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Professional paper

SELECTION OF DEMOLITION SILO TECHNOLOGY

IZBOR TEHNOLOGIJE RUŠENJA SILOSA

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Abstract: Demolition represents a sequence of operations that are referring to removal of the objects. Defect, damage or deformations of the objects are just some of the reasons why it accesses different demolition of building structures. The goal of demolition includes the construction of new objects or simply freeing up space for other purposes. For all these reasons, special emphasis should be placed on the technology of the performance of works. The most dominant technologies that are now successfully applied are demolition technology using explosives and demolition technology using mechanization. In this paper, we will try to select optimal demolition technology of silo that has a specific location.

Key words: selection of demolition technology, multi-criteria decision making, rank of alternatives, TOPSIS method

Apstrakt: Rušenje predstavlja skup operacija koje se odnose na uklanjanje objekata. Dotrajalost, oštećenje ili deformacija objekta samo su neki od razloga zbog kojih se pristupa rušenju različitih građevinskih konstrukcija. Cilj rušenja podrazumeva izgradnju novih objekata ili jednostavno oslobađanje prostora za neke druge namene. Zbog svega navedenog, poseban akcenat treba staviti na tehnologiju izvođenja radova. Najdominantnije tehnologije koje se danas uspešno primenju su tehnologija rušenja eksplozivom i tehnologija rušenja mehanizacijom. U ovom radu, pokušaćemo da izaberemo najpovoljniju tehnologiju rušenja silosa koji ima specifičnu lokaciju.

Ključne reči: izbor tehnologije rušenja, višekriterijumsko odlučivanje, rangiranje alternativa, TOPSIS metoda

1. INTRODUCTION

In the last decades, there is an increasing need for the demolition buildings, structures or parts of construction objects. Buildings to be demolished are commonly located in urban areas, which impose additional caution and the need for good knowledge of demolition techniques and technologies.

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The demolition industry has experienced radical transformation during the past 25 years. High reach hydraulic excavators and specialist attachments have superseded crawler cranes and demolition balls; demolition site safety and procedures have been improved significantly; and demolition contractors have become highly specialised experts in the art of demolition (Abdullah, 2003).

Building demolition is very required and complex process which involves knowledge of many activities. There is a many of the definitions of the demolition. These definitions can be summarized as the removal, dismantling, destruction, razing, wrecking, pulling down or knocking down of any building or structure by pre-planned and controlled techniques to cause complete collapse of the whole or part of the building or structure (Abdullah, 2003).

Because the mining is comprehensive science, mining engineers also have to be trained and familiar with this type of work. The basic requirements that are placed in front of engineers are disruption of static building structure and the absolute necessity to protect the environment from the negative effects of works. Accordingly, their main task is selection of demolition technology.

Next step is refers to define an input data (criteria) which help us to select optimal solution (alternative). Finally, special attention should be devoted on the multi criteria decision making of demolition technology using TOPSIS method.

2. TOPSIS METHOD

TOPSIS method is a technique for order preference by similarity to ideal solution proposed by Hwang and Yoon (1981). The basic concept of this method is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. Positive ideal solution is a solution that maximizes the benefit criteria and minimizes cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria (Wang and Elhag, 2006).

In general, a multiple criteria decision making problem can be concisely expressed in matrix format as:

$$D = \left| x_{ij} \right| = \begin{vmatrix} A/C & C_1 & C_2 & \cdots & C_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{vmatrix} \qquad (1)$$

Where A_1, A_2, ..., A_m are possible alternatives, C_1, C_2, ..., C_n are criteria which measure the performance of alternatives and x_{ij} is the rating of alternative A_i with respect to criteria C_j.

The TOPSIS method is based on the following steps.

Step 1. Construct the normalized decision matrix R

The first step concerns the normalization of the judgment matrix $D = \left| x_{ij} \right|$. Each element x_{ij} is transformed using the following equation:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} = \frac{\left(a_{ij}, b_{ij}, c_{ij}\right)}{\sum_{i=1}^{m}\left(a_{ij}, b_{ij}, c_{ij}\right)} \qquad j = 1, 2, \ldots, n \tag{2}$$

The normalized decision matrix is as follows:

$$R = \left|r_{ij}\right| = \begin{vmatrix} A/C & C_1 & C_2 & \cdots & C_n \\ A_1 & r_{11} & r_{12} & \cdots & r_{1n} \\ A_2 & r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & r_{m1} & r_{m2} & \cdots & r_{mn} \end{vmatrix} \tag{3}$$

Step 2. Construct the weighted normalized decision matrix *V*

Criteria importance is a reflection of the decision maker's subjective preference as well as the objective characteristics of the criteria themselves (Zeleny, 1982). In order to determine criteria importance, we applied concept of the entropy method. Shannon and Weaver (1947) proposed the entropy concept and this concept has been highlighted by Zeleny (1982) for deciding the objective weights of criteria. Entropy is a measure of uncertainty in the information formulated using probability theory. To determine weights by the entropy measure, the normalized decision matrix $R = \left|r_{ij}\right|$ given by (3) is considered (Gligoric et al. 2010). The amount of decision information contained in (3) and associated with each criterion can be measured by the entropy value e_j as:

$$e_j = -k \sum_{i=1}^{m} r_{ij} \cdot \ln\left(r_{ij}\right) \tag{4}$$

Where $k = 1/\ln(m)$ is a constant that guarantees $0 \le e_j \le 1$. The degree of divergence d_{ij} of the average information contained by each criterion C_j ($j = 1, 2, ..., n$) can be calculated as:

$$d_j = 1 - e_j \tag{5}$$

The objective weight for each criterion C_j ($j = 1, 2, ..., n$) is thus given by:

$$w_j = d_j \Big/ \sum_{j=1}^{n} d_j \tag{6}$$

Finally the weighted normalized decision matrix is as follows:

$$V = \left|r_{ij} w_{ij}\right| = \begin{vmatrix} A/C & C_1 & C_2 & \cdots & C_n \\ A_1 & r_{11}w_1 & r_{12}w_2 & \cdots & r_{1n}w_n \\ A_2 & r_{21}w_1 & r_{22}w_2 & \cdots & r_{2n}w_n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & r_{m1}w_1 & r_{m2}w_2 & \cdots & r_{mn}w_n \end{vmatrix} \tag{7}$$

Step 3. Define the ideal and the negative-ideal solutions

Let us suppose that A^+ identifies the ideal solution and A^- the negative one. They are defined as follows:

$$A^{+}=\left\{\left(\underbrace{\max}_{i=1,2,\ldots,m} v_{ij}\,\middle|\, j\in J\right),\left(\underbrace{\min}_{i=1,2,\ldots,m} v_{ij}\,\middle|\, j\in J'\right)\right\}=\left\{v_1^{+},v_2^{+},\ldots,v_n^{+}\right\} \quad (8)$$

$$A^{-}=\left\{\left(\underbrace{\min}_{i=1,2,\ldots,m} v_{ij}\,\middle|\, j\in J\right),\left(\underbrace{\max}_{i=1,2,\ldots,m} v_{ij}\,\middle|\, j\in J'\right)\right\}=\left\{v_1^{-},v_2^{-},\ldots,v_n^{-}\right\} \quad (9)$$

Where

$J=\left\{ j=1,2,\ldots,n \,\middle|\, j \quad \text{associated with the benefit criteria}\right\}$

$J'=\left\{ j=1,2,\ldots,n \,\middle|\, j \quad \text{associated with the cost criteria}\right\}$

With benefit and cost attributes, we discriminate between criteria that the decision maker desires to maximize or minimize, respectively.

Step 4. Measure the distance between alternatives and ideal solutions

To calculate the *n*-Euclidean distance from each alternative to A^+ and A^- the following equations can be easily adopted:

$$S_i^{+}=\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^{+}\right)^2} \qquad i=1,2,\ldots,m \quad (10)$$

$$S_i^{-}=\sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^{-}\right)^2} \qquad i=1,2,\ldots,m \quad (11)$$

Step 5. Measure of the relative closeness to the ideal solution and final ranking

The final ranking of alternatives is obtained by referring to the value of the relative closeness to the ideal solution, defined as follows:

$$Q_i=\frac{S_i^{-}}{S_i^{+}+S_i^{-}} \qquad i=1,2,\ldots,m \quad (12)$$

The best alternative is the one which has the shortest distance to the ideal solution.

3. MODEL OF SELECTION OF DEMOLITION TECHNOLOGY

3.1. The concept of the model

The problem of selection of demolition technology can be represented as Alternatives, Criteria, Evaluations model. We consider:

1. A finite set of alternatives: $A=\left\{A_1,A_2,\ldots,A_m\right\}$.
2. A finite set of criteria: $C=\left\{C_1,C_2,\ldots,C_n\right\}$.
3. A set of evaluations of alternatives with respect to defined criteria: $D=\left|x_{ij}\right|$.

4. DESCRIPTION OF ALTERNATIVES

4.1. Demolition technology using mechanization - Alternative 1

Demolition technology using mechanization respectively demolition machinery technology is increasingly being applied to building demolition. The mechanisation of demolition work started in the late 1950s with the introduction of pneumatic hand hammer breakers and steel balls as far as concrete structures are concerned (Kasai, 1988). This demolition technology is quite expensive because it uses very big and strong machines that cost a lot. However, it provides a large certainty and safety for all equipment and personnel. Excavators and mini excavators are used for almost every conceivable job from dismantling the roof to breaking up and removing the foundations, replacing almost totally the once dominant track loader and crawler crane and drop ball (Polman, 2000). During demolition object using mechanization its necessary to provide the bigger and larger pieces of demolished materials as well as to perform loading more easier and safer and therefore haulage of demolition parts of object.

Considering to mechanization operating mode on construction (building), demolition technology using mechanization can be:

a) Crushing demolition (hydraulic tools for crushing installed on hydraulic excavator with an increased reach of hands);
b) Cutting demolition (diamond saw blades and cable for cutting concrete, plasma cutting operations, oxygen cutting with special electrodes, water cutting, etc.) - these operations of demolition are constantly evolving, and most commonly used at partial demolition of object;
c) Impact demolition (wrecking ball installed on excavator with cables) - in the world, these operations of demolition are not almost used.

One of the important advantages of demolition technology using mechanization is safely and successfully demolition. Also, from the aspect of ecology and environmental protection this demolition technology is enough acceptable because it enable controlled and completely fragmentation of materials with the lowest possible noise, dust and vibration. However, the big disadvantage is expensive mechanization and investments in equipment that be using for demolition. The excavators which are used for demolition are up to 100% more expensive than comparable "normal" excavators from the same class. For all these reasons, this demolition technology is successfully applied in conditions when application of explosive does not give the best results and when location of object is specific and does not allow the application of explosive.

4.2. Demolition technology using explosive - Alternative 2

Since the use of explosives to safely fell structures dates back over 300 years, many chemists, inventors, blasters and demolition experts worldwide have played important roles in the evolution of what has become the modem-day explosive demolition industry (Blanchard, 2002).

Demolition technology using explosive includes the following phases:
I phase - development works;
II phase - blast hole drilling;
III phase - charging blast holes with explosives and carry out the protection measures;
IV phase - blasting.

First phase

First phase refers to operations needed to prepare the object to be demolished. It is composed of the following activities:

- prospect the location in terms of identification of parameters having the most influence on this technology, such as object dimensions, state of the object, vicinity of another objects that must not be damaged;
- making the detail plan of the demolition process, which include the list of activities and order of their appearances.

Second phase

Drilling represents a complex operation that is referred on the blast hole creation in the specified work environment. Drilling perform on internal and external side depending of structural elements of object that be demolished. After determining physical - mechanical properties as well as technical properties of working space it accesses to make a selection of system of drilling. Also, it is defined a basic parameters of drilling such as: hole diameter, hole depth, slope angle of hole, required number of drills, time of drilling one blast hole with all auxiliary operations, etc.

Third phase

Hole charging is one of the important activities for successfully blasting and building demolition. Depending of type, layout and position of elements in object we differentiate several commonly used forms of hole charging. These are: column, concentrative, cumulative and combined charging. Also, we should make a selection of optimal amount of blasting charge to obtain the best results of demolition. In order to protect object that be demolished its necessary to carry out the protection measures to prevent unwanted and unpredicted effects of blasting as well as the uncontrolled bursting clearance.

Fourth phase

Blasting has a wide application both in mining and in other branches of industry. Blasting is the final action of the demolition technology using explosive. After make a selection of explosive and means of initiation of explosive charge we define a basic parameters of blasting such as: amount of explosive per linear meter, line of least resistance, distance between blast holes, means of initiation of explosive charge, etc. Suitable technical - technological, technical - blasting, as in the highest measure possible technical - safety features of contemporary explosives, completely provide controlled blasting of object. It means that it is possible to realize planned demolition of the object which includes his directional drop on the basis.

4.3. Description of combined demolition technology - Alternative 3

In addition of demolition technology using explosive as well as demolition technology using mechanization we differentiate combined demolition technology. If the object that be demolish very high or it is located on inaccessible place or for some other reason than we applied combined demolition technology. Investments in equipment is very expensive as well as total costs of demolition are very high. Also, safety and security of execution of works are at the very high level.

On the selection of demolition method affects the investor's request which is connected on characteristic of equipment that it owned and a dynamic of building demolition and the big influence has the profitability of demolition.

5. DESCRIPTION OF CRITERIA

5.1. Capital Investments – Criterion 1

This criterion is related to purchasing of equipment and defined as quantitative criterion. It is expressed in monetary units. This criterion should be minimized.

5.2. Unit operating costs – Criterion 2

This criterion is also defined as quantitative. It is expressed in monetary units needed to demolish one meter of silo, including all specific operating costs such as costs of drilling and blasting, costs of mounting and demounting, costs of lubricants and oils, labor costs etc. This criterion should be minimized.

5.3. Complexity of demolition technology – Criterion 3

Complexity of demolition technology is primarily referred to engagement of equipment and personals during the works. This criterion is defined in qualitative way and represented by adequate scale. The scale is defined by interval [1-10] and this interval is divided into four levels. These are: low [1-3], medium [3-5], high [5-7] and very high level [7-10]. From complexity point of view, the process of demolition should be as simple as possible and acceptable to investor. Accordingly, this criterion should be minimized.

5.4. Safety – Criterion 4

Demolition technology must fulfill all safety requirements such as personnel protection, protection of surrounding buildings, equipment protection, environmental protection, etc. This criterion is also expressed in quality way, i.e. by adequate scale. We use the same level valued scale related to Criterion 3. This criterion should be maximized.

6. NUMERICAL EXAMPLE

Silo represents object for storing different materials. The most common are: grain, cement, coal, food products, etc. There are three basic types of silos: tower silos, bunker silos and bag silos. They mainly differ according to capacity, height, purpose, type of material etc.

In our case, object that be demolished belongs to a group of complexity construction elements which consists of walls of the block – brick and parts of reinforced concrete such as: vertical and horizontal reinforced concrete beams (cerclage), ceilings, staircases and platforms.

As it mentioned earlier, silo has a very specific location. With research works is determined that silo is located on the coal deposits. Considering that it is evaluated that value of building land respectively coal mining is much higher than value of silo itself and therefore decision was made to removing this object because of possibility of surface mine opening.

Table 1 - Input parameters

Demolition technology	Capital investments [$]	Unit operating costs [$/m']	Complexity	Safety
Mechanization	500,000	8,000	4	9
Explosive	30,000	4,000	9	2
Combined	600,000	15,000	7	6

Table 2 - Decision making matrix

	C_1	C_2	C_3	C_4
A_1	500	8	4	9
A_2	30	4	9	2
A_3	600	15	7	6

Value of criterion C_1 is expressed in thousands of $ and C_2 in $/m'

Table 3 - Normalized decision matrix

	C_1	C_2	C_3	C_4
A_1	0.442478	0.296296	0.20	0.5294118
A_2	0.026549	0.148148	0.45	0.1176471
A_3	0.530973	0.555556	0.35	0.3529412

Table 4 - Weighted normalized decision matrix

	C_1	C_2	C_3	C_4
A_1	0.215619	0.144385	0.0974597	0.2579815
A_2	0.012937	0.072192	0.2192843	0.0573292
A_3	0.258742	0.270721	0.1705544	0.1719876

Table 5 - Ideal and the negative - ideal solutions matrix

	C_1	C_2	C_3	C_4
A^+	0.012937	0.072192	0.0974597	0.2579815
A^-	0.258742	0.270721	0.2192843	0.0573292

Table 6 - Measure the distance between alternatives and ideal solutions matrix

S_1^+	0.215155	S_1^-	0.270043
S_2^+	0.234739	S_2^-	0.315965
S_3^+	0.335517	S_3^-	0.124584

Table 7 - Measure of the relative closeness to the ideal solution and final ranking matrix

S_1	0.556563
S_2	0.573747
S_3	0.270775

The final rank of alternatives is A_2 (0.573747), A_1 (0.556563) and A_3 (0.270775).

7. CONCLUSION

Demolition objects with blasting i.e. his descending on the ground level, with regard to demolition using mechanization is multiple profitable both in economic and in terms of time saving, engagement of personnel and equipment. Special emphasis should be placed on the parameters of drilling and blasting that have exceptional importance for successfully execution of works.

However, a big influence on the selection of demolition technology has location of the object as well as profitability and safety of execution of works. Therefore, in certain cases, very good results can provide a combination of the two methods and also application of each method individually.

Regarding the application of demolition technology using explosive in future, it can be expected that blasting still have its application in specific cases of building demolition, when any other demolition technology is inapplicable or unprofitable, respectively when due to different limits demolition of blasting is the only choice.

REFERENCES

[1] ABDULLAH, A. (2003) *Intelligent selection of demolition techniques*. Doctoral thesis (PhD), Loughborough University.

[2] BLANCHARD, B. (2002) A History of Structural Demolition in America. In: *Proceedings of the 28th Annual Conference on Explosives and Blasting Technique (Volume I), Las Vegas, February 2002*. Cleveland: International Society of Explosives Engineers, pp. 27-45.

[3] GLIGORIC, Z., BELJIC, C. and SIMEUNOVIC, V. (2010) Shaft location selection at deep multiple orebody deposit by using fuzzy TOPSIS method and network optimization. *Expert systems with applications*, (37) 2, pp. 1408-1418.

[4] HWANG, C.L. and YOON, K. (1981) *Multiple Attribute Decision Making - Methods and Applications A State-of-the-Art Survey*. Berlin Heidelberg: Springer-Verlag.

[5] KASAI, Y. (1988) Guidelines and the present state of the reuse of demolished concrete in Japan. In: LAURITZEN, E.K. (eds.) *Demolition and Reuse of Concrete and Masonry, Proceedings of the Third Ineternational RILEM Symposium (Rilem Proceedings 23)*. London: Chapman & Hall, pp. 97-113.

[6] POLMAN, M. (2000) *Demolition and Recycling an Ever Changing Industry*. [Online] European Demolition Association, EDA. Available from: http://www.europeandemolition.org/supplierservices.html [Accessed 01/02/2001].

[7] SHANNON, C.E. and Weaver, V. (1947) *The mathematical theory and communication*. Urbana: The University of Illinois Press.

[8] WANG, Y.M. and ELHAG, T.M.S. (2006) Fuzzy TOPSIS method based on alpha level sets with an application to bridge risk assessment. *Expert systems with applications*, 31, pp. 309-319.

[9] ZELENY, M. (1982) *Multiple criteria decision making*. New York: McGraw Hill.