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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 Modelowania 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 $\Delta T$ 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 $a_i, i=1, \ldots, n$, $i \in I$, represents $i$-th activity, and the vertex $v_j, j=1, \ldots, m$, $j \in J$, represents $j$-th event. This depends immediately on $i$-th activity and $j$-th event is described value of incidence $\omega_{ij}$, [3].

A. The value of incidence

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

$$
\begin{align*}
\omega_{ij} &= 0, & \text{if edge } a_i \text{ is incident into the vertex } v_j, \\
&= 1, & \text{what represents immediate dependence of } j\text{-th event on } i\text{-th activity,} \tag{1a}
\end{align*}
$$

$$
\begin{align*}
\omega_{ij} &= 0, & \text{if edge } a_i \text{ is incident out of vertex } v_j, \\
&= 1, & \text{what represents immediate dependence} \tag{1b}
\end{align*}
$$

$$
\begin{align*}
&= 0, & \text{of } i\text{-th activity on } j\text{-th process,} \\
&= I, & \text{in other cases.} \tag{1c}
\end{align*}
$$

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 \( a_i, i = 1, ..., n \), which describes the relationship representing the level of advancement of the \( i \)-th activity, is defined as follows:

\[
x_i = \begin{cases} 
0 & \text{if the } i\text{-th activity represented by the edge } a_i \text{ has not commenced yet,} \\
0 < x < 1 & \text{if the } i\text{-th activity represented by the edge } a_i \text{ goes on,} \\
1 & \text{if the } i\text{-th activity represented by the edge } a_i \text{ is accomplished.}
\end{cases}
\]

\( i = 1, ..., n \).

### C. Incidence moment

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

\[
\mu_{ij} = x_i \omega_{ij}, \quad i \in I, j \in J.
\]

\( \omega_{ij} \) is incidence moment of edge \( a_i \) directed towards the vertex \( v_j \).

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 \cite{4}.

A vertex is characterized, Fig 1, \cite{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](image-url)

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 \( v_j, j = 1, ..., m, j \in J \) (at the instant \( t, t \in T \), in consideration \( T \)) is called the sum of incidence moments \( \mu_{ij} \) of all edges \( a_i, i = 1, ..., n \), incident into the vertex \( v_j \):

\[
M_j = \sum_{i=1}^{n} \mu_{ij}, \quad j \in J.
\]

where

\( \mu_{ij} \) 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 \( \theta_j \) is called the sum of incidence moments \( \mu_{ij} \), necessary for activation of the vertex \( v_j, j = 1, ..., m, j \in J \) (at the instant \( t, t \in T \), in consideration \( T \)) of edges \( a_i, i = 1, ..., n \), \( i \in I, i^* \in I^* \) directed towards the vertex \( v_j \) (for some particular receptors \( i^* = i \)):

\[
\theta_j = \sum_{i^* \in I^*} \mu_{ij}, \quad j \in J.
\]

where

\( \mu_{ij} \) is incidence moment of edge \( a_i \) directed towards the 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 \( a_i, i = 1, ..., n, i \in I \), incident into the vertex \( v_j, j = 1, ..., m, j \in J \), equals the threshold value \( \theta_j \) demanded by corresponding receptor:
where 
\[ \theta_j = M_j, \wedge_{k \in I}, \wedge_{j \in J} \]  
(6)

\[ \omega_{jk} = P_{jk}, \wedge_{k \in K}, \wedge_{j \in J} \]

\[ \mu_{ij} = \wedge_{k \in \mathcal{I}}, \wedge_{j \in \mathcal{J}} \]

\[ \beta_{k} = P_{jk}, \wedge_{k \in K} \]

\[ \alpha_{i} = \wedge_{k \in \mathcal{I}} \]

\[ \gamma_{j} = \wedge_{k \in \mathcal{K}} \]

\[ \delta = \wedge_{j \in \mathcal{J}} \]

\[ \epsilon = \wedge_{i \in \mathcal{I}} \]

\[ \zeta = \wedge_{k \in \mathcal{K}} \]

\[ \chi = \wedge_{j \in \mathcal{J}} \]

\[ \theta_{2} = M_{2}, \wedge_{k \in I}, \wedge_{j \in J} \]

\[ \phi = \wedge_{k \in \mathcal{K}} \]

\[ \psi = \wedge_{j \in \mathcal{J}} \]

\[ \xi = \wedge_{i \in \mathcal{I}} \]

\[ \eta = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

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\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

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\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]

\[ \omega = \wedge_{k \in \mathcal{K}} \]

\[ \nu = \wedge_{j \in \mathcal{J}} \]

\[ \kappa = \wedge_{i \in \mathcal{I}} \]

\[ \lambda = \wedge_{k \in \mathcal{K}} \]

\[ \sigma = \wedge_{j \in \mathcal{J}} \]

\[ \tau = \wedge_{i \in \mathcal{I}} \]
\[ \theta_j = \sum_{i=1}^{n} (-1)^i = -n, \text{ so:} \]
\[ \theta_j = \begin{cases} 
-n, & \text{till the first activation,} \\
+\infty, & \text{in other cases.} 
\end{cases} \tag{10da} \]
\[ j = 1, \ldots, m. \]

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:
\[ M_j = \sum_{i=1}^{n} M_{ij}, \tag{10e} \]

B. Deterministic emitter \([x \land] \), symbol is shown in Fig 3.

Fig 3. Deterministic emitter \([x \land]\)

A vertex equipped with the deterministic emitter \([x \land]\) symbolizes, that occurrence 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 \([x \land]\) 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:
\[ y_j = 1, \land_{j \in J}, \tag{11a} \]

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:
\[ \omega_{jk} = 1, \land_{k \in K}, \land_{j \in J}, \tag{11b} \]

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 \( a_k \):
\[ p_{jk} = 1, \land_{k \in K}, \land_{j \in J}, \tag{11c} \]

d) according to (8) the value of the emission function \( e_k = 1 \cdot 1 \cdot 1 \), so:
\[ e_k = 1, \land_{k \in K}, \land_{j \in J}. \tag{11d} \]

2.3. Vertices and realization of edges

Besides the deterministic receptor \(\text{\&\&} \) [\&], and emitter \([x \land]\), there are distinguished and described in the publication [5], also receptors: \(\text{\& with release} \) – \([\lor]\), \(\text{\&OR} \) (inclusive or) – \([\lor \land]\), \(\text{\&EOR} \) (exclusive or) – \([\lor]\), decisive – \([d]\), and emitters: stochastic – \([x \lor d]\) and decisive \([x \land d]\), 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

<table>
<thead>
<tr>
<th>Emitter</th>
<th>Receptor R</th>
<th>&quot;AND&quot;</th>
<th>&quot;With release&quot;</th>
<th>&quot;OR&quot;</th>
<th>&quot;EOR&quot;</th>
<th>&quot;Decisive&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterministic</td>
<td>[x \land]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stochastic</td>
<td>[x \lor]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decisive</td>
<td>[x \land d]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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A change in value of the emission function $e_k$, according to (10a), takes place at the instant $t^0_j$ of activation of the vertex $v_j$, i.e. at the time of occurrence 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 $e_k = 1$, i.e. at the moment $t^0_j$, the edge $a_k$ is entered upon. As a result, the instant $t_k^i$ - at which the edge $a_k$ was entered upon (commencement of the \(k\)-th activity):

$$t_k^i = t^0_j;$$

(12)

And the instant $t_k^f$ of accomplishment of the \(k\)-th activity:

$$t_k^f = t_k^i + t_k(t),$$

(13)

where:

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

3. An example of a socio-economic 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 m² plot; its localization conditions in Cracow are deemed to be the average standard conditions in 1998.

A building structure’s cycle period $\Delta T$ 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 $\Delta T$, 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 $\Delta T$. 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 $\Delta T$, in the \(t\)-th moment, where: \(\tau\) - versor of an infinite time period $T$; asymptotes, crossing the points $t^d, t_k^i, t_k^f, t^l$, limit time intervals during which an individual process is carried out, in a general case](image-url)
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 \( \Delta T \). 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) – \( [v1 \land \lor] \). 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 \( [xd] \) 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: \( 10 \{v1 \land \lor \times d\} \). 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

<table>
<thead>
<tr>
<th>No.</th>
<th>Edge $ij$</th>
<th>Vertex $j$</th>
<th>Distribution parameters*</th>
<th>Distribution</th>
<th>Costs ${zl}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>(11,10)</td>
<td></td>
<td></td>
<td></td>
<td>10-11</td>
</tr>
<tr>
<td>3</td>
<td>(12,10)</td>
<td></td>
<td></td>
<td></td>
<td>10-11</td>
</tr>
<tr>
<td>4</td>
<td>(13,10)</td>
<td></td>
<td></td>
<td></td>
<td>10-11</td>
</tr>
<tr>
<td>5</td>
<td>(14,10)</td>
<td></td>
<td></td>
<td></td>
<td>10-11</td>
</tr>
</tbody>
</table>

* 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 $\Delta T$, the following parameters have been taken into consideration, separately for each year $t$, $t = 0,1,2,\ldots, n$; $\text{CIF}_t$ - cash inflow, $\text{COF}_t$ - cash outflow, [9].

The cash inflow $\text{CIF}_t$ in the year $t$ corresponds to the takings from renting apartments:

$$\text{CIF}_t = \sum_{i=1}^{m} p_{li} \Delta t_{ui}, \quad t = 0,1,2,\ldots, n, \quad (14)$$

where $p_{li}$ is unit price in [\text{zl/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 $p_{li}$ 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), $\Delta t_{ui}$ – 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 $\text{COF}_t$ 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:

$$\text{COF}_t = \text{COF}_{ct} + \text{COF}_{st} + \text{COF}_{r} + \text{COF}_{d}, \quad (15)$$

where (in the $t$-th year)

- $\text{COF}_{ct}$ is amount in [\text{zl}] 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 $T = 40\%$ ),
- $\text{COF}_{st}$ is amount in [\text{zl}] of the project insurance costs (this amount corresponds to the insurance tranch to be paid in the $t$-th year),
- $\text{COF}_{r}$ is amount [\text{zl}] 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),
- $\text{COF}_{d}$ is amount [\text{zl}] of direct costs.

Within the preparation and construction stages, the amount of a direct cost $\text{COF}_{d}$ 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 $\text{COF}_i$ value (similar for each individual $i$-th process carried out in the $t$-th year, and including the calculations in the $\text{NNM}$ 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 $\text{NPV}_b$ on the building structure is expressed in the form of an updated net present value by means of the equation:

$$\text{NPV}_b = \sum_{t=0}^{n} \frac{\text{CIF}_t - \text{COF}_t}{(1+k)^t}.$$  \hfill (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 $\Delta T$ of the building structure’s cycle.

The more consequential results of the net present value $\text{NPV}_b$, obtained in the $\text{NNM}$ model representing the process realization within the analyzed building structure’s cycle, are shown in Table 3, Fig 6.

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

<table>
<thead>
<tr>
<th>A $t$-th year of the building structure’s cycle</th>
<th>Credit repayment period.</th>
<th>\text{years}</th>
<th></th>
<th></th>
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<tr>
<td></td>
<td>20</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Real interest rate, $k^*$ [%]</td>
<td>5.5</td>
<td>5.5</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>Values of $E_p(t)$ [\text{\text{$}} \text{ million}]</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>102</td>
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</table>
building structure, should be considered within the entire building structure cycle \( \Delta T \); 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):

\[
NPV_b = PV_e + B_e(\Delta T) + B_i(\Delta T)
\]  

(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 \( \text{z}\text{\l/m}^2/\text{month} \), and the monthly income earned from renting offices – 33 \( \text{z}\text{\l/m}^2/\text{month} \) (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 2$ 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 $\int P_e (\Delta T) = 2$ 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 $B_f (\Delta T)$ 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:

$$B_f (\Delta T) = NPV_b - PV_e + B_e (\Delta T) \geq 0.$$  (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 $B_f (\Delta T)$ should be, in accordance with the ecological development rules, invested in the form of an anthropogenic (manufactured) capital.

References


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SKAITMENINIO TINKLO MODELIAVIMO (STM) METODAS IR JO TAIKYMAS SOCIOEKONOMINELI STATYBOS OBJEKO REALIZAVIMO ANALIZEI

A. Więckowski

Santrauka

Metodas, vadinas MATLAB (angl. NN), taikomas analizuojant, planuojant ir kontroliuojant sudetingus, tarupavojusius susijusių procesus, vykstantys besikeičiantiems sąlygoms, per daugelį metų išgiją skirtingų įpatybų. STM tinklas turi dviejų punktų struktūrą. Viršūnės logika, sudaryta biologinio neurono pavzdžiu, taikoma tinklui, kuris visiškai skiriasi nuo dirbtinių neuronų tinklų. Ji leido analizuoti aprašytą ir lengvai tirti bei sudaryti tiek deterministinius modelius (pvz., PERT), tiek GAN klasės tikimybinius modelius, o drauge ir sprendžiamuosius modelius. Be to, ji sudaro galimybę individualiai pateikti priemonių, aktyviausių ir emisijų sąlygų. Ji tinka ir pasirenkiamiems briaunams bei trajektorijų pavyzdžiams. Analizu apima visas procesus, kurie sudaro organizuotą veiksmų (ciklų) seka, pradedant statybos objektu, baigiant pasirengimu, eksploatacija bei priežiūra. Tai procesai, prasidėję nuo pirmosios idejos apie objektą, vėliau perėję į planavimą, pasirengimą ir statybą, ilgą eksploataciją, remontus ir užsibaigė veiklos nutraukimu.

Socioekonominė analizė atsirūšiai į investicijų naudingumą $B_f (\Delta T)$, aplinkosauginis privalumas $B_e (\Delta T)$ ir neįvertintas išlaides aplinkosaugai $PV_e$.

Patiekalai statybos objekto analizės pavyzdžiai.

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