

# Information models of tactical and operational planning levels in energy construction

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**Abstract.** The strategic, tactical and operational levels of energy construction planning are considered. The purpose of the article is to present information models for solving multi-criteria tasks of forming schedules of various types. For the first information model based on vector representations of aggregations, a multilevel classification of criteria and ranking algorithms for multi-criteria tasks is proposed. A structural analysis of criteria and ranking algorithms for multi-criteria tasks is carried out. Schemes of hierarchies of multiple inclusion of criteria and ranking algorithms for information planning models are presented. Recursive definitions of criteria and ranking algorithms are obtained. For the second information model, a heuristic paradigm of centralized scheduling is described for various types of presentation of source data, namely: sets of independent applications, sets of application vectors and sets of hierarchical or network structures of applications. The scheduling paradigm is based on the use of two schemes for generating schedules and priority rules. Using the first constructive scheme, the initial schedule is cyclically formed.

## 1 Introduction

Energy construction is concerned with the construction and maintenance of facilities associated with the production and transmission of energy. It plays a key role in ensuring energy security and sustainable development of the country. The construction of energy facilities contributes to economic development, creation of new jobs and attraction of investment. It stimulates the development of other industries such as construction, equipment manufacturing and transport.

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Planning for energy construction, like any other type of construction, includes the following levels - strategic, tactical and operational. Issues of strategic planning [1] are the prerogative of federal and regional authorities. The tasks of the tactical and operational planning levels are solved by the direct executors of energy construction. Returning to the initial phrase, it should be noted that there is a significant difference between the methods of planning the creation of energy facilities and planning their maintenance. What unites these different planning methods is the final result - calendar plans (schedules), that is, a time-distributed sequence of planned work, indicating the allocated resources. In general, such a sequence is a schedule. As precisely formulated by the authors, "planning is the optimal allocation of resources to achieve a set goal" [2]. Optimal resource allocation is also included in the range of issues solved by scheduling problems [3]. Also noted in [2] are the shortcomings of planning in energy construction associated with insufficient qualifications of performers and the lack of appropriate means of information support. To this must be added the lack of consideration of the multicriteria nature of planning problems, which is presented for the construction industry, for example in [4-6].

Thus, the purpose of this article is to present models of multicriteria scheduling problems of various types.

To achieve this goal, it is necessary to present two information models:

- hierarchy of criteria and ranking algorithms in multicriteria problems;
- paradigm for generating schedules of various types.

## 2 Hierarchy of criteria and ranking algorithms

Hierarchy as a geometric term describes the relative placement of parts and the whole. In general, hierarchy can be defined as "the position of parts or elements of a whole in an order determined by a relationship of interconnection." Interconnection relationships determine the type of hierarchy. For example, the dominance relation defines a hierarchy of generalization with order from the highest level to the lowest level. It is the hierarchy of generalization that is implied in most cases of use of the concept "hierarchy". This type of hierarchy underlies hierarchical ordering, the patterns of which were identified and studied by L. von Bertalanffy [7]. In further studies on general systems theory [8], instead of hierarchical ordering, operations of horizontal and vertical unification were proposed.

The relationship relationships "consists of", "is part of", "contains", define a hierarchy of inclusion with order from the lowest level to the highest level. Structurally, the hierarchies of a single inclusion are composite toys - Russian nesting dolls, Japanese Fukuruma [9]. An example of a hierarchy of a single inclusion is a tree, the levels of history of which are displayed by tree rings. The transition to each next level is associated with a change in the emergence of the tree system. Tree rings in the form of a set of concentric circles can be taken as a diagram of a multi-level hierarchy of a single inclusion, as shown by studies of an integrated university educational process management system [10, 11].

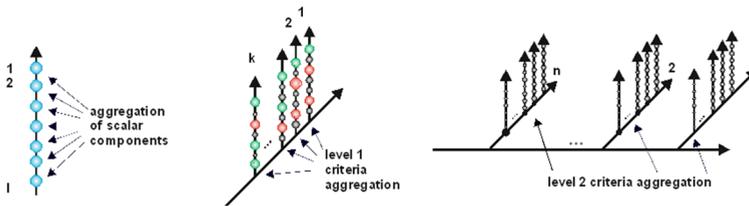
You can define two types of multiple containment hierarchies. The first type is based on a union, when one object is part of another object that contains it, for example, a car and its components. The second type of multiple inclusion hierarchy is based on aggregations. That is, within one object there is a set of objects that can exist on their own. For example, a home library includes bookcase/shelf aggregations and book aggregations. In this study, vector representations of aggregations will be used.

An important feature of complex systems is their multicriteria, due to the difference in the goals of individual subsystems and the requirements of the external environment [12, 13]. Multi-criteria decision making and multi-criteria decision analysis perform selection, comparison, classification tasks using multi-criteria ranking methods. When studying problems in well-structured systems of various types, selection criteria with vector

and multi-vector components are formed based on assessments (indicators, characteristics) [14]. The criterion is some function of the decision made. A function that allows you to quantify the feasibility of a solution. The specific value of the criterion characterizes the level of achievement of the goal, the effectiveness of the methods and means used. If a goal generally indicates the direction of action, then the criterion complements the concept of a goal and indicates an effective way to achieve it. The study [9] shows the existence of a hierarchical ordering of criteria and ranking methods.

Multilevel classification of criteria in multicriteria problems can be defined as follows (Figure 1):

- vector criterion of the 1st level – aggregation of scalar components;
- vector criterion of the 2nd level - aggregation of criteria of the 1st level;
- vector criterion of the 3rd level - aggregation of criteria of the 2nd level;
- etc.

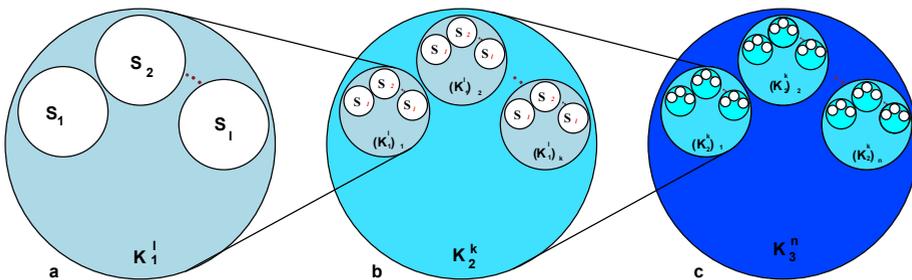


**Fig. 1.** Structure of the criteria: (a) - 1st level criterion; (b) level 2 criterion; (c) level 3 criterion.

The proposed classification of criteria is structurally a hierarchy of multiple inclusions of the second type. Let us introduce the following designations for the components of criteria aggregations:

- scalar –  $S$ ;
- vector criterion of the 1st level -  $K_1^l = \{S_i\}, i = 1, 2, \dots, l$ ;
- vector criterion of the 2nd level -  $K_2^k = \{(K_1^l)_i\}, i = 1, 2, \dots, k$ ;
- vector criterion of the 3rd level -  $K_3^n = \{(K_2^k)_i\}, i = 1, 2, \dots, n$ .

Visualization of the hierarchy of multiple criterion inclusions uses the concept of Euler-Venn diagrams. Circular representations (Figure 2) contain designations of criteria and specified quantities of their components.



**Fig. 2.** Hierarchy of multiple inclusion of criteria: (a) - 1st level criterion; (b) level 2 criterion; (c) level 3 criterion.

Using the introduced notations, we obtain a recursive definition of criteria for any levels.

$$K_n^j = \begin{cases} \{S_i\}, i = 1, 2, \dots, j & n = 1 \\ \{(K_{n-1}^k)_i\}, i = 1, 2, \dots, j & n > 1 \end{cases} \quad (1)$$

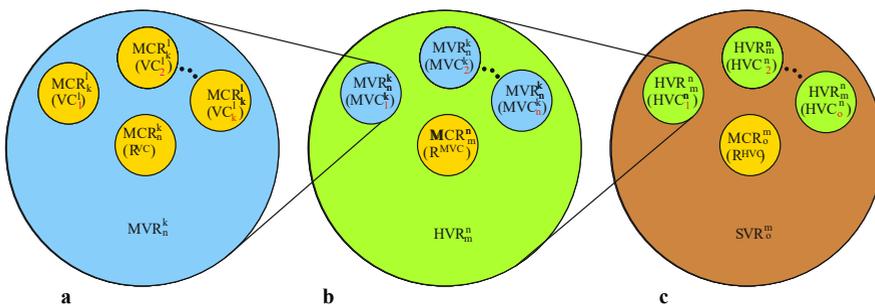
where  $K_n^j$  – nth level criterion;  $j$  – number of components of the nth level criterion;  $k$  – determined by the structure of the (n-1)th level criterion.

Diagram in Figure 2 represents a direct recursion of the introduced criteria. Expansion of the hierarchy of multiple inclusion of criteria (Figure 2) can be carried out by sequentially adding new levels to form criteria of a more complex structure. For example, you can predict a vector criterion of the 4th level containing an aggregation of a given number of criteria of the 3rd level.

Vector criteria of each level require multi-criteria ranking algorithms for the corresponding level. Let's add the following group of notations:

- $Fr_1^j\{(K_1^l)_i\}, i = 1, 2, \dots, j$  – multi-criteria ranking function of the 1st level returns an aggregation of  $j$  ranks of the 1st level  $R_1$ ;
- $Fr_2^j\{(K_2^k)_i\}, i = 1, 2, \dots, j$  – 2nd level multi-criteria ranking function returns an aggregation of  $j$  2nd level ranks  $R_2$ , formed by the 1st level ranking function from  $j$  aggregations of  $k$  ranks  $R_1$ ;
- $Fr_3^j\{(K_3^n)_i\}, i = 1, 2, \dots, j$  – 3rd level multi-criteria ranking function returns an aggregation of  $j$  3rd level ranks  $R_3$ , formed by the 1st level ranking function from  $j$  aggregations of  $n$  ranks  $R_2$ ;
- $Fr_4^j\{(K_4^o)_i\}, i = 1, 2, \dots, j$  – level 4 multi-criteria ranking function returns aggregation  $j$  4th level ranks  $R_4$ , cformed by the 1st level ranking function from  $j$  aggregations by  $o$  ranks  $R_3$ .

The study [3] shows the invariance of ranking algorithms, starting from the second level, in relation to the ranking algorithm of the first level, and therefore the hierarchy diagram of multiple inclusion of ranking algorithms (Figure 3) begins with the second level algorithm. The diagram (Figure 3) shows the forecast of the 4th level ranking algorithm (Figure 3.c). A detailed description of the studied algorithms is presented in [15,24].



**Fig. 3.** Hierarchy of multiple inclusion of multicriteria ranking algorithms: (a) - 2nd level; (b) - 3rd level; (c) - 4th level.

### 3 Creating schedules

Scheduling problems are the tasks of forming and optimizing the process of servicing a finite set of requests for actions in a system with limited resources [16]. The differences in tasks

are related to the nature of the connections between schedule actions and, accordingly, the connections between requests. Lots of requests:

- there can be many independent applications;
- may consist of subsets of request vectors;
- or subsets of hierarchical or network structures of applications.

The first type includes the tasks of creating class schedules, exams, duty schedules and the like. The second type is typical for tasks of operational calendar planning and the formation of transport schedules. The third type includes the tasks of creating project management schedules and multi-project planning. The specificity of the subject areas of research for each type of schedule determines the differences in models and methods for solving problems of creating schedules.

What all researchers have in common is the recognition of the NP complexity of scheduling problems and the need to find various heuristics that lower the order of exhaustive search operations. The multicriteria nature of scheduling problems is also noted.

Interesting, from the point of view of generalization, is the experience of multi-project planning [17, 18], in which the basis of heuristic approaches is the use of schedule generation strategies (SGS - schedule generation scheme) and priority rules (PR - priority rules). Priority rules are understood as specified sequences of techniques and methods for determining the order of work/projects competing in terms of resources. The priorities in this context are criteria that are scalar values of various characteristics of applications/works and projects, including allocated and required resources [19]. Priority rules predominantly use a single-criteria ranking of scalar priority values, which is most convenient for “manual” processing. One of the few works [20] presents a more complex ranking of project characteristics using the hierarchy analysis method. In studies on scheduling of other types of approaches, the use of scheduling strategies and priority rules was not found.

In the context of scheduling problems, the use of resource-oriented criteria for workload and uniformity is proposed in priority rules. Load criteria characterize the need for applications or sets of applications in system resources. The uniformity criteria determine the distribution of system resource consumption in the schedule interval. Both types of criteria have a complex structure, so the priority rules require the use of the ranking algorithms presented in Section 2.

The proposed paradigm for generating schedules of any nature for systems with limited resources is a heuristic, which is described as follows. To solve the problems of generating schedules, it is proposed to use two sequentially applied strategies:

- constructive strategy  $SGS_1$  – cyclical formation of the initial schedule (initial solution);
- optimizing strategy  $SGS_2$  – cyclic optimization of the initial schedule.

The  $SGS_1$  scheme uses two priority rules  $PR_{11}$  and  $PR_{12}$ . In each  $SGS_1$  cycle the following is carried out:

- preparation of initial data for rule  $PR_{11}$  - determination of criteria for the workload of applications or sets of applications;
- in rule  $PR_{11}$ , the most loaded application or set of requests in terms of required resources is selected among those not included in the initial schedule;
- determination of times or time intervals for inclusion of an application or a set of applications selected by rule  $PR_{11}$ ;
- preparation of initial data for rule  $PR_{12}$  - determination of criteria for the uniformity of the initial schedule in the execution interval of the request or set of requests selected by rule  $PR_{11}$ ;

- rule  $PR_{12}$  determines the start time of execution of an application or a set of applications in the initial schedule, ensuring the greatest uniformity in the consumption of system resources.

The scheme is completed by including all requests or sets of requests in the initial schedule. Depending on the type of workload and uniformity criteria, rules  $PR_{11}$  and  $PR_{12}$  use appropriate ranking algorithms.

The  $SGS_2$  scheme also uses two interrelated priority rules  $PR_{21}$  and  $PR_{22}$ . In each  $SGS_2$  cycle the following is carried out:

- preparation of initial data for rule  $PR_{21}$  - determination of criteria for the uniformity of actions or a set of schedule actions;
- in rule  $PR_{21}$ , the most uneven resource consumption action or set of schedule actions is selected;
- determination of times or time intervals for rearranging the action or set of schedule actions selected by rule  $PR_{21}$ ;
- preparation of initial data for rule  $PR_{22}$  - determination of criteria for uniformity of the schedule in the interval of execution of the action or set of actions selected by rule  $PR_{21}$ ;
- rule  $PR_{22}$  determines the time for rearranging the start of an action or set of actions, at least not deteriorating the uniformity of system resource consumption.

The operation of the scheme is completed either after one pass - rearrangement of all actions or a set of actions, or after several passes, depending on the adopted optimization strategy. The type of uniformity criteria determines the corresponding ranking algorithms in rules  $PR_{21}$  and  $PR_{22}$ .

In multicriteria problems [4-6], either the hierarchy analysis method [21] or the ELECTRE method [22] are used. Both methods are widely used in world practice, but at the same time, the methods developed by Professor V.V. Safronov are undeservedly little used [23].

The inclusion of multicriteria ranking algorithms of various levels finally completes the description of the scheduling paradigm, and its implementation is presented in.

## 4 Conclusion

As a result of the conducted research, descriptions of information models of multi-criteria tasks of schedules for tactical and operational levels of energy construction planning are presented.

In addition, the use of resource-oriented criteria of workload and uniformity is proposed. The workload criteria characterize the need for applications or sets of applications in the system resources. The uniformity criteria determine the distribution of system resource consumption in the schedule interval. Both types of criteria have a complex structure, so ranking algorithms must be used in priority rules.

Thus, it can be concluded that both models are widely used in world practice, but the use of multicriteria ranking algorithms at various levels is more effective in describing the scheduling paradigm.

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