# MODELS OF DEVELOPMENT OF THE INDUSTRIAL ENTERPRISE UNDER COMPLEX CRISES CONDITIONS

**Tarasova Hanna, Kiev National University of Technologies and Design**
**Iryna Pavlenko, University of Warsaw**
**Mykhailyshyn Liliia, Vasyl Stefanyk Precarpathian National University**
**Kovalenko Viktoriia, Ternopil National Economic University**
**Lukasevych-Krutnyk Iryna, Ternopil National Economic University**

## ABSTRACT

*The paper considers the combinatorial approach to the development of an industrial enterprise under complex crisis conditions has been developed, based on a set of models that provide a representation of anti-crisis measures as an arc-oriented graph, and the state of development of an industrial enterprise as a result of the implementation of these measures - as vertices of the graph, the use of which is provided by combinatorial planning of development of the industrial enterprise under complex crises conditions.*

**Keywords:** Model, Complex Crises, Multidimensional Graph, Industrial Enterprise, Development, Anti-crisis Measures, Combinatorial Planning.

## INTRODUCTION

The development of an industrial enterprise under crisis conditions requires the availability of tools to develop appropriate solutions that ensure the adaptation of the enterprise to crises or maximize the use of those opportunities that open up global crises. The world economy is characterized by a complex crisis, when several crises arise due to various factors, the external economic crisis is superimposed on the personal internal crisis of an industrial enterprise.

As a result of the analysis of alternative approaches, it was concluded that the majority of researchers who studied the problem of developing an industrial enterprise under crisis conditional, consider the crisis as a homogeneous process, which does not take into account the possibility of imposing several different crises one to another. Adoption of managerial decisions in the conditions of the simultaneous presence of several crises requires not only the definition of anti-crisis measures but also the coordination of their implementation in order to ensure the adequacy of the necessary resources and the prevention of the mutual negative effects of these measures. It is proposed to distinguish between the types of crises in the formation and substantiation of managerial decisions on the development of an industrial enterprise: a complex crisis, when all components of the crisis are internal; a complex crisis, when all components of the crisis are external; complex crisis, in which both internal and external crises are present at the same time.



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It is proposed to use a multidimensional oriented graph for building a system of anti-crisis measures, for each dimension in the direction of crisis measures, and the vertices of the graph are values of the indicators characterizing the crisis overcoming and enterprise development. A set of models for the description of various types of complex crises in the form of a multidimensional oriented graph is developed and methods for finding the minimal maple tree are determined, which is the optimal plan for realization of measures for the development of an industrial enterprise under complex crises conditions. When forming plans for the development of industrial enterprise, it was established that the stages of mastering the production of new types of products include the stages of updating the production equipment of development, therefore these measures can be combined. Thus, upgrading production equipment was carried out taking into account the need for equipment for the development of the production of new products. As a result of the calculation of the minimum connected map tree, which reflects measures for enterprise, a sequence of measures were taken in which the expenditures of resources and time are expected to be minimal.

### Goals and Objectives of the Research Study

This paper aims to help overcome the complex crisis of the industrial enterprise. The process is presented in the form of a graph, where the vertices correspond to the state of the enterprise, and the arcs-measures to change states. Each of the areas of anti-crisis measures can be represented by a separate layer of the schedule. Management means a separate component of a complex crisis or area of activity of the enterprise. In addition, in the case of complex external crises, we offer an additional layer of environmental conditions that change under the influence of the enterprise and have a reverse effect on the state of the enterprise.

The aim of the paper is to improve approaches to the presentation and analysis of anti-crisis measures, as well as the formalization of the process of building an anti-crisis strategy. This presentation facilitates the analysis of the anti-crisis strategy and can optimize measures by combining measures (combinatorial approach) that simultaneously solve crises in several areas.

The paper proceeds as follows. The first section is the introduction. The following section discusses the literature on the factors influencing the problems of building an effective anti-crisis strategy. The third section describes the research methods. The fourth section describes the research results and discussion. The last section presents the conclusion and future works.

## LITERATURE REVIEW

Crisis management is the process by which an organization deals with a disruptive and unexpected event that threatens to harm the organization or its stakeholders (Bundy & Coombs, 2017). Development of managerial decisions on the development of an industrial enterprise under complex crises conditions is a relatively new direction of crisis management, the vast majority of researchers consider the crisis as a homogeneous process.

Potential crises are enormous, but crises can be clustered (Coombs, 2014). James & Roberts (2009) categorizes five phases of crisis that require specific crisis leadership competencies: signal detection; preparation and prevention; containment and damage control; business recovery; learning.



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Each phase contains an obstacle that a leader must overcome to improve the structure and operations of an organization. James's research demonstrates how leadership competencies of integrity, positive intent, capability, mutual respect, and transparency impact the trust-building process (James & Roberts, 2009). During the crisis management process, it is important to identify types of crises in that different crises necessitate the use of different crisis management strategies (Coombs, 2014).

Lerbinger (1997) categorized eight types of crises: natural disaster; technological crises; confrontation; malevolence; organizational misdeeds; workplace violence; rumors; terrorist attacks/man-made disasters.

Artyukh-Pasyutay (2013) also considers various crises in the enterprise, investigates the crises depending on the spheres of activity in which they arise and the structure of relations, which is conditioned by the emergence of the crisis. Artyukh-Pasyuta (2013) proposes to consider the following spheres of activity of the industrial enterprise: marketing, production, management, personnel, financial. Depending on the structure of the relationship (Artyukh-Pasyuta, 2013), there are different crises: social (conflict of interests between different groups of employees), economic (caused by the economic condition of the enterprise), organizational (due to inconsistency with the environment of the structure, management rules, regulation of authority, etc.), psychological due to the psychological state of individual groups of workers), technological (due to differences between the technological capabilities of the enterprise and the needs of new technologies). The disadvantage of this study is the lack of suggestions as to how to develop managerial decisions for each of the specific types of crises at the industrial enterprise.

The techniques of crisis management include a number of consequent steps from the understanding of the influence of the crisis on the corporation to preventing, alleviating, and overcoming the different types of crises (Groh, 2014). Crisis management consists of different aspects including the response of perception of crisis; establishing metrics to define what scenarios constitute a crisis; the response of emergency management scenarios.

Solovyov (2013) proposes to solve the problems of developing management solutions under complex crisis conditions through a network approach, which makes time series analysis and conclusions about the network dimension of complexity. But the developed approach was adapted only to the analysis of financial crises through the construction of graphs of indices of the American stock market, at the same time, the question of analyzing indices of an industrial enterprise or other types of the crisis remained unnoticed.

In general, it can be concluded that, despite a significant number of studies on the problem of the development of an industrial enterprise under crisis conditional, most researchers consider the crisis as a homogeneous process, which does not take into account the possibility of imposing several different crises on one another.

## RESEARCH METHODOLOGY

Adoption of managerial decisions in the conditions of the simultaneous presence of several crises requires not only the definition of anti-crisis measures but also the coordination of their implementation in order to ensure the adequacy of the necessary resources and the prevention of the mutual negative effects of these measures.



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In addition, the definition of measures for the development of an industrial enterprise under complex crisis conditions and its coordination requires formalized tools for quantitative scientific substantiation of expediency and effectiveness of these measures. We propose to use a combinatorial approach to the sustainable development of an industrial enterprise under complex crisis conditions based on a set of models, which were developed using graph theory, optimization theory, and methods for finding the minimum connected tree of a graph using Liu-Chu or Dinitz algorithms.

## RESULTS AND DISCUSSION

When forming and justifying managerial decisions on the development of an industrial enterprise under complex crises conditions, it is proposed to distinguish types of complex crises:

*A complex crisis, when all components of the crisis are internal*

*A complex crisis, when all components of the crisis are external*

*A complex crisis, at which both internal and external crises are present*

Depending on the type of complex crisis, different types of solutions can be formed for the development of an industrial enterprise and there are various restrictions on the joint implementation of these solutions (Tarasova et al., 2018; 2019). Each managerial decision to develop an industrial enterprise under crisis condition consists of the steps to be implemented and the resources required for these activities, as well as the results that characterize the development of an industrial enterprise as a result of the implementation of the measures. The task of management is a combination of measures to achieve the desired results at a minimal cost of resources and time. The combination of managerial decisions on the development of an industrial enterprise under complex crises conditions is carried out using common universal instruments and with the use of specialized tools for each type of complex crisis. For each type of crisis, depending on its cause, appropriate groups of activities for the development of the enterprise may be offered.

For internal reasons such groups are: organizational measures related to the reforming and development of the organizational structure of the enterprise; personnel measures related to changes in staffing, human capital development, etc.; technological and technical measures that involve the development and improvement of production capacities; measures to improve the organization of resources.

It should be emphasized that these measures are aimed at overcoming the crises caused by internal reasons, for example, the improvement of production capacity in this aspect is due to their deterioration, and not because of non-compliance with market requirements. Similar measures, caused by external causes, are proposed to be considered separately.

For external causes of crisis phenomena, the following groups of measures are established at the enterprise: organizational measures caused by changes in the environment, for example, the need to reduce affiliates, or vice versa, to create new ones; technological and technical measures are conditioned by the need to meet the requirements of the competitive environment; marketing measures due to the need to stimulate the demand for products of an industrial enterprise; logistical measures to improve the interaction with suppliers and consumers for the transfer of raw materials



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and finished products; measures to lobby the interests of the industrial enterprise in the legislative and executive authorities.

So, some measures to overcome internal and external crises intersect in the direction, but differ in the reason that they must eliminate. Among the main differences that should be taken into account in determining measures for the development of an industrial enterprise in the context of external and internal crises is the presence of exogenous factors and the reciprocity. Development in the context of internal crises aims to overcome the problems that have arisen through endogenous factors, and also does not have a direct rapid impact on the external environment. Development in the conditions of external crises, on the contrary, is carried out in the conditions of constant interaction of the industrial enterprise with the external environment, while exogenous factors change both through their own processes, and due to the presence of feedback with the industrial enterprise. For example, marketing activities have a direct impact on consumers of industrial products.

Thus, to overcome the internal crisis, it is necessary to determine what measures can be taken to minimize the negative impact of endogenous factors and maximize the use of those opportunities that the crisis provides. One of the problems that arise in developing anti-crisis measures for the development of an industrial enterprise is the need to reconcile resources that are essentially the same for different measures in one direction. The second problem is the need to establish a sequence of activities, their distribution in time and mutual dependencies. To solve these problems, it is proposed to use the theory of graphs, through which quantitative justification of the sequence of implementation of anti-crisis measures can be made. To build a system of anti-crisis measures, an oriented graph should be used. Moreover, this should be a multidimensional graph, for which each dimension or layer is the direction of crisis measures (organizational, marketing, technological, etc.). The top of the graph is the meaning of indicators characterizing the crisis and business development. Some vertices may have connections in more than one dimension, if they are influenced by actions in different directions. The arches between the peaks are anti-crisis measures. An example of a multi-level graph of measures for the development of an industrial enterprise in conditions of internal complex crises is shown in Figure 1.

A graph of measures for the development of an industrial enterprise under internal complex crises conditions can be described by a set of vertices that correspond to the cutoffs of the states of the industrial enterprise, and a set of arcs, for which their cost in resources and in time costs is given. Under such a state of the industrial enterprise is meant the value of the indicator or several indicators, which are established for the corresponding direction of anti-crisis measures. For example, for the "technological and technical measures" direction, the degree of wear of industrial equipment or the industrial capacity of an industrial enterprise can be taken as an indicator.



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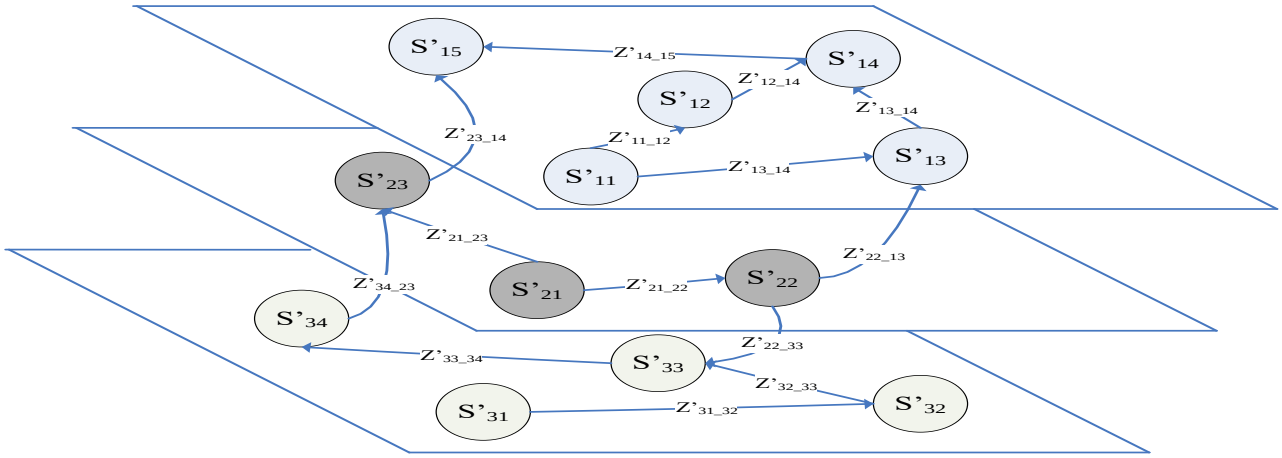


**FIGURE 1**

## AN EXAMPLE OF A GRAPH OF MEASURES FOR THE DEVELOPMENT OF AN INDUSTRIAL ENTERPRISE UNDER INTERNAL COMPLEX CRISES CONDITIONS

Thus, a model describing a plurality of managerial decisions regarding measures for the development of an industrial enterprise (Hroznyi et al., 2018; Kwilinski et al., 2019) under internal complex crisis conditions has the form:

$$S' = \{S'_{i,j}\}, i = 1, \dots, I, j = 1, \dots, J_i \quad (1)$$

$$S'_{i,j} = (H_{i,1}, \dots, H_{i,p} \dots, H_{i,P_i}), p = 1, \dots, P_i \quad (2)$$

$$Z' = \{Z'^{u}_{i,j_{k-d}}\} \quad (3)$$

$$Z'^{u}_{i,j\_k,d} = (R^u, T^u) \quad (4)$$

Where,

$S'$ - A set of states of an industrial enterprise that characterizes the stages of the development strategy of an industrial enterprise under internal complex crisis conditions;

$S'_{i,j}$ - The state of the industrial enterprise that characterize the j-stage of the development strategy of the industrial enterprise under the internal complex crisis conditions on the i$^{th}$ direction of anti-crisis measures;

$H_{i,j}$ - An indicator that characterize the results of anti-crisis measures on the i$^{th}$ direction for the j-stage;

$Z'$ - A set of anti-crisis measures for the development of an industrial enterprise under internal complex crisis conditions;



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$Z'^{u}_{i,j\_k,d}$ - Anti-crisis measure for the transition from the j-state on the i$^{th}$ direction to the d$^{th}$ position on the k$^{th}$ direction;

$R^u$ - Resources required for the implementation of the u$^{th}$ anti-crisis measure in the transition from the j-state on the i$^{th}$ direction to the d-state on the k$^{th}$ direction;

$T^u$ - Time taken for the implementation of the anti-crisis measure on the transition from the j-state on the i$^{th}$ direction to the d-state on the k$^{th}$ direction;

$I$ - Number of directions of anti-crisis measures;

$J_i$ - The total number of stages of development of an industrial enterprise in the conditions of the internal complex crisis on the i$^{th}$ direction of anti-crisis measures;

$P_i$ - The number of characteristics used on the i$^{th}$ direction of anti-crisis measures.

In most cases $i = k$, because measures are planned on one of the anti-crisis directions. In the case of transitions between the directions of the link there is a logical, if $i \neq k$ then the cost of resources and time is zero $Z'^{u}_{i,j\_k,d} = \emptyset$. Each of the states or stages of the development of an industrial enterprise under crisis conditions can be achieved not necessarily by only one measure; the oriented graph has several possible minimally connected trees. For example, the result of "staff development" in the direction of staffing can be achieved both by training staff and recruitment of new workers with high qualifications.

To find the minimum connected tree on the graph of measures for the development of an industrial enterprise under internal complex crises conditions is proposed to use the Yongjin and Tenghong algorithms. These algorithms provide the ability to find the minimum binding tree for the oriented graph, but they are designed to assume that each arc graph has one quantitative characteristic. Therefore, for the transition from two characteristics to one, it is necessary to aggregate the indicator of resources and time to one indicator. It is suggested to do this by the formula:

$$K^u = \alpha^R \frac{R^u - 1}{R^{max} - 1} + \alpha^T \frac{T^u - 1}{T^{max} - 1'} \quad (5)$$

Where,

$K^u$ – Aggregate indicator that characterize the u$^{th}$ arc of the graph or the cost of resources for the corresponding anti-crisis measure;

$\alpha^R, \alpha^T$ – Coefficients reflecting the relationship between resources and time on the implementation of anti-crisis measures, $\alpha^R + \alpha^T = 1$;

$R^u$ – Resources required for the implementation of the u$^{th}$ anti-crisis measure;

$T^u$ – The time that need for realization u$^{th}$ anti-crisis measure;

$R^{max}$ – The maximum resource requirements that are among all anti-crisis measures;

$T^{maz}$ – The maximum time needs that are among all the anti-crisis measures.



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Thus, the developed model of the formation of a system of measures for the development of an industrial enterprise under internal complex crises conditions makes it possible to establish a sequence of implementation of the enterprise development plan by finding a minimal log tree on the graph. For the case of an external crisis, it is necessary to take into account the presence of external factors or states of external entities that are changing under the influence of anti-crisis measures being implemented by an industrial enterprise. That is, on the graph there is an additional dimension that reflects external states are shown in Figure 2. The outer states and connections with them are represented by dashed lines.

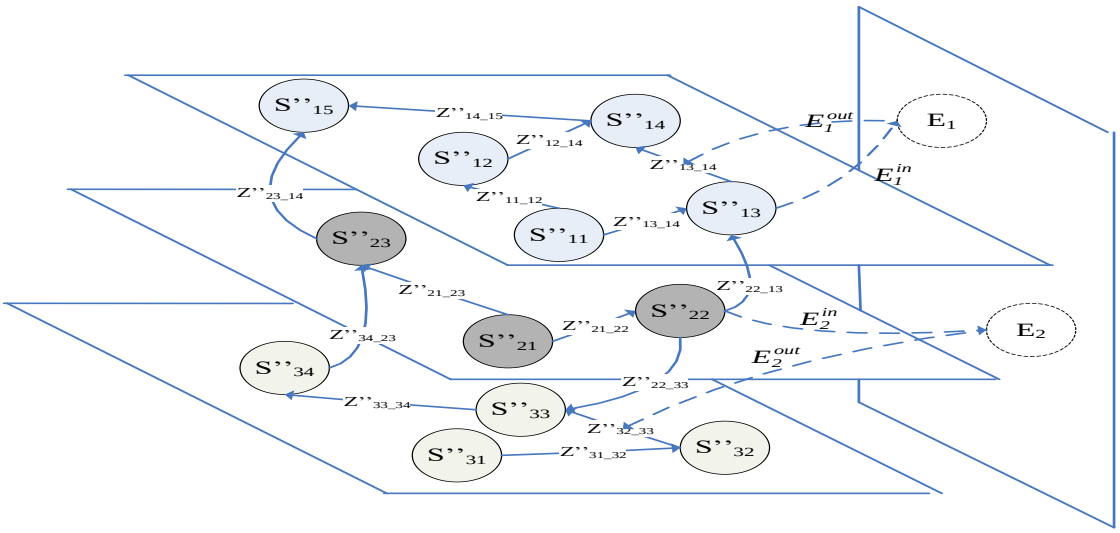


**FIGURE 2**

## AN EXAMPLE OF A GRAPH OF MEASURES FOR THE DEVELOPMENT OF AN INDUSTRIAL ENTERPRISE UNDER EXTERNAL COMPLEX CRISES CONDITIONS

A feature of external states is the change as well as changes in the state of the industrial enterprise. For example, if an industrial company has taken measures to develop the marketing sector, then competitors may lower prices for products, which will change the cost of resources for further measures of the industrial enterprise. Thus, the graph becomes dynamic.

The model describing the graph of measures for the development of an industrial enterprise under complex crises conditions has the form:

$$S'' = \{S''_{n,m}\}, n = 1, \dots, N, m = 1, \dots, M_n \quad (6)$$

$$S''_{n,m} = (H_{n,1}, \dots, H_{n,b} \dots, H_{n,B_n}), b = 1, \dots B_n \quad (7)$$

$$Z'' = \{Z''_{n,m\_f,g}(E_q)\}, q = 1, \dots, Q \quad (8)$$



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$$Z''^{w}_{n,m\_f,g}(E_q) = \left(R^w(E_q)T^w(E_q)\right) \quad (9)$$

Where,

$S''$ – A set of states of an industrial enterprise that characterizes the stages of the development strategy of an industrial enterprise under external complex crisis conditions;

$S''_{n,m}$ – The state of the industrial enterprise characterizing the m-stage of the development strategy of the industrial enterprise in the context of an external complex crisis on the n$^{th}$ direction of anti-crisis measures;

$H_{n,m}$ – An indicator that characterize the results of external anti-crisis measures on the n-th direction for the m-stage;

$Z''$ – A set of anti-crisis measures for the development of an industrial enterprise under complex external crisis conditions;

$Z''^{w}_{n,m\_f,g}(E_q)$ – Anti-crisis measure for the transition from the m-state on the n$^{th}$ direction to the g-state on the f$^{th}$ direction, which depends on the value of the external state $E_q$;

$R^w(E_q)$ – The resources necessary for the implementation of the w-th anti-crisis measure in the transition from the m-state on the n$^{th}$ direction to the g-state on the f$^{th}$ direction, which depend on the value of the external state $E_q$;

$T^w(E_q)$ – The time taken by the implementation of the w$^{th}$ anti-crisis measure for the transition from the m-state on the n$^{th}$ direction to the g-state on the f$^{th}$ direction and depend on the value of the external state $E_q$;

$N$ – Number of directions of anti-crisis measures;

$M_n$ – The total number of stages of development of an industrial enterprise under external complex crisis conditions on the n$^{th}$ direction of anti-crisis measures;

$B_n$ – Number of characteristics used on the n$^{th}$ direction of anti-crisis measures;

$E_q$ – The state of the q$^{th}$ external entity;

$E_q^{in}$ – Inverse effect of q$^{th}$ external entity;

$E_q^{out}$ – Input influence q$^{th}$ external entity;

$Q$ – The number of external entities that influence the development of an industrial enterprise under external complex crises conditions.

As in the case of finding solutions for development in conditions of complex internal crises, for the graph of measures for the development of an industrial enterprise under external complex crises conditions, it is necessary to find the minimum connected tree, which may be used by the Yongjin and Tenghong algorithms. But, unlike the classical variants of these algorithms, it is



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necessary at each step of the algorithm to recalculate the value of the cost of activities, depending on the states of external entities.

Thus, the developed model of the formation of a system of measures for the development of an industrial enterprise under external complex crises conditions makes it possible to establish a sequence of implementation of the enterprise development plan by finding the minimum connected tree on the graph and taking into account the reactions of external actors on the actions of the industrial enterprise.

In addition to cases of internal or external complex crisis, it is also possible that an industrial company faces simultaneously with both types of complex crises. At the same time, there is a problem of imposing measures on one another for the same direction for the external and internal crisis. For example, an industrial enterprise has a significant depreciation of production equipment, which is an internal crisis that requires measures in the field of technological and technological development. At the same time, competitors have more modern and economical equipment, that is, there is an external crisis, which also refers to the direction of technological and technological development. In such a situation, it is necessary to combine measures for the development of an industrial enterprise under external and internal crisis conditions.

In order to combine anti-crisis measures for external and internal crises, it is proposed to carry out a pairwise comparison of the state of the industrial enterprise within each direction of the anti-crisis development. To do this, it is necessary to compare the indicators which characterize the results of each pair of anti-crisis measures, and in the case when all the indicators of one state are included in the indicators of another, these states can be combined. An expression that compares pairs of states is represented as:

$$\Omega\left(S'_{i,j}, S''_{n,m}\right) = \begin{cases} S'_{i,j}, S'''_{n,m}, if H_{i,j} \neq H_{n,m} \\ S'_{i,j}, \ if H'_{i,j} \geq H''_{n,m} \\ S''_{n,m}, if H'_{i,j} \leq H''_{n,m} \end{cases} \quad (10)$$

$$i = n, j = m \quad (11)$$

$$n = 1, \dots N, m = 1, \dots, M_n \quad (12)$$

$$i = 1, \dots, I, j = 1, \dots, J_i \quad (13)$$

Where,

$S'_{i,j}$ – The state of the industrial enterprise characterizing the j-stage of the development strategy of the industrial enterprise under internal complex crisis conditions on the i$^{th}$ direction of anti-crisis measures;

$S''_{n,m}$ – The state of the industrial enterprise, that characterize the m-stage of the development strategy of the industrial enterprise in the context of an external complex crisis on the n$^{th}$ direction of anti-crisis measures;



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$H'_{i,o}$ – A set of values of indicators, that characterize the results of external anti-crisis measures on the i[th] direction for the j-stage;

$H''_{n,m}$ – A set of values of indicators that characterize the results of external anti-crisis measures on the n[th] direction for the m-stage.

Under the operator $\geq$ implies the result of qualitative evaluation in terms of enterprise development, if $H'_{i,j} \geq H''_{n,m}$ that means the indicator $H'_{i,j}$ is better than $H''_{n,m}$ or the same.

Thus, the graph, that reflecting a number of measures for the development of an industrial enterprise in a combination of external and internal crisis described by the model:

$$S = \{S_{e,v}\}, e = 1, \dots, E, v = 1, \dots V_e \quad (14)$$

$$S_{e,v} = \Omega(S'_{i,j}, S''_{n,m}) \quad (15)$$

$$Z = Z' \cup Z'' \setminus Z^{\Omega} \quad (16)$$

$$Z' = \{Z'_{i,j\_k,d}\} \quad (17)$$

$$Z'' = \{Z''_{n,m\_f,g}(E_q)\}, q = 1, \dots, Q \quad (18)$$

Where,

$S$ – A set of states of an industrial enterprise that characterizes the stages of the development strategy of an industrial enterprise in a complex internal and external crisis;

$S_{e,v}$ – The state of the industrial enterprise that characterizes v-stage of the development strategy of the industrial enterprise in the conditions of the internal complex crisis for the e[th] direction of anti-crisis measures;

$E$ – Number of directions of anti-crisis measures, which is the result of crossing the directions of anti-crisis measures of external and internal complex crises;

$S'_{i,j}$ – The state of the industrial enterprise that characterizes the j-stage of the development strategy of the industrial enterprise under internal complex crisis conditions for the i[th] direction of anti-crisis measures;

$S''_{n,m}$ – The state of the industrial enterprise characterizing the m-stage of the development strategy of the industrial enterprise in the context of an external complex crisis for the n-th direction of anti-crisis measures;

$\Omega(S'_{i,j}, S''_{n,m})$ – An operator that compares a pair of states $S'_{i,j}$ and $S'_{n,m}$;

$Z$ – A set of anti-crisis measures for the development of an industrial enterprise under complxed internal and external crisis conditions;



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$Z'$ – A set of anti-crisis measures for the development of an industrial enterprise in an internal complex crisis;

$Z''$ – A set of anti-crisis measures for the development of an industrial enterprise under complex external crisis;

$Z^{\Omega}$ – A set of anti-crisis measures for the development of an industrial enterprise, the stages of which were reduced during processing by the operator $\Omega$;

$Z'_{i,j\_k,d}$ – Anti-crisis measure for the transition from the j-state on the i$^{th}$ direction to the d-stage on the k$^{th}$ direction;

$Z''_{n,m\_f,g}(E_q)$ – Anti-crisis measure for the transition from the m-state on the n$^{th}$ direction to the g-state on the f$^{th}$ direction, which depends on the value of the external state $E_q$;

$Q$ – The number of external factors influencing the development of an industrial enterprise under the external complexity of the crisis.

Consequently, the developed model of the system of measures for the development of an industrial enterprise under complex external and internal crises conditions enables to optimize anti-crisis measures and plan the development of the enterprise with the simultaneous resolution of both internal and external crises.

## INTERPRETATION OF RESULTS OBTAINED

The general scheme of the implementation of a combinatorial approach to the development of an industrial enterprise under complex crises conditions is shown in Figure 3.

Thus, a set of models of the formation of a system of measures for the development of an industrial enterprise under complex crises conditions that can be internal, external or both internal and external, based on the presentation of anti-crisis measures as arcs of the oriented graph, and the state of development of the industrial enterprise as a result of the implementation of these measures, has been developed - as the vertices of the graph. This complex of models based on a combinatorial approach to the development of an industrial enterprise under complex crises conditions. Due to the use of the developed approach, a combinatorial planning of the development of an industrial enterprise under crises conditions can be carried out.



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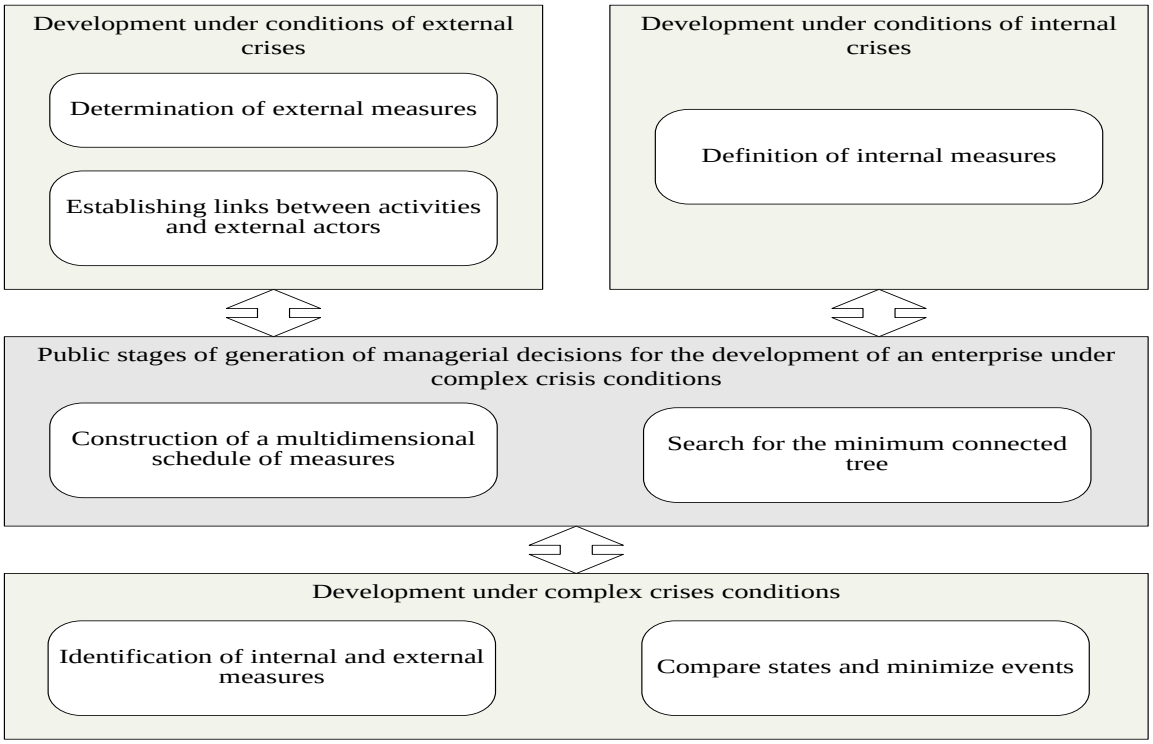


**FIGURE 3**

## IMPLEMENTATION OF A COMBINATORIAL APPROACH TO THE DEVELOPMENT OF AN INDUSTRIAL ENTERPRISE UNDER COMPLEX CRISES CONDITIONS

"Kerammash" PJSC was selected to verify the results of the study. The main products of the company are thermal equipment the demand of which depends on its efficiency and energy efficiency. The growth of energy prices in Ukraine is a source of crises for thermal equipment manufacturers. Improvements in production and technologies require the availability of skilled personnel. The situation with skilled labor force is worsening in Ukraine due to the outflow of "blue collar workers" to the West, which is a future source of crisis for PJSC "Kerammash". Thus, PJSC "Kerammash" operates in the conditions of frequent crises, which are superimposed on one another, therefore, especially requires the availability of modern methods for managing development under complex crises conditions.

At approbation of the developed complex of models of formation of system of measures for development of the industrial enterprise under complex crises conditions at PJSC "Kerammash" measures for the development of the enterprise under conditions of simultaneous external and internal crises were considered are shown in Table 1.

**TABLE 1**



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| MEASURES FOR ANTICRISIS DEVELOPMENT OF PJSC "KERAMMASH" | | |
|---|---|---|
| The direction of anti-crisis measures | Aggregate anti-crisis measures for external crises | Aggregate anti-crisis measures for internal crises |
| Technological and technical | Mastering the production of new types of products | Upgrade of production equipment |
| Marketing | Participation in exhibitions in Belarus and Kazakhstan | - |
| Personnel | - | Professional development of workers |

The external crisis, which adversely affects the development of PJSC "Kerammash", has a manifestation in reducing sales volumes due to the high cost of production of the company in comparison with competitors and the overall decline in economic activity.

The external crisis needs to be addressed in two directions. The first direction is technological and technical measures that are conditioned by the need to meet the requirements of the competitive environment. This direction concerns the development and introduction into production of new types of products. First of all, it is a regenerative burners and that is more effective than conventional burners and provides a competitive edge in the market for gas ovens. There is also a demand for such products as cremator-insinerator and coloring chambers, the development of which will allow PJSC "Kerammash" to enter new markets and increase sales volume. The second direction of overcoming the external crisis is marketing measures, due to the need to stimulate demand for products of industrial enterprises. This is a participation in exhibitions in Belarus and Kazakhstan, which is expected to compensate for the decline in demand for products from PJSC "Kerammash" by Russian industrial enterprises.

The internal crisis at PJSC "Kerammash" manifests itself in the exhausted part of the production equipment of the resource, which for a considerable time was not renewed and not upgraded and lack of skilled personnel. In order to address the problem of outdated and worn production assets, measures are planned to purchase new production equipment (magnetic drilling machine, equipment for turning and drilling) and modernization of existing production equipment (gas equipment, turning equipment, ventilation systems).

The manpower crisis has a manifestation in the retirement of highly skilled working design units. In order to solve the personnel crisis, workers' skills training was carried out.

## CONCLUSIONS

It has been established that traditional approaches to enterprise development under crisis conditions are not effective in imposing several crises one to another. To solve this problem, a combinatorial approach to the development of an industrial enterprise under complex crisis conditions has been developed, based on a set of models that provide representation of anti-crisis measures as an arc-oriented graph, and the state of development of an industrial enterprise as a



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result of the implementation of these measures- as vertices of the graph, the use of which is provided by combinatorial planning of development of the industrial enterprise under complex crises conditions.

When forming plans of development of PJSC "Kerammash" it was established that the stages of mastering the production of new types of products include the stages of updating the production equipment of development, therefore these measures can be combined. Thus, upgrading of production equipment was carried out taking into account the needs for equipment for the development of the production of new products. As a result of calculation of the minimum connected map tree, which reflects measures for PJSC "Kerammash", a sequence of measures was taken in which the expenditures of resources and time are expected to be minimal.

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