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THE FLOW NETWORKS APPROACH TO DECISION ANALYSIS IN CONSTRUCTION INDUSTRY

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Abstract: The application of flow networks on the example of the types of works distribution as well as the distribution of construction workers qualification structure according to particular types of buildings is presented in the paper. The flow networks considered were proposed by Zdzislaw Pawlak and are the tools for the new mathematical models related to the information regarding flow explorations in decision algorithms. The decision algorithms consist of series of decision rules for each particular case of various types of construction objects interdependence, as well as of various kinds of workers and their qualification structure. It is all generated in the paper.

Keywords: Flow network, decision algorithm, construction industry, qualification structure.

1. INTRODUCTION

The flow networks considered in this paper were proposed by Pawlak [7,8], the creator of the theory of rough sets [5]. He started from the concept of use of the logic as probability theory base, which was proposed in 1913 by Ian Lukasiewicz [4]. Lukasiewicz stated his attitude that the probability was "purely logical concept" and that his approach freed probability from its obscure philosophical connotation. Then Lukasiewicz suggested the replacement of the concept of probability by truth values if indefinite propositions, which in fact represented propositional functions.

Let U be a non empty finite set, and let $\Phi(x)$ be a propositional function. The truth value of $\Phi(x)$ is defined as *card* $|\Phi (x)|$ / *cardU*. For example, if $U = \{1, 2, 3, 4, 5, 6\}$, and $\Phi(x)$ is the propositional function $x > 4$, then the truth value of $\Phi(x) = 2/6 = 1/3$. If the truth value of $\Phi(x) = 1$, then the propositional function is true, and if it is 0, then the function is false. The truth value of any propositional function could be a number between 0 and 1. The truth values can be treated, in that way, as probability, and that all laws of probability can be obtained by means of logical calculus [7].

In his work *Probability, Truth and Flow Graph* [7], Pawlak expresses Lukasiewicz's idea in a different manner. Instead of using truth values in place of probability, stipulated by Lukasiewicz, Pawlak proposes using the deterministic flow analysis in flow networks. Flow is governed by some probabilistic rules (e.g., Bayes' rule[1]) or by the corresponding logical calculus proposed by Lukasiewicz, though, formulas have entirely deterministic meaning, and need neither probabilistic nor logical interpretation. They simply describe flow distribution in flow graphs. Flow networks, proposed by Pawlak, are different to those introduced by Ford and Fulkerson [3].

The flow networks, in this case, do not refer to physical media, but to information flow examination in decision algorithms. Therefore, branches of a flow graphs are interpreted as decision rules. With every decision rule three coefficients are associated: the strength, certainty and coverage factors. In classical decision algorithms language they have probabilistic interpretation. According to Lukasiewicz [4], these coefficients can be interpreted as truth values. According to Pawlak [7], they can be interpreted simply as flow distribution ratios between branches of the flow graph, without referring to their probabilistic or logical nature.

One of the problems appearing in the construction engineering is how to determine principle or actual distribution, i.e. arrangement of workers groups, in particular groups (for example, building construction), depending on the type of works and qualification structure (professional training) and according to the type of facilities being constructed.

It is not easy to determine distribution and distribution trends, since a large number of influences to be analyzed is present: inappropriate qualification structure of work groups in relation to the necessary one in accordance with standards, manpower fluctuation – by location / geographically, according to the type of facilities and owner structure of construction firms; also, the subjectivity is present frequently, as well as uncertainty and vagueness of particular parameters.

The flow networks generate decision rules/algorithms, and cited problems with the manpower structure frequently fail to enable making of precise decisions. Therefore, the application of the flow networks, as the model for qualitative support to decision, is presented in the paper. The flow networks, in that sense, should enable the decision to be made on distribution/arrangement of types and structures of manpower according to different types of construction facilities, both on the level of chambers and institutions at the highest level of the construction engineering as an economic branch, and on the level of management structure of construction firms.

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[1] Statistic conclusion based on Bayes' theorem is used for previous knowledge confirmation, when data become available. In the field of rough sets, the conclusion based on Bayes' theorem uses relations between data revealed by the Bayes' theorem application.

2. MATHEMATICAL BASE OF FLOW NETWORKS[2]

According to Pawlak [8], flow network is a directed, acyclic, finite graphs G = (N, B, φ), where N is a set of nodes, $B \subseteq N \times N$ is a set of directed branches, $\sigma : B \to$ < 0,1 > is a flow function.

Input of $x \in N$ is the set $I(x) = \{y \in N : (y, x) \in B\}$; output of $x \in N$ is defined as $O(x) = \{y \in N : (x, y) \in B\}$ and σ (x, y) is called a strength of the pair (x, y).

Input and output of a graph G, are defined by $I(G) = \{x \in N : I(x) = \emptyset\}$; $O(G) = \{x \in N : O(x) = \emptyset\}$, respectively.

Input and output nodes of G are external nodes of G; other nodes are internal nodes of G.

With every node of a flow graph we associate its inflow and outflow defined as

$$\varphi_+(y) = \sum_{x \in I(y)} \varphi(x,y)$$

$$\varphi_-(x) = \sum_{y \in O(x)} \varphi(x,y)$$

respectively.

Similarly, inflow and outflow for the whole graph G are defined as

$$\varphi_+(G) = \sum_{x \in I(G)} \varphi_-(x)$$

$$\varphi_-(G) = \sum_{y \in O(G)} \varphi_+(x)$$

We assume that for any internal node x, $\varphi_+(x) = \varphi_-(x) = \varphi(x)$, where $\varphi(x)$ is a throughflow of node x.

Obviously, $\varphi_+(G) = \varphi_-(G) = \varphi(G)$, where $\varphi(G)$ is a throughflow of a graph G.

2.1. Properties of Flow Networks (Graphs)

With every branch (x,y) we associate its strength defined as

$\sigma(x,y) = \varphi(x,y)/\varphi(G)$. $0 \le \sigma(x,y) \le 1$. It is a normalized flow of the branch (x,y).

With every branch of a flow graph we associate the certainty and the coverage factors, which are defined as:

$$cer(x, y) = \sigma(x, y) / \sigma(x), \quad cov(x, y) = \sigma(x, y) / \sigma(y) \tag{1}$$

where σ(x) is the normalized troughflow of x, defined as:

$\sigma(x) = \sum_{y \in O(x)} \sigma(x, y) = \sum_{y \in I(x)} \sigma(x, y)$, resulting in the following equalities:

$$\sum_{y \in O(x)} cer(x, y) = 1 \tag{2}$$

2 The entire Section 2 has been made according to the references [7] and [8].

$$\sum_{x \in I(x)} \text{cov}(x, y) = 1 \tag{3}$$

$$\text{cer}(x, y) = \text{cov}(x, y)\, \sigma(y) / \sigma(x) \tag{4}$$

$$\text{cov}(x, y) = \text{cer}(x, y)\, \sigma(x) / \sigma(y) \tag{5}$$

The above properties seem to have a probabilistic character. However, these properties can be interpreted in deterministic way and they describe flow distribution among branches in the network.

2.2. Paths and Connections

A directed path from *x* to *y*, for x,y ∈ N, denoted [x…..y] is a sequence of nodes $x_1,\dots,x_n$, such that $x_1 = x$, $x_n = y$ and $(x_i, x_{i+1}) \in B$ for $1 \le i \le n - 1$.
The certainty of a path $[x_1 \dots x_n]$ is defined as:

$$\text{cer}[x_1 \dots x_n] = \prod_{i=1}^{n-1} \text{cer}(x_i, x_{i+1}) \tag{6}$$

The coverage of a path $[x_1 \dots x_n]$ is defined as:

$$\text{cov}[x_1 \dots x_n] = \prod_{i=1}^{n-1} \text{cov}(x_i, x_{i+1}) \tag{7}$$

The strength of any path [x…..y] is defined as:

$$\sigma[x \dots y] = \sigma(x)\text{cer}[x \dots y] = \sigma(y)\text{cov}[x \dots y] \tag{8}$$

The set of all paths from x to y (x ≠ y), denoted < x,y >, will be called a connection from x to y. In other words, connection < x,y > is a sub – graph determined by nodes x and y.

The certainty of connections < x,y > is:

$$\text{cer} < x,y > = \sum_{[x\dots y] \in <x,y>} \text{cer}[x \dots y] \tag{9}$$

The coverage of connections < x,y > is:

$$\text{cov} < x,y > = \sum_{[x\dots y] \in <x,y>} \text{cov}[x \dots y] \tag{10}$$

The strength of connections < x,y > is:

$$\sigma < x,y > = \sum_{[x\dots y] \in <x,y>} \sigma[x \dots y] \tag{11}$$

Let x, y (x ≠ y) be any pair of nodes of G. If we substitute the sub - graph < x,y > by a single branch (x, y), such that σ (x,y) = σ < x,y >, then cer(x,y) = cer < x,y >, cov(x,y) = cov < x,y >, and σ(G) = σ(G'), where G' is the graph obtained from G by substituting in G (x,y) instead of the subgrapf < x,y >.

2.3. Decision Algorithms

With every branch (x,y) we associate a decision rule $x \to y$, read *if x then y*.

Thus every path $[x_1....x_n]$ determines a sequence of decision rules $x_1 \to x_2$, $x_2 \to x_3$, ..., $x_{n-1} \to x_n$.

This sequence of decision rules can be replaced by a single decision rule $x_1x_2...x_{n-1}$, in short $x^* \to x_n$, where $x^* = x_1x_2...x_{n-1}$, characterized by:

$$cer(x^*, x_n) = cer[x_1....x_n] \quad (12)$$

$$cov(x^*, x_n) = cov[x_1....x_n] \quad (13)$$

$$\sigma(x^*, x_n) = \sigma(x_1)cer[x_1....x_n] = \sigma(x_n)cov[x_1....x_n] \quad (14)$$

Similarly, every connection < x,y > can be interpreted as a single decision rule $x \to y$, such that:

$$cer(x,y) = cer< x,y > \quad (15)$$

$$cov(x,y) = cov< x,y > \quad (16)$$

$$\sigma(x,y) = \sigma(x)cer< x,y > = \sigma(y)cov< x,y > \quad (17)$$

Let $[x_1....x_n]$ be a path such that x_1 is an input, and x_n an output of the flow graph G. Such a path and the corresponding connection $< x_1,x_n >$ will be called complete path.

The set of all decision rules $x_{i_1}\ x_{i_2}\ ....\ x_{i_{n-1}} \to x_{i_n}$ associated with all complete paths $x_{i_1} .... x_{i_n}$ in G will be called a decision algorithm determined by flow graph G.

2.4. Inference in Flow Networks

Reasoning in deductive logic consists in using inference rules, which are implications in the form, *if Φ then Ψ*, where Φ is called the premises, and Ψ consequence of the rule. Inference rules allow us to obtain true consequences from true premises. Fundamental rules of inference are, *modus ponens*[3] i *modus tollens*[4](Pawlak, 2003).

Modus ponens has the following form:

if $\Phi \to \Psi$ is true
and Φ is true
----
then Ψ is true

[3] Hypothetical conclusion, in which the second premise confirms a condition expressed in the first premise.

[4] Hypothetical conclusion, in which the second premise denies a condition expressed in the first premise.

Modus tollens has the following form:

if $\Phi \rightarrow \Psi$ is true
and $\sim \Phi$ is true
----
then $\sim \Psi$ is true

Modus tollens can be regarded as the inverse of *modus ponens*, i.e., gives reason for a consequence.

In reasoning about data, according to Pawlak [7], the situation is slightly different. Instead of true sentences we consider propositional functions, which are true to a "degree", i.e., they assume truth values which lie between 0 and 1. In the flow network setting the concepts of truth is replaced by the flow intensity in branches of the flow network, and logical inference is boiled down to flow distribution analysis.

Thus a flow network can be regarded as a schema of reasoning about data patterns – i.e., a network of decision rules, which lead from propositional functions expressing properties of initial data to other propositional functions about data.

According to Pawlak [7], the previous idea can be formulated more exactly as follows:

$$\sigma(y) = \sigma(x)\mathrm{cer}\langle x,y\rangle/\mathrm{cov}\langle x,y\rangle = \sigma(x,y)/\mathrm{cov}\langle x,y\rangle \tag{18}$$

$$\sigma(x) = \sigma(y)\mathrm{cov}\langle x,y\rangle/\mathrm{cer}\langle x,y\rangle = \sigma(x,y)/\mathrm{cer}\langle x,y\rangle \tag{19}$$

Formulas (18) and (19) derived from formulas (3) and (4), and represent consequently Bayes' rules. Obviously, they have the same role in data analysis as *modus ponens* and *modus tollens* in logic reasoning [7].

3. APPLICATION OF FLOW NETWORKS IN CONSTRUCTION ENGINEERING

The use of optimal resources and exploitation in construction engineering are one of the most important conditions for qualitative termination of a project in a set deadline.

Resources necessary for the undisturbed performing of activities at the construction site are the manpower, material and mechanization. The manpower will be analyzed in this paper, and the application of the flow network will be presented on the distribution of manpower on the construction facilities, in accordance with their type and structure.

Construction workers are assumed to have the necessary level of capability, qualification and motivation for a particular work performed. This comprehends particular qualification structure and number of workers in the group. The number of workers should be such so as (a) to enable broad scope of work in relation to the entire construction site, and (b) to enable continuous work performing (without stoppage due to insufficient or exceeded number) in relation to the job position. In order to successfully complete a working task, an organizational and technological preparation is necessary. This can be achieved by proper selection of work group qualification structure [1]. The qualification structure of a work group is formed based on (a) the type of works performed by the group, and (b) amount of particular types of work in the facility being built, depending on the type of facility.

Quotas of time, material and construction machines for each activity have to be applied in order to achieve the insight into necessary resource (manpower, material, mechanization), and to calculate the time needed for performing the activities. (Quotas represent an average consumption of working hours, material and mechanization for obtaining the unit of measure of products according to the technical regulations).

The qualification structure is presented in Table 1, on the basis of the construction standards [10]: non-qualified workers - NQ[5], qualified workers- QU (IV. V, and VI group) and highly qualified – HQ (VII and VIII group) for carpenters and bricklayers by types of work and averagely, on the basis of amount of particular types of work in residential facilities.

Table 1: Qualification structure of carpenter and bricklayer groups by types and amount of work

					averagely		
Type of Worker	Type of Work	NQ %	QU %	HQ %	NQ %	QU %	HQ %
Carpenters	Classical formwork	61	39	/	22	71	7
	Cornice formwork	13	87	/			
	Beam formwork	9	40	51			
	Pillar formwork	7	51	42			
	Wooden roof structure	/	50	50			
	Movable formwork	32	67	1			
	"Omnia" ceilings	14	86	/			
	Tunnel formwork	25	75	/			
	Small section concreting	7	93	/			
	Large section concreting	12	88	/			
Bricklayers	Brick laying	51	49	/	32	50	18
	Façade brick laying	27	/	63			
	Chimney brick laying	27	/	63			
	Gypsum board brick laying	29	22	49			
	Siporex brick laying	35	65	/			
	Wall plastering	34	66	/			
	Ceiling plastering	37	63	/			
	Cement floor screed	28	72	/			
	Thermal insulation	/	100	/			
	Façade scaffold	37	63	/			

* Average in relation to the amount of particular types of works in he facility

5 Quotas also envisage semi-qualified workers of III group, but II and III qualification groups are considered as non-qualified in this paper.

The analysis of necessity of manpower for the activities of fabrication, mounting, dismounting and striking of formwork from the assembly board wall by the "Neue Schallung" system (movable formwork), quota code number 601-216.1.1 ("Work quotas and standards in construction engineering "), is made in Table 2.

Table 2: Fabrication, mounting, dismounting and striking of formwork from the assembly board wall by the "Neue Schallung" system - movable formwork

Number and position of construction quota	DESCRIPTION unit of measure m^2	Hour quota per unit of measure	QUALIFICATION		% PARTICIPATION
601-216.1.1	1. Formwork fabrication 0.0697 hour quota / m^2	0.0009	VIII	HQ	1%
		0.0366	VI	QU	67%
		0.0040	V		
		0.0060	IV		
		0.0180	III	NQ	32%
		0.0042	II		
601-216.1.1	2. Formwork mounting 0.2935 hour quota / m^2	0.0750	VI	QU	63%
		0.1100	V		
		0.1085	III	NQ	37%
601-216.1.1	3. Formwork dismounting 0.2088 hour quota / m^2	0.0600	IV	QU	29%
		0.0339	III	NQ	71%
		0.1149	II		
601-216.1.1	4. Formwork striking 0.0280 hour quota / m^2	0.0150	IV	QU	54%
		0.0130	III	NQ	46%

The analysis shown in Table 2 (shaded fields) corresponds to shaded field in Table 1 – carpenter works.

The qualification structure cannot be practically presented by Descartes' triangle [9]. (a) Certain (hypothetical) points A, B, C and D reflecting particular qualification structure are presented in Figure 1 by Descartes' triangle, as well as (b) and (c) particular fields for corresponding relations of NQ, QU and HQ workers, and (d) points T, Z and F reflecting respectively qualification structure of carpenter, brick layer and physical manpower, and certain inter-values M and N.

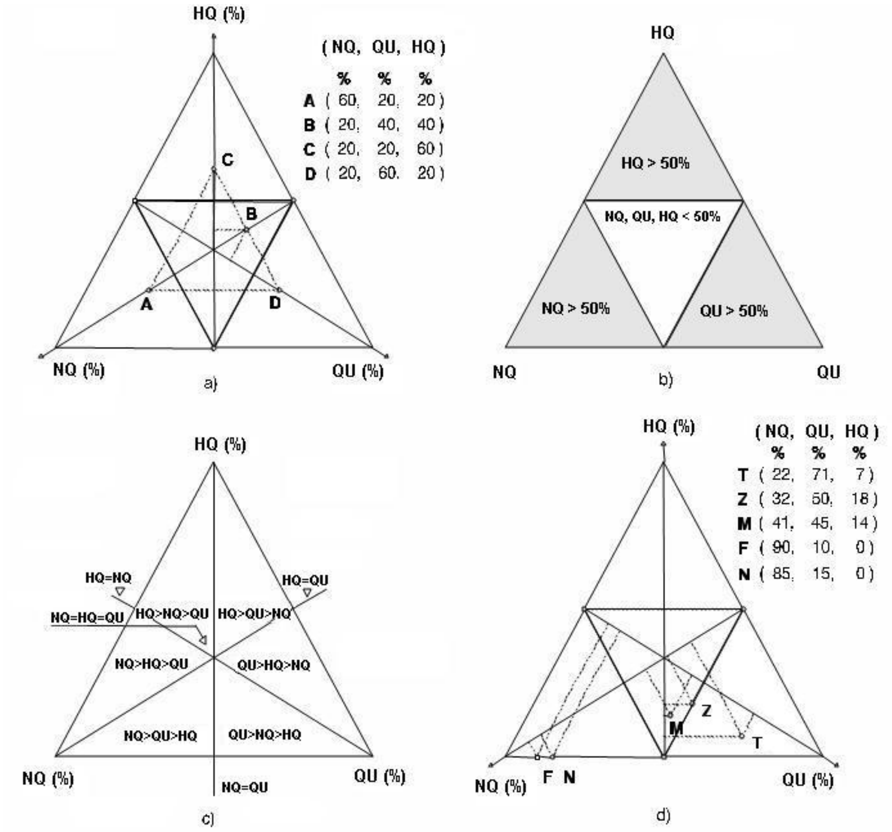

Figure 1: Descartes' triangles for manpower

Points T and Z in Figure 1 respond to the qualification structure of carpenter and brick layer work groups accordingly to the existence of particular types of works on residential facilities presented in Table 1.

3.1. Types of workers, qualification structure and distribution in construction facilities

The qualification structure in relation to the technologically uniformed work of the work group (usual according to quotas) has been previously presented. The stated problem consists of determining the type of workers (having in mind types of works, i.e. work groups) and workers qualification structure participating in the construction of particular types of facilities, and of determining future trends in this distribution. Let us take buildings for example. The following types of workers (work groups), workers (qualification) structure and construction facilities are considered:

Types of workers:

1. Carpenters – x_1
2. Brick layers – x_2
3. Bar benders – x_3
4. Craftsmen and installers – x_4

Workers structure:

1. Non-qualified (II and III group) – y_1
2. Qualified (IV, V and VI group) – y_2
3. Highly qualified (VII and VIII group) – y_3

Construction facilities:

1. Individual – z_1
2. Big – standard – z_2
3. Assembly and semi-assembly – z_3
4. Superstructures and reconstructions – z_4

Figure 2 presents the distribution of type of workers (work groups) and qualification structure in construction facilities most frequently built in the field of building construction [2]. The distribution of proportional participation of workers, i.e. types of works, is proportionate to the financial participation of those works in the total price of particular construction facilities.

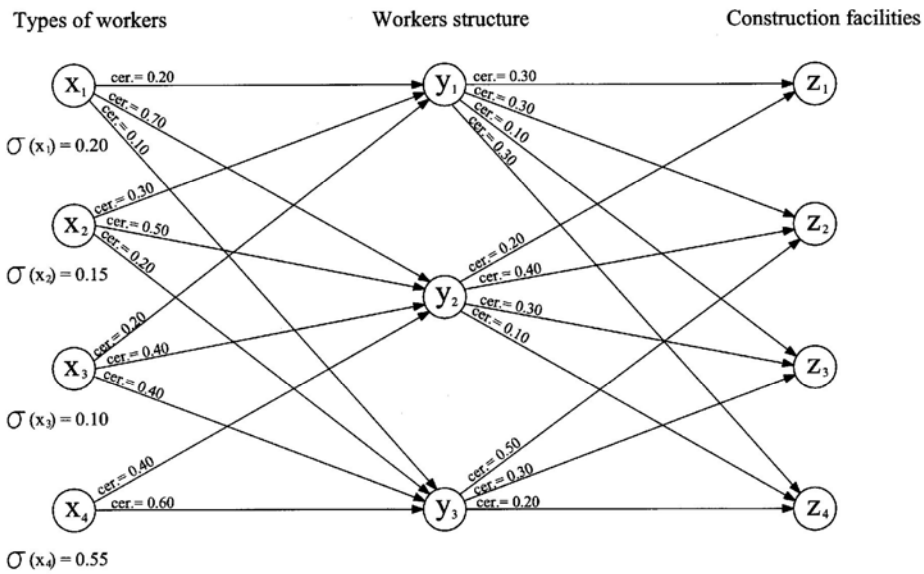

Figure 2: Distribution of type of workers and workers qualification structure in construction facilities

3.2. Results

The distribution of proportionate participation (according to facility surface) of four types of considered construction facilities in the building construction obtained by the flow network application, in relation to the manpower qualification structure, is shown in Figure 3.

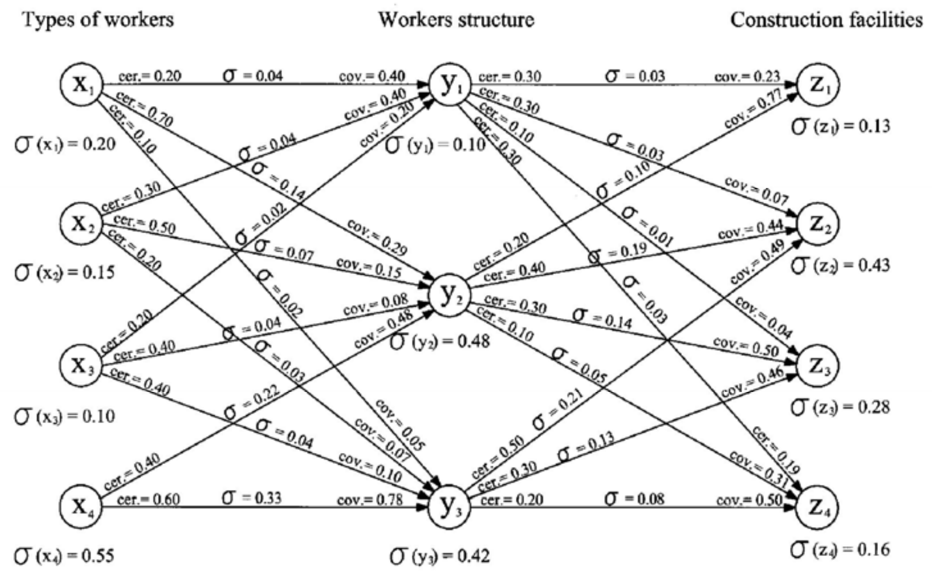

Figure 3: Distribution of proportionate participation of construction facilities in relation to the manpower qualification structure

The procedure of necessary coefficients calculations is very voluminous. Therefore, only the calculus of coefficients in the node y_1: $\sigma(x_1, y_1)$, $\sigma(x_2, y_1)$, $\sigma(x_3, y_1)$, $\sigma(y_1)$ and cov (x_1, y_1), cov (x_2, y_1), cov (x_3, y_1),[6] is presented

$$\sigma(x_1, y_1) = \sigma(x_1)\ \mathrm{cer}(x_1, y_1) = 0.20 \cdot 0.20 = 0.04 \quad (20)$$

$$\sigma(x_2, y_1) = \sigma(x_2)\ \mathrm{cer}(x_2, y_1) = 0.15 \cdot 0.30 = 0.04 \quad (21)$$

$$\sigma(x_3, y_1) = \sigma(x_3)\ \mathrm{cer}(x_1, y_1) = 0.10 \cdot 0.20 = 0.02 \quad (22)$$

$$\sigma(y_1) = \sigma(x_1, y_1) + \sigma(x_2, y_1) + \sigma(x_3, y_1) = 0.04 + 0.04 + 0.02 = 0.10 \quad (23)$$

$$\mathrm{cov}\ (x_1, y_1) = \sigma(x_1, y_1) / \sigma(y_1) = 0.04 / 0.01 = 0.40 \quad (24)$$

$$\mathrm{cov}\ (x_2, y_1) = \sigma(x_2, y_1) / \sigma(y_1) = 0.04 / 0.01 = 0.40 \quad (25)$$

$$\mathrm{cov}\ (x_3, y_1) = \sigma(x_3, y_1) / \sigma(y_1) = 0.02 / 0.01 = 0.20 \quad (26)$$

6 It can be ascertained tha during the calculus of (1) – (19) formulas small errors in numerical values of final results can be made, as the consequence of errors made when rounding off.

Evidently, the procedure of calculation of corresponding coefficients in other nodes is analog to the procedure presented by formulas (20) – (26).

From the flow network presented in Figure 3 it is obtained that the individual facilities participate with 13% in the building construction and that from the workers qualification structure performing their construction non-qualified workers participate with 23% and qualified workers 77%.

According to the same calculus, big, i.e. standard construction facilities are mostly present in building construction, making 43%, and in their construction all three qualification structures of workers take part: non-qualified - 7%, qualified - 44%, and highly qualified - 49%.

Assembly and semi-assembly facilities make 28% of building construction and, according to Figure 3, 4% of non-qualified workers, 50% of qualified and 46% highly qualified workers work on their construction.

According to the calculus, superstructures and reconstructions participate with 16% in building construction, and 19% of non-qualified, 31% of qualified and 50% of highly qualified workers work on their construction.

The distribution of proportionate participation (according to facility surface) of four types of considered construction facilities in the building construction obtained by the flow network application, in relation to types of workers (work groups) is shown in Figure 4. In order to obtain such distribution, qualification structure needs to be eliminated previously from the flow network.

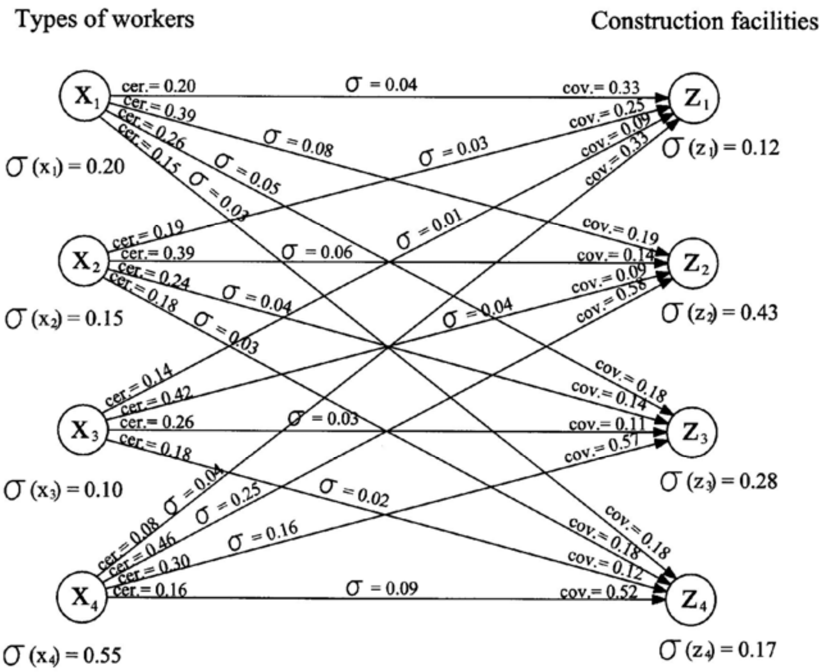

Figure 4: The distribution of proportionate participation of construction facilities in relation to types of workers (work groups)

From the flow network shown in Figure 4 the following results are obtained:

1. Individual construction facilities – 12% of participation in the building construction with the following participation of types of workers:
   - Carpenters – 33%
   - Brick layers – 25%
   - Bar benders – 9%
   - Craftsmen and installers – 33%

2. Big, i.e. standard construction facilities – 43% of participation in the building construction with the following participation of types of workers:
   - Carpenters – 19%
   - Brick layers – 14%
   - Bar benders – 9%
   - Craftsmen and installers – 58%

3. Assembly and semi-assembly construction facilities – 28% of participation in the building construction with the following participation of types of workers:
   - Carpenters – 18%
   - Brick layers – 14%
   - Bar benders – 11%
   - Craftsmen and installers – 57%

4. Superstructures and reconstructions – 17% of participation in the building construction with the following participation of types of workers:
   - Carpenters – 18%
   - Brick layers – 18%
   - Bar benders – 12%
   - Craftsmen and installers – 52%

3.3. Decision algorithm

A decision algorithm can also present results obtained by the flow network application.

The following decision rules are obtained from the flow network shown in Figure 3:

If construction facility (z_1) then workers structure (y_1) (0.03)
If construction facility (z_1) then workers structure (y_2) (0.10)

If construction facility (z_2) then workers structure (y_1) (0.03)
If construction facility (z_2) then workers structure (y_2) (0.19)
If construction facility (z_2) then workers structure (y_3) (0.21)

If construction facility (z_3) then workers structure (y_1) (0.01)
If construction facility (z_3) then workers structure (y_2) (0.14)
If construction facility (z_3) then workers structure (y_3) (0.13)

If construction facility (z_4) then workers structure (y_1) (0.03)
If construction facility (z_4) then workers structure (y_2) (0.05)
If construction facility (z_4) then workers structure (y_3) (0.08)

The following decision rules are obtained from the flow network shown in Figure 4:

If construction facility (z_1) then types of workers (x_1) (0.04)
If construction facility (z_1) then types of workers (x_2) (0.03)
If construction facility (z_1) then types of workers (x_3) (0.01)
If construction facility (z_1) then types of workers (x_2) (0.04)

If construction facility (z_2) then types of workers (x_1) (0.08)
If construction facility (z_2) then types of workers (x_2) (0.06)
If construction facility (z_2) then types of workers (x_3) (0.04)
If construction facility (z_2) then types of workers (x_2) (0.25)

If construction facility (z_3) then types of workers (x_1) (0.05)
If construction facility (z_3) then types of workers (x_2) (0.04)
If construction facility (z_3) then types of workers (x_3) (0.03)
If construction facility (z_3) then types of workers (x_2) (0.16)

If construction facility (z_4) then types of workers (x_1) (0.03)
If construction facility (z_4) then types of workers (x_2) (0.03)
If construction facility (z_4) then types of workers (x_3) (0.02)
If construction facility (z_4) then types of workers (x_2) (0.09)

The *inversion* of decision rules is possible to be performed as well. In that case, the following decision rules are obtained from Figure 4:

If types of workers (x_1) then construction facility (z_1) (0.04)
If types of workers (x_1) then construction facility (z_2) (0.08)
If types of workers (x_1) then construction facility (z_3) (0.05)
If types of workers (x_1) then construction facility (z_4) (0.03)

If types of workers (x_2) then construction facility (z_1) (0.03)
If types of workers (x_2) then construction facility (z_2) (0.06)
If types of workers (x_2) then construction facility (z_3) (0.04)
If types of workers (x_2) then construction facility (z_4) (0.03)

If types of workers (x_3) then construction facility (z_1) (0.01)
If types of workers (x_3) then construction facility (z_2) (0.04)
If types of workers (x_3) then construction facility (z_3) (0.03)
If types of workers (x_3) then construction facility (z_4) (0.02)

If types of workers (x_4) then construction facility (z_1) (0.04)
If types of workers (x_4) then construction facility (z_2) (0.25)
If types of workers (x_4) then construction facility (z_3) (0.16)
If types of workers (x_4) then construction facility (z_4) (0.09)

4. SENSIBILITY OF THE METHOD

The sensibility of the presented method has been analyzed in two cases: (1) input data value and (2) model structure.

4.1. The analysis of the sensibility in relation to the input data value

Figure 5 shows the change of input data value, i.e. distribution of types of workers (work groups) and qualification structure in construction facilities.

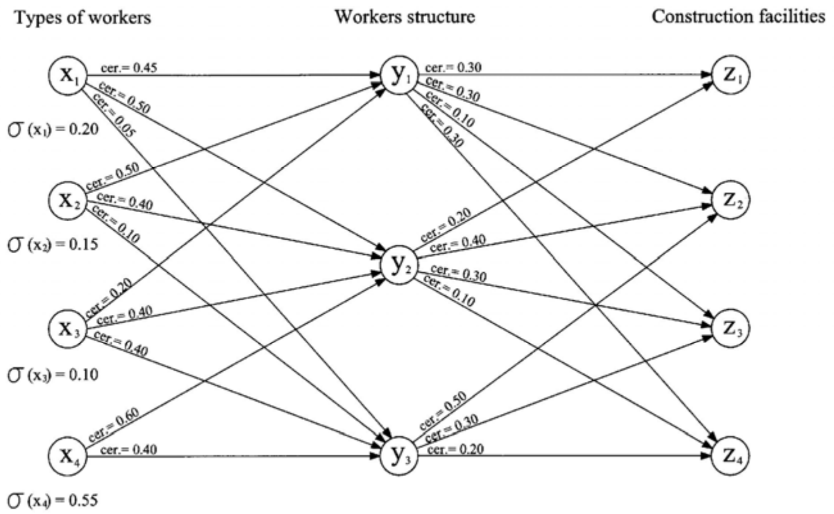

Figure 5: Change of distribution of types and structure of workers in construction facilities

The obtained results are presented in Figure 6.

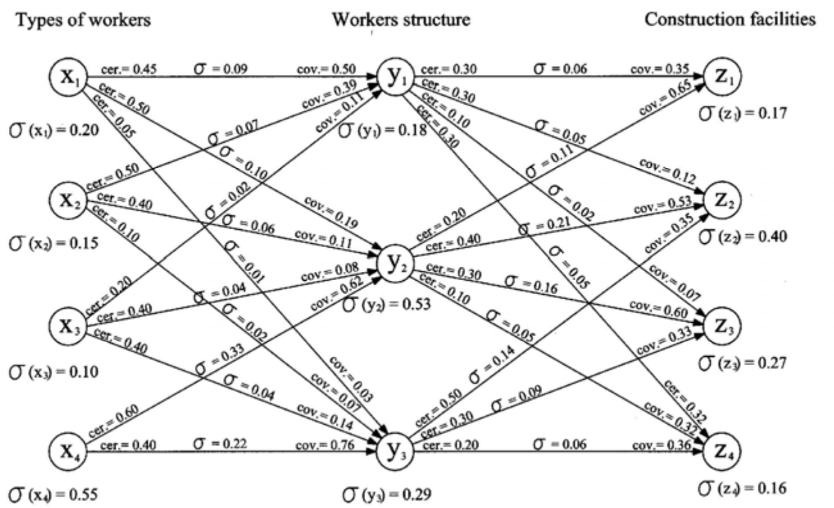

Figure 6: Distribution of changed proportionate participation of construction facilities in relation to the manpower qualification structure

Evidently, the method is highly sensitive to input data value changes[7].

[7] The obtained results are more real in relation to previously presented case, since the output data values are more uniform.

4.2. The analysis of the sensibility in relation to the model structure

Figure 7 shows the change of input data structure when eliminating the relation in the workers structure distribution in types of facilities.

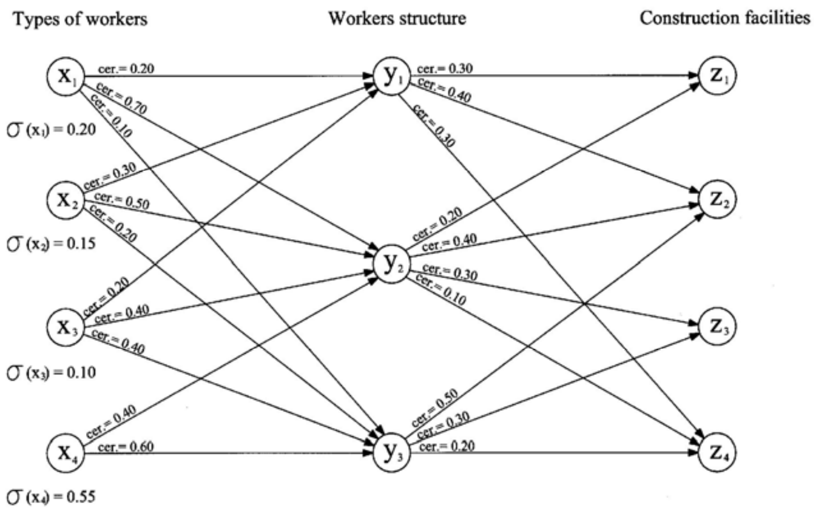

Figure 7: Change of model structure

The obtained results are presented in Figure 8.

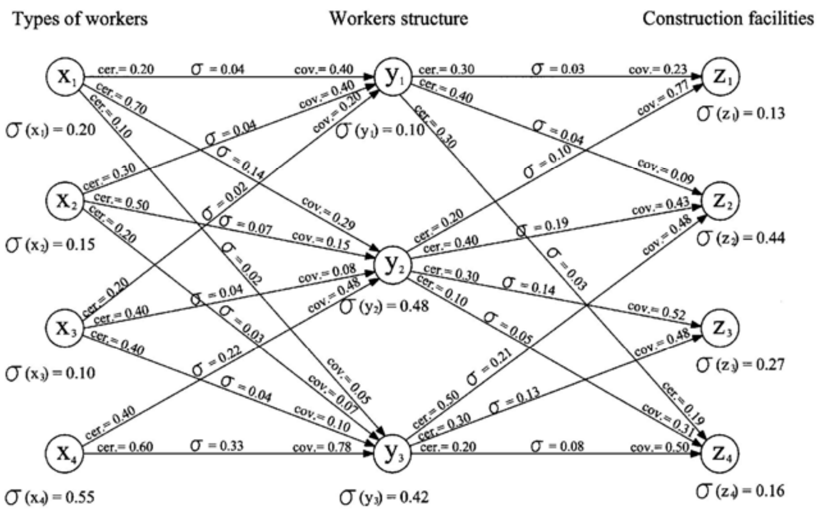

Figure 8: Distribution of proportionate participation of construction facilities in relation to the manpower qualification structure for the changed model structure

Practically the only relation really possible to be cancelled has been cancelled (participation of non-qualified workers in the construction of assembly and semi-assembly facilities), which, previously as well, had a low proportionate participation. The cancellation of other relations with higher proportionate participation would surely cause bigger changes of output results.

5. CONCLUSIONS

The basic aim of this paper was to point out the possibility of the flow network application in the decision algorithm analysis in construction engineering. The problem of distribution of types of work groups and workers qualification structure in particular types of construction facilities, typical for building construction, has been considered, as well as the determination of future trends in this distribution. This is particularly significant because of the specific position and interrelations of the construction engineering, as well as the manpower as an important resource for undisturbed performing of construction production. These specifics refer, above all, to the outstanding trend of workers fluctuation (from public to private firms; from less attractive to more attractive construction facilities, in sense of earnings; from the construction engineering to other similar or different activities, etc.), as well as to the problem that the planned manpower, in accordance with construction quotas, most frequently fails to correspond to real construction production conditions. Obviously, this is also about technical-technological and social-economic aspect of considered problems.

The proportionate participation of workers qualification structure and the distribution of types of construction facilities have been determined by the flow networks applications, firstly on the basis of the qualification structure and then on the basis of the types of workers (work groups).

The decision algorithm has been separately generated by the flow networks application, presenting all decision rules related to this problem and inversion decision rules for each particular case of considered interrelation. Decision algorithms obtained are the support to the decision maker, since the subjectivity, uncertainty and insecurity of particular parameters (as the consequences of already mentioned specifics of the construction production) are frequently present in the process of making decision on the distribution/arrangement of manpower (both of types of manpower and of the workers qualification structure).

The flow network application on given examples proves this method to be sensitive both to the input data value (the most frequent proportionate participation of particular indicators/features) and to the model structuring.

Actual problems (workers qualification structure, types of facilities and works, and their distribution) have been solved in this paper with the aim of demonstrating the possibility of the flow networks application. Evidently, other similar problems as well can be analyzed applying similar methodology.

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