and hierarchy. The main questions posed in the study are whether the work organisation system influences the selection of dining solutions and, in the other sense, whether the canteen typology can reflect the hierarchical structure of the personnel. Since the exemplary projects had all to fulfil the applicable legal requirements, being also based upon existing design manuals [13, 14], the discussion will focus particular attention on the moment in which the designer makes his decision regarding the dining option he selects to provide in a specific project.
5.1. Canteens in the swarm organisation model

Less popular so far, the swarm organisation system relies on a more collective working manner, with a flexible structure of personnel, who are in general equally skilled and have similar competences. [10] Nine exemplary projects using this work organisation system represent diverse industry branches related to the crafts (e.g. wooden toys and chairs production), advanced electronic branches (e.g. 3D printers and drones manufacturing plants) as well as creative and culture industries (e.g. publishing plant). A large variety of branches as for only nine examples proves that swarm organisation model is a developing trend and can be applied to numerous types of industry which currently base on polarised model. The swarm organisation also places emphasis on the egalitarian treatment of employees, which unveils new perspectives for inciting a social innovation, as discussed by Daniel Buhr. [9]

In relation to the canteen typology, nine out of nine referred examples use single dining option for the entire factory staff. Its location on the factory plan is not necessarily central, about one half of analysed designs can be said to have a centrally located canteen, while the other half has a different location. This situation does not allow drawing general assumptions about the suitability of this particular location for the swarm organisation model. Nonetheless, the central location of a single canteen has been used by one of the designers to illustrate the growing egalitarian trend regarding the arrangement of social facilities for factory employees (Figures 1-2) which is aimed at staff integration. Further analysis of exemplary design has also revealed the focus on the aesthetics of interior design as well as on the differentiation of sitting options.

![Figure 1. Chair factory, design idea [15]](image1)

When it comes to the functional types of canteens implemented in the examples of factories that follow swarm organisation model, all of nine projects contain full dining facilities, which correspond to the type III provided for by the applicable occupational safety and health regulations. (OSH
regulations, *pl.* BHP, Journal of Laws 2003, No 169, pos. 1650) It allows drawing an assumption that this type of canteen, provided with a fully equipped catering facility, is particularly suitable for swarm organisation projects with single dining option.

5.2. Canteens in the polarised organisation model

The analysis of exemplary factory layouts shows that the polarised organisation model is more frequently adopted, which seems closely related to the contemporary design practice standards. The polarised model, which assumes diversification of staff competences and responsibilities [10], involves providing many catering solutions in most of the cases analysed (27 out of 38), while the typology of a single canteen is implemented in fewer projects (11 out of 38).

The solution to provide multiple dining options for the employees has many different forms of application. In most of the study cases referred, one large canteen is provided for the largest group of employees, usually the staff of the physical production stage, while one or several smaller social nodes are designated to serve more limited groups of the office staff. These nodes are located in dispersed places on the factory plan and can be of various types and sizes. What draws attention is their “home-like” furnishing and common combination with recreational areas. In terms of functional typology, the configuration of one large and the additional small dining areas refers to, respectively, type III and type I of dining options resulting from the applicable occupational safety and health regulations. (OSH regulations, *pl.* BHP, Journal of Laws 2003, No 169, pos. 1650)

Less than a third of the exemplary projects based on the polarised work organisation model uses a single canteen solution. This is usually done in relation to a high degree of automation. As discussed by Daniel Buhr, the automation of manufacturing processes is oriented towards excluding humans from the physical production process, while they continue to play a key role in the industry as innovators and contributors. [9 p. 8] This change causes a decrease in the number of employees per area ratio, as well as an important reduction in job types and less variation in the level of skills. Therefore, a single canteen seems to be pragmatically the most suitable solution. As a general principle, single canteens in automation scenario are found to be situated on the edge of the factory plan, in the part reserved for humans, comprising, among others, offices and social facilities. Quite frequently, the dining areas have a direct connection to an outdoor recreational area while the design standards are conformed to the currently used models.

Figure 3. Graphic presentation of research results
6. Conclusions
The typology of the canteen facility in modern manufacturing plants depends on many factors. The first to mention is the project location and availability of the gastronomic offer at the place, which is one of the basic elements of the preliminary studies that precede any project. Another one is the obligation of the design compliance with the applicable occupational safety and health regulations. Moreover, taking into consideration the disadvantage of the selected study case method, which is not valid for major generalisations, it would be scientifically incorrect to provide simplified assumptions regarding real dependence of canteen typology on work organisation system. Nonetheless, some significant trends in this regard can be observed on the basis of evidence delivered by the study. (Figure 3) The first observation is that swarm organisation system favours single canteen solution, while the polarised system will most frequently induce the appearance of multiple facilities of different types and sizes, usually consisting of one large canteen and one or several smaller social rooms with kitchens. While the second option is frequently used in the factories of nowadays and proves to remain valid for the modern smart factories that use a polarised system of work organisation, the first option, which consists in providing single dining facility in industries using swarm organisation, gives ground for major innovations in architectural and interior design. The reason for such a potential is that its implementation coincides with the emphasis being placed on staff integration in swarm organisation model. Therefore, a further study of dining areas proposed for this organisation model can be valuable. Another conclusion that can be drawn from the study is that the type of single dining area is also suitable for highly automated production plants, where the trend leading to the popularisation of a humanless factory model has a reducing effect on the number of employees as well as on the diversification of jobs and relevant skill levels.

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