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THE METHOD *NNM* AND ITS APPLICATION IN A SOZOECONOMIC ANALYSIS OF THE PROCESS REALIZATION WITHIN A CYCLE OF A BUILDING STRUCTURE

A. Więckowski

1. Introduction

The method of Numerical Network Modelling *NNM* (in Polish: metoda *Numerycznego Modelowamia Sieciowego NMS*) is a technique of mappings and analyses as well as of planning and supervision of the process execution.

The network model is constructed on the base of the two-point rule, and, so, the realization of every activity is bounded in time by a preceding event (an immediate predecessor) and the subsequent event (an immediate successor). An activity is characterized by a probability of its accomplishment and a random variable of its duration (including deterministic processes).

In order to identify differentiated conditions, necessary for an event to happen, and created by specific events, the model applies adequate variants of vertices (containing more variants than the GAN class, of [1]. Thanks to the mathematically formalized „logic" of a vertex and using computer simulation, an easy and comprehensive network analysis is obtained with a good mapping of technological and organizational peculiarities of production processes realization.

Below only necessary paragraphs justifying assumptions, run of reasoning and the mathematical model are presented.

It is necessary to consider nature and resources conservation and protection with regard to a building structure, that is to meet human needs and requirements over the entire period of its long-term existence and under circumstances of indisputable, permanent development and many-years' service, and to include it in the sozoeconomic analysis [2] of the process realization. This is a prerequisite to ensure the proper operation stability and service life of the building structure. For this purpose, a sozoeconomic criterion is to be applied in the evaluation. With this criterion, the following parameters can be included and correctly counterbalanced: economic profits, benefits resulting from nature conservation, and this particular part of outlays not included in the price but always contained in: raw material mining and processing, wastes disposal, special management.

The general objective of the evaluation is to determine economic profits $A_p(\Delta T)$ made on the building structure project, ie on investing money in this project that can be, then allocated for an economic entity for its own disposal. All processes within an entire building structure's cycle performed during a long-term period ΔT are included in this evaluation-analysis. The *NNM* method has been applied to map the processes realization.

2. Principles of the *NNM* method

Numerical network model of a process – the network is constructed in accordance with the two-point rule, so the edge a_i, $i = 1,\dots,n$, $i \in I$, represents i-th activity, and the vertex v_j, $j = 1,\dots,m$, $j \in J$, represents j-th event. This depends immediately on i-th activity and j-th event is descripted value of incidence ω_{ij}, [3].

A. The value of incidence

Immediate relation between i-th activity and j-th event, represents ω_{ij} – value of incidence of edge a_i, $i = 1,\dots,n$ on vertex v_j, $j = 1,\dots,m$, where:

$$\omega_{ij} \overset{df}{=} \begin{cases} -1, & \text{if edge } a_i \text{ is incident into the vertex } v_j \text{, what represents immediate dependence of } j\text{-th event on } i\text{-th activity,} \quad (1a) \\ 1, & \text{if edge } a_i \text{ is incident out of vertex } v_j \text{, what represents immediate dependence of } i\text{-th activity on } j\text{-th process,} \quad (1b) \\ 0, & \text{in other cases.} \quad (1c) \end{cases}$$

In order to express the level of advancement of an i-th activity, represented by an edge a_i, $i \in I$, a measure is introduced in the form of edge function, and for an edge a_i, $i \in I$, incident on a vertex v_j, $j \in J$, a measure in the form of incidence moment is proposed.

B. Edge function

Function x_i of edge a_i, $i = 1,\dots,n$, which describes the relationship representing the level of advancement of the i-th activity, is defined as follows:

$$x_i \overset{df}{=} \begin{cases} 0, & \text{if the } i\text{-th activity represented by the edge } a_I \text{ has not commenced yet,} \quad (2a) \\ 0 < x < 1, & \text{if the } i\text{-th activity represented by the edge } a_i \text{ goes on,} \quad (2b) \\ 1, & \text{if the } i\text{-th activity represented by the edge } a_i \text{ is accomplished.} \quad (2c) \end{cases}$$

$i = 1,\dots,n$.

C. Incidence moment

Incidence moment μ_{ij} of an edge a_i, $i = 1,\dots,n$, $i \in I$ about a vertex v_j, $j = 1,\dots,m$, $j \in J$, is defined as the product of value of the function x_i and value of the incidence ω_{ij} of the edge a_i on the vertex v_j:

$$\mu_{ij} \overset{df}{=} x_i\omega_{ij}, \bigwedge_{i\in I}, \bigwedge_{j\in J}, \quad (3)$$

where

x_i is edge function of a_i; according to (4a, b, c), it represents the level of advancement of the i-th activity, for example in the time interval T, at the instant $t = t_a \in T$, the value of the edge function equals $x_i(t_a)$.

2.1. Vertex

In the network model under consideration a vertex represents an event, so it is required that it should reflect attainment of a specified state, for which, on the one hand, definite initial conditions necessary for the state to be attained must be fulfilled, ie it should reflect activation; on the other hand, the activation creates certain output conditions [4].

A vertex is characterized, Fig 1, [5], by:

- receptor R which describes input conditions necessary for the activation,
- activation A,
- emitter E which describes output conditions created by the activation.

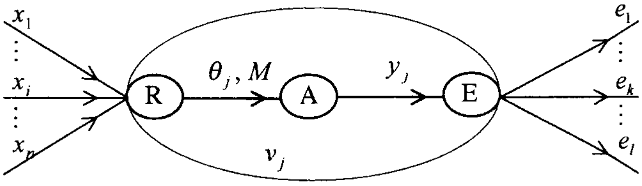

Fig 1. Model of vertex v_j mapping the j-th event

2.1.1. Receptor

At input, in the receptor R, the reception moment and the threshold value of reception are determined.

A. By the reception moment M_j about the vertex v_j, $j = 1,\dots,m$, $j \in J$ (at the instant t, $t \in T$, in consideration T) is called the sum of incidence moments μ_{ij} of all edges a_i, $i = 1,\dots,n$, incident into the vertex v_j:

$$M_j \overset{df}{=} \sum_{i=1}^{n} \mu_{ij}, \bigwedge_{j\in J}, \quad (4)$$

where

μ_{ij} is incidence moment of edge a_i directed towards the vertex v_j, according to (3) it is the actual value of the moment, for example, at the instant t, $t = t_a \in T$.

B. By the threshold value of reception θ_j is called the sum of incidence moments μ_{i^*j}, necessary for activation of the vertex v_j, $j = 1,\dots,m$, $j \in J$, demanded from the edge a_{i^*}, $i^* \in I^*$, from among all edges a_i, $i = 1,\dots,n$, $i \in I$, $I^* \subset I$, directed towards the vertex v_j (for some particular receptors $i^* = i$):

$$\theta_j \overset{df}{=} \sum_{i^*\in I^*, I^*\in I} \mu_{i^*j}, \bigwedge_{j\in J}, \quad (5)$$

where

μ_{i^*j} is incidence moment of edge a_{i^*} about vertex v_j (necessary for activation),

i^* and I^* - resp. index i^* and set I^* of edges a_{i^*}, necessary for activation of vertex v_j.

2.1.2. Activation

The state, in which the reception moment M_j from all edges a_i, $i = 1,\dots,n$, $i \in I$, incident into the vertex v_j, $j = 1,\dots,m$, $j \in J$, equals the threshold value θ_j demanded by corresponding receptor:

$$\theta_j \overset{df}{=} M_j, \bigwedge_{i\in I}, \bigwedge_{j\in J}, \tag{6}$$

where

θ_j is threshold reception value of vertex v_j,

M_j – reception moment at the vertex v_j (from all edges a_i, $\bigwedge_{i\in I}$, incident into the vertex v_j), is called the activation of vertex v_j.

The activation function y_j of the vertex v_j is defined as follows:

$$y_j \overset{df}{=} \begin{cases} 1, \text{ when } \theta_j = M_j, \bigwedge_{i\in I}, \text{ at the instant of activation } t = t_j^a \in T, & (7a) \\ 0, \text{ in all other cases,} & (7b) \end{cases}$$

$j = 1,...,m$.

2.1.3. Emitter

At output (Fig 1) in the emitter E, an emission function e_k is determined for every edge a_k, $k = 1,...,l$, $k \in K$, incident out of the vertex v_j, $j = 1,...,m$, $j \in J$.

By the emission function e_k of vertex v_j into the edge a_k is called the relation representing a possibility of the commencement of k-th activity, immediately dependent on occurence of the j-th event:

$$e_k \overset{df}{=} y_j \omega_{jk} p_{jk}, \bigwedge_{k\in K}, \bigwedge_{j\in J}, \tag{8}$$

where

y_j is value of the activation function of vertex v_j,

ω_{jk} is value of incidence of edge a_k incident out of vertex v_j,

p_{jk} is probability of commencement of activity represented by edge a_k, directed out of the vertex v_j, in the experiment under consideration.

The value of the emission function $e_k = 1$ means the fulfilment of all necessary conditions: a) $y_j = 1$, b) $\omega_{jk} = 1$, c) $p_{jk} = 1$, and points out that after the activation of the vertex v_j, the edge a_k can be entered upon. When any of the conditions a, b, c is not fulfilled, the value of the emission function $e_k = 0$.

A probability p_{jk} of entering upon the edge a_k, $k = 1,...l$, from the vertex v_j, $j = 1,...,m$, represents the chance that in the given experiment, the commencement of k-th activity is possible after the occurence of j-th event.

$$p_{jk} \overset{df}{=} \begin{cases} 1, \text{ provided that in the given experiment, after activation of vertex } v_j \text{, entering upon the edge } a_k \text{ is the certain event; } k\text{-th activity can commence,} & (9a) \\ 0, \text{ in other cases.} & (9b) \end{cases}$$

$j = 1,...,m$.

2.2. The characteristics of a deterministic receptor as well as a deterministic emitter

Only the characteristics of a deterministic receptor as well as a deterministic emitter are shown below, with input as well as output conditions analogous to these of events in, among others, the CPM and PERT methods.

A. Deterministic receptor „and", math. $[\wedge]$, graphical symbol as on Fig 2.

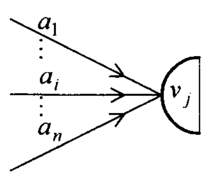

Fig 2. Receptor „and", $[\wedge]$

Activation of a vertex with receptor $[\wedge]$ represents accomplishment for the first time of every i-th activity, $i = 1,...,n$ (here $i^* = i$, as it is demanded for each activity to be finished) immediately indispensary for j-th event to happen, $j = 1,...,m$.

The receptor $[\wedge]$ conditions that:

a) every edge a_i, $i = 1,...,n$, $i \in I$, respectively, representing every i-th activity, is incident into the vertex v_j, $j = 1,...,m$, $j \in J$, so according to (2a) the value of incidence:

$$\omega_{ij} = -1, \bigwedge_{i\in I}, \bigwedge_{j\in J}, \tag{10a}$$

b) every i-th activity, represented by edge a_i, is accomplished, so according to (2c) the value of the edge function:

$$x_i = 1, \bigwedge_{i\in I}, \tag{10b}$$

c) according to (3) the incidence moment of the edge a_i on the vertex v_j equals $\mu_{ij} = 1(-1)$:

$$\mu_{ij} = -1, \bigwedge_{i\in I}, \bigwedge_{j\in J}, \tag{10c}$$

d) till the first activation of the vertex v_j the conditions (10a, b, c) are fulfilled by every edge a_i, what, according to (5), yields the threshold value of reception

$$\theta_j = \sum_{i=1}^{n}(-1) = -n \text{, so:}$$

$$\theta_j = \begin{cases} -n, & \text{till the first activation,} \quad (10da) \\ +\infty, & \text{in other cases.} \quad (10db) \end{cases}$$

$j = 1,\ldots,m.$

(the second and every consecutive activations of the vertex v_j are forbidden, so after the first activation the threshold value is set to $+\infty$)

and in the time interval T under consideration;

e) the actual sum, at the instant $t \in T$, of incidence moments from all edges a_i incident into the vertex v_j, equal to the reception moment according to (4), attains the value:

$$M_j = \sum_{i=1}^{n}\mu_{ij}, \quad \bigwedge_{j \in J}. \tag{10e}$$

B. Deterministic emitter $[\times \wedge]$, symbol is shown in Fig 3.

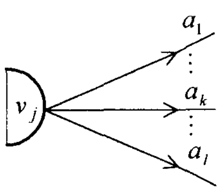

Fig 3. Deterministic emitter $[\times \wedge]$

A vertex equipped with the deterministic emitter $[\times \wedge]$ symbolizes, that occurence of the j-th event, $j = 1,\ldots,m$, created the possibility of commencement of every, immediately dependent, k-th activity, $k = 1,\ldots,l$.

The emitter $[\times \wedge]$ conditions, that:

a) the j-th event, represented by activation of the vertex v_j, $j = 1,\ldots,m$, $j \in J$, took place, so according to (7a) the value of the activation function:

$$y_j = 1, \quad \bigwedge_{j \in J}, \tag{11a}$$

b) edge a_k, $k = 1,\ldots,l$, $k \in K$, is incident out of the vertex v_j, so according to (1a) the value of incidence:

$$\omega_{jk} = 1, \quad \bigwedge_{k \in K}, \bigwedge_{j \in J}, \tag{11b}$$

c) possibility of commencement of every k-th activity is certain (in agreement with assumptions of deterministic networks), so along (9a) the probability of entering upon the edge a_k :

$$p_{jk} = 1, \quad \bigwedge_{k \in K}, \bigwedge_{j \in J}, \tag{11c}$$

d) according to (8) the value of the emission function $e_k = 1 \cdot 1 \cdot 1$, so:

$$e_k = 1, \quad \bigwedge_{k \in K}, \bigwedge_{j \in J}. \tag{11d}$$

2.3. Vertices and realization of edges

Besides the deterministic receptor „and" $[\wedge]$, and emitter $[\times\wedge]$, there are distinguished and described in the publication [5], also receptors: „with release" – $[\forall]$, „IOR" (inclusive or) – $[\vee/\wedge]$, „EOR" (exclusive or) – $[\vee]$, decisive – $[d]$, and emitters: stochastic – $[\times\vee]$ and decisive $[\times d]$, as shown in Table 1.

In order to construct a vertex v_j, $j = 1,\ldots,m$, of needed input and output characteristics, one can apply a suitable receptor and a suitable emitter from among these listed in the Table 1. Each of the five receptors can be joined with each of the three emitters. As a result, fifteen vertex variants are obtained, that brings a vast possibility of description of technological and organizational relations.

Table 1. Symbols of receptors, emitters and vertices

Emitter E \ Receptor R		„AND"	„With release"	„IOR"	„EOR"	„Decisive"
		$[\wedge]$	$[\forall]$	$[\vee/\wedge]$	$[\vee]$	$[d]$
Deterministic	$[\times\wedge]$	$[\wedge\times\wedge]$	$[\forall\times\wedge]$	$[\vee/\wedge\times\wedge]$	$[\vee\times\wedge]$	$[d\times\wedge]$
Stochastic	$[\times\vee]$	$[\wedge\times\vee]$	$[\forall\times\vee]$	$[\vee/\wedge\times\vee]$	$[\vee\times\vee]$	$[d\times\vee]$
Decisive	$[\times d]$	$[\wedge\times d]$	$[\forall\times d]$	$[\vee/\wedge\times d]$	$[\vee\times d]$	$[d\times d]$

A change in value of the emission function e_k, according to (10a), takes place at the instant t_j^a of activation of the vertex v_j, ie at the time of occurence of the j-th event. The edge a_k is entered upon, if the value of the emission function equals $e_k = 1$ (or is not entered upon, if $e_k = 0$, cf. (11)). So, when $e_k = 1$, ie at the moment t_j^a, the edge a_k is entered upon. As a result, the instant t_k^- – at which the edge a_k was entered upon (commencement of the k-th activity):

$$t_k^- = t_j^a . \tag{12}$$

And the instant t_k^+ – of accomplishment of the k-th activity:

$$t_k^+ = t_k^- + t_k(\iota) , \tag{13}$$

where:

$t_k(\iota)$ is duration of the k-th activity, for example, value of the realization time random variable in the actual ι-th simulation experiment, or a *constans* in case of a deterministic activity.

3. An example of a sozoeconomic analysis

An example of such a building structure is a reinforced-concrete, monolithic, 12-storey house with 66 apartments and 2 offices located on the first floor; this house has all installation systems, coupling and service lines, in its environs there are: parking place, necessary access roads for both motor vehicles and pedestrians, thus, the use of this building structure is as designated in the design; it is situated on a 5830 m^2 plot; its localization conditions in Cracow are deemed to be the average standard conditions in 1998.

A building structure's cycle period ΔT covers a full time interval beginning with the very first project idea: that a building structure can be erected, up to the completion of the very last control action. During this building structure's cycle period ΔT, the following processes are carried out: preparation of the whole project, construction of a building structure, operation of and services rendered by this completed building structure, its physical demolition, closing measures and check-up (closing measures comprise engineering, economic and legal procedures to be settled and finally accomplished although the building structure does not physically exist (for it has been demolished), Fig 4, [6].

The organization schedule of the entire project is as follows: an economic entity, in this particular case: General Investor GI which invests in a specific building structure, is a Project Manager throughout the time interval ΔT. An Assistant Investor AI (which acts on behalf and in the name of the General Investor, in accordance with the assumed procedure) supervises and controls the performance of the preparation and construction processes. An Administrative Unit AU (the status of which is similar to that of the Assistant Investor) supervises and controls the realization of the following project processes: building operation services rendered by it (including checking-up the progress in designing, construction, and, also, repair work in the building), physical demolition and closing measures.

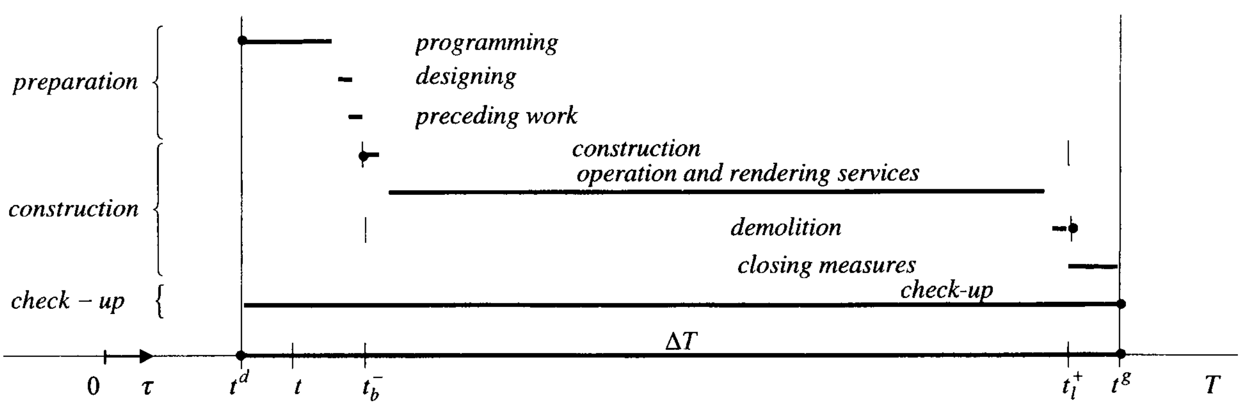

Fig 4. A representation of the processes realization within a full cycle of a selected building structure during a time interval ΔT, in the t-th moment, where: τ – versor of an infinite time period T; asymptotes, crossing the points t^d, t_b^-, t_l^+, t^g, limit time intervals during which an individual process is carried out, in a general case

3.1. *NNM* Network Model

All processes pertaining to a building structure are carried out during a long-term interval (several years, several ten years, several hundred years). Such an interval is always characterized by varying circumstances, interrelations and correlation that essentially influence the realization of those processes and their specific attributes. In order to include those changing factors, the *NNM* method (numerical network modelling) was applied in the analysis and evaluation procedures.

The initial section of the project realization model, presented as the *NNM* model, is shown in Fig 5, and its narrative part – in Table 2.

The interpretation of this model is as follows:

The edge ($S1$,10) represents the process: *development of the initial project idea*; this process is a part of a standard analysis of preliminary estimates with respect to the most profitable investments to be analyzed in the range of the economic entity's development, [2].

The edge (10,11) – *determination of the aim:* NPV_b, in this particular case, it is an optimum financial profit to be made by this economic entity, owing to its long-term project investment, and calculated with regard to the full building structure's cycle ΔT. The process: *determination of the aim:* NPV_b is characterized by varying parameters of the realization time and costs (Table 2, columns 8, 9, 10); those parameters depend on the following aspects:

– whether the aim is determined for the first time, and, then, it is required to perform a complete analysis, for example, after the edge ($S1$,10) has been carried out (Table 2, row 2), and whether the aim has been determined several times already. In this case, this aim should be improved, corrected, and/or amended because new circumstances/events took place during the much progressed project performance that needs to be considered, for example, upon the completion of the edge (13,10) (Table 2, row 4).

In order to create a representation of the activation in vertex 10 upon the completion of any edge directed towards this particular vertex, it is indispensable to incorporate a receptor „IOR" (inclusive or) – $[\vee / \wedge]$. And for the purpose of the individual representation of parameters changed owing to the accomplished d -th process (Table 2, column 4), a decisive emitter $[\times d]$ is required in vertex 10 (in other cases, d characterizes a process within a building structure's cycle, however, this process is not incident to the given vertex). Thus, the description of vertex 10 is: $10[\vee / \wedge \times d]$. As soon as any d -th process is carried out, the parameters: realization time and costs (contained in Table 2, columns 8, 9, 10, in the respective row) are attributed to the process: *determination of the aim* NPV_b .

A graphic model of such mapping and its description, both developed on the basis of the *NNM* method, are given in [8], on the example of the similar analysis of process conditions and realization, as well as events occurring within the full building structure's cycle.

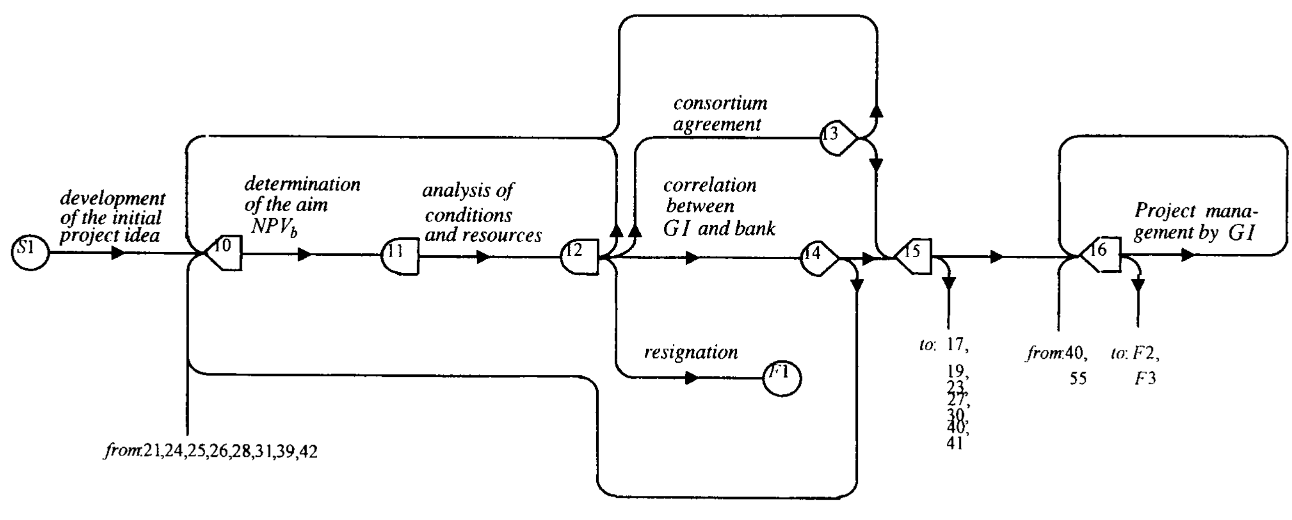

Fig 5. Initial section of the *NNM* model depicting realization procedures of processes within the full building structure cycle

Table 2. Characterization of the initial section of the *NNM* processes realization model within the full building structure's cycle

No.	Edge ij	Vertex j			Edge jk				
	(v_i,v_j)	v_j	d	$p_{jk}(d)$	(v_i,v_j)	Process	Distribution parameters*	Distribution	Costs [zł]
1	2	3	4	5	6	7	8	9	10
1		$S1$ [×∧]		1	$S1$ -10	development of the initial project idea	$m=12$	exponential	**
2	($S1$ 10)	10 [∨/∧×d]	$S1$ - 10	1	10-11	determination of the aim: NPV_b	$m=6$, $k=2$	*Erlang*	32570
3	(12,10)		12-10	1			$m=1$, $k=8$	*Erlang*	3250
4	(13,10)		13-10	1			$m=3$, $k=8$	*Erlang*	4880
5	(14,10)		14-10						
6	(21,10)		21-10	1			$m=1$, $k=4$	*Erlang*	
7	(24,10)		24-10						
8	(25,10)		25-10						
9	(28,10)		28-10						
10	(31,10)		31-10						
11	(39,10)		39-10	1			$m=3$, $k=8$	*Erlang*	
12	(42,10)		42-10	1			$m=1$, $k=4$	*Erlang*	
13	(44,10)		44-10						
14	(47,10)		47-10						
15	(53,10)		53-10						

* The distribution parameters characterize the process realization time expressed in months.
** The process: *development of the initial project idea* has been included in the costs of the entity's development analysis.

3.2. Pattern of cash flow

Whilst making a financial analysis of cash flow within the full building structure's cycle ΔT, the following parameters have been taken into consideration, separately for each year t, $t = 0,1,2,\ldots,n$; CIF_t – cash inflow, COF_t - cash outflow, [9].

The cash inflow CF_{lt} in the year t corresponds to the takings from renting apartments:

$$CIF_t = \sum_{l=1}^{m} p_{lt}\Delta t_{lt},\ t = 0,1,2,\ldots,n, \qquad (14)$$

where

p_{lt} is unit price in [z³/month] for renting l-th apartment (this price corresponds to the monthly rent for the l-th apartment; in this skyscraper there are totally m apartments, and $m = 68$: a) dwellings – 66; b) offices – 2; the price amounts to p_{lt} in the year t, $t = 0,1,2,\ldots,n$; each time this price is calculated as a prospective value, the inflation rate assumed for the calculation purposes is $IP = 5\%$, and capitalization to be made at the end of each year),

Δt_{lt} – period of renting the l-th apartment, expressed in [months], in the year t (the period of renting is currently determined in the *NNM* model of the entire project).

The cash outflow COF_t in the t-th year correspond to the expenditures resulting from the building structure and accrued at the stages: programming, designing, preceding work, construction, operation, demolition, closing measures, check-up:

$$COF_t = COF_{ct} + COF_{st} + COF_{it} + COF_{dt}, \qquad (15)$$
$$t = 0,1,2,\ldots,n,$$

where (in the t-th year)

COF_{ct} is amount in [zł] of the capital charges (here: all accrued costs of a bank credit calculated with regard to the limiting rate of the General Investor's taxes being $T = 40\%$),

COF_{st} is amount [zł] of the project insurance costs (this amount corresponds to the insurance tranch to be paid in the t-th year),

COF_{it} is amount [zł] of indirect costs (it corresponds to the expenditures involved in and resulting from the project management, supervision and checking-up measures as performed by the General Investor in the t-th year),

COF_{dt} is amount [zł] of direct costs.

Within the preparation and construction stages, the amount of a direct cost COF_{dt} corresponds to the sum costs: of each individual i-th processes, carried out in the t-th year, was determined on the basis of results in the *NNM* model.

Within the operation of the building structure and services rendered by it, the following cost components have been distinguished, on the basis of the specified cost COF_{dt} value (similar for each individual i-th process carried out in the t-th year, and including the calculations in the NNM model):

- administration costs of the skyscraper and its fixtures (among other things, terrain belonging to this skyscraper, the so-called small architecture, traffic roads and pedestrian routes, places, etc),
- expenditures involved in the maintenance, cleaning routines, green places, current repair work , etc,
- expenditures such as electricity, water supply and wastewater discharge, heating (they refer to all joint parts in the whole building),
- material costs (cleaning agents, plant protecting and cultivation agents, etc),
- expenditures involved in tools and other devices such as grass cutter, devices to cultivate plants and to perform necessary work to prepare the building for the winter period),
- costs covering all the obligatory and facultative building structure insurance policies,
- fiscal charges such as tax on land, tax on real estate, etc.

3.3. Financial profit of the building

As for an economic entity, in this particular case for the General Investor GI, it shall measure the earning power of its project investment by applying an net present value. A financial (economic) profit NPV_b on the building structure is expressed in the form of an updated net present value by means of the equation:

$$NPV_b = \sum_{t=0}^{n} \frac{CIF_t - COF_t}{(1+k)^t} . \qquad (16)$$

It is a total made up of differences, updated at a given moment, between the income earned from the project investments (ie earned owing to various activities performed by this entity and related to the project investment) and the total of actual costs borne in each t-th year, $t = 0,1,2,\ldots,n$, during the entire time interval ΔT of the building structure's cycle.

The more consequential results of the net present value NPV_b, obtained in the NNM model representing the process realization within the analyzed building structure's cycle, are shown in Table 3, Fig 6.

According to the sozoeconomic criterion, the human impact on nature and environment, exercised by the

Table 3. Updated net present value NPV_b, made on the investments in the building structure project as presented in the example, at the beginning of the t-th year

A t-th year of the building structure's cycle	Credit repayment period, [*years*]		
	20	30	
	Real interest rate, k^* [%]		
	5,5	5,5	9,5
	Values of $E_p(t)$ [zł million]		
0	0	0	0
4	-13171	-13171	-13171
10	-10569	-11918	-12501
20	-3863	-8690	-10140
24	0	-6831	-8409
30	3210	-3176	-4292
34	5085	0	0
40	7896	2936	3374
41	5262	960	740
50	12039	6961	8723
60	17389	12126	15143
70	22075	17019	20776
71	17735	13726	16425
80	24661	20103	24490
90	29347	25268	30113
100	336984	30161	35334
102	344527	-	-

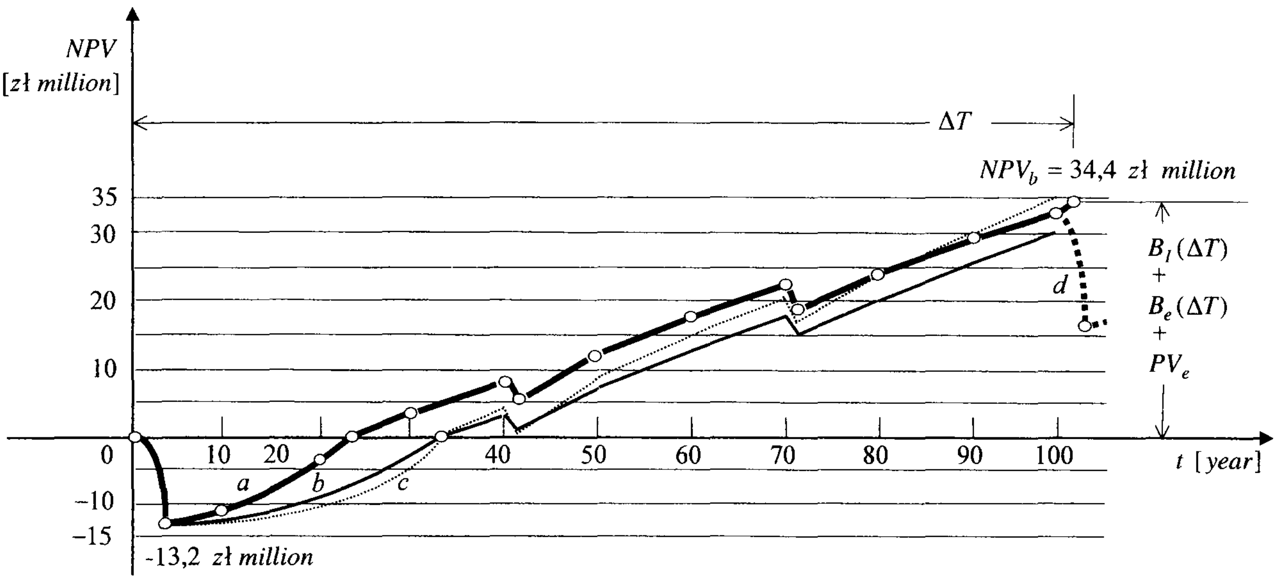

Fig 6. Updated net present values NPV_b up to the t -th moment during the project investing period (investing in the skyscraper) where a, b, c – corresponding to the real interest rates 5.5%, 5.5%, and 9.5%, d refers to general renovation work, ΔT is time interval of the building structure's cycle, and values: PV_e is non-assessed environmental outlays, $B_e(\Delta T)$ is environmental benefits, and $B_I(\Delta T)$ is investing benefits

building structure, should be considered within the entire building structure cycle ΔT; this impact should be evaluated with regard to the not assessed environmental outlays – PV_e (present value; that cause losses to or spoil environment owing to raw materials exploitation or/and processing, wastewater disposal, special management); whilst evaluating the human influence, both the environmental benefits $B_e(\Delta T)$ resulting from nature conservation, and the investing benefits $B_I(\Delta T)$ should be once more and equivalently assessed.

Thus, the pattern of the financial profit of the building structure is as follows (Fig 6):

$$NPV_b = PV_e + B_e(\Delta T) + B_I(\Delta T) . \tag{17}$$

With regard to the equation (17), the economic entity may expect investing benefits $B_I(\Delta T)$ on its investments in the building structure project that equal only part of the difference amount between the net present value NPV_b and the non-assessed environmental outlays PV_e. The other financial profit NPV_b which constitutes the amount of environmental outlays beyond the assessment PV_e and environmental benefits on nature conservation $B_e(\Delta T)$ belongs to the third parties [10].

4. Recapitulation

A method of numerical network modelling called *NNM* [in Polish – *NMS*] is a technique for analysis, planning and supervision of execution of composed, interdependent processes, which, when active during several years, in changing conditions, have different characteristics. The *NNM* network posses a two-point structure. The vertex logic, allowed a homogeneous formalisation of description and an easy examination and solution of both the deterministic models – like *CPM* or *PERT* – and stochastic ones of the *GAN* class, as well as models with decisive vertices, with the possibility of individual declaration of conditions of reception, activation and emission, also for selected patterns of edges and paths.

2. In the above-indicated example, the building structure (a skyscraper with 66 apartments and 2 offices) was constructed by means of a bank credit granted on terms and conditions in force in Cracow, in 1998. The results obtained (Fig 6) allow for the following conclusions:

– in order to repay the credit and real interests of 5.5% within a 20-year period, the monthly income to be earned from renting dwelling apartments should range between 17 and 22 $z^3/m^2/month$, and the monthly income earned from renting offices – 33 $z^3/m^2/month$ (which means that the commercial rent to be paid by tenants must be very high, and only very few people in need of flats are able to pay such high rents); should the monthly rent be lower by 18.79% on average, the period necessary to repay the credit would be 30 years, but again, in order to be able to repay this credit within 30 years, and all involved interests of 9.5% (presently, banks apply the real interest rate of 9.5%), the rent should be higher by 20.02% on average. Thus, the only conclusion is that the state (government) should step in and initiate appropriate measures to assist people of lower income in obtaining flats,

– in the subsequent period, with the fully repaid credit amounts and with commercial rents as fixed above, the incomes earned from the project will exceed expenditures, and by the end of the building's operation period, the financial profit will be Zł 33.7 *million*; the costs of partial renovation work, to be performed after 40 and 70 years, shall be 20% and 33% of the total building value, respectively, thus, those costs will not cause any temporary change in the financial profits, ie these profits, previously positive, shall not become negative. At the end of the entire building cycle, the financial profit will be highly increased and will total $E_p(\Delta T) =$ Zł 34.4 *million* because the value of the retrieved plot shall essentially exceed all the building demolition costs, especially that the law in force does not require recycling, and hauling the demolished elements onto the waste dump is very cheap.

3. An economic entity, investing in the building structure project, may expect that investing benefits $B_I(\Delta T)$ on this investment to be at its individual disposal shall be part of the difference between the net present value NPV_b and the non-assessed environmental outlays PV_e, those economic profits should be also balanced against the environmental benefits on nature conservation $B_e(\Delta T)$, and their value should exceed zero:

$$B_I(\Delta T) = NPV_b - PV_e + B_e(\Delta T) \geq 0 . \qquad (18)$$

4. For the purpose of ensuring sources of profits for future generations (and nature/natural environment is deemed the capital) that are not lower than our own present sources, the equivalence of PV_e and $B_e(\Delta T)$ should be, in accordance with the ecological development rules, invested in the form of an anthropogenic (manufactured) capital.

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SKAITMENINIO TINKLO MODELIAVIMO (STM) METODAS IR JO TAIKYMAS SOCOEKONOMINEI STATYBOS OBJEKTO REALIZAVIMO ANALIZEI

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S a n t r a u k a

Metodas, vadinamas STM (angl. NNM), taikomas analizuojant, planuojant ir kontroliuojant sudėtingus, tarpusavyje susijusius procesus, vykstantys besikeičiančioms sąlygoms, per daugelį metų įgyja skirtingų ypatybių. STM tinklas turi dviejų punktų struktūrą. Viršūnės logika, sudaryta biologinio neurono pavyzdžiu, taikoma tinklui, kuris visiškai skiriasi nuo dirbtinių neuronų tinklų. Ji leido analizuoti aprašymą ir lengvai tirti bei sudaryti tiek deterministinius modelius (pvz., CPM ar PERT), tiek GAN klasės tikimybinius modelius, o drauge ir sprendžiamuosius modelius. Be to, ji sudaro galimybę individualiai pateikti priėmimo, aktyvacijos ir emisijos sąlygas. Ji tinka ir pasirinktiems briaunų bei trajektorijų pavyzdžiams.

Analizė apima visus procesus, kurie sudaro organizuotą veiksmų (ciklų) seką, pradedant statybos objektu, baigiant pasirengimu, eksploatacija bei priežiūra. Tai procesai, prasidėję nuo pirmosios idėjos apie objektą, vėliau perėję į planavimą, pasirengimą ir statybą, ilgą eksploataciją, remontus ir užsibaigę veiklos nutraukimu.

Socoekonominė analizė atsižvelgia į investicijų naudingumą B_I (ΔT), aplinkosauginius privalumus B_e (ΔT) ir neįvertintas išlaidas aplinkosaugai PV_e.

Pateikiama statybos objekto analizės pavyzdžių.

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