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SYNERGETIC CHARACTER OF ARCHITECTURAL ELEMENTS OF TRANSPORTAION NETWORKS OF INDUSTRIAL AREAS

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Abstract

The objective: *Stability of the flow processes in industrial areas directly depends upon the degree of synergetic character of the elements, that make up the architecture of their transpiration networks. The bulk of specialists consider railway and automobile transportation networks to be transportation thoroughfares with static architecture only, although, primarily, they are but a series of structural and functional elements, acting according to synergetic principles, typical of industrial regions, having an essential impact both on environmental safety and supporting their functioning. In many industrial areas transportation networks also represent historical monuments to architectural and engineering ideas. Territories, located along transportation networks possess a substantial town-planning, architectural, historical and cultural potential. All aforementioned confirms the necessity of compiling a mechanism of evaluation of functionality of the existing architecture of transportation networks of industrial areas (hereinafter ATNIA), based on the principle of synergetic.* ***The principles:*** *The proposed mechanism of evaluation of functionality of ATNIA elements, characterize as synergetic is based upon an electric-dynamic model of control over transportation flows and was named on the analogy with gravitational model, in which bodies' masses correspond to the zones of arrivals and departures, while the distance between zones to transportation expenses.* ***The results:*** *The operational hypothesis, regarding the fact that a transportation network of an industrial area represents a combinatorial space and can be evaluated by means of different methods of electrical engineering, according to Kirchoff's laws proved to be true. Owing to development of electrodynamic, giving an evaluation of behaviour of transportation flows within boundaries of transportation networks in industrial areas there appeared an opportunity of determining the level of functionality of the latter.* ***The novelty of research:*** *appears due to development of an electrodynamic model on the basis of the main principles of synergetic, which determine functionality of ATNIA methods.* ***The practical value:*** *Application of theoretical issues, taken from electrostatics, the branch of physics makes it possible not only to give a quantitative evaluation of transportation flows, within the boundaries of combinatorial space of transportation network of industrial areas, but also evaluate ATNIA functionality.*

Keywords: architecture of transportation networks; combinatorial space; framework of transportation networks; linear elements of transportation elements; synergetic of transportation network.

1. Introduction

Synergetic of transportation networks of industrial areas is caused by different tasks they have to solve, they being aimed at one and the same targets, namely, communicative servicing of industrial districts and maintaining interaction between elements of territorial structure (junctions, centres, zones, regions), it also serves as a configurator of production and residential systems.

2. Analysis of researchs and publications

The configuration of transportation network of an industrial area has an essential influence upon "the architecture of the picture" of the territory and residents' settling.

S.A. Tarkhov [1] introduced a statement that transportation networks are compiled of similar and naturally expressed configuration parts. Simple elements of a transportation network of industrial areas comprise cycles (closed loops,-frameworks) and branches (not closed treelike and linear elements). Though such configuration elements are of human creation, configurations are formed and develop according to internal laws, caused by social and economic development of industrial regions. Evolution of the architecture of transportation networks is characterized by a strict sequence of alternation of its transportation network –Fig.1. (а, б, в) shows the process of architectural evolution of transportation networks on the example of the city of Mariupol in 1826-2010.

A common regularity for the period from 1950 to 2010 is growth of the industrial potential of industrial districts and as a result a transition of the architecture of transportation networks from simpler schemes to more complicated ones. The complexity of the architecture of transportation networks of the contemporary industrial districts is caused by a synthesis of tram, trolley-bus, railway and automobile networks into a unified transportation network of the investigated areas, see Fig.2. The results, obtained within the framework of this investigations [2,3] gave rise to the hypothesis that the architecture of transportation systems of industrial districts , on the example of the city of Mariupol, is combinatorial. In other words- the basic network components-transportation areas, were synthesized by the dynamic configuration of transpositions, arrangement and combination of its linear and junction elements.(roads and crossroads).

3. Problem statement

Stochastic behaviour of the nature of ATNIA formation on example of Mariupol revealed a number of drawbacks in the process of its exploitation, particularly:

- ✓ "a diametric" type of connection between the city and external transportation thoroughfares;
- ✓ weak development of "the meridian" direction of cargo and passenger routes;
- ✓ the presence of detached sections or railway lines, not connected functionally with the street-roads network, ensuring cargo traffic between industrial and transportation enterprises urban districts.

For evaluation of the functionality of the city's architecture correspondence of the transportation architecture to the level of economic development of the particular district should be taken into account.

If the architecture runs ahead it usually stimulates economic development. However if such "lead" is too big, some architectural capacities may not be used, it resulting to extension of the terms of the payback period of investments into the architecture of the transportation network of the industrial district and vice versa.

In the point of bifurcation of ATNIA as a synergetic system the parameters of the system begin to change rapidly, the stability drops, entropy grows due to reaching the critical values of external actions (e.g. of the economic component-crisis), or due to internal forces, or their integration. In the point of bifurcation appears an opportunity of directing an evolutionary process along a different line. The point of bifurcation acts as a point of maximal sensitivity of the system to external and internal impulses and their minor fluctuations.

Now, let us consider the degree of the influence of the economic component upon the evolution of the investigated system with indicator-points – points of bifurcation, determining the degree of the system's critical state, at which it becomes unstable with regard to fluctuations and appears uncertainty if the state of the system will become chaotic, or it will pass to a new more differentiated and higher level of organization (Fig. 3) [6].

Let us analyze the economic scenario of the evolution of the investigated system after the point of bifurcation –the attractor , according to which the system is likely to go [6]. However, it is impossible to predict beforehand what new attractor the system will take. Let us discuss three variants of the attractor in ATNIA evolution space, under conditions of an economic crisis.

1. variant of the attractor. The evolution of ATNIA under condition of a stepwise economic recession in an industrial area- " a standard" crisis, this type of crisis is caused by the lack of resources for development of architecture and can be surmounted by means of implementation of new technologies into the evolution process of ATNIA, with a gradual withdrawal of obsolete elements with low indices of functionality*T(t)* (the so-called "selection" of the best technologies of development). from its structure norma

In this case, as we suppose, the action of the factor of "crisis" upon the index of ATNIA functionality, characterized by the value of the functionality coefficient of ATNIA Φ_n, possesses a "soft" character and expenses on support of the resources, ensuring functionality of the architecture of the transportation network are increased stepwise, the amplitude of such steps depends on economic stability Illustration of the degree of the influence of Φ_n coefficient and its residual resource *T(t)* in an industrial area can be depicted in a view of a theoretical graph of dependence (see Fig. 4) and can be described by an equation of normal distribution law [9].

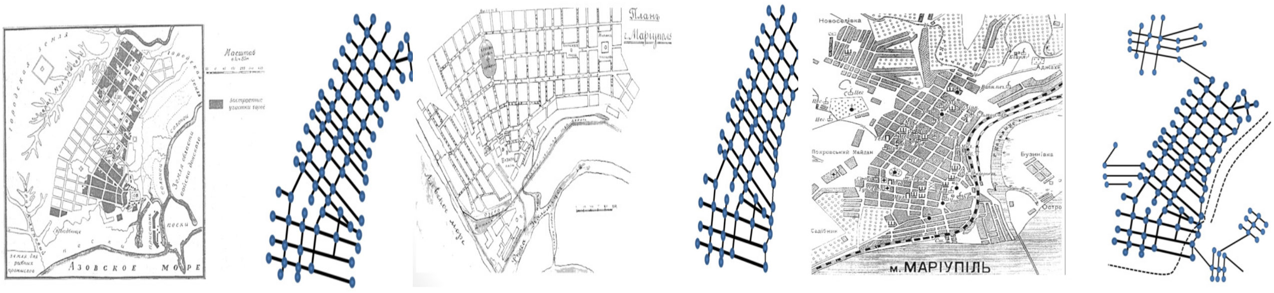


Fig. 1. The map of the city of Mariupol and its transportation network а) -1826; б) 1910; в) 1930

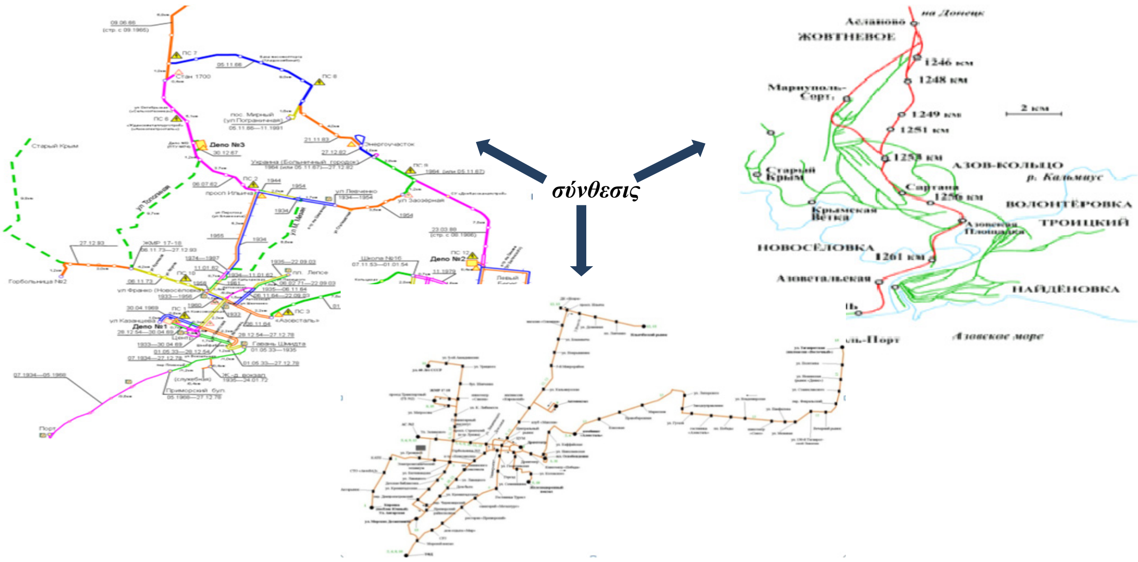
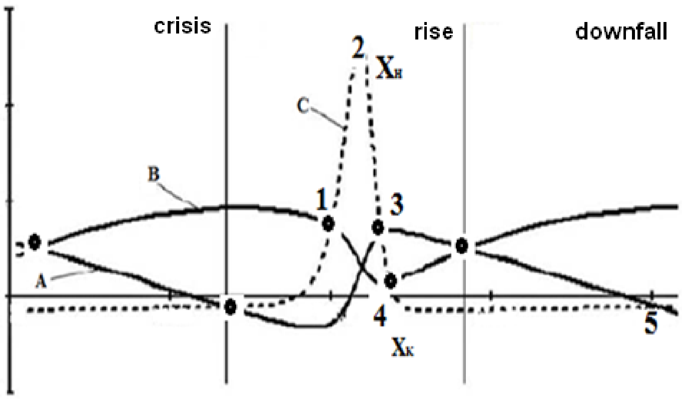


Fig. 2. The diagram of synthesis a (*σύνθεσις*), of the components , comprising the architecture of the picture of transportation networks (from the bottom to the top: tramlines, trolley-bus lines and railways) in Mariupol.



Evolution sectors of elements' development of ATNIAT on economic scale: «1-2» – logistical dependence of ATNIA development; «2-3» –development of collapse in ATNIA; «3-4» – slight development of a critical state of ATNIA; «4-….» – harmonization of the medium; $X_{н}$ –original state of control over ATNIA; $X_{к}$ – point of collapse in ATNIA.

The curves of indicator processes on the investigated scalee: *A* – the amount of transportation "high-quality" work (V_p); *B* – overall time losses (T) at "high-quality" work; *C* – investments, directed at stabilization of "environmental balance' of the transportation sector of the medium of industrial district;

● – the point of bifurcation

Fig. 3. Evolutionary-bifurcation regularities of the evolution of the process of urbanization of ATNIA in the context of economic cycles

2-nd attractor's variant: development of events, when the governing and governed systems are not doing any work on overcoming the external action, which, however makes unreachable the target set for the system – "operational whirlpool" (Fig.5). In this case the character of the indices' behaviour, depicting the functionality of ATNIA can be described by the linear law of distribution

The structure of stationary states of ATNIA functionality depends on its parameters and will change alongside with their changes.

If $\lambda = \lambda_0$, then, the process corresponds to the stationary state, satisfying the quality of functioning of ATNIA.

From an arbitrary point of bifurcation an arbitrary number of branches of solution of the equation may originate. This multitude of bifurcation points plays a tremendous part in ATNIA evolution , while we connect the entire topology of $Y(\lambda)$ stationary states with the characteristics of the process of urbanization of the process of ATNIA. The system's behaviour , its functioning will largely depend upon the value of λ parameter, whether it will be bigger or smaller than bifurcation parameter.

Let us suppose that at an initial instant t_0 it was in a certain state x_0 (see Fig. 5, point $X_н$). Let us also suppose that this point was within the sphere of attraction of some solution $€_1(\lambda)$. It means that in absence of fluctuations ξ the system as time goes will be likely to tend to go to its original state $x = €_1(\lambda)$, and will try to get into its vicinity at comparatively weak impact. On it. If λ changes, then the flow of ATNIA evolution will also change.

For simulation of transportation networks of industrial areas (ATNIA) gravitation and entropy models are applied in most cases, which on the mesolevel of industrial area connect the intensity of flows in ATNIA between the zones of arrival and departure (full number of departures from the zone of departure and full number of arrivals to the zone of arrival) and also expenses on travelling between these zones Entropy models contain the probabilistic characteristics of joint behaviour of the traffic participants [7] and takes into account drivers' preferences in choosing the traffic routes. The main drawback of these models is that they are not linked to individual characteristics of ATNIA, determined by urbanization of the territories under investigation [4].

Variant 3 of the attractor. The events are developed under conditions, when the governing system is in the state of maximal load and in the governed system the work is not done- "the crisis of the loss of control" (Fig.6).

A new "electrodynamic" model is proposed in this article for the framework of ATNIA. It functions on the micro-level, its linear and junction elements and it is specified for a mathematical evaluation of the "points" with high turbulence in the existing ATNIA – "the plugs" and sections with reduced passability. The model does not require construction of a correspondence matrix, as it operates the exiting density of transportation flows , appearing on the roads of industrial areas at rush hours.

This electrodynamic model was named on analogy with the gravitational model, in which mass of bodies corresponds to the zones of departure and arrival and the distance between the zones corresponds to travel expenses. In the electrodynamic model transportation model transportation notions correspond to the notions and characteristics of electric circuits, particularly:

– electric flow поток – a transportation cluster, which completely adapted to the transportation networks of an industrial area. Transportation cluster is a value, proportional to traffic intensity to density of transportation flow in the combinatorial space of an industrial area. The value of this transportation cluster as compared to the space unit is called the flow density;

– intensity of the transportation flow on the traffic lane I is equivalent to the force of the electric current in the conductor;

– the number of traffic lanes g в in one direction of the road is equivalent to resistance of the circuit R (or its conductivity);

– density of the transportation flow q corresponds to density of electric flow;

– the drop in intensity of the transportation flow on the lane's passability is equivalent to the voltage on the sub-circuit, i.e. $U = IR$ or $U = I/g$;

– the actual index of ATNIA potential , that compiles an evaluation of attraction of ATNIA components is compared to the electromotive force E (EMF). Numerically it is equal to the product of the traffic speed in the cluster υ and its density on the traffic section q, i.e. $F = q \cdot \upsilon$;

– transportation capacity of the flow $P = I \cdot F$ as a product of the traffic intensity of the cluster and its motive force is an analogue of electric capacity $P = UI = EI$;

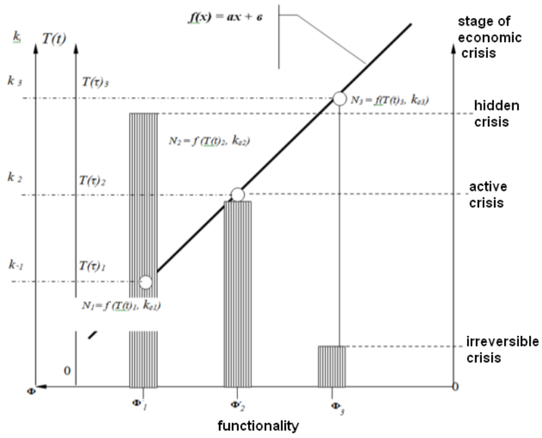


Fig. 4. The diagram of the degree of influence of the economic component of ATNIA evolution upon its functionality in the medium of an industrial area under the conditions of a "standard" crisis

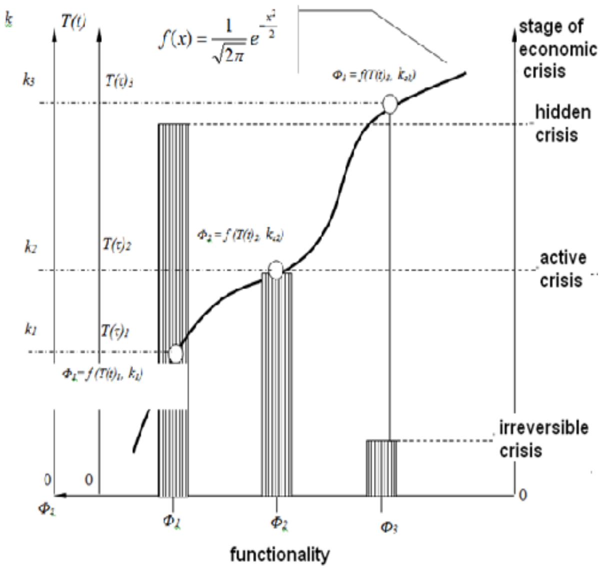


Fig. 5. The diagram pf the degree of the influence of the economic component of ATNIA evolution upon its functionality on the industrial area under the condition of an "operational whirlpool".

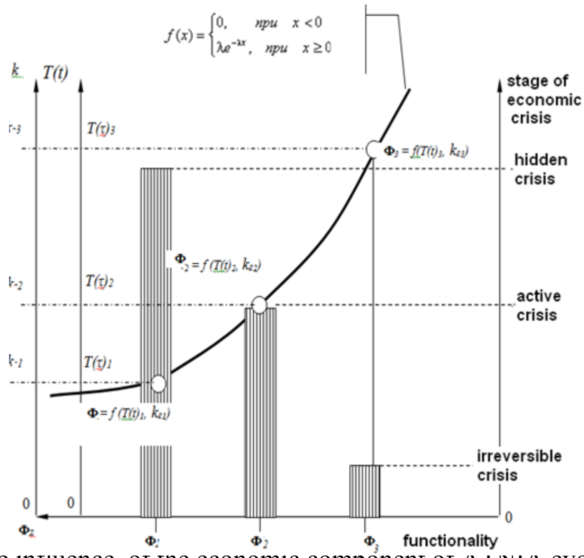


Fig. 6. The diagram of the influence of the economic component of ATNIA evolution upon its functionality in the medium of an industrial area under the conditions of "loss of control crisis".

– the quality of electric power is determined by special indices: fluctuations in frequency and voltage, fluctuations in voltage, often asymmetric and the like. For ATNIA, the index of the quality of electric power is identical to the criterion of the level of service (LOS). A stepwise algorithm of evaluation of LOS includes the following operations 1) Correction of the quantity of transportation means or evaluation of hour intensity of traffic for evaluation of the prevailing road conditions 2) correction of the speed of undisturbed traffic for the prevailing traffic conditions on the investigated sector of ATNIA. The quantitative evaluation of this index is carried out according to this formula [6]:

$$V_p = \frac{V}{PHF \times N \times f_{HV} \times f_p}, \quad (1)$$

where:
V_p – an equivalent 15-minutes index of intensity of vehicles traffic(number of vehicles /hour/traffic lane);
V –hour intensity of traffic (number of vehicles /hour);
PHF – coefficient of the period of the peak load ;
f_{HV} – correction coefficient of the influence of heavy trucks;
f_p –coefficient of drivers' categories ;
N –number of traffic lanes.

For electrodynamic transportation scheme the laws and methods of evaluation of electric circuits are valid:

1. Ohm's law for transportation conductor can be formulated like this: "Intensity of the flow of transportation means is directly proportional to the velocity of its traffic υ and the road's width (the number of traffic lanes) ".
2. The first law of Kirchhof: "the number of vehicles that have come to the crossroads is equal to the number of vehicles that have left it".
3. The second law of Kirchhof: "In a closed loop of roads the algebraic sum of the products of flows intensity *Ii* and resistance of loop's section is equal to the algebraic sum of motive forces acting in it *F*.

For transportation networks, determining the functionality of ATNIA all methods of evaluation of electric circuits are justifiable: – the method of Kirchhof's laws, the method of circuit currents etc.

The electric diagram of an ATNIA fragment is pictured in Figure 7.

In it each direction of a linear element is represented by intensity of vehicles flow *I*, resistance of a linear element to traffic *R* and transportation motive force *F*. the junction elements ("points of turbulence") of the diagram correspond to the crossroads and are marked with Arabic figures.

A system of equations was compiled by means of circuit currents that gives a quantitative evaluation of the functionality fragment of ATNIA.

The determined criteria include intensity of the transportation flow at specified number of traffic lanes, density of the transportation flow in each direction, comprising the cell of ATNIA linear elements:

$$\begin{cases} I_{11}(R_1+R_2)-I_{22}R_2=-F_1-F_2 \\ I_{11}R_2+I_{22}(R_2+R_3+R_4+R_6)-I_{33}R_6-I_{44}R_4= \\ =F_2-F_3+F_4+F_6 \\ -I_{22}R_6+I_{33}(R_6+R_7)=-F_6-F_7 \\ -I_{22}R_4+I_{44}(R_4+R_5)=-F_4-F_5 \end{cases} \quad (2)$$

4. The results

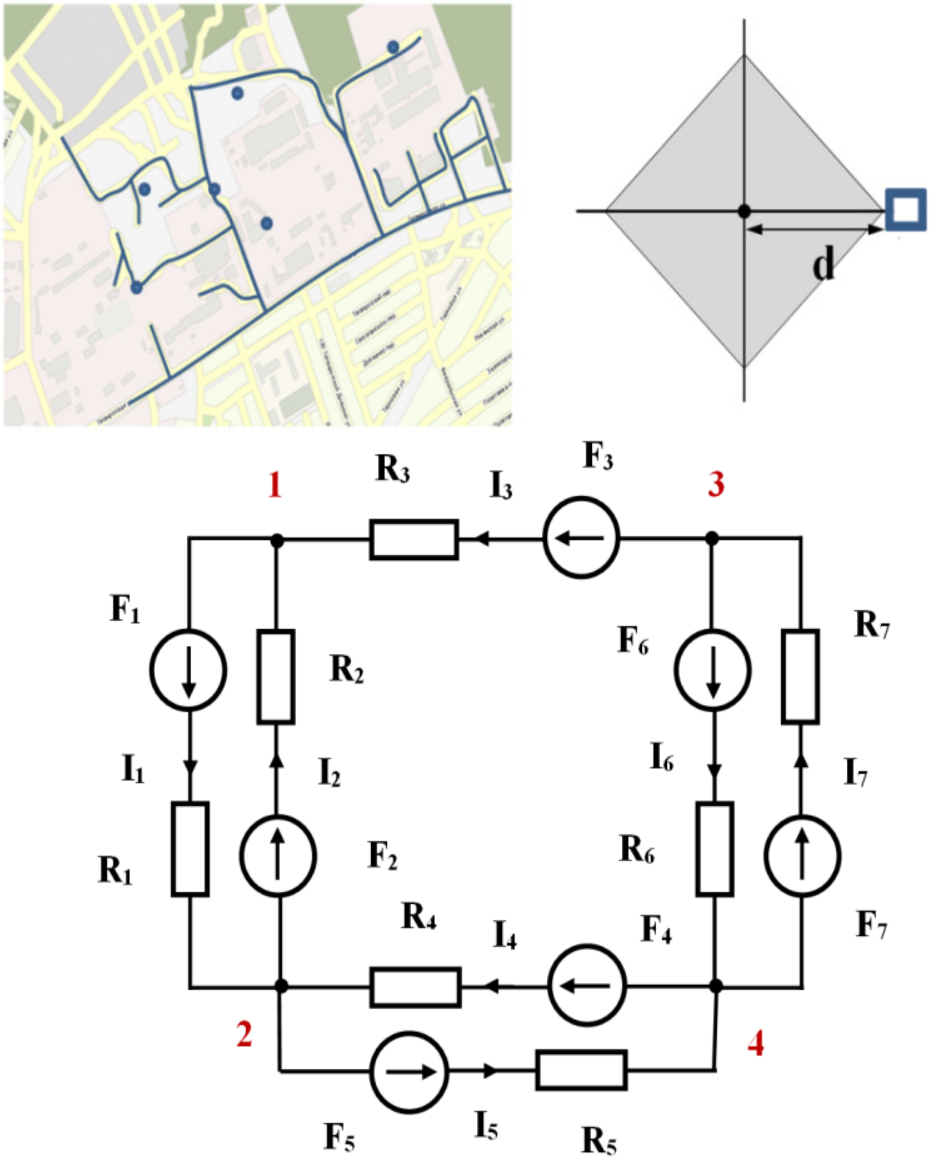
The reliability of the operational hypothesis was confirmed, marinating that a transportation network of an industrial area is a combinatory space and can be represented by an equivalent electrodynamic diagram and calculated according to Kirchhof's laws , applying different methods of electrical engineering. Owing to development of the electrodynamic model, capable of evaluating the behaviour of transportation flows within the boundaries of industrial areas an opportunity of determining the level of the functionality of the latter was obtained.

5. Research novelty and practical value

The research novelty is in development on the basis of main synergetic principles of an electrodynamic model, capable of determining the functionality of the elements of the architecture of the transportation networks of industrial areas.

6. Conclusions

1. The results of the conducted investigation of the functionality of the existing architecture of an industrial area (on the example of the city of Mariupol) allowed to state a hypothesis regarding a dynamic functionality of the architecture of the transportation network and synergetic character of its elements.



● – the point of initiation and absorption of cargo and passenger flows;
□ – the point of optimal distance (d) to the next cell of the element of the network under investigation.

Fig. 7. Electrodynamic diagram of a fragment of the architecture of the transportation network of an industrial area (on the example of the city of Mariupol)

2. Development of the electrodynamic model allows not only to give a quantitative evaluation of transportation flows within the boundaries of combinatory space of the transportation network of industrial area and regions, but also get an evaluation of the functionality of ATNIA.

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Мета: Стійкість потокових процесів в промислових районах знаходиться в прямій залежності від ступеня сінергетичності елементів, що формують архітектуру їх транспортних мереж. Залізничні і автомобільні транспортні мережі в промислових районах більшістю фахівців розглядаються тільки як транспортні магістралі з статичною архітектурою, тоді як це, перш за все, структурно-функціональні елементи, що діють на сінергетичних засадах характерних для промислових районів і роблять істотний вплив як на безпеку навколишнього середовища так і на забезпечення їх життєдіяльності. У багатьох промислових районах транспортні мережі є також історичним пам'ятником архітектурної та інженерної думки. Території уздовж транспортних мереж мають значний містобудівних, архітектурних і історико-культурним потенціалом. Все вище наведене підтверджує необхідність розробки механізму оцінки функціональності існуючої архітектури транспортних мереж промислових районів (АТСПР), заснованого на принципі сінергетики. **Методика:** Запропонований механізм оцінки функціональності елементів АТСПР характеризуються як синергетичні, базується на електродинамічної моделі керування транспортними потоками і отримала свою назву за аналогією з гравітаційної, в якій зонам вибуття і прибуття відповідають маси тіл, а відстань між зонами - витратам на поїздки. **Результати:** Підтверджено достовірність робочої гіпотези того, що транспортна мережа промислового району є комбінаторним простором і може бути представлена еквівалентною електродинамічною схемою й розрахована за законами Кірхгофа різними методами електротехніки. Завдяки розробці електродинамічної моделі, що дає оцінку поведінки транспортних потоків в межах транспортних мереж промислових районів, отримана можливість визначити рівень функціональності останніх. Наукова новизна полягає в розробці на основі базових принципів сінергетики електродинамічної моделі, яка визначає функціональність елементів АТСПР. **Практична значимість:** Застосування теоретичних положень з розділу фізики – електростатики, дозволяє не тільки давати кількісну оцінку транспортних потоків в межах комбінаторного простору транспортної мережі промислових районів, а й давати оцінку функціональності АТСПР.

Ключові слова: архітектура транспортних мереж; каркас транспортних мереж; комбінаторний простір; лінійні елементи транспортних мереж; сінергергетика транспортної сітки.

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Цель: Устойчивость потоковых процессов в промышленных районах находится в прямой зависимости от степени синергетичности элементов, формирующих архитектуру их транспортных сетей. Железнодорожные и автомобильные транспортные сети в промышленных районах большинством специалистов рассматриваются только как транспортные магистрали со статической архитектурой, тогда как это, прежде всего, структурно-функциональные элементы, действующие на синергетический основе характерных для промышленных районов и оказывают существенное влияние как на безопасность окружающей среды так и на обеспечение их жизнедеятельности. Во многих промышленных районах транспортные сети также историческим памятником архитектурного и инженерной мысли. Территории вдоль транспортных сетей имеют значительный градостроительных, архитектурных и историко-культурным потенциалом. Все выше приведенное подтверждает необходимость разработки механизма оценки функциональности существующей архитектуры транспортных сетей промышленных районов (АТСПР), основанного на принципе синергетики. **Методика:** Предложенный механизм оценки функциональности элементов АТСПР характеризуются как синергетические, базируется на электродинамической модели управления транспортными потоками и получила свое название по аналогии с гравитационной, в которой зонам выбытия и прибытия соответствуют массы тел, а расстояние между зонами - расходам на поездки. **Результаты:** Подтверждена достоверность рабочей гипотезы того, что транспортная сеть промышленного района является комбинаторным пространством и может быть представлена эквивалентной электродинамической схеме и рассчитана по законам Кирхгофа различными методами электротехники. Благодаря разработке электродинамической модели, дает оценку поведения транспортных потоков в пределах транспортных сетей промышленных районов, полученная определить уровень функциональности последних. Научная новизна заключается в разработке на основе базовых принципов синергетики электродинамической модели, которая определяет функциональность элементов АТСПР. **Практическая значимость:** Применение теоретических положений из раздела физики - электростатики, позволяет не только давать количественную оценку транспортных потоков в пределах комбинаторного пространства транспортной сети промышленных районов, но и давать оценку функциональности АТСПР.

Ключевые слова: архитектура транспортных сетей; комбинаторный пространство; линейные элементы транспортных сетей; каркас транспортных сетей; синергергетика транспортной сети.

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