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IMPLEMENTATION OF SYNERGETIC PLANNING FOR FACTORY

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Purpose: This paper studies the role of the implementation of synergistic planning in manufacturing plants as a method for unifying in one system reorganization or re-planning processes. The higher quality of technological design is the more effective design of industrial plants can be. Performing the analysis of technological plans together with architectural and construction plans before construction starts enables achieving competitive advantage already at the design stage, what in consequence leads to the increase of design efficiency, costs reduction, and the improvement of cooperation within design teams.
Design/methodology/approach: The emphasis is placed on the joint design data for which the correct synergistic relationships between the projects arise. The existing synergy between technological planning and facility planning makes it possible to consider re-planning as a single system. The main contribution is detailed analysis of connections between synergetic planning phases. Rational re-planning is performed according to Layout Design Methods using CAD tools and BIM technology. The former is also used in factory planning as a combined design software. In the publication, the authors present an original 8E method as a framework for synergetic planning.
Findings: The paper provides an approach to synergetic planning, describes stages of synergetic design, functional and spatial scheme of the assumptions of the concept of 8E.
Practical implications: Due to the Synergetic Factory Planning, it is possible to generate a solution, which enables the implementation of the project in accordance with the requirements of each design area.
Originality/value: The contribution of this paper is an original OLESTR method which is based on synergistic planning and oriented towards practical aspects of planning. The OLESTR method can improve planning new industrial plants as well as redesigning existing ones.

Keywords: facility planning, technological planning, synergetic planning, technological and architectural design.

Category of the paper: Research paper.

1. Introduction

Nowadays, solutions using renewable energy sources (RES) – starting from solar and photovoltaic panels, through heat pumps, and ending with wind energy – get more and more frequently implemented in manufacturing plants. Manufacturers need to satisfy the requirements corresponding to the Technical Conditions for 2021 which not only allow the use of renewable energy sources but also reduce operating costs and investment costs. For that reason, it is necessary to implement "Intelligent Architecture in the Factory" – the concept focused maximizing synergy at every stage of design and planning processes. The distinguishing feature of intelligent architecture are great adaptability to factory reconstruction and ecological balance. Furthermore, this approach is in line isp smart factory concept which emphasizes variability and flexibility of a factory's functions, possible constant adaptation to the environment, and modularity. Contemporary approach to planning must include balance between the natural environment and a factory's needs, this is maximization of technological solutions affecting production quality is necessary (Hellmuth et al., 2020).

2. Synergetic Planning

The Intelligent Architecture focuses to the highest possible extent on the "3R" principle: reduction-revitalization-recycling. This concept refers to the priority for reconstruction and transformation of already used spaces instead of taking new pieces of land. A smart factory concept dictates innovative solutions in the context of global changes, transformations, and trends as well as alternative and pro-ecological solutions. Using natural resources during a factory construction and using renewable resources during the exploitation process are the key elements of synergy, so that the production environment can be attractive in terms of maintaining natural resources.

Furthermore, the construction project plays a key role in the search for synergies between projects run in parallel. Their execution takes place at the same time, so it can result in: the exchange of current information, the implementation of changes, the search for the optimal solution within a strictly defined period, and the synchronization of current project data. Therefore, close cooperation of project teams allows finding an individual approach to each implemented project and achieving the synergistic effect, which is expressed in effective control of the planning process. This approach helps avoid potential mistakes made when project teams work separately. From the perspective of processes, among the main components of concept formation may be listed: productivity, quality, production time, product life cycle, etc., while the spatial perspective concentrates on: ecology, energy, identity, and communication. It should be noted that variability and ergonomics are common components of these two perspectives. It is generally assumed that synergy is the interaction of various areas/factors between which proper functional relations arise and their effect is greater than the sum of individual separate interactions (see Fig. 1).

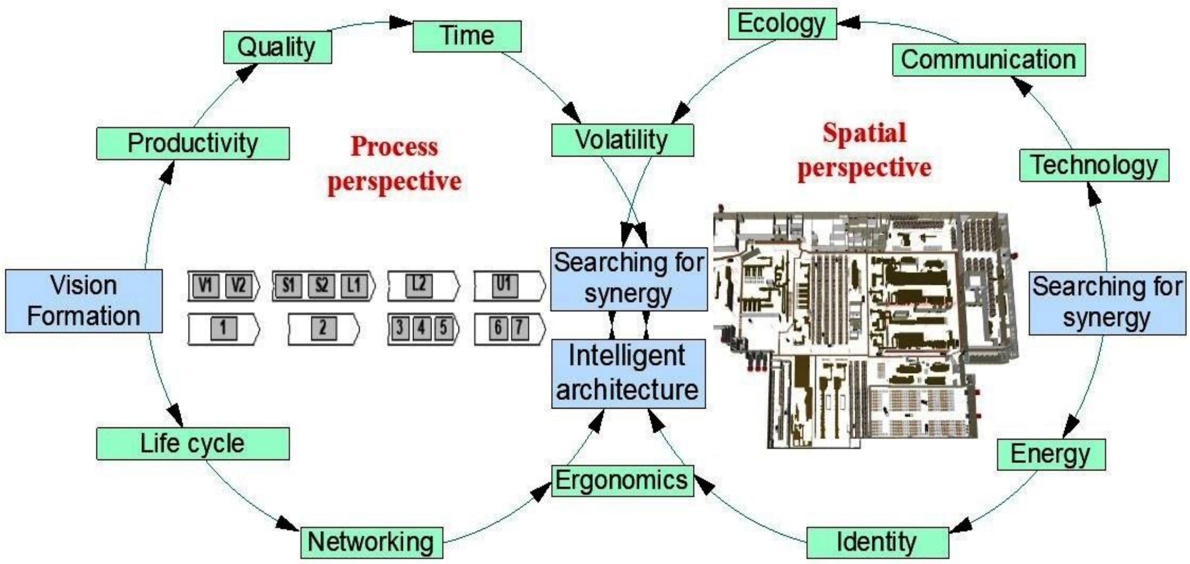

Figure 1. An approach to synergetic planning. Source: (Stryhunivska, Karkula, 2018; Stryhunivska, 2019; Wiendahl, Reichardt, Nyhuis, 2014).

For example, in order to start planning or redesigning a factory, it is needed to obtain primary information on at least the following issues: (1) company location, (2) master plan, (3) land development plan, (4) the layout of the factory's facilities, (5) the current spatial factory layout, (6) the layout of the existing production equipment. In addition, it is also necessary to obtain information about the availability of (1) utilities (water, gas and electricity supply, sewage and waste disposal, communication system), and (2) transport infrastructure and possible connections. The next group of needed information concerns the specific features of the factory with respect to: (1) production capacity, (2) assortment, products, and services, and (3) transportation means and logistics.

Above-mentioned pieces of information are utilized both when a facility is planned but also at every stages of design process. Technological planning covers production processes, whereas facility planning is focused on general design (architecture, installations, utilities, etc.).

3. Intelligent Architecture in an Industrial Environment

Economical, elastic, energy-saving, effective, ecological, ergonomic, efficient, enduring process (i.e. 8E) – these features constitute a genetic code of a planning process and without them the intelligent architecture cannot be user-friendly and rational. The 8E principle provides a basis to which additional elements can be added if necessary. The 8E concept used in the study to which this paper refers was extended by adding modules representing location (including the climatic zone associated with the natural landscape), communication, and the management of intelligent systems in an industrial environment (see Fig. 2). The E8 modules should be identified to both a single factory as well as a set of factories combined together with manufacturing processes.

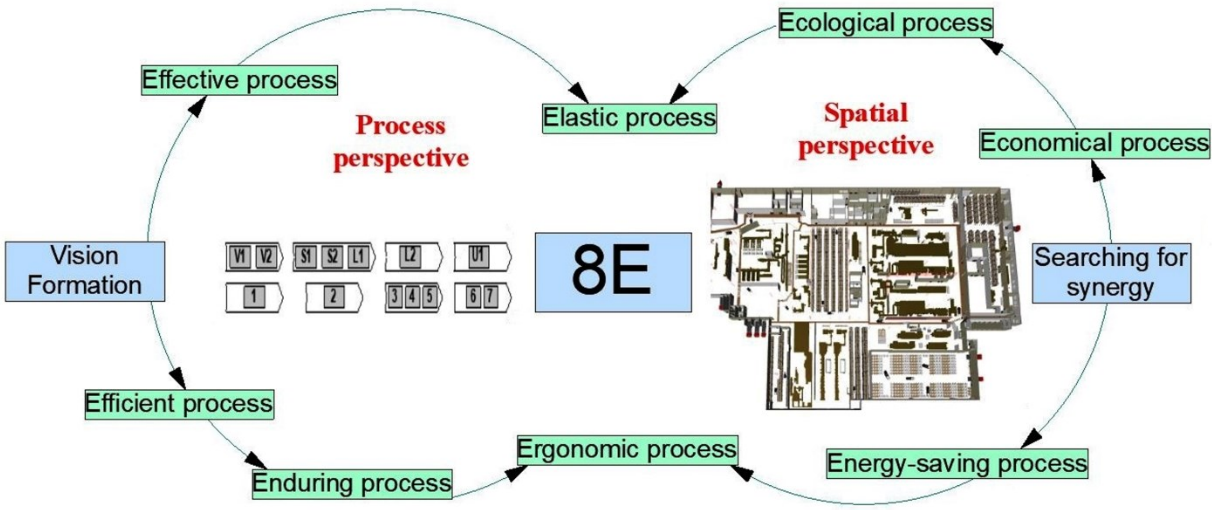

Figure 2. Functional and spatial scheme of the E8 concept. Source: own elaboration based on (Biskup, 2018).

E8 modules can be characterized in the following way:

1. Ecological process: the synergy of the industrial environment architecture with an innovative technological approach in the field of increasing the production capacity of equipment and in the field of technologies increasing Energy Efficiency (EE) or in the area of Renewable Energy Sources (RES) in the factory should be taken into account, and therefore should protect the natural environment in a manner, which emphasizes the selection of building materials; utilization of low built-in energy materials; utilization of natural and/or renewable energy sources (RES). For example, installations based on renewable energy technologies generate free energy (solar, wind, hydro, and geothermal energy).
2. Economic process: synergy in the context of rational solutions to technological processes considered during functional and spatial, as well as architectural and urban planning. Synergy aims at obtaining optimal parameters of financial outlays in the manufacturing process (construction process) and subsequent operation (production use process). Materials and construction solutions should be attractive in terms of economic analysis of utilized materials and construction solutions utilized.

3. Energy-saving process: synergy thanks to which the appropriate location, architectural form of the factory as well as material and technological solutions will contribute to the optimization of energy efficiency. The use of installation and technological solutions that obtain thermal energy from unconventional sources, but affect the saving of natural resources and the use of renewable energy sources.
4. Ergonomic process: synergy thanks to which the considered impact of design on the entire society in a way to increase security, carrying out an analysis of the social construction of value systems applied to diverse human and non-human work.
5. Enduring process: synergy influences the creation of an enduring process in production, in which technological tasks are closely intertwined with the tasks of spatial planning. All these tasks are subordinated to a single goal, to ensure an enduring process in the factory.
6. Efficient process: it is a synergy in the parallel development of architecture, technology, and production. An effective process covers the entire area of improving architectural planning and ensuring effective technological planning and is characterized by modern forms of their development.
7. Effective process: synergy further develops the 'Effective Process Time' modeling framework for the performance analysis of manufacturing systems and for the analysis of the efficiency of construction processes.
8. Elastic process – thanks to synergy, the idea was born to erect modular modeling, the so-called small repetitive blocks (modules) mapping simplified elements of an existing industrial plant into a certain logical whole, maintaining the relationship between production processes and applied technologies (Müller, 2012). With the modularity of the logistics area with all its components, the concept of flexibility was created, i.e., the ability to quickly adapt the production system within certain limits to changing factors with acceptable financial outlays. The presentation of changes could be visualized using a 2D layout and redesign of the modified area, as well as applying flexible, modular functional solutions of industrial space. Flexibility has been expressed in the factory's self-sufficiency process in terms of production (construction process) and use process (Biskup, 2018; Stryhunivska, 2019).

The components of a given module can be selected and blended according to the project requirements. Nevertheless, intelligent architecture does not exist only under the assumption that all selected technological criteria are met jointly. Its universal nature allows certain exclusions or individual extensions with additional parameters according to production processes.

4. Stages of Synergetic Design

As shown in Figure 3, the stages of production processes design (technological design) can be divided into the following phases: preparation, project structure, layout design, and implementation. Furthermore, the identification of technological substages is important. The first phase, 'preparation', consists of performing 'analyze of a company' (V1) and 'analysis of production processes' (V2). At this stage, the objective is to define the company's goals, to summarize information about the factors influencing design phases, to define the dynamics and structure of the implementation of changes, and to analyze the planning costs and project completion date. The next phase is about defining the structure of the project. The following substages of this phase can be distinguished: 'structure development planning' (S1) and 'design draft planning' (S2). They aim at determining the interrelationships between individual elements of the structure, so that the visual representation of these relations can be drawn using diagrams and sketches.

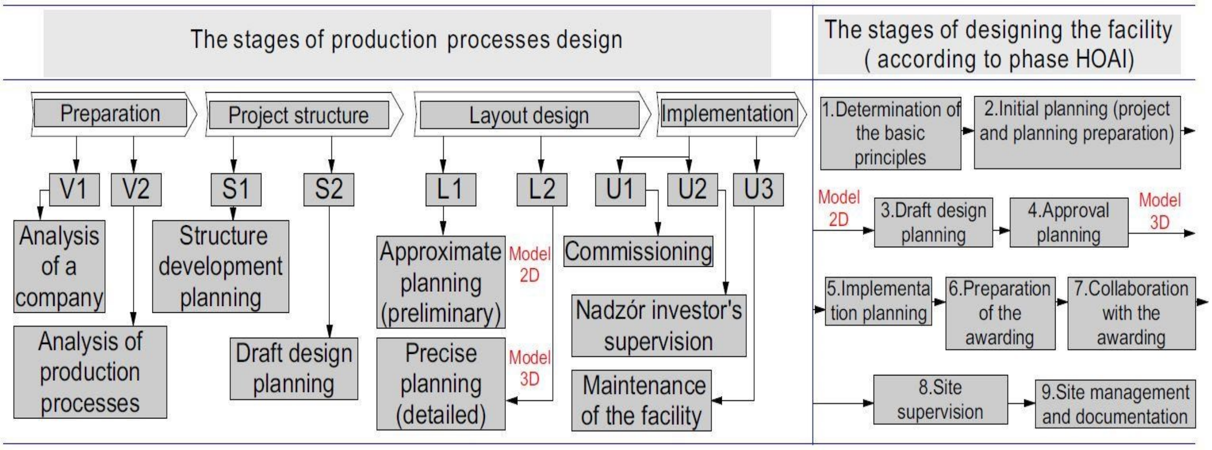

Figure 3. Stages of synergetic design. Source: (Stryhunivska, 2019; Synergetische Planung wandlungsfähiger Fabriken).

In addition, conceptual planning reproduced as simple outlines of the production hall highlights important planning aspects. Mapping both the space and the flow of materials which do not show any noticeable differences in relation to the design standards is possible during designing the layout. The following substages can be distinguished: 'approximate planning' (preliminary) (L1) and 'precise planning' (detailed) (L2), which are interdependent. The 2D spatial layout which duplicates the mapping of geometric dependencies in the form of approximate planning, does not include the requirements of the production process and spatial limitations. Moreover, it only presents an approximate estimation of investment costs, preliminary data, and design guidelines. Based on preliminary planning, a smooth move to the development of detailed plans in 2D and 3D (precise planning) can be done. At this stage, the infrastructure, technological machines, and all production processes are linked depending on the production areas. The final phase, implementation, consists of conducting a commissioning, investor's supervision, and maintenance of the facility. Commissioning facilitates the handover of the plant and responsibility from construction to operations.

Analyzing the process of designing the facility according to the HOAI standards (German: Die Honorarordnung für Architekten und Ingenieure), resulted in identifying nine stages of this process, which can be gathered into three groups (HOAI, 2021):

Service phase HOAI 1-2: (1) determination of the basic principles, and (2) the initial planning (project and planning preparation).

Service phase HOAI 3-6: (3) design planning, (4) approval planning, (5) implementation planning, (6) preparation of the awarding.

Service phase HOAI 7-9: (7) collaboration with the awarding, (8) site supervision, (9) site management and documentation.

The course of creating the target system depends on updated information on the relation between technological design and changes in the spatial object design. Combining these two phases results in synergetic planning (Stryhunivska, 2019, Wiendahl, 2014). This approach allows planning production and spatial processes along with the life cycle of the facility. Note that synergy appears between technological and architectural designs due to the use of shared knowledge and the exchange of up-to-date information. Additionally, the active participation of project teams to create a 'proper factory' was conducive to coordinating the overall planning of the spatial layout according to the stages of the design of a synergetic industrial plant (Stryhunivska, 2019).

A sustainable future requires changes in both the approach to factory planning and the principles of designing the built environment. To create new concepts and solutions for a sustainable future, designers should derive knowledge and experience from the past, rely on the knowledge and technologies of the present, and introduce innovative systems and new methods in planning. Combining knowledge on factory design with technological processes run in it helps to rebuild synergy and obtain balance with the environment respecting natural conditions.

In the diagram shown in Figure 3, the steps: 'analysis of a company' (V1) and 'analysis of a production process' (V2) belong to the first stage of facility design: 'determination of the basic principles'. 'Project structure' (S1, S2) and "approximate planning" (L1) correspond to the second stage of facility planning - 'draft design planning' and are mapped in the 2D model. Furthermore, 'precise planning' (L2) represents the third, fourth and fifth stage of designing an object which are mapped in 2D and 3D models. The above division seems to be the most important for obtaining a proper spatial arrangement with visualization. From the practical side, it would be advisable to conduct a study of appropriate methods that would allow quick and effective creation of a detailed layout considering the limitations, the possible implementing changes, and cost reduction. Another connection is represented by the 'commissioning' stage (U1) with the sixth and seventh phases of the facility design as 'implementation planning. Finally, it is possible to find the combination of 'author's supervision' (U2) with the eighth and ninth stages of facility planning into 'implementation supervision'. Author supervision is an indispensable element of the service, which allows controlling the construction phase and compliance with the project (Neufert, 2012; Stryhunivska, 2019).

The last stage 'maintenance of the facility' (U3)/'site management and documentation' (the last stage of facility design) is visible in practice in the form of a 3D model as a functioning industrial plant. Combining the simulation of production processes and virtualization creates a model consistent with the synergetic factory planning concept.

It is worth highlighting that the use of digitization gives a chance to improve the process of designing an industrial plant. It also provides the possibility to optimize the selection of locations for the distribution of production lines with respect to manufacturing technology (Stryhunivska, 2017). Considering that the consumer with their needs should be placed first place at the center of implemented solutions, it is important to obtain the agility and flexibility of the industrial plant. It should be noted that digitization enables not only tracking of the production processes chain but also observing the processes from the moment when the raw material enters the warehouse through its processing until the preparation for shipment of the final product. Due to this fact, it is possible to analyze client's needs on an ongoing basis as well as predict future changes according to the client's vision. With the Synergetic Factory Planning concept, it is possible to come to a solution that enables making design changes even in the planning stage.

Therefore, Intelligent Architecture influences the optimization of functional and spatial solutions as well as the optimization of technological solutions in the factory; moreover, it focuses on synergetic, ecological, and sustainable design solutions. The following issues are important elements in the design process: economic and ecological aspects, energy efficiency, flexibility, location, management of intelligent systems in the factory, as well as communication. The implementation of synergetic planning within industrial plants serves as the use of ingenuity and technical knowledge to solve key aspects, including designing and building in harmony with the environment with respect to natural conditions. Finding a balance between environmental conditions and economic requirements is undoubtedly a challenge and proves a high ecological awareness.

5. Conclusions

In conclusion, the synergy between technological planning and plant facility planning enables perform it properly and to treat the reorganization processes or re-planning as a unified system. It should be emphasized that the factory design of the factory is based on the stages of synergetic planning with consideration of the spatial requirements of a tested plant and design standards. The prospects for further factory development of factories are based on the integration of 3D visualization with modern design methods. Due to the visualization, it is possible to facilitate a 3D representation of the plant under examination and verify errors occurring during re-planning (Heragu, 2018).

This increases the agility of re-planning and enhances generation of correct decision variants. In order to present spatial planning processes in industrial plants in a systemic way, synergetic planning should be combined with modern design methods and their interdependence affecting the final result of replanning. One of such methods is the original OLESTR method which is closely related to synergetic planning and constitutes a practical approach to planning (Stryhunivska, 2019). Furthermore, the implementation of renewable energy sources during the design of the factory supports the transition to the concept of a "green factory". The transformation of a factory to use 100% renewable energy is a key step in development, as caring for sustainable development and local communities is a priority scribed in a long-term strategy of each enterprise. Furthermore, the purchase of clean energy is another element of the sustainable development policy in a factory.

It is worth mentioning that intelligent architecture in an industrial environment uses the newest technologies to shape and develop the concept of technological space. It presents how the production environment can be positioned against the backdrop of new spatial experiences and ecological solutions. Intelligent architecture goes beyond the design framework, as technology is not only designed to automate everyday activities, but also linked to synergetic design. However, new technologies are to influence intelligent shaping of industrial space, contact with it, and its improvement, however, without detaching it from the factors determining the architecture of sustainable development and the symbiosis of the production environment with nature. The industrial space of intelligent architecture is to have a positive impact on the quality of production and propose comprehensive technological solutions. The latter would address the issue that constitutes the core of intelligent architecture in the industrial environment, namely, the balance between ecology, which is rational from the point of view of economic issues in connection with energy efficiency, aesthetics, location, and communication as well as the method of managing systems that support the maintenance of synergy in further changes in design.

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