SYSTEM ANALYSIS OF FORMATION OF EMERGENCY RESCUING EQUIPMENT SETS

Vasyl Kryshtal, Vitaliy Snytyuk

Abstract: *Aspects of four scientific paradigms are analyzed: system approach, system analysis, system design and system models, which are used in task solving of determining the optimal set of rescue equipment. Received results from the scientific basis for the definition of the set and its support for all stages of the life cycle.*

Keywords: *emergency rescue equipment, system approach, system model, system analysis, optimality.*

ACM Classification Keywords: H.4: Information systems application

Introduction

Rapid dynamics of modern world is one of the main causes of the amount and types of industrial and ecological catastrophes and accidents growths. Such threats and challenges to the mankind are the motives for the formation and development of safe environment for residing.

A task of emergency rescuing technique (ERT) complicating is analyzed according to system positions, which consist of system approach and system analysis. It is known that system approach is a scientific and practice methodology of difficult problems solving, and systematization is a determinative aspect of it, formalization and aim orientation [Tymchenko, 1991]. In turn, system analysis is a scientific and practice methodology of complicated systems investigation, that consists of such stages as system aim formulating, its elements basis clarification, structural peculiarities defining, the amount of internal system parameters and the amount of external functions of definition of system state and indicators of its efficiency forming, system effectiveness criterion identification [Zhurovskiy, 2005]. The process of completing itself is meant as dual to system projecting – a process of getting system project in the basis of system properties, system recourses and structures of vital cycle [Tymchenko, 1991]. The research is based on system model (SM), which is a row of elements with corresponding reflexing [Tymchenko, 1996] . These four constituents are represented constructively.

At first, we point out that the environment Ω has three constituents relatively to our task (fig. 1)

$$\Omega = < P, AS, NS >, \quad (1)$$

where P – human population, AS – artificial systems (manmade), NS – natural systems.

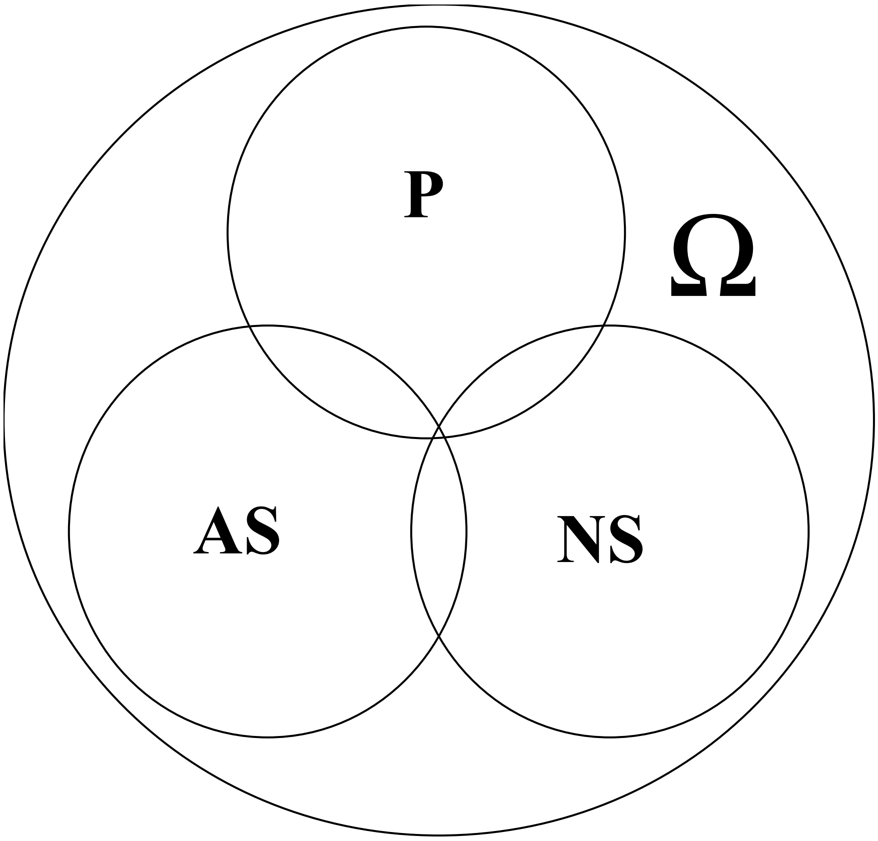

Figure 1. Costituents of environment

Processes of existing and functioning of denoted components is not always independent, in most cases they cross. When are fires, accidents, disasters, emergencies, etc. happen, people suffer, artificial and natural systems get harm in different quantities and proportions. In particular, chemical accidents affect natural systems and people, fires cause damage to people and artificial systems, emergencies hurt people, accidents and disasters of another nature may cause other variants of damage. Exceptions out of all these cases should be noted. It is important that their consequences are negative for people directly or indirectly.

Components of the system model

We regard an area $\Xi \subset \Omega$, which denote territorially determined administrative unit that is frequently a region or a city. We construct a SM of a process of ERT complicating in a region Ξ. It is known [Tymchenko, 1996] that, a SM is a row (fig. 2)

$$SM =< G, M, T, A >, \quad (2)$$

with reflexions:

$$H_1 : G \to M,\ H_2 : M \to T,\ H_3 : T \to A, \quad (3)$$

where G, M, T, A are sets of goals, models, methods, tools, in accordance.

As long as goal is a desired outcome, in our case it is people rescuing (G_{11}), material losses reducing (G_{12}), manmade and environmental disasters preventing (G_{13}), that is:

$$G =< G_0, G_{11}, G_{12}, G_{13}, ..., G_{1n}, G_{11}1, ... > \quad (4)$$

where G_0 is the main aim, which means minimizing of negative effects of accidents, fires etc. G_{ij}, G_{ijk} – goals of the main aim that form a hierarchical graph like structure. Reaching at least one of the G goals or set of goals, or all G goals as elementary structures "and-or" column depends on solution of the set of tasks

$$V =< V_1, V_2, ..., V_m, V_{11}, ... >, \quad (5)$$

where V_i, V_{ij} – verbal task formulations. It is known, a task that have formalized setting can solved, it means that it is necessary to build a reflection of a set $V \to M$. Composition of the set M, justified earlier in [1], includes F_1 – cost of an equipment set, F_2 – its functionality, F_3 – power, F_3 – reliability on macro level.

Then the appropriate tasks are:

$$F_1 \to \min,\ F_2 \to \max, F_3 \to \max, F_4 \to \max . \quad (6)$$

Including limitations on the dimensions of the equipment. Identification structural as well as parametric belongs to tasks and models of lower hierarchy levels. Its features are considered in [2]. Tasks as well as appropriate models also have graph like hierarchical structure.

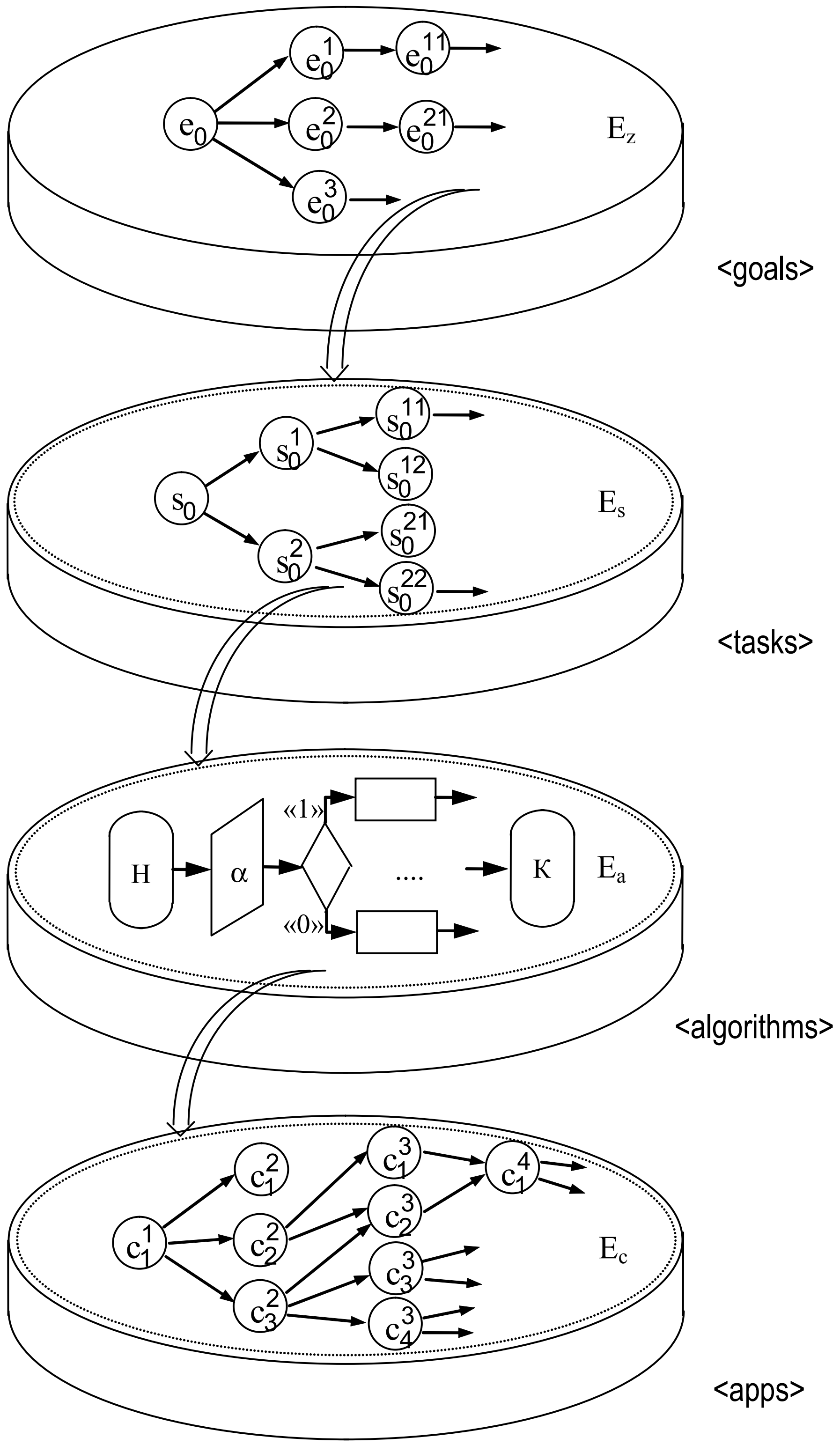

Fig. 2. System model

In order to obtain useful data and knowledge, information set V tasks should be solved. Since certain models of a not empty set (bank) correspond to the objectives, methods (W), also known as ways of task solving, should be used for their processing. It is obvious that a certain class of models and tasks can be solved with methods class. Thus, there is a reflection

$$Q : M \to W, \tag{7}$$

which is not mutually unequivocal and creates a need for optimization, which is to select the best method (determining of the most accurate result in certain resource constraints). One way to implement it is to use an approach with the use of ensemble of methods.

In particular, even and odd multiple linear regression, nonlinear regression, neural networks, polynomial Kolmogorov-Gabor and others belong to the set M. The set of methods includes the least squares method, Brandon method, group method of data handling, neural network learning methods (stochastic, direct, based on back propagation) etc. The majority of the methods mentioned above are too time-consuming, especially for large power source data set.

Whereas solving problems (6) requires significant computational cost, a stage of reflecting of a set of methods (T) on a set of algorithms (U) as formal structures for practical computer implementation is important. As well as methods allow their parametric optimization, algorithm that corresponds to one method can be built a lot of ways. If a set of parametric options of one method is N, the power of a set of appropriate algorithms is M, while $M >> N$.

A problem of execution (implementation) algorithm remains. For the problem of acquisition of ERT, despite the level of technology and computing technologies, regarding combinatorial complexity this problem is urgent. Therefore, the choice of tools (Z) is an important step in its solution and is implemented in reflection $U \to Z$.

In this matter, all components of the system model are denoted. Its construction at the macro level is to implement the set of reflections

$$G \to V \to M \to T \to U \to Z ... \to M \to T ... \tag{8}$$

Reflection chain corresponds to the implementation of the iterative process, because the requirements of a particular method cannot meet the goals or objectives of completing ERT. It is possible that the effectiveness of tools prevents receiving solution of the problem for existing baseline data, or resources, or the requirements of the process solution. System model (2) and (3) enables vision system features for solving the problem of acquisition of ERT. It is an integrating element of the range of emergency rescue tools, financial resources, organizational and administrative measures.

Levels of implementing a system approach to the problem of recruitment rescue equipment

The need to solve the problem of ERT completion stipulates a systematic study of retrospective features. In particular, Google produces about 105,000 links for key phrases "emergency rescue equipment" and "Acquisition of rescue equipment" in Ukrainian and Russian references about 455000. Analysis of the content of links pointing to research topics of acquisition of ERT in Cherkasy Institute of Fire Safety named after Chernobyl Heroes National University of Civil Defense of Ukraine. Other links let us get acquainted with different samples of ERT, which nomenclature is very broad and therefore there is the problem of forming a set of ERT. As far as this task had been solved only by experts from this institution, as evidenced by Google, we paid attention to the tasks that are relevant to certain aspects of our problem. In particular, the request "Task package" received 789,000 options. There is several dozen varieties of such problem solving. That is a two-dimensional packing, linear packaging, packaging according to weight, cost etc. The feature of such problems is their mono criterion nature [Smirnov, 1991]. Analysis and systematization of technologies for solving the problem of acquisition of ERT shows either little researches of evidence of relevant problems or neglect its multi criterion nature. This conclusion allows us to formalization of ERT completing tasks [Kryshtal, 2015]. Building a model, the purpose of each item as ERT and their set, should be considered.

Stages of system analysis and the process of ERT completing

The initial phase of system analysis is system aim formation; in this case, such aim of ERT set functioning is defined as a set of desired results. In the next stage we identify and order components base, forming row database table

$$< N, ID, Name, TS1, TS2, ..., TSn_N, f_1, f_2, ..., f_{n_N}, s1, s2, s3, \Pr >, \tag{9}$$

where N – is a serial number of a record in the database table, ID – is an identificator or abbreviated name of an equipment item, $Name$ – is a full name of the equipment, $TS1-TSn_N$ – are equipment specifications, $f_1 - f_{n_N}$ – are functions that equipment performs, $s1, s2, s3$ – are its dimensions, *Pr* – is a price. The data in the table (9) is an initial information for task solving (6). The knowledge of technical specifications and functional features of equipment items is necessary to incorporate structural features while forming optimal set of equipment. In particular, if for two equipment items i's and j's we have $f_k^i = f_k^j \ \forall k \in \overline{1,n},$ the equipment set should be supplied with the item technical specifications value of which are not worse, and at least one is better, that is,

$$\forall k \ TSk^i \geq TSk^j \ i \ \exists l : TSl^i > TSl^j . \tag{10}$$

There are other situations:

– if the number of functions i's element is larger than of j's ones, we choose j's element in all other equal condition;

– if the number of functions i's element is larger than of j's ones, but at least one important technical specification is better with the meanings not worth of all others, the choice of the element is made either by using technologies of reducing of multicriteria task to monocriterion or of forming of a collective system of preferences using system analysis [Kryshtal, 2016].

The predominant aspect of the choice is different aspectness of items of equipment, that is, ideally there shouldn't be two elements i's and j's in one set, because $\exists k \in \overline{1,l}: f_k^i = f_k^j$. At the same time, the situation is desirable when $\cup f_i = \Phi,$ where Φ – is the space of all possible functions that a set of ERT should perform. These features will determine the optimal structure of a potential set of ERT. Note that the price of a ERT set is crucial.

Thus, the initial problem can be reduced to this: to find a ERT set, that

$$\left|\cup f_i\right| \to \max \vee \left|\Phi \setminus \cup f_i\right| \to \min, \qquad (11)$$

where $|\Theta|$ – is the power of a set amount (number of items) Θ, $\min$ or $\max$ are found according to possible sets of equipment subject to limitations on their dimensions. A task (11) can be specified taking into account technical characteristics values

$$(\left|\cup f_i\right| \to \max \ \& \sum_k TSk \to \max) \vee (\left|\Phi \setminus \cup f_i\right| \to \min \& \sum_k TSk \to \max), \text{ or, the same}$$
$$(\left|\cup f_i\right| \to \max \vee \left|\Phi \setminus \cup f_i\right| \to \min) \& \sum_k TSk \to \max. \qquad (12)$$

Let's consider in more details the system of functions performed by the hardware element of ERT. May f_k^j is the main function of the set of all possible features $\{f_1^j, f_2^j, ..., f_k^j, ..., f_n^j\}$ of j's element equipment set. In addition to the main features j's element can perform a number of utility functions, so our set of features can be ordered as follows:

$$\{f_0^j, f_1^j, ..., f_g^j, f_{g+1}^j, ..., f_{n-1}^j\}, \qquad (13)$$

where f_0^j – is the main function of the equipment, f_i^j – are indirect functions, $i = \overline{1,g}$, f_i^j – are functions, that the element j's of ERT does not perform, $i = \overline{g+1, n-1}$. To determine the effectiveness of j's element of ERT we use an indicator of effectiveness j's element its functions performance $\{y_0(f_0^j), y_1(f_1^j), ..., y_g(f_g^j)\}$. Integral estimation of effectiveness is a quantitative characteristic effectiveness indicators,

$$E^j = E^j(y_0(f_0^j), y_1(f_1^j), ..., y_g(f_g^j)) \tag{14}$$

and can be identified using expert opinions analytically. For example, as an additive convolution

$$E^j = \sum_{i=0}^{g} \beta_i \cdot y_i(f_i^j), \ \forall j = \overline{1,m}, \tag{15}$$

where m – is a number of items of ERT, β_i – is i's effectiveness indicator weight performance. Note that the four evaluation criteria of ERT set: price, functionality, capacity and reliability are previously established. The same criteria can be considered for a particular item of equipment. It is also clear that there is a relationship between functionality (F_2) and efficient items of equipment, that is

$$F_2(e^j) = Q(E^j), \tag{16}$$

where e^j – is the piece of equipment. Identification Q requires additional research. Note that F_1, F_3, F_4 as an item of equipment is known. Price is determined by the supplier or manufacturer, reliability is known according to statistics, power – is a rated characteristic of the equipment element.

Rationally, while functionality determining of the equipment item the relevance of all of its functions should be considered. The more frequently emergent situation, where it was necessary to implement a function, arose, the more functional the equipment with this function was. This actualization brings to the construction of dependency that defines the functionality of ERT element

$$F_2(e^j) = Q(E^j) = Q(\sum_{j=0}^{g} \beta_i \cdot y_i(f_i^j)), \forall j = \overline{1,m}, \tag{17}$$

where $\beta_i = \gamma_i \cdot \delta_i$, and γ_i – is a weight coefficient of i's functions defined by manufacturer, δ_i – is a weight coefficient, indicating the urgency of i's functions implementing, $i = \overline{0,g}$. Common criterion of ERT set effectiveness is formed on the basis of the features denoted above.

Aspects of system designing

While solving the task of ERT completing, the characteristics that accompany the process of system design are to be considered. In this case financial resources, as well as carrier safety equipment – special vehicles can be included to system resources. System properties of ERT set include: openness – the ability to include new elements to a set or to exclude them, scalability – the ability to use a set of ERT on vehicles of various types, system – the ability to perform the broadest set of features, integrity – the property of collaboration of diverse items of equipment while performing a problem etc. Finally it should be noted the need to implement the requirements of the proposed operation programmable of ERT set, which will provide not only an effective work today but also in the future that may be associated with the need to replace used items to new and perspective.

Conclusion

Consistency in any task solving is a prerequisite for obtaining effective solution and optimization of all stages of its life cycle. System features of acquisition of ERT, investigated in the article, let us obtain the best (affordable) options in acquisition of ERT, which, in turn, will be targeted at strengthening the rescue people, minimization of material losses, the effects of natural and man-made disasters.

In the future, attention should be paid to technology of an integral objective function forming, methods of group result forming by selecting individual preferences, as far as these tasks are parametric and mostly subjective.

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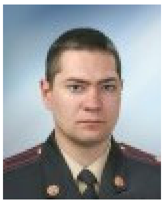

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