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Industrial Clusters in Slovakia-Urban Development

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Abstract: For almost three decades, Slovakia has been undergoing reform processes related to restructuring industry and in expectation of the sustainability of the industrial structure with an important link to the landscape. The aim of this article is the presentation of the development models of the industrial clusters in synergy with the economic dimension, landscape, settlement structure, and sustainability. The background of the article is an evaluation of industry and its impact on the landscape between the 19th and 21st centuries. The development of industry influenced the territorial and spatial development of towns and landscapes, forcing a new identity on them. Development mirrored the rate of innovation in the domain of technologies and construction. The issues examined herein required the application of a combination of quantitative and qualitative research methods, including a creative method called SCAMPER. Our scheme and models of industrial parks and cooperation clusters are a result of theoretical and field research and reflect variable mobility and sustainability. The conclusions of the research indicate a turnover in the original order of importance in the industrial activity: environment–man–production. This is the contribution of evolution and the building of eco-friendly industrial structures.

Keywords: industrial cluster; industrial parks; landscape; urbanism and architecture; sustainability; environment; synergy

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1. Introduction

After a hectic period at the end of the 1980s, the mosaic of the manufacturing industries collapsed in Slovakia due to the break-down of the then relatively stable economy that had a major impact on the new formation of settlements and landscape. Heavy industry and arms production were hit the hardest. The index of industrial production has been gradually declining since 1990 (in 1990 it was 91.5%, in 1996 it was only 59.7%) [1]. The process of restructuring industrial production was thus necessary even under the influence of new geopolitical, technological, and market conditions and the formation of the European Union.

In the history of industry, the dynamics of development are accelerated by breakthrough socio-political situations and technical and technological discoveries. This is evidenced by many inventions from the 18th and 19th centuries (e.g., steam engine, diesel engine) which subsequently influenced the construction of manufacturing plants and the development of cities, industry, and transport. A modern turning point was the invention of the Internet (1993), which caused a radical technological change in the information transmission system and the development of modern industry. Similarly, the landscape changes are the most complex and depend on social and political changes [2].

The end of the 20th century is considered to be a period of great socio-political change in the world with many accompanying phenomena, especially in the reform of social systems. There has been an uncompromising trend in globalization in the broadest sense of the word, with both positive and negative effects. In this context, it was necessary to determine the degree of acceptance of globalization trends and to adapt the visions of the

development of society and industry to them. The direction of industrial development could be built on past experience, on the picture of local development, the domestic economy, and traditions.

In Slovakia, this path was not sustained, and industrial production began to atomize without any conception, subsequently inevitably succumbing to globalization in economic trends. The positive side was the growth index of industrial production, especially in 2008–2018 in the amount of almost 30% [3]. In parallel, the development of urbanism and the architecture of new industrial premises followed this direction. Mostly in the second half of the 20th century, compact industrial territories (zones) were established in settlements with links to labor, energy, and raw material resources focused on the metallurgical, construction, chemical, footwear, and food industries. This fact influenced the planned development of cities, the economy of post-war socialist industrialization, and the urbanization of Slovakia [4,5]. The positive economic development was later overshadowed by the negative effects on the landscape, which resulted from one-sided solutions, regardless of the environmental impact.

In this paper, we capture these development trends in urbanism and architecture in the context of social development which are related to the development of industry in Slovakia at the turn of the 20th and 21st centuries.

The relevance of the research is based on the fact that the towns and cities in Slovakia have undergone significant expansion since 1990, which has resulted in almost uncontrolled growth of urban suburbs in the form of mono-functional development of housing units, shopping centers, and the construction of large industrial and logistics parks with huge "land consumption" [6]. An inadequately located industry can cause an irreversible imbalance in the landscape, in agricultural areas, or in the system of settlements [7].

This paper deals with the evaluation of industry as an important phenomenon of development that constantly affects the territorial and spatial development of cities and gives them a new identity. It points out the factors of current development and the future in the industry, which are the value of knowledge and information (new information technology (IT) sector, Industry 4.0). It presents a vision of spatial development influenced in a positive direction by globalization, which brings about smart technologies.

The paper aims to examine the spatial schemes (models) of industrial clusters against the background of industrial development under the conditions in Slovakia. The research identified two basic research questions focused on the relationship between industry territory and cities and the current situation in the development of industrial clusters: How did the relationship: city–industry–landscape develop in the 19th to 21st centuries? What are the general models of industrial clusters in Slovakia?

Such a viewpoint is missing from the literature in the context of history, and the goal of this research was to contribute to the theory of the development of industrial areas in Slovakia. The difficult issue of the development of industry with its strong economic background must be presented within the context of development and in schemas and territorial models.

Historical Background

Polačková [8] states that to understand the development of society, it is important that the essence of various, sometimes contradictory theories, opinions, or propositions is also understood synthetically. This is symptomatic of the relatively complex development of industrial architecture and urbanism as a mirror of society, its technical maturity, and its cultural level. The rapid development of industry during the second half of the 19th century and at the beginning of the 20th century determined the way of life, the development of cities, and landscape formation in Slovakia as well.

From the point of view of urban formation, it is understandable that the emerging industrial cities were not prepared for the rapid growth of the immigrant population (e.g., England, a textile great power, recorded a 60% increase in 40 years [9]). The increase made it necessary almost overnight to deal with the accommodation of workers. Builders,

owners, and patrons of factories often abused the reality that people who came to the city desperately needed work and thus had to accept poor working and living conditions.

Massive social, technical, and economic changes during the nineteenth century provided the catalyst for the rise of modernism in architecture but also produced examples of negative and inhospitable spaces [10].

It was not until the first half of the 20th century that the adverse effects on workers' lifestyles were gradually eliminated. The exceptions were sometimes controversial concepts of utopian and modernist views (the most famous being that of Ebenezer Howard or Tony Garnier). Howard's visionary Garden Cities (1898) served as an escape from the city to the landscape [4], and his systemic solution of transport can be appreciated. Howard combined the perfect territorial system with railway transport, with an emphasis on fast transport connections between cities and fast intra-city transport [11]. This idea from today's point of view turns out to be progressive and applicable. Garnier's Cité Industrielle (1904) is one of the most comprehensive idea plans seeking to project a modern city with well-located and connected zones (residential, industrial, public, and agricultural) [12].

The modern, visionary concepts responded to the context of development and the environment. They emphasized a new way of thinking, an orientation on the logic of functional units, and analytical methods of the architectural design of a new visual style [13]. The connection of modernism with the first industrial revolution gradually evokes another connection of "higher modernization" with the consequent industrial revolutions. The origin and production of new building materials and the development of technological methods of construction have influenced and inspired architectural design, characterized by a synthesis of technological and technical progress and a simplicity of architectural expression [14].

With the development of industry and technology, the modernist approach and rational planning expanded in architecture and urban planning. Governments usually consider modernist urban planning to be an active force and to be the 'best method, or process, of conducting planning [15].

Despite the image of Slovakia as a typical agricultural country in the first half of the 20th century, here we also find examples of modernist industrial plants from this period. Bat'a's plants in the localities of Svit and Partizánske left the most significant industrial, modern, and modernist footprint [16] and changed the image of the rural and agrarian landscape. The construction of these industrial areas fulfilled Bat'a's principle in the field of social care for workers: to work collectively, live individually, and relax [17].

On the other hand, there are also critical responses to modernist planning as ideal planning. Its implementation caused a time-consuming traffic transfer to work and back by consistent segmentation of the territory and the division of the city into mono-functional zones. In addition to the individual loss of time, there is no room for interaction between the population, so the possibility of forming communities and social contacts declines [15,17–19]. The mono-functional system leads to a decline in relationships within the residential community, as too much time is spent on transport. Alexander et al. indicated that the separation of home and workplace 'reinforces the idea that work is toil, while only family life is living' [18]. It may be disputable, but it provokes thinking about the issue.

Logically, the question arises as to whether it is possible to squeeze industry into the residential areas and vice versa, or rather to create the principle that industrial zones will be multi-functionally colored zones. The answer offered by Alexander et al. [19] is that every increment of construction must be made in such a way as to heal the city. The expansion of the city and the construction of its industrial parts must respect the environment, and be considerate in the widest possible context (especially in the impact on the immediate surroundings, nature, construction, employees, society…).

In the traditional understanding of industry, the historically existing industry in cities appeared to be a territorial and functional matter. In the context of the city's expansion, there is growing pressure to expand central public functions in the city with the new industrial production being pushed into the hinterlands. Another opinion points out

that overwhelming meticulous planning is too often a disaster if it is based on incorrect predictions about the future [20].

What can be dangerous, as the previous idea suggests, is a boundless, biased technocracy. Technocrats are professionals who influence the political decision-making and behavior of government by relying on their own abilities in industrial management. The conflicts connected to technocrats relate to the promotion of their ranks as policy-makers and specialists who understand needs better than others [21]. It is positive that technocratic planning today introduces a new epistemology, based on the idea that the production and elaboration of knowledge is gaining ground in many scientific fields at the same time [22]. Perhaps the best way of tackling challenges of global sustainability is a city and industry built by experts and on expert consensus in architecture, urban and landscape planning, engineering, and housing.

2. Materials and Methods

The diversity of the examined issues of the spatial schemes (models) of industrial clusters under the conditions in Slovakia required the application of a combination of quantitative and qualitative research methods [23].

The starting point for the creation of the theoretical models was the analysis of statistical data, research, and discovery of the territorial issues, existing industrial zones, and industrial parks in terms of the theory of territorial categories and practice with the application of grounded theory research (GTR), as a qualitative method.

The grounded theory allows for cyclic evaluations (codifying) of progressively discovered facts and connections, and their reflection in models and case studies. It opens up space for creativity and flexibility in creation (architectonic–urbanistic). The coding process in grounded theory follows the creative process of proposing, including repeat cycles of analysis, comparisons, looking for links (town, country, park, cluster), the interpretation of relationships in schemas, critical resolutions, and checking of functioning [24].

New models used a "rediscovered" creative method called SCAMPER, based on team brainstorming. The name is an acronym from active verbs: Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, Reverse, [25,26]. The created models, concepts, and theories of expected industrial territory development can be further compared and verified as alternatives to concrete case studies and with the interdisciplinary cooperation of experts.

GTR and SCAMPER are *a living method* that allows models, theories, and concepts to be constantly elastically evaluated and revised (Figure 1). Potential studies, with reference to the possibility of modification, alternative exploitation, critique and elimination of unsuitable proposal solutions, are tools in the concrete decision-making process. In the context of spatial development, it is extremely important to be able to respond to possible social and economic changes, to increase the level of knowledge, and subsequently to correct the models.

The issues of industrial policy, the functioning of clusters, and the works by analysts, economists, and area and spatial planning engineers were studied [1,27–31]. Other materials were the analyses of the Ministry of Economy of the Slovak Republic and materials of the European Union as well as research by the authors [3,32,33]. Many of the materials have become background sources and research inspiration.

The following factors were seen to be decisive for determining the territorial type of clusters and for locating industrial clusters:

- Geographical and geomorphological conditions of the area,
- Raw material resources and technical infrastructure,
- Cooperation conditions and the assumption of production efficiency,
- Potential of a skilled workforce in terms of industry focus,
- Creditworthiness of investors,
- Ownership relations,
- Assumptions of a comprehensive sustainability.

Based on the analysis of the economic environment and the above-mentioned factors, 529 localities of cluster fragments (industrial parks) were selected in Slovakia in two stages for the period 1995–2025 (see more detail in Figures 2 and 3). The first stage was of interest to municipalities, and the second step was selection, after taking into account the complex factors of economy and sustainability. The degree of suitability of interconnection between segments of the cluster was not taken into account. The result of the selection was a total of 66 localities.

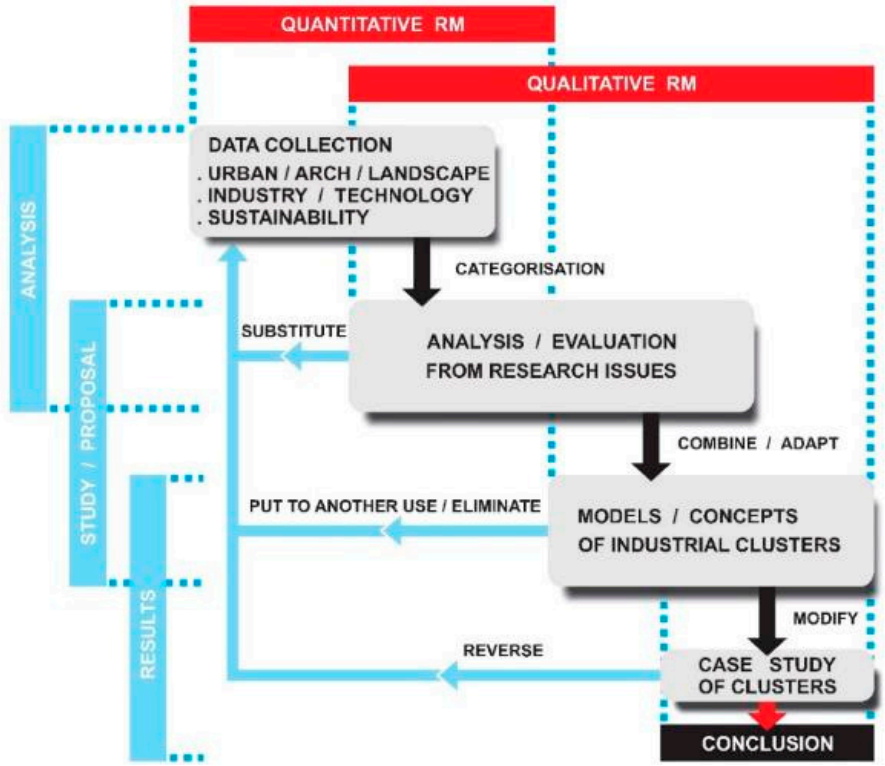

Figure 1. Flow diagram of the presented research method (authors' diagram).

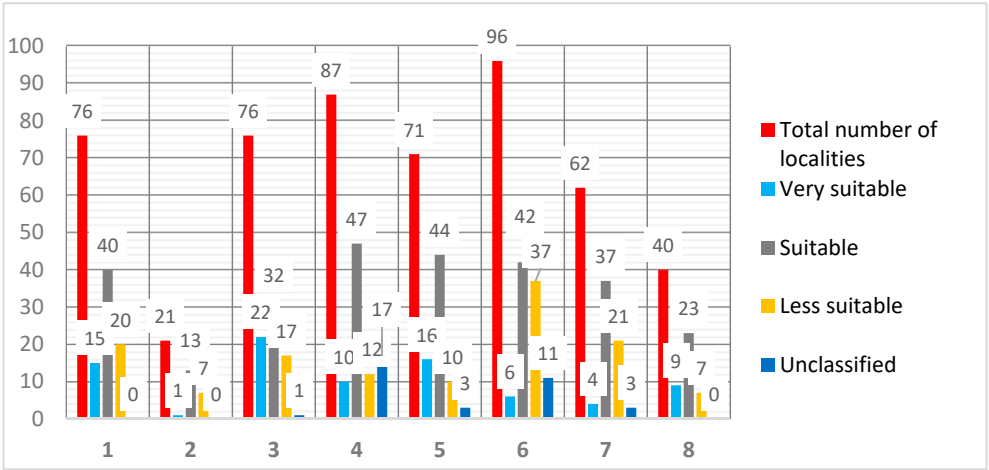

Figure 2. Overview of Slovak regions (1–8) with the number of potential localities for cluster developments (more detailed data in Supplementary Material) [32].

Figure 3. Map of the Slovak Republic with the Centers of Slovak regions (1–8), see Figure 2. The size of the circles represents the number of potential localities for clusters in the regions (authors' figure).

The selection of localities confirmed the dominant factors: the available (transport) infrastructure, with the distance of the locality from the transport artery of 50 km, and the background of a quality workforce. The production focus proved to be a secondary factor. The planned number of jobs was 85,844, but the real state at the end of 2018 was 43,710 jobs [3,32,34]. Overestimating the possibilities of economic development was a logical consequence of the enthusiasm from the change of establishment in the 1990s. The stated information served as input data for research to determine the location and type of clusters.

3. Research Results—Localization, Territorial Models and Sustainability of Clusters

Currently, in the 21st century, we are seeing a transition from a post-industrial society to the building of a knowledge-oriented economy and an information society with a vision of a new industrial era, Industry 4.0. This dynamic process has started making changes in Slovakia as well.

The emergence of new IT industries and digitization caused a breakthrough in the system of work. The mutual ratio of the input components of work in the creation of material products is fundamentally changing, with the phenomenon of information and new, economically usable knowledge gaining in importance. The matter recedes and, on the contrary, the commodity becomes the latest knowledge at a given time. The view of creating environmental friendliness and environmental sustainability is gradually coming to the fore.

We must point out that sustainability is a concept whose implementation varies due to cultural and socio-economic specificities, and the integration of industry can be achieved using various old or innovative concepts and methods [35].

Industry is working with a new territorial and spatial dimension where the localization of sophisticated industries is also possible as part of the multifunctional residential area [36]. In the efforts to have smart concepts of production, logistics is in the first place and industry expands into the landscape in terms of sustainability intentions and environmental considerations.

The results of the research presents models of how the city–industry–landscape relationship has developed. Until 1990 and partly up to the present, industry was located within the inner city and in factory zones at the boundaries of cities (Figure 4). In the present and in expected development, the multifunctional city center expands, and diversified production is located at the edges of cities (Figure 5). At the same time, new territories are being created for industrial and science–technology parks. The research confirmed four basic alternatives of the cluster models in Figure 6.

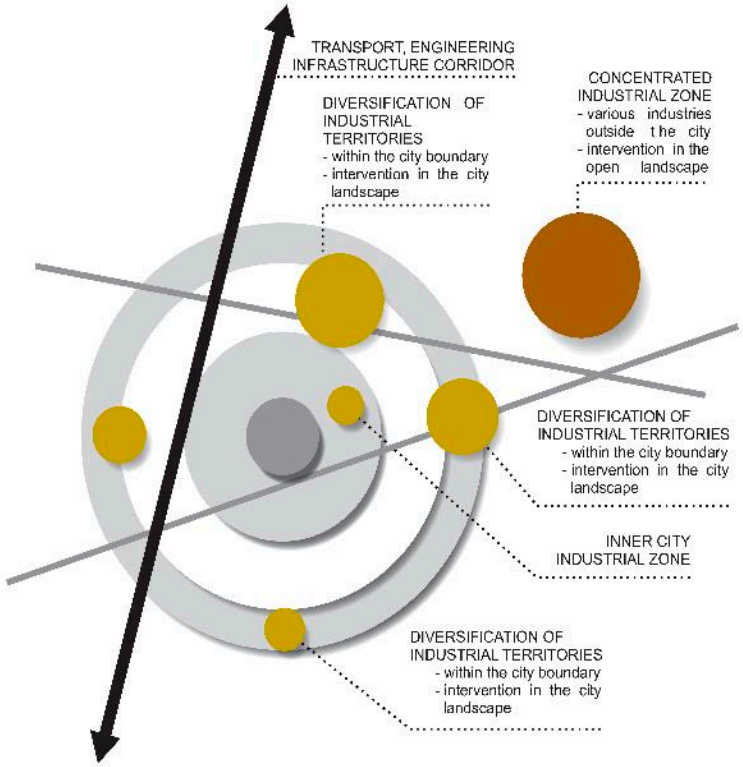

Figure 4. Model of urban development: the relationship between town and industry until 1990 (authors' scheme).

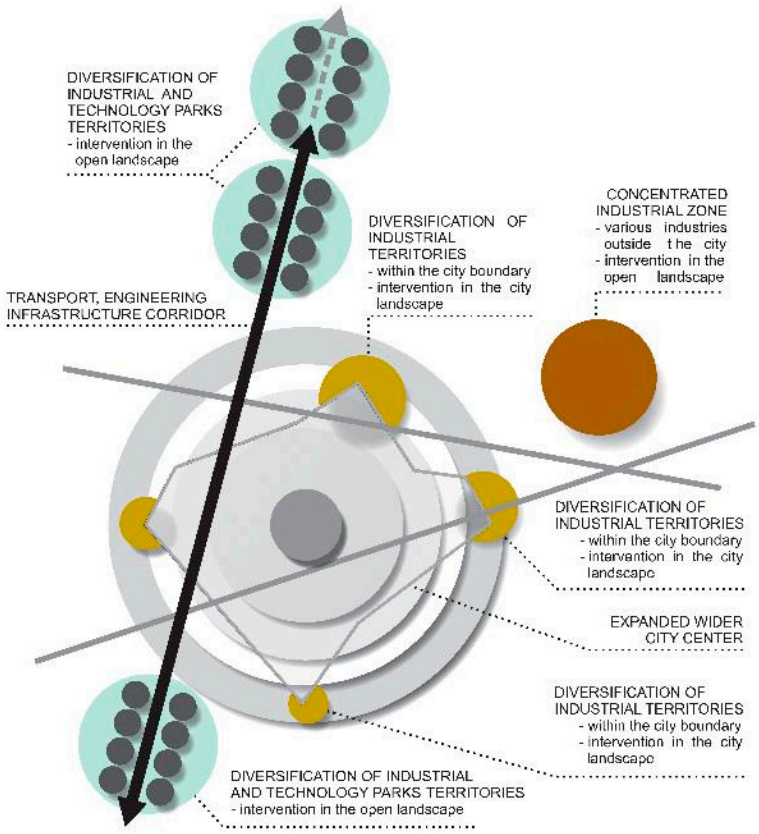

Figure 5. Model of the urban development: the relationship between town and industry from the present to the future (authors' scheme).

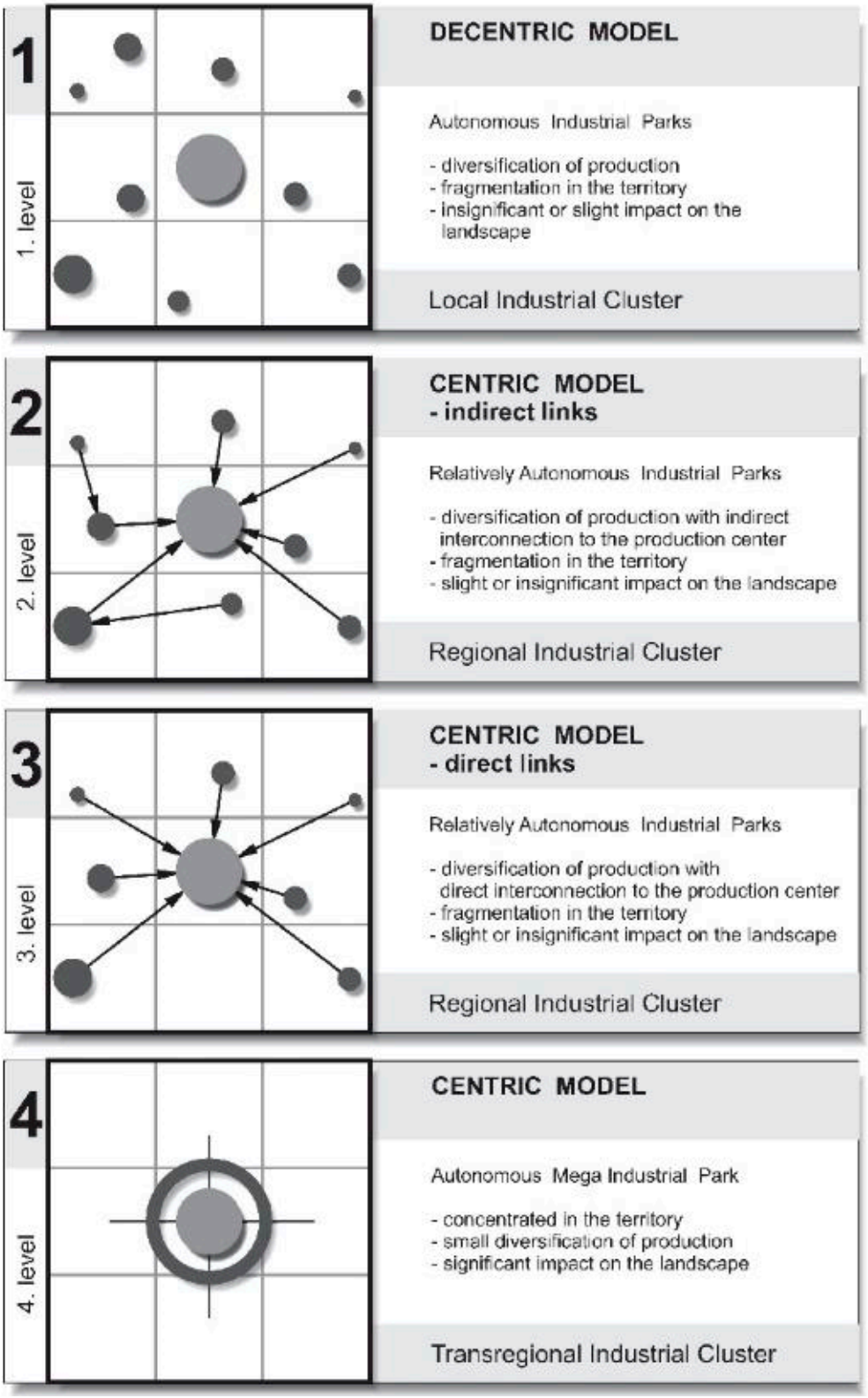

Figure 6. Models and relationships within industrial clusters (authors' scheme). (For application of these models in the territory, see the Supplementary Material).

The solution of modern industry is not just an economic challenge. The complex solution combines several phenomena—in addition to the economy, there are social area, environment, and construction considerations. At present, well-functioning social contacts

are essential for prosperous companies and a society which is supported by a high-quality urban–architectural concept.

A group focused on the revival of industrial production with a focus on the automotive industry and IT sector resides in Slovakia, while individual fragments of production are covered by a strong foreign economic entity. The results of the study showed that the assumptions for localization are different, depending on the degree of overall development of the locality (region). The poorer the region, the greater the readiness to locate an industrial park. It is a matter of formal readiness and not complex preconditions, including the quality of the workforce. At the same time, they reflect the degree of urbanization and the concentration of population and economy. An exception is the Bratislava region, which has the most significant urbanization and thus the preconditions for the development of industry are territorially limited.

The focus of production in these localities is categorized into the following industries:

- Engineering and automotive industry (components, assembly),
- Information and communication technologies, electrical industry–components,
- IT services, network processing, and communications,
- Pharmaceutical industry and manufacture of medical devices,
- Technologically used chemistry and biotechnology,
- Construction,
- Strategic business services–customer support, technical support, centralized services,
- Logistics centers and services.

The central economic bonds within the supranational monopolies will copy the sustainability of the entire system, which is determined by foreign capital in Slovakia [37]. Today, the category of industrial parks based on cooperating clusters prevails. This can be considered part of the modern structure of industrial activities. They are a symbol of the current development of industry [38]. The understanding of industrial relations and of the spatial characteristics of industrial development also helps the development of local economies, as well as providing references for the development of industrial clusters in the respective regions [39].

Cluster is an already established concept with various characteristics. It is a business style based on the principle of teamwork at regional and transnational levels [40]. Porter [41] and Zhang [42] offer a realistic definition of clusters. They state that clusters are geographically concentrated, horizontally and vertically interconnected manufacturing and non-manufacturing companies, and innovative institutions in a particular field through competition and cooperation. The modern organizational and hierarchical structure of the industry in Slovakia also derives from this definition. Špirková et al. [43] argue that cluster organizations follow a whole range of goals. Among the most important priorities is the building of an identity for the cluster and for the building of a brand for the cluster/region, the initialization of innovative projects and investments in research and development, the creation of a strategy and a vision for the cluster. Establishing a 'Slovak' identity for the cluster is the goal of the presented research.

One of the possibilities for the development of industry in Slovakia is the construction of new production areas outside the city structure, in the form of industrial parks as part of industrial clusters, securing the harmonization of three aspects: the social, the economic, and the environmental [44]. It can be assumed that the future of industrial architecture in Slovakia will depend on production areas of this type. Their specificity is the location mostly on the "green field" and the overall philosophy of designing the production area with regard to the place of the human in the production process. Characteristic examples can be specified, e.g., Industrial park (IP) Kechnec at Košice–with research potential for the Technical University of Košice; a cluster composed of segments in Trnava focused on the automotive industry; IP Žilina and IP Nitra focused on the automotive industry; and the newly formed IP Sered', which is logistics-oriented but with no other specifications at present.

According to Bar [45], autonomous industrial parks can be built, underlining the local, regional character. Despite the criticism associated with fragmentation, they complement the structure of such parks at the regional level in contact with the city.

Another possibility is technology parks (science-production parks), which are national or regional centers of integration, research, and sophisticated production, including fragments of typical industrial activity and services, focused on the IT sector and especially the most advanced technology. Four types of cluster models were created and based on urban typology. Models are presented in Figure 6.

All industries forming the modern economy are often referred to as the TMT sector (Telecommunications, Media, and Technology) and colloquially referred to as the "technology" industries for the 21st century; they include trends of changing demands on the production and production environment. The nature of energy (E) changes to renewable (E_R, E_{R-X}), and the material becomes recyclable materials (M_R, M_{R-X}).

In material production (MP), the demands on work (W) are increasing in the environment of information technologies (W_{IT} and W_{IT-X}), and in the environment of digital twins, the Internet of Things, and the knowledge economy. Production technology (T) is increasingly focused on information technology (I_T, I_{T-X}).

Communication in production between workers (H_A–H_B) logically changes to communication between machines (M_A–M_B). These megatrends and their permanent development are presented in Figure 7. Knowledge and information are the basis of the orientation of the current economy to the knowledge economy.

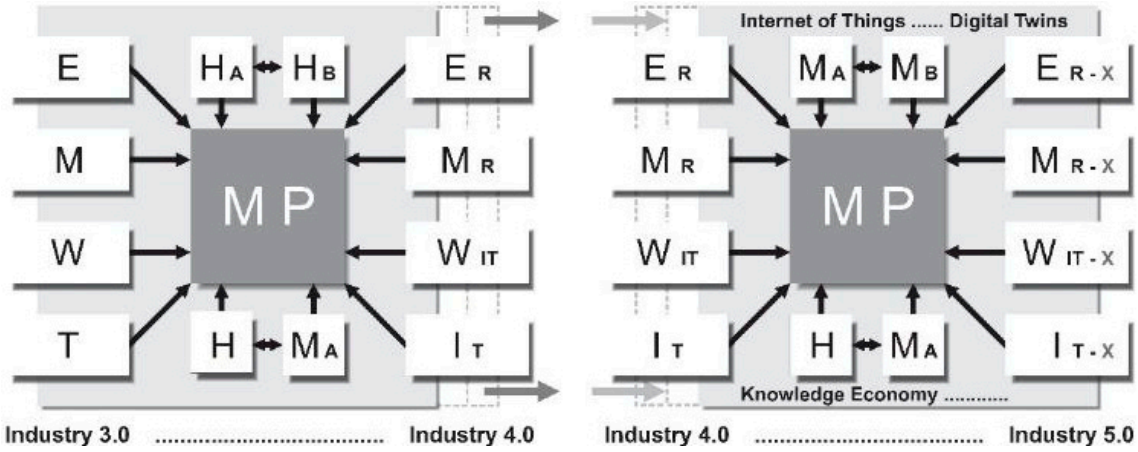

Figure 7. Influence of the so-called Megatrends of Material production/MP development. Legend: E/energy, M/material, W/work, T/technology, H/human, H_A–H_B/human to human communication, M_A–M_B/machine to machine communication, E_R/energy renewable, M_R/material recycled, W_{IT}/work with information technology, I_T/Information technology; authors' scheme.

When defining a technology park, it should be noted that this is not a typical industrial park (industrial zone) with a predominance of traditional industrial activity. Technology parks differ from the classic type of industrial and business parks in terms of location requirements, and requirements for the timelessness of architecture and environment with the application of progressive trends in construction–economic, ecological, and energy.

In Slovakia, the area surrounding the Gabčíkovo Hydro-electric Plant provides great potential for a Centric model of a transregional technology park cluster with a significant impact on the landscape. The cluster is based on sustainability and the SMART concept, with the main idea being to design a technology cluster in the green park/landscape. These are the theoretical considerations of the model studies presented in Figure 8.

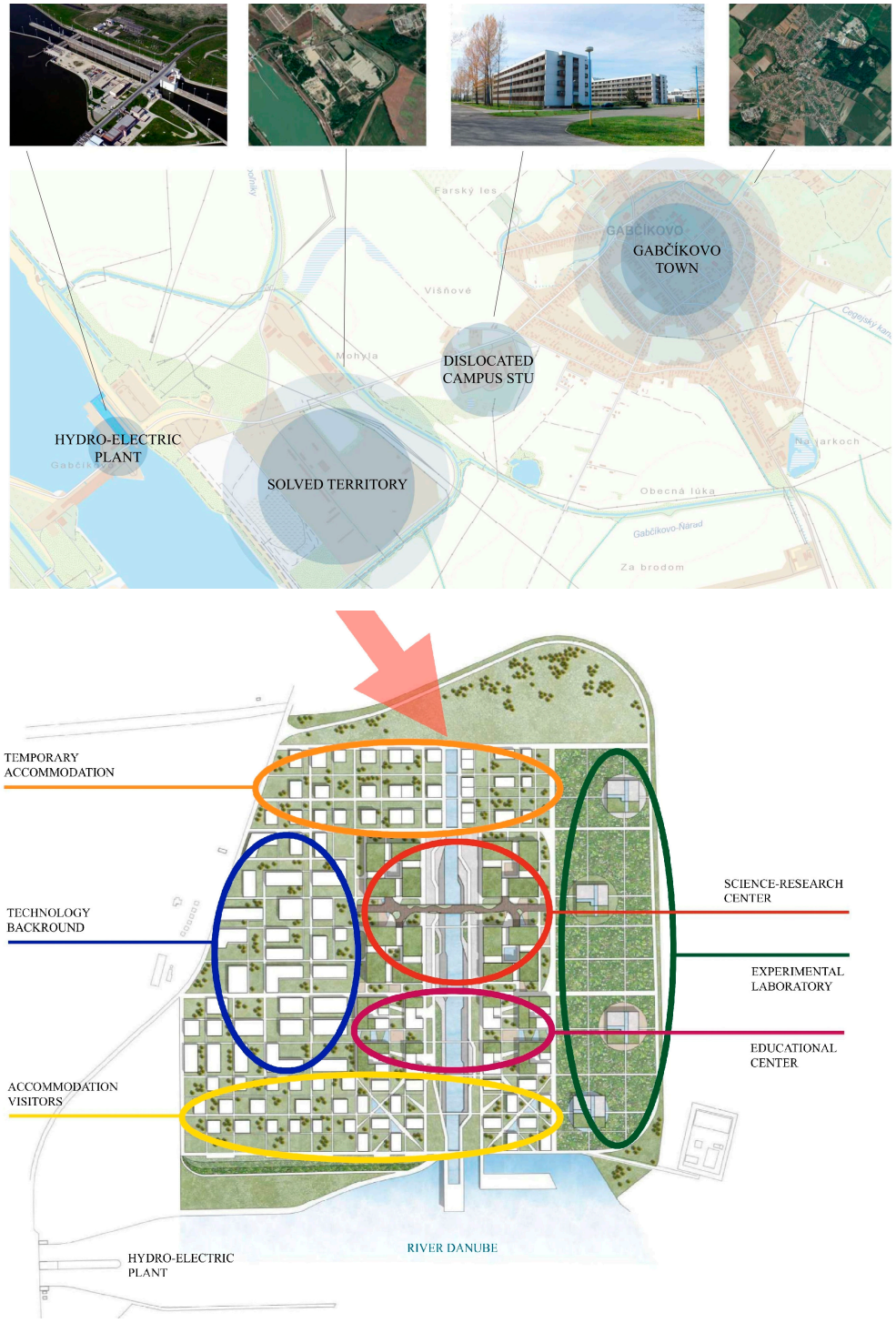

Figure 8. Research and case study: Technology park Gabčíkovo, (authors' design studio, L. Tomášová).

The results of the research based on the evaluation of the graph (Figure 2) confirm the trend of localization of production units and knowledge clusters in interaction with educational epicenters–universities (Bratislava, Trnava, Nitra, Žilina, Zvolen, Košice) which lie on important transport arteries (see Figures 9 and 10a,b).

Figure 9. Map of the Slovak Republic with the transport arteries and important epicenters/cities with industrial parks and universities (knowledge and science centers); D1—highway, R1, R2—expressway (authors' figure).

(**a**) (**b**)

Figure 10. (**a**,**b**) Trnava–epicenter with automotive cluster [46].

4. Discussion—Localization of Modern Industry, Clusters, Sustainability

As Evers et al. indicate [47], knowledge clusters have the organizational capability to drive innovations and create new industries. Examples of such organizations in knowledge clusters are universities and colleges, research institutions, think tanks, government research agencies, etc. In these centers, regional sectoral clusters are being established, focusing mainly on the automotive, engineering, food, and IT industries, and at the same time, they represent a higher degree of connection to foreign monopolies [36].

Comprehensive mobility is an accompanying phenomenon of globalization. Current globalization's communication technologies today provide the means by which future resolutions that arise may be perpetuated, expanded, multiplied, and differentiated into locally sensitive global solutions in the best tradition of sustainable development [48]. This concept evokes a different idea in each of us. It is a general pattern of movement, both within the boundaries of the settlement structure but also outside of it. In the economical area, this can mean rapid mass distribution of products. In the last decade, the pattern of movement has almost completely changed. The dimension of the movement is made more relative when distance is not a decisive factor, while the speed of general availability in the market space from information (knowledge) to product is decisive. The scheme in Figure 4 reflects the movement and alternatives of the operation of clusters. Mobility in today's society is gaining momentum and intensity in all social sectors. Experts from several fields consider dynamic mobility as the threshold of a new revolution of the 21st century, which is also evident in Slovakia [49].

Many utopian visions in the past have now become reality. Kitchin et al. [50] say that over the past decade, many cities have adopted policies and rolled out programs and

projects designed to transform them into a 'smart city'. It is clear from the plethora of initiatives underway globally that the idea and ideals of smart cities are quite broadly conceived. An ideal smart city cannot develop without a link to smart production. The model of the city in Figure 5 fulfills this idea.

Production technologies are advancing at an incredible pace, and technological processes are automated and robotized, which fundamentally changes the degree of human physical participation in the value of the product. The product becomes to a greater extent a product of the technological order. A new production order code is being created with a newly defined and philanthropically designed work environment [51]. Social functions will increase alongside production processes, and the erasure of the accentuated qualification stratification of the workforce will be significant.

Hanson [52] stressed that if the problem of the nineteenth- and twentieth-century industrial city was urban concentration and the solution was segregation, then it is becoming increasingly clear that today's issue is the apparent loss of face-to-face connections between people, as a result of the decay of the old industrial base, the rise of consumerism, and the impact of modern telecommunications, including the internet and the virtual world.

Anthropocentric orientation is therefore a message of the future, a message of the transfer of labor in the structure of sectors from the first to the fourth sector–the transition from an industrial society (*Homo industrialis*) to an information digital society (*Homo digitalis*). It is the vehicle of a change in the expression of industrial architecture.

The tendencies of designing modern industrial architecture are based on the principle of context, i.e., the acceptance of the environment through its external action (scales, tectonics, forms) with the maximum degree of consideration for mankind. The architecture reflects the intentions of 'smaller is more aesthetically pleasing' and thus enables a higher degree of sustainability and form of eco-friendly architecture.

Due to the influence of new production technologies, building materials, and processes, architecture becomes an integrating element in an environment without traditional industrial architectural expression. Expressive elements and materials from the area of non-production buildings are taken over, such as perimeter cladding, window fillings, materials, and color. Architecture does not turn away from man, but, on the contrary, it is more "civil" in its operation. Architecture is elementally and expressively universalized regardless of the type of capital and location (capital without borders – architecture without borders) with a sensitive approach to the application of corporate identity in expressiveness. This was the aim of the solution in the case study of the modern Gabčíkovo technology park in Figure 8 and in the Supplementary material.

Sustainability is not an independently functioning phenomenon. Just as urban sustainability is based on four pillars (economic, social, environmental, and cultural), the sustainability of industrial production (industrial architecture) is based on a functioning economy, modern technologies, and solutions for spaces with respect to the environment [53].

The phenomenon of sustainability is not fixed. The importance, scope, and irreplaceable basis of every human activity is constantly expanding. It has a priority in areas that directly affect the land and are related to waste issues. Similarly, the redevelopment of derelict industrial areas (brown and grey fields) has received significantly more attention in the last few years and has become a major landscape-related issue (Figure 11).

The physical reintegration of abandoned brownfields (located in the city center) and grey fields (located in the industrial zones of cities) has positive consequences beyond the localities themselves and beyond their physical dimensions [54].

New design strategies to reclaim derelict industrial sites have been proposed in recent years, focusing on the sustainability, quality, and multi-functionality of the space. This strategy is inherently sustainable because it encourages positive re-use with the possibility to keep the genius loci of the old industrial architecture [55]. We must point out that sustainability is a concept whose implementation varies in dependence on cultural and socio-economic specifics. We will achieve sustainability by integrating and using appropriate proven or innovative concepts and methods. Multifunctional development is an

extremely important concept of sustainable development that is tied to the implementation of social and technological innovations [35,56].

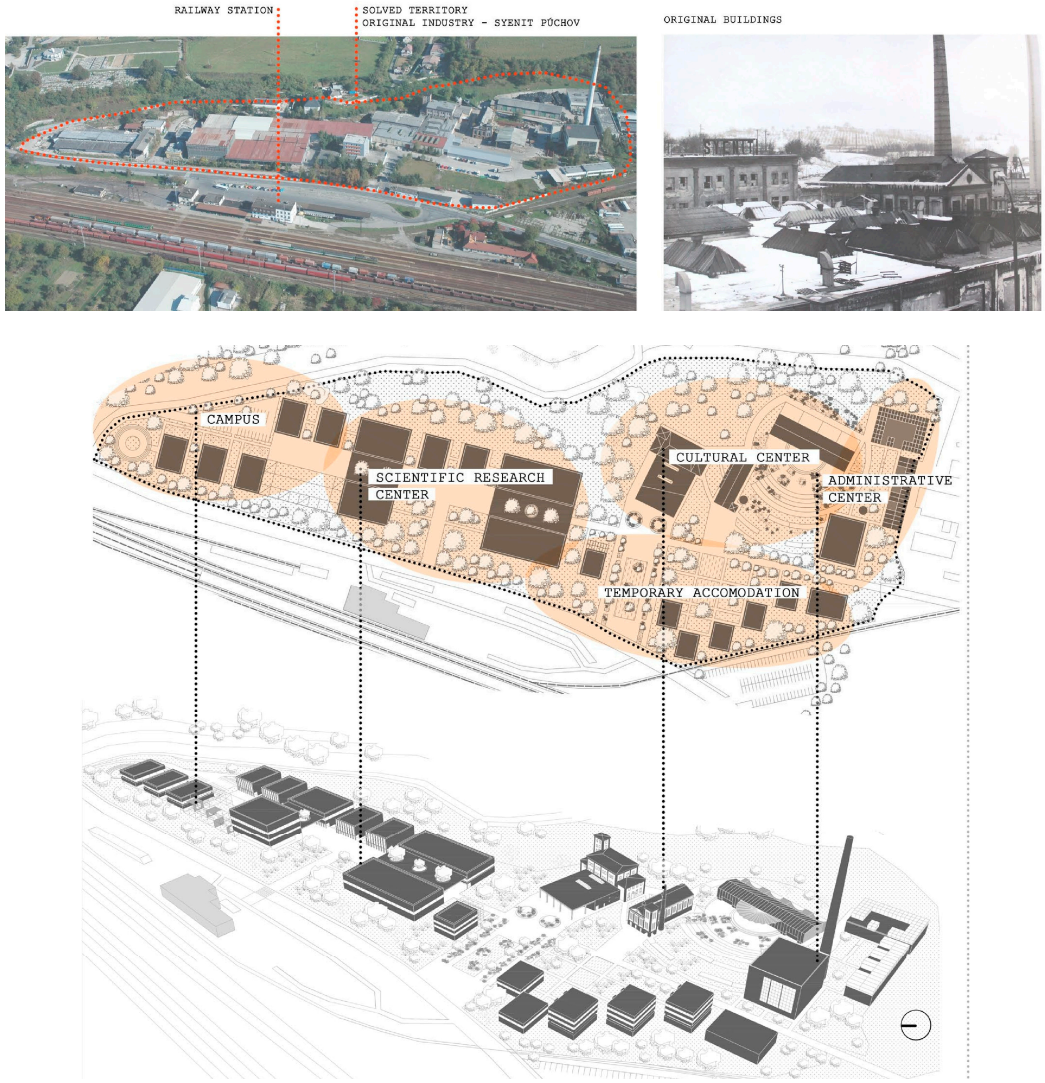

Figure 11. Example of sustainability of industrial landscape—a case study of the conversion and revitalization of a former Industry field at the city border—Syenit Púchov (authors' design studio, H. Mikešová).

The vocabulary of modern industry in the 21st century currently includes the terms Industry 4.0, Industry 5.0, circular economy, and reduction of the carbon footprint. Industry 4.0 focuses more on digitization and management, and the Industry 5.0 concept emphasizes the importance of research and innovations, and respect for the landscape in the long-term service to humanity [57,58]. These phenomena are associated with another term ('smart') and are part of sustainable production concepts. The connection between Industry 4.0, 5.0, and smart technologies with architecture can be characterized by key determinants [30]:

S: sustainability—display in overall concept, industrial eco-park designing, landscape;

M: materiality—application of low tech in the construction and material solution of buildings (use of local or recycled materials);

A: aesthetics—quality architecture, harmonization of people, harmonization with landscape;

R: research in the field of production and transformation in architecture;

T: technology and environment technology at a high level (work environment).

Our research has confirmed that the most important change in the design of the SMART industrial complex lies in the comprehensive approach. Trends are transferred to the localization in the landscape, to the architecture. They require universality, modularity, flexibility, reusability, and harmonization of the working environment. An ideal territorial–architectural and sustainable model for Industry 4.0–5.0 is applied in four consecutive positions: industrial park (cluster)—a building–production technology–production and working environment.

The need for a comprehensive view of industrial construction requires the involvement and coordination of professionals from many fields. The application of fusion of knowledge from different scientific fields influences new trends and further innovations [59]. The solution of modern industry is not just an economic challenge. The goal should be long-term economic clusters cooperating with each other, and not only ephemeral parks [60]. Dynamic clusters where new ideas emerge mark the direction of development, and presume strong social and education structures. Clusters therefore represent fertile grounds for innovation [61].

Urban economy clusters are modern, sustainable concepts that focus on smart manufacturing. They focus on IT and creative industries. Planning in the city system means adapting to the functional diversity in the form of construction in the context of landscape and typology of buildings. What is built must be sustainable, and considerate. Research in this area looks at how individual functions work in space, what scale of buildings is appropriate, and what sectors contribute to sustainability (e.g., circular economy and green economy). As Moore [62] says, cyclical economics will also play a major role: all materials must be seen as part of the cyclical flow of matter through the ecosystem or industrial system. A sustainable economy will rely to a greater extent on human labor to make products that last longer, and to repair, reclaim, and recycle all materials.

According to Martins [63], important factors include the location and arrangement of functions so that they are easily accessible in time, and therefore alternative transport options are being addressed. A certain advantage may be the expansion directed "inwards". This effect is emphasized by Kuah [27]. He argues that smaller parts of clusters are growing faster and more dynamically economically than their multinationals and thus are sustainable.

When locating the industry, it is then realistic to consider inserting fragments of production into residential areas (and vice versa) which brings about a change in the view of the Industry 4.0 architecture [64]. The introduction of industry into the residential area allows for a new, avant-garde typology of buildings. The term 'hybrid building' appears, where hybridism is classified as spatial, economic, but also typological [65]. It automatically leads to production that is clean, open, waste-free, and without other negative impacts on the landscape and on the working environment. It is necessary to deal with sound ecology, as reported by Jaszczak [66], to eliminate any possible excessive shocks and dust from production to the surroundings.

What was blamed on the modernists, consistent zoning, and mono-functional zones can be eliminated in this case. Only a modern Innovation Factory with a precisely adhered to eco-concept contributes to the functional color scheme of the city's zones. It is logical that the concept of industrial parks has been supplemented for two decades with the concept of eco-industrial parks which are closely related to the establishment of industrial ecology. The main potentials of eco-production schemes (friendly to the landscape) are highlighted in the context of the benefits of centralized management and use of services and systems with a shared infrastructure and with administrative simplification for the participating companies [67].

Strategies based on clusters—as part of industrial, innovative, regional, and scientific policies—should correspond with the greening of established industrial branches in Europe and, at the same time, prepare the grounds for newly appearing industries, as well as for the disappearance of certain branches [61]. This is also declared by the European Cluster Collaboration platform, which supported the initiative of New European Bauhaus (NEB),

leading to European groupings, especially those active in construction, digitization, and creative and cultural branches, as well as renewable energy ecosystems. Euro clusters support the complex processes for strengthening transformations to greener and more digitalized economies [68].

According to EC, the NEB is characterized by a trans-disciplinary and participatory approach. These approaches support development on a regional level, innovation in industry, and creativity in the interest of improving the quality of life [69]. The models of clusters and resolutions (Figures 5, 6, 8 and 11) point to the possibility of their real on-site transformation and represent the NEB message, since their implementation contributes to the development of regions and leaves space for innovation and freedom for creativity.

5. Conclusions

Slovakia has been affected by "clustering and parkmania". The economic response to this phenomenon is positive, and the productivity in clusters is much higher than elsewhere because of the collective learning within clusters through innovations and imitation [39].

It is necessary to control and direct the territorial–spatial development on the basis of sustainability and respect for the environment. It is the only way to avoid the mistakes of the past while creating a quality environment. The number of built production areas has already captured this trend but the overall development of industries represents other new challenges in urban planning, architecture, and smart technologies.

In order to emphasize the main goal, this paper did not focus on the "color" of the park (green, brown, grey, agro-park, eco-park, etc.). The important conclusion of the research are as follows:

- Trends of the overall industry development in Slovakia reflect global development, which was presented in the form of abstracted functional territorial models of interaction: city–landscape–industry. Given the central economic ties within the supranational monopolies, the sustainability of industrial clusters in Slovakia will copy the sustainability of the entire system which is mainly determined by foreign capital.
- The issue of the development of industry with its strong economic background must be presented within the context of education in schemas and territorial models.
- Under the conditions in Slovakia, it is necessary to focus on parks and clusters that work with a diversified structure of the industry, as a certain part will be set aside for the domestic industrial equivalent. Last but not least, it is an advantage in the case of a recession in some segments. Internally cooperating production components can be more stable and without market fluctuations under the influence of the global labor price.
- The smaller components or separate industrial parks are more embedded in the regions. They represent decentralized and dispersed models of localization, and also an opportunity for a new character of smart concepts.
- A positive big step is the focus on the construction of decentralized eco-parks, a friendly landscape, and a more perfect pair of classic industrial parks.
- An architectural solution responds to the main trends in the concept of industrial construction, with its quality and environmental spirit and will not lag behind the typological types of public buildings.
- Industrial development trends in the 21st century (Industry 4.0 and 5.0) will need to be implanted in the concepts of industrial clusters, from the creation of territorial relations to the solution of the working environment. The dominance of digital technologies and artificial intelligence will determine spatial relationships and will affect the workforce regrouping.

Industry clusters are "sponges" in the territory that comprehensively absorb the necessary components of production. The fact that the location of larger groups of clusters is reasonably close to transport arteries and infrastructures, transfer hubs, and logistics centers has been confirmed. The interaction with the research and educational centers is also substantial.

A partial distortion of these trends can be expected in the following period under the negative impact of the COVID-19 pandemic, which may be marked by an overall economic stagnation with an impact on the entire spectrum of industrial development.

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