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LOGISTICS CONTROL OF THE RESOURCES FLOW IN ENERGY-SAVING PROJECTS: CASE STUDY FOR METALLURGICAL INDUSTRY

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Keywords: energy-saving, metallurgical enterprise, logistics management, resource flow
Abstract: The multilevel model for the formation and assessment of resource flows of a metallurgical enterprise is presented, which, at the logistics positions, reconcile the enterprise flow processes at all management levels, providing procedures for regulating the parameters of material and financial flows due to parametric and structural coordination in the short period of time and system coordination and adaptation of goals in the long term period. Drawing on the theory of logistics, it is possible to define the resource flow in project management as an aggregate of the enterprise's own and attracted resources, considering in the process of interconnected and interdependent changes and movements carried out to achieve the objectives of the project. Optimization models of rational options selection for attracting additional resources, which allow implementing energy-saving projects under conditions of suspending finances at definite time periods due to a change in the project implementation schedule are described.

1 Introduction

Metallurgical enterprises are large consumers of electric and thermal energy [1,2], therefore, solving energy conservation problems is impossible without the development of a comprehensive program and projects portfolio in the main areas of energy conservation with their mandatory coordination with the development program of the main production.

The metallurgical industry characterized by the complexity of processes and it's important to provide their efficiency [3], productivity [4], and continuous improvement [5,6]. Therefore, process planning, simulation tools, and implementation techniques are the first-priority issues for the industry [7-9], particularly within the Industry 4.0 strategy [10,11]. The trend for enterprises is the development and implementation of process-oriented management systems that support the life-cycle of products [12,13] and satisfy the requirements of the market [14].

This in its turn, requires an integrated approach to the formation of an effective system for resource flows managing of projects and programs aimed at selecting the volume, cost and time of attracting some resources to the corresponding parameters of other resources; multi-project dynamic planning of the realizability of various complexity work on scarce resources accounting risks; balancing the flow and usage of resources [15,16].

Project resourcing management is a target impact of process participants on the variable characteristics of resource flows to achieve their goals by reallocating resources [17]. The object of actions in the project's resourcing management system is the process of movement of resource flows aggregate, the subject (matter) is a closed cycle of resources' spending and renewal, and the performer is the participants of the project management process. This position reflects a systematic approach to the formation and management of resource flows aggregate, which should ensure the optimal ratio of cost and quality of service of internal and external consumers due to the dynamic stability of the integral characteristics and indicators of each flow, synergies of their aggregate and adaptability in the external environment. Flow processes are the main objects of the study of logistics. The specificity of logistics is as follows: the choice of a single function to manage disparate material and other flows; integration of individual parts of the logistics chain into a single system that provides effective management of flow-through material and other flows. The concept of logistics is a system of views on improving the efficiency of enterprises based on the optimization of flow processes.

One of the most important and difficult stages of managing the resource flows of a project portfolio is its optimization [18]. Enterprise resource optimization in the process of project management consists of the selection of indicators reflecting efficiency, a measuring tools system of consumed resources and optimization methods (of solution options at resource flows management).

The most common methods to obtain optimal values of financial or resource markers are linear and nonlinear programming [19]. Difficulties of such models' implementation in practical situations are often associated with the choice of a specific type of target function from a variety of known ones, as well as with the complexity of determining and processing preferences.

Complex planning tasks, as a rule, are differed by extremely computational complexity, and the search for an "optimal" solution cannot be completed within a reasonable time. In addition, several goals that often conflict with each other, are usually pursued at the same time (lowering the volume of overdue works, increasing the resource utilization ratio, etc.).

Thus, in practice, it is necessary to find a satisfactory (rational) solution in which these goals are balanced and can be obtained with minimal computational expenditures. Therefore, in practice, heuristic algorithms of scheduling within the limited resources are used.

Tasks of constructing calendar plans for project implementation, which are mainly associated with the distribution of limited resources, constitute a significant part of the models and methods of project management [20].

The tasks of accounting and distribution of resources are reduced to the construction of such resource consumption schedules for all works of the pre-investment and investment stages of the project. They satisfy the accepted criteria of achieving the set goals and which are the best. Depending on the accepted criterion of optimality of goals, one can distinguish [19]: the tasks of minimizing deviation from the given deadlines (or minimizing the deadlines themselves) of the implementation of the complex of works or a group of complexes at limited resources; tasks of minimizing the need for resources at specified deadlines; tasks with mixed criteria.

An analysis of the existing methods and models of resource flows management of the enterprise project portfolio showed that an integrated approach is required for the formation of an effective system for managing the resource flows of the portfolio of energy saving of the metallurgical enterprise that is aimed at selecting the volume, cost and time of attracting one kind of resources to the corresponding parameters of another kind of resources.

2 Methodology

The essence of the process of increasing the energy efficiency of production lies in the reduction of energy-specific consumption for production, rationalization of energy use regimes, change the structure of energy consumption, increase of environmental efficiency of production [21,22]. Purposeful conceptual management of the process of the resource base and expenditure obligations' formation is necessary for effective management of the resource flows of the energy-saving projects portfolio of a metallurgical enterprise, the outline representation of which is shown in Figure 1.

The main objective of effective management of financial flows is the complete and punctual provision of the necessary volume of financial resources to the set dates from guaranteed sources of financing. The object of this provision within the enterprise is the process of financing of the enterprise project activities in order to increase realization and efficiency and optimization of the movement of financial flows of the enterprise in order to increase its financial stability on the whole. Hence, when forming the investment resources of a portfolio of enterprise development projects, one should calculate the impact of their formation on financial stability and current solvency.

For the implementation of the concept of financial flows effective management, it is necessary to solve problems, associated with the structuring of the underlying flows, determining their characteristics, choice of instruments of action, development of response mechanism to changes of the internal and external environment parameters.

Modeling of financial processes helps to understand the general relationship of the characteristics of flows and determine the points at which control action should be directed.

The main task in the development of a model for financial flows management is the organization of movement of financial flows in a rational, for the enterprise and its projects portfolio, way. Flow control is carried out through the control of their speed, power, direction, periodicity, and other parameters. In this case, it is important to optimize the consistency of flows among themselves, i.e. the movement of the financial flows must be interfaced with information, material and other flows in a certain way.

Therefore, the resource flow management system should provide the maximum positive balance of financial flows, allowing composing a financial strength supply for the portfolio of energy-saving projects of the enterprise.

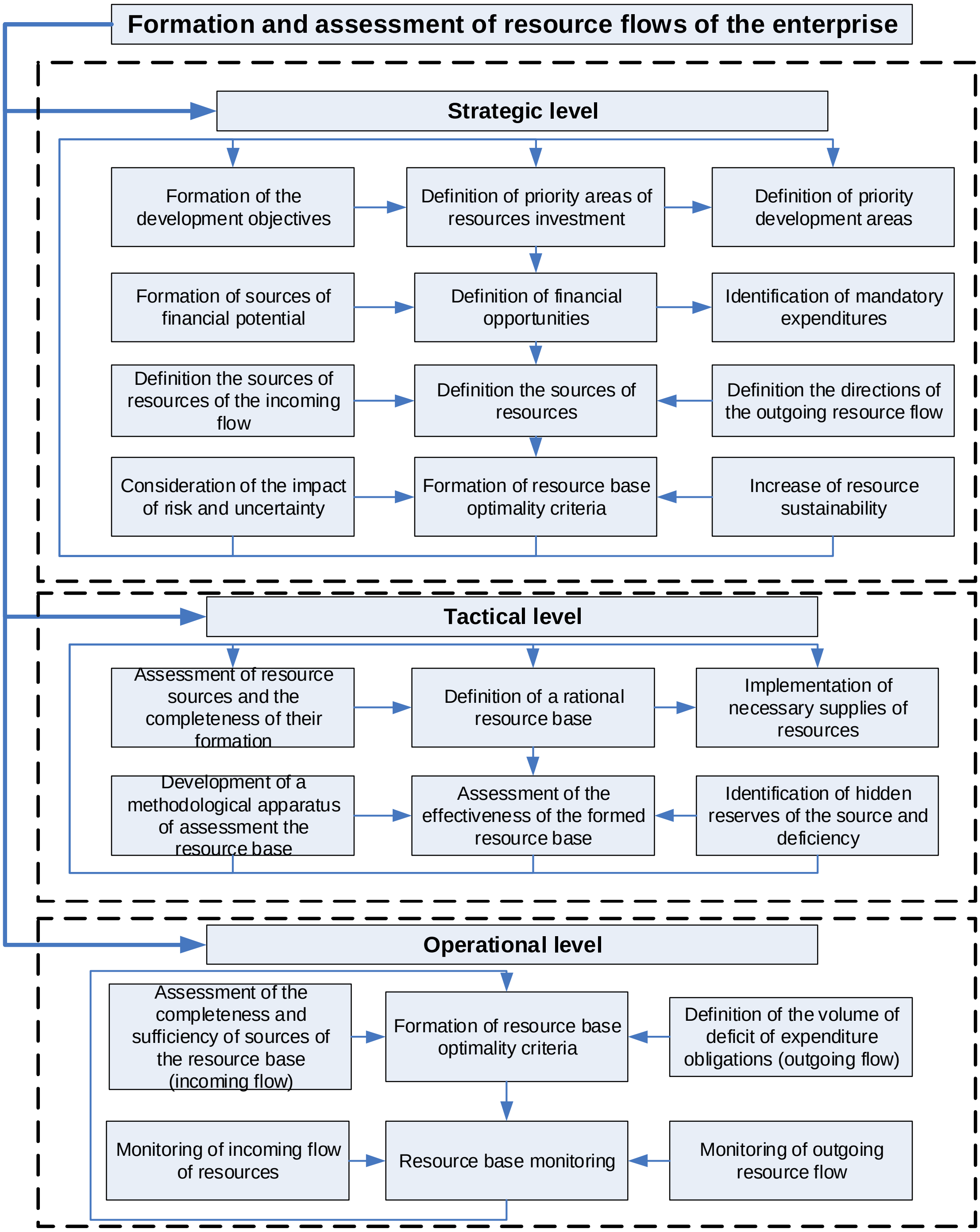

Figure 1 Multilevel model of formation and estimation of enterprises resource flows

The main sources of financing of the energy-saving project for various types of resource deficiencies are to be defined:

- in case of technology deficiency, possible ways to attract additional investment are: credit activities, the additional issue of securities;
- in case of equipment deficiency, possible ways to attract additional investment are: credit activities; stocks and bonds; leasing (installment purchase);
- in case of personnel deficiency, possible ways to attract additional investment are: credit activities; short-term bonds;
- in case of resources deficiency for the implementation of business processes, possible ways of attracting additional investments are credit activities, short-term bonds.

When implementing energy-saving projects at domestic metallurgy enterprises in modern conditions

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there is often a deficiency of financial resources and as a result, companies cannot ensure the dynamics and plans of the energy strategy even on the basis of frontier capabilities (Figure 2).

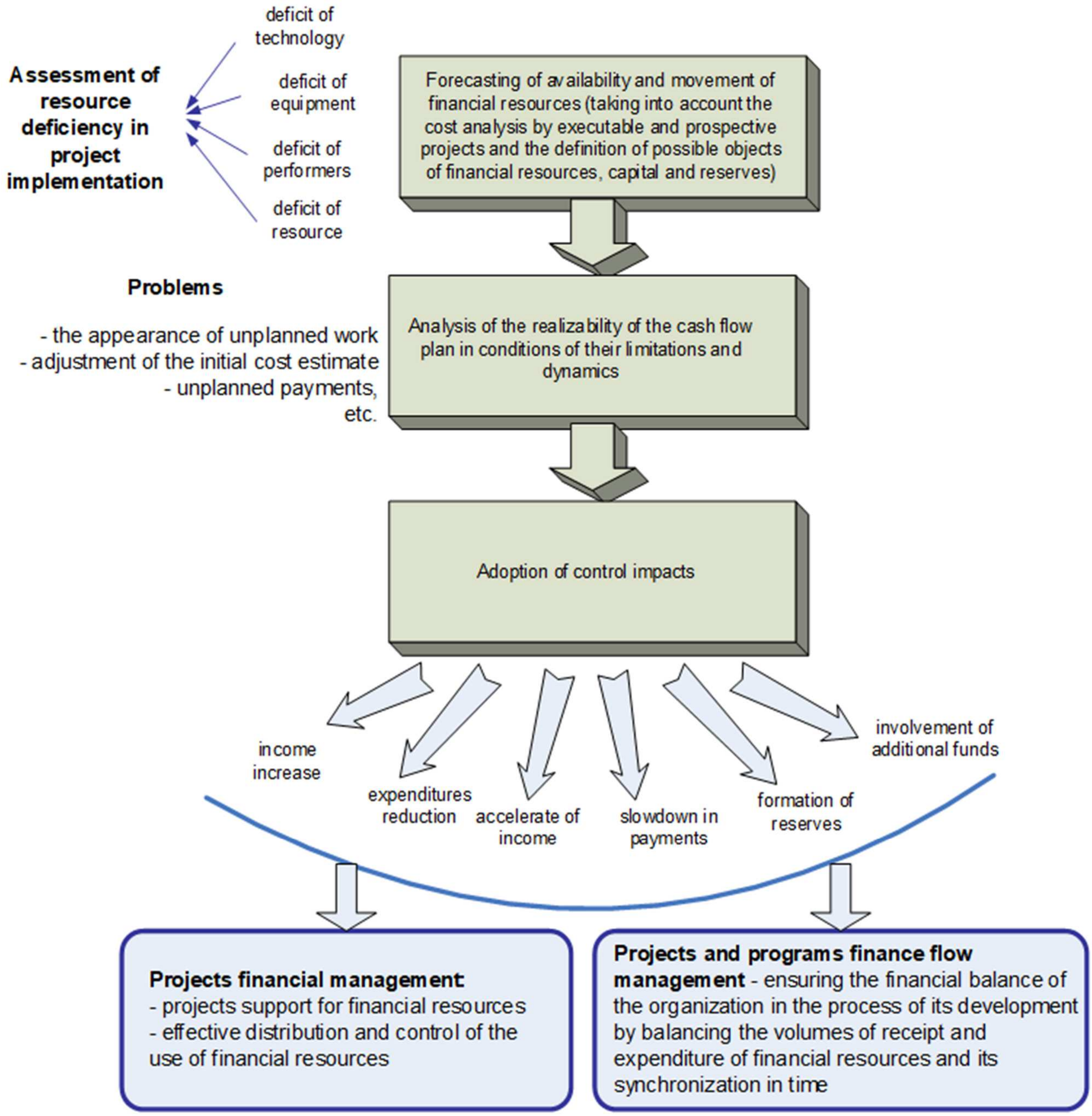

Figure 2 Extended scheme of management of financial flows while projects' portfolio realization

The deficiency of financial resources and the urgent necessity of energy-efficient re-equipment make it urgent optimization of the capital structure and reduction of risks, as well as provision of financial needs with appropriate sources (own and loan).

The search for financing options for the portfolio of energy-saving projects can be formulated as the task of choosing the ratio of types of financing from available own, loan and attracted funds, in which it is necessary to obtain the maximum value of the net present income and the minimum risk level.

Thus, the formation of an energy-saving portfolio should be based on the selection of projects. Four key objectives should be taken into account, deciding on the acceptability of one or another source of project financing: maximization of energy efficiency; maximization of profit generated by the project; minimization of cost for attracting a particular source of funding; reduction of risks that accompany the implementation of each specific project.

It is assumed that all the resources necessary for the implementation of projects are presented in terms of value. Figure 3 shows the scheme of optimization of the financing of the energy-saving projects portfolio of the enterprise. The proposed system allows optimizing the financing of the project within a consistent and parallel scheme of work performance under conditions of finance deficiency.

In the case of a consistent work performance option, in the event of a finances deficiency, it is proposed to move the deadlines of work performance for future periods, i.e. "Freeze" the stages without affecting the sequence of their implementation.

Also, partial financing is possible with this option, i.e. when the shared payment of work depends on the availability of financial resources.

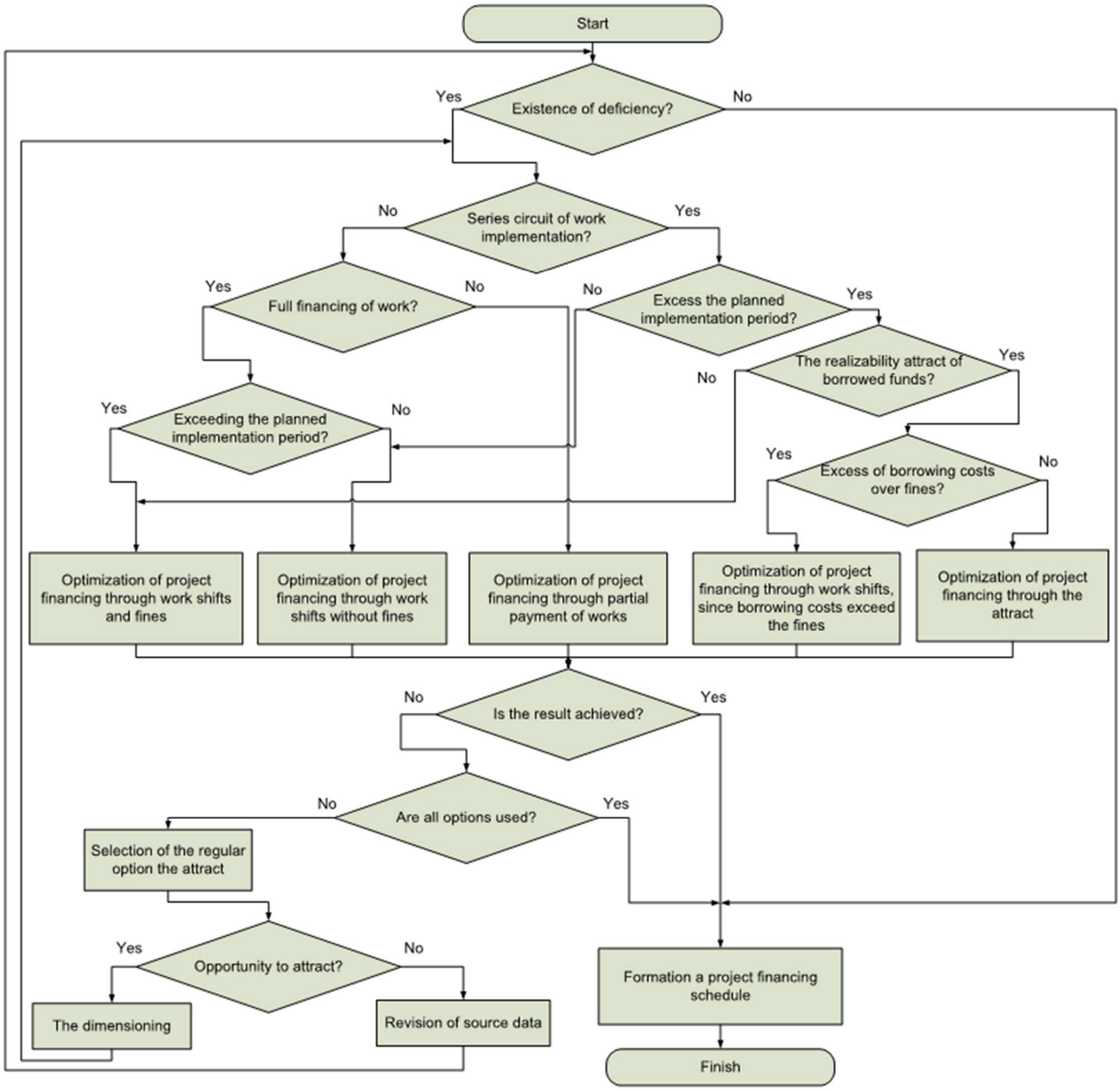

Figure 3 Optimization scheme of enterprise projects' portfolio financing

In the second option, in case of deficiency of financial resources, it is proposed to convert the planed version of the implementation schedule, including branches with parallel execution of work stages, using changes in the financing of the project stages, including the delaying of financing till later period, attracting of loan finances and accounting for penalties (losses caused by the "freezing" of the works will be taken into account in the model through a penalty simulated by the penalty function).

The metallurgical enterprise project portfolio will be associated with the vector PPR (project portfolio review) which in its size corresponds to the number of projects in a great number of projects under consideration $P=\{P_1,P_2,...,P_n\}$, which values are binary pp_i, where 1 means that i - project is included in the portfolio, 0 means that i -project is not included in the portfolio. Thus, for example, projects that cannot be excluded from the portfolio under any conditions are set this way.

Each project that is a part of the portfolio $i \in P$ is a management object and has a number of characteristics that require clarification and formalization. The totality of energy efficiency projects of a metallurgical enterprise, or project portfolio is also a management object and has parameters such as profitability, risk, implementation time, required resources, etc. Moreover, the implementation of each project affects the implementation of other projects included in the portfolio, and thereby affects the parameters of the entire project portfolio. Taking into account the absolute significance of the characteristics of each of the projects included in the portfolio, it should be noted that the strategic competitiveness and development of the enterprise depend on the characteristics of the entire project portfolio.

The project can formally be presented in accordance with the directions of increasing energy efficiency of an enterprise in the form of a combination of the following components (1):

$$P_i = \langle X_i, W_i, R_i \rangle, \tag{1}$$

where X_i – vector of initial characterization i -project; W_i – is the vector of characteristics of the attractiveness and feasibility of the project; R_i is total project risk..

The vector of initial characteristics of the project can be represented as (2)

$$X_i = \langle C_i, Y_i, S_i, H_i, T_i, R_i, I_i \rangle, \tag{2}$$

where C_i – the objectives of the project; Y_i – a complex of work on the project; S_i – required financial investments in the project; H_i – a resource intensity of the project; T_i – the expected time of the project implementation; I_i – a vector of mutual influence on other projects in the portfolio. In the vector of mutual influence I_i coefficients are put down, which can take values from 0 to 1, showing the level of dependence of project i on other projects portfolio.

The analysis significant step is the grouping of the projects into a portfolio on the following aspects: from the point of view of energy efficiency goals, finances, conditions (resources).

Attractiveness indicators along with realization are used for this realization which in complex reflect the capacity of project implementation at the particular enterprise, considering the enterprise's activity strategic directions, resource, financial and temporary support (3).

$$W_i = \langle SC_i, E_i, SR_i, HR_i \rangle, \tag{3}$$

where SC_i – index of conformity to the enterprise strategic goals and to the improvement of energy efficiency during the project implementation; E_i – project economics indicators; SR_i – project financial realization; HR_i – project resource realization.

The objectives of the project C_i are formulated as a set of indicators indicating their values that should be achieved as a result of the project $\{K_j^{P_i}\}$.

Further, it is possible to implement a comparison of the values of the energy efficiency strategy indicators $\{K_j^{Str_i}\}$ with the corresponding project parameters $\{K_j^{P_i}\}$.

The compliance indicator $SC_j^{Str_i}$ is considered for all strategic goals in the four projections indicated.

If the parameter $K_j^{Str_i}$ is absent in the project description, and then the compliance indicator $SC_j^{Str_i}$ or the strategic goal Str_i is zero.

Otherwise, the target values of this indicator in the project $K_t^{P_i}$ and the strategy $K_t^{Str_i}$ are compared taking into account the current value (at the time t) of this indicator for the enterprise (4) K_t^E:

$$SC_t^{Str_i} = \frac{K_t^{Str_i} - K_t^E}{K_t^{P_i} - K_t^E}. \tag{4}$$

The strategic conformity of the project with respect to the energy efficiency strategy Str_i can be calculated by averaging the estimates by individual indicators after determining the conformity assessments according to individual parameters (5):

$$SC^{Str_i} = \frac{1}{N_{KPI}^{Str_i}} \sum_{t=1}^{N_{KPI}^{Str_i}} SC_t^{Str_i}, \tag{5}$$

where $N_{KPI}^{Str_i}$ – is the number of indicators in the description of the strategy Str_i.

This is suitable if only one strategic objective is assigned to each project. In reality, a situation with several goals is possible. In this case, after determining conformity assessments by each goal, the strategic conformity of the project P_i can be calculated by averaging the assessments SC^{Str_i} by individual indicators. The importance of strategic objectives by introducing weight coefficients, which can be obtained by expert way using the method of analysis of hierarchies or a pair comparisons method should be taken into account. In case N_i^{Str} of strategic goals is associated with each portfolio project, the compliance index is calculated as follows (6)

$$SC_i = \frac{1}{N_i^{Str}} \sum_{k=1}^{N_i^{Str}} w^{\mathrm{Str}_k} SC^{Str_k} , \tag{6}$$

where w^{Str_k} – strategic objectives importance, wherein $\sum_k w_k^{\mathrm{Str}_i} = 1$.

Thus, an index of conformity of the project of the energy efficiency strategy is formed $SC_i \in [0,1]$, its values are interpreted as follows: $SC_i = 1$, if the project is fully in line with the strategy; $SC_i = 0$, if the project is not in line with the strategy; $0 < SC_i < 1$, if the project is partially in line with the strategy and is related to the development of the strategic potential of the enterprise.

Now consider the project financial realization. Denoting S^S – the volume of financing of the projects portfolio from its own resources. If $S_{PR} > S^S$ (significantly, as a rule) then the difference $D_{PR} = S_{PR} - S^S$, that represents the deficiency of funds for the project portfolio is funded by extrabudgetary sources – loans or raised funds, which naturally increase the value of the project portfolio.

In general, the structure of the expenditure of the project can be presented as a table, the fields of which reflect the payment of work j at a point in time t, for this it might be used $X_i = \| x_{ji}^t \|$ – matrix of financing of i-project, an element of which x_{ji}^t characterizes the payment of work j at a point in time t, where $\forall j, \forall t \;\; 0 \le x_{ij}^t \le 1$, $\sum_{t=1}^{T} x_{ij}^t = 1$.

NPV_i – net present value will be used as the main indicator for determining the economic efficiency of the project.

The net present value of the project is calculated (7):

$$NPV_i = \sum_{t=1}^{T} \frac{R_i - S_i}{(1+d_t)^t} , \tag{7}$$

where R_i, S_i – income and expenditure of funds in the project i during the projected period a $t = 1...T$; d_t – the discount rate in time t. It is obvious that for all projects that meet the necessary conditions of efficiency $NPV_i > 0$.

The financial resources flow is carried out in three types of activity: operational; investment; financial (Figure 4). Whatever source of financing is chosen, the amounts of finances received from the sources of funding and the amounts of finances paid to them should be indicated. Thus, the value of the discounted financial flow *NPV* will be adjusted depending on the type of funds involved.

The financing of the project works in absolute/monetary units is presented in the form of a matrix $C_i = \| C_{ij} \cdot x_{ij}^t \|$, where C_{ij} – the amount of money required for the payment of j-project's work.

In case of a deficiency, it is proposed to postpone payment of work and supplies for future periods, i.e. "freezing" the stages without affecting the relationship among their implementation, as a result of it the amount of delay for each job l_{ij}, is determined, which is calculated as the difference between the planned and actual end of work.

Losses caused by the "freezing" of works are taken into account in the model through the penalty, which is modeled by the penalty function $PN(E)$ and is subtracted from the pure, discounted *NPV* flow at all stages of the project. The penalty function for non-performance of obligations in time depends on the time of delay and comprises an additional amount of finances, sourced from the planned income. In general, the penalty function can be represented as follows (8):

$$PN(E) = \sum_{t=1}^{L} \frac{E^t}{(1+d)^{t+T}} , \tag{8}$$

where E^t – the amount of the penalty in absolute terms for the delay of the project in each of the periods under consideration; L – project delay term.

Since not all the delays in completing work lead to a delay in the entire project, not each delay will cause a penalty. This can be taken into account in the model using the concept of time reserve. Each project work corresponds to a full reserve of time for its implementation T_{ij}^f. Therefore, if the shift of work does not exceed the reserved time of its implementation ($l_{ij} \le T_{ij}^f$), that is, there is no delay in the implementation of the entire project, i.e. the enterprise implementing the project is not subject to penalty sanctions. If the shift exceeds the reserved time ($l_{ij} > T_{ij}^f$), then there is a delay in the completion of the project, therefore, the enterprise bears additional expenditures, which are modeled by the penalty function. These conditions can be described mathematically through the stability indicator и u_{ij} as follows (9):

$$u_{ij} = \begin{cases} 0, & if \ \forall j = 1,..,n_i^p \ \ I_{ij} \le T_{ij}^f \\ 1, & if \ \forall j = 1,..,n_i^p \ \ I_{ij} > T_{ij}^f \end{cases}. \tag{9}$$

In case of timely financing of the project work, the matrix X_i will be square-shaped; in case of untimely, it will be rectangular-shaped. Columns in the number L will be added to the source square-shaped matrix in case of untimely funding to the duration of the critical path T (10):

$$L_i = \sum_{j=1}^{n_i^p} (I_{ij} - T_{ij}^f) \cdot u_{ij} \ , \tag{10}$$

where L_i – project delay.

Elimination of the deficiency (a situation when there is a temporary shortage of financial resources necessary to finance expenditures) is possible not only by means of a "freezing" of the stages of the project but also by means of attraction of loan funds.

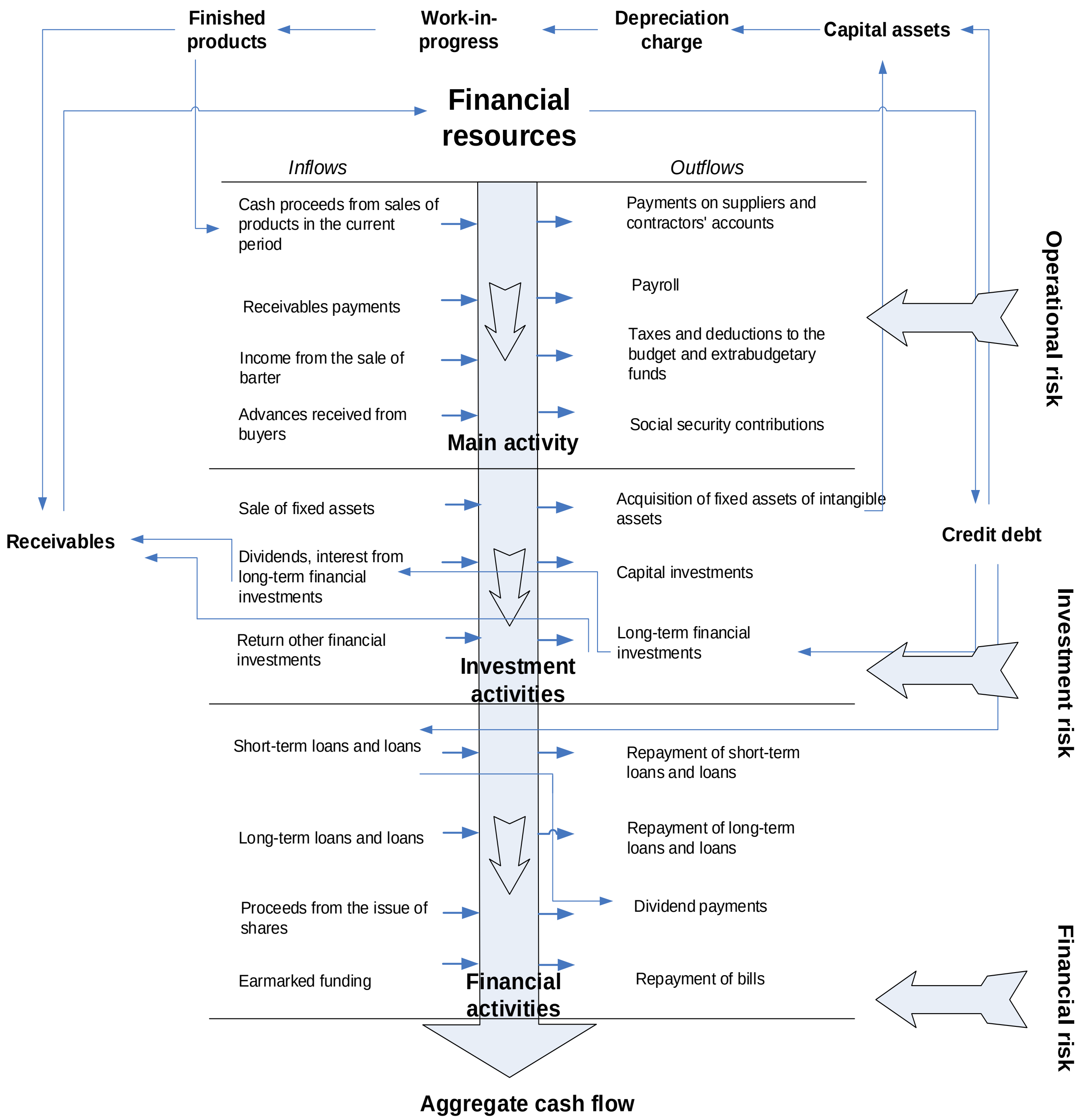

Figure 4 Formation of financial flow at the enterprise

The loan should cover not only the current deficiency but also provide the necessary minimum balance of the company's funds in each period. The choice of any other funding source will only affect the *NPV* calculation (11). The selected funding source set at each stage should ensure that funds are sufficient to finance the project.

By solving the problem, we can find a combination of financing sources in which the optimal portfolio will be obtained. The overall objective is to choose a portfolio PR_O, that has maximum efficiency

$$\sum_{i \in PR} NPV_i \to \max . \qquad (11)$$

To solve the problem, a method of optimization of the project financing schedule, which is based on a heuristic algorithm, is proposed (Figure 5).

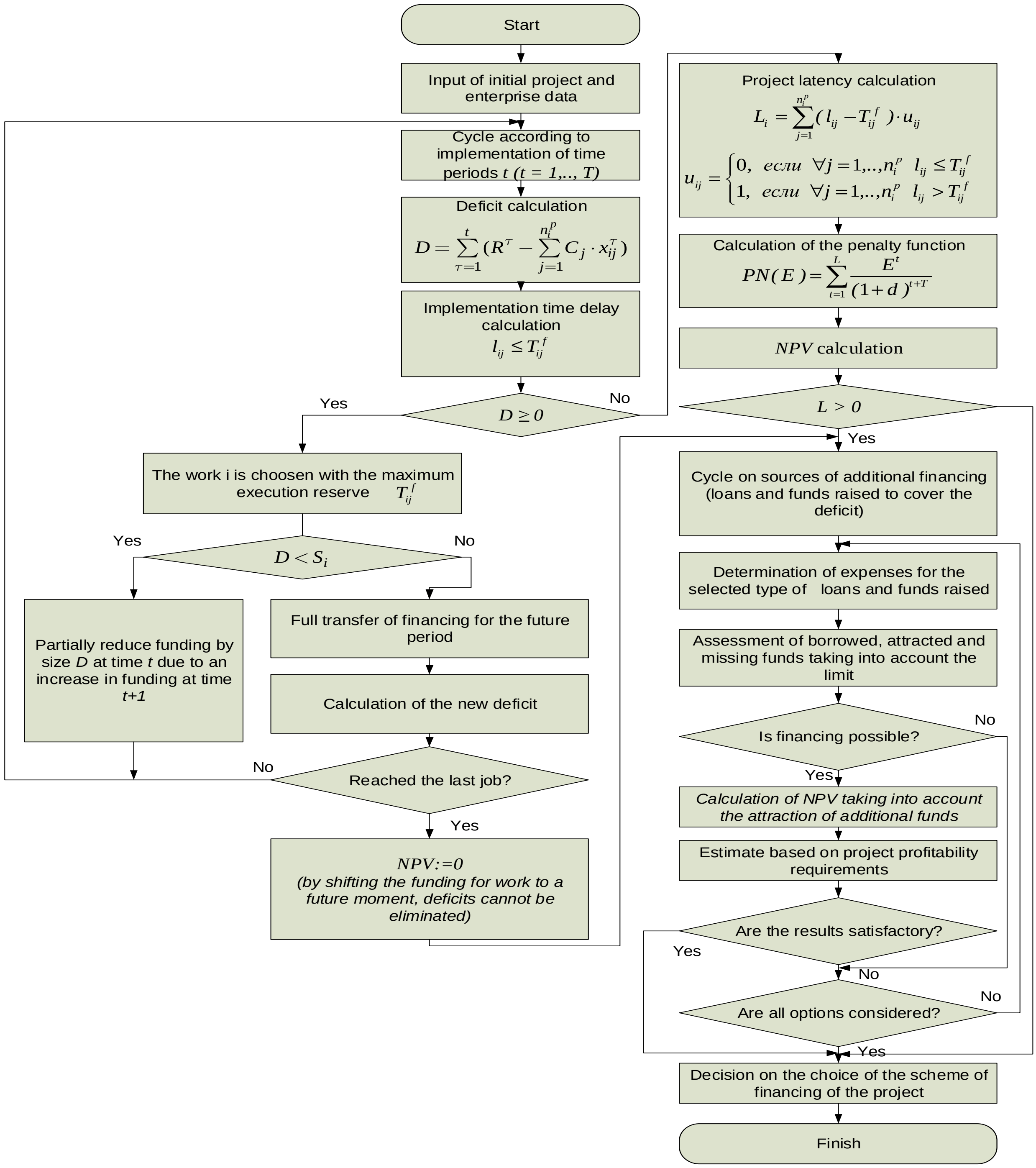

Figure 5 Scheme of optimization of financing of enterprise projects portfolio

3 Results and discussion

With the help of the proposed approach and models, the project portfolio for the energy saving of PJSC Dneprospetsstal (Zaporizhzhia) was formed, which included promising projects in accordance with the energy strategy. Thus, in the period from 2016 till 2018, the enterprise implemented energy-saving projects, some of which are presented in Table 1. It shows the purpose of the project, estimated and actual expenditures, as well as indexes of energy efficiency.

Table 1 Resource-saving results for the implementation of the energy-saving project portfolio

Project title	Project objective	The essence of the project	Predicted investments, thousand UAH	Actual expenditures, thousand UAH	Deviation	Energy efficiency
Thermal shop. Modernization of chamber furnace №10 with the replacement of lining, burners and automated control system	Reduce fuel consumption for heating and heat treatment of metal	Removal of existing furnaces. Works on restoration of foundation, energy supply to the furnaces. Manufacture, delivery, and installation of metal constructions of the furnace, lining, gas-burner equipment, natural gas, and air pipelines through the furnace, control and measuring devices and automation, cable routing through the furnace and connection. Startup and commissioning.	5518,3	5432,0	-86,0	*Savings on gas consumption - 426.4t.t/year* Annual economic effect 2566.3 thousand UAH
Heat recovery of waste gases from the GCF unit of the steelmaking shop SPC-2	Increase of energy security level of the enterprise, reduction of thermal energy expenditures and reduction of expenditures of non-productive nature	Installation of heat recovery system of waste gases from the GCF unit. The heat generated, will allow providing heating and water supply with hot water of SPC-2, the building of the substation	959,6	846,6	-113,1	*Savings on steam consumption - 652Gcal/year* *Saving on the consumption of hot water - 1880Gcal/year* *Annual economic effect 1630,23 thousand UAH*
Construction of a local electric boiler house based on nitrogen station	Increase of energy security level of the enterprise, reduction of thermal energy expenditures	Construction of a local electric boiler house with a thermal capacity of 270 kW for heating and hot water supply based on nitrogen station of the EC	1086,3	875,68	-210,21	Savings on steam consumption - 1074Gcal/year Energy efficiency savings of 154.5kWt/h Energy efficiency savings of 92,7kWt/hr Annual economic effect 570.76 thousand UAH
Total					-409,31	4767,29

In particular, within the frames of the first project from the table, the heating and thermal furnaces were modernized, which allowed to reduce the fuel consumption for heating and heat treatment of the metal by means of application of high-efficiency thermal insulation and impulse combustion control; automation of all heat processing processes, ensuring temperature maintenance with a mini-scale deviation.

The second and the third projects in the table are connected with the fact that PJSC Dneprospetsstal was buying steam and hot water for technological and sanitary needs at OJSC Zaporizhstal since it was the only supplier of steam and hot water in that part of the industrial site, Where the Dneprospetsstal plant is located. From the heat networks "Zaporozhstal" steam and hot water through distribution networks of the plant "Dneprospetsstal" came to consumers. One of the significant shortcomings of such a scheme was significant heat loss during transportation. This is because of the long-distance of the heat transport system, low thermal insulation properties of thermal insulation materials, significant wear of heat transport systems. In addition, dependence on a single supplier reduced the level of the enterprise's energy security, and the constant growth of the cost of heat energy increased non-production expenditures. The transition to an alternative method of heating of buildings and obtaining hot water in the second project through recycling the heat of the waste gases from the gas-oxygen refining unit (GCF), and in the third project through building a local electric boiler house allowed: to increase the level of energy security of the enterprise; to reduce the cost of heat energy; to reduce expenditures of non-productive nature.

4 Conclusions

The multilevel model of formation and estimation of resource flows of the enterprise is presented, which links the flow processes of the enterprise at all levels of management, providing procedures for regulating parameters of material and financial flows through parametric and structural coordination in the short-term period and system harmonization and adaptation of goals in the long term period.

The model of choice of directions of product development through the realization of projects taking into account the possibility of attraction of additional investments is considered.

Optimization models for selection of rational options for attracting additional investments are developed: a model with a delay in the execution of works, allowing to implement projects in conditions of suspension of financing in separate periods of time by means of a "freezing" of works; a model with partial financing of works, providing implementation of the project in conditions of delay of financing; a model with a parallel scheme of execution of works, taking into account the attraction of loans funds and the function of fines.

Further research will be focused on the development of an agent-based simulation model for analyzing the energy management processes of a metallurgical enterprise while implementing a portfolio of energy-saving projects. Using this model will allow analyzing projects consistently in order to identify the possibility of their implementation at the enterprise, to coordinate project implementation plans and enterprise plans at various planning levels.

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