Intercomparison of Building Dismantling Methods

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Abstract. The choice of the most suitable method can be based on various criteria, such as the dismantling period, production per 1 m³, noise exposure. Often it is quite difficult to determine the appropriate method of dismantling, taking into account the specification of the structure, its location, area wide, the complexity of the analysis of the building and other conditions. To make a decision on the choice of the most suitable method of dismantling, it is proposed to use the analytical hierarchical procedure of Saaty, based on a pairwise comparison of methods, and then determining the criteria for dismantling. This method of decision-making allows you to make decisions based on the specific conditions of dismantling and determine the proportion of each criterion for the most appropriate solution to the problem.

1. Introduction
Nowadays, the construction industry can offer many ways and methods of dismantling constructions, buildings and structures. The choice of the method of the structure dismantling has influence on the work time, however, the choice is not limited by the time of work, but also includes many parameters. This article discusses the comparison of methods of dismantling using hierarchical T. Saaty’s process [11], by the 3 independent parameters: production, duration, noise exposure per each of the proposed methods of dismantling.

2. Materials and methods
There are several methods of dismantling, which are used in the construction industry: manual method, mechanized using small and large mechanization devices, technological explosion, dismantling by hydorobot, chemical and ultrasonic methods.

Manual method of disassembly of structures is used in cases where the work should be carried out very carefully, for example, when disassembling not the entire structure, but its parts. The need for manual dismantling occurs if the high density of buildings and the close location of the next buildings, without opportunity to use of special equipment. As a rule, manual dismantling is used only in cases where the building does not exceed 5 levels.

For point disassembly of houses and buildings used diamond cutting method and such types of equipment as jackhammers, hand drilling machines with carbide drills, diamond cutting tools machines (circles, ring drills), equipment for gas and electric arc cutting and other types of small mechanization devices. Manual dismantling is convenient for performing restoration and repair work, as during the construction and operation periods, and the partial maintenance of building elements, e.g. foundations or Foundation slabs, if it is necessary.
Dismantling of a structure by the mechanized method is the most popular and often used type of dismantling. This method allows you to dismantle the object and get rid of debris formed in the process of destruction shortly. A wide range of special equipment can be clarifying by the performance of this method and machines, which are helps to make possible in a short time to completely dismantle the building up to 60 meters.

![Figure 1. Mechanized dismantling method by the excavator](image)

Technological explosion is used when removing the quarter development, and it is used very rarely in the dismantling of buildings and structures. The basic principle of the explosive method is to create dynamic loads that ensure the destruction of the bearing structures of the lower and upper floors, resulting in a loss of stability of the building and its collapse. The point explosion technology is using to reduce the scattering of the elements of destruction.

Zones of collapse and dangerous areas during the demolition of the object by the explosional method are determined by special guidelines. The design of the object, the type of explosives, the magnitude of the charges, the distance between them, the order of detonation and other parameters have strong influence on the zones. Local conditions (building area, underground utilities and structures) are considering as well.

The usage of a hydrorobot is the most environmental friendly and clean dismantling method. One hydrorobot is able to dismantle up to $2.5 \text{ m}^3$ of concrete, 2 install operators help it round-the-clock functioning. The hydrorobot destroys the concrete by use of water, sucking in the resulting solution, which then creates new concrete blocks for the construction of prefabricated houses. The main task of the engineers was to create a device capable to destroy outdated buildings as efficiently as possible and with a minimum loss, since the existing machines consume enormous amounts of energy and do their work "dirty", raising clouds of concrete dust into the air.

Chemical (thermal) method is used for the destruction of strong building materials, since their use excludes fire and explosion. The popularity of this method can be explained by the absence of excess
litter during the work, which is one of the main characteristic of the explosion. In addition, this method is considered quiet. LDC-1 powder is often used because it contributes to rapid destruction. Dismantling consists of several stages: drill the holes in the concrete part. They shall be 80 mm in diameter and 560 mm apart. In each hole, pour a pre-prepared mixture – a means of water. After that, you need to wait two days, during this time the reagent will begin to crystallize and gradually destroy the building material.

The use of ultrasound for the destruction of concrete structures is a tendency method. The use of ultrasonic devices for the destruction of concrete in the industry has high accuracy. This allows you to perform effective surface treatment with complex terrain. However, it is necessary to take into account many specific factors of the use of ultrasonic waves. To obtain holes with a variable diameter, it is necessary to use special ultrasonic devices with many functions, thanks to which holes with a diameter of less than 4 cm are obtained.

In most cases, the weight of the device is able to provide the required downforce, which allows processing the material effectively. To ultrasonic waves correctly penetrate into the concrete mass, it’s necessary to apply water to the surface. In addition, this will be a special kind of gel or grease.

To compare the methods of dismantling, a pair comparison is used in accordance with the analytical hierarchical procedure of Saaty [12], which is based on the comparison of the selected criteria. The comparison is carried out by an expert (a person, decision maker (DM)) based on the specifications of the equipment, or on the basis of the description of the method of dismantling described in the building codes and standards NOSTROY.

The first step is to compare the methods of dismantling for the development of 1 m$^3$. The comparison is carried out on the example of a panel five-stories four-section house of type I-515/5 with a total cubic capacity of 14 207.4 m$^3$.

The DM compares alternatives contain points where 1 equivalence, 2 – slight advantage of 3 – moderate advantage, 4 – medium advantage, 5 – strong advantage, 6 – a substantial advantage, 7 – a significant advantage, 8 – very strong advantage, 10 – the highest advantage.

Then the matrix of comparison of alternatives is formed.

**Table 1. The pairwise comparison of alternatives methods for the production**

| Methods          | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic |
|------------------|--------|------------|-------------------------|------------|----------|-----------|
| Manual           | 1/1    | 1/4        | 1/6                     | 1/6        | 1/1      | 1/2       |
| Mechanized       | 4/1    | 1/1        | 1/3                     | 1/3        | 4/1      | 4/1       |
| Technological explosion | 6/1    | 3/1        | 1/1                     | 4/1        | 6/1      | 5/1       |
| Hydrorobot       | 6/1    | 3/1        | 3/1                     | 3/1        | 1/1      | 2/1       |
| Chemical         | 1/1    | 1/4        | 1/6                     | 1/2        | 1/1      | 1/2       |
| Ultrasonic       | 2/1    | 1/4        | 1/5                     | 1/4        | 2/1      | 1/1       |

*The top of the cell shows the ratio in points, the bottom of the cell shows the value in decimals.

The obtained values in the cells reflect the non-critical structuring of the set of alternatives, for the calculation of the most effective method, the string sums are calculated.
Table 2. Sum lines of alternatives for the production

| Methods             | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic | Line amount |
|---------------------|--------|------------|-------------------------|------------|----------|------------|-------------|
| Manual              | 1.00   | 0.25       | 0.16                    | 0.16       | 1.00     | 0.50       | 3.07        |
| Mechanized          | 4.00   | 1.00       | 0.33                    | 0.33       | 0.25     | 4.00       | 9.91        |
| Technological explosion | 6.00   | 3.00       | 1.00                    | 4.00       | 6.00     | 5.00       | 25.00       |
| Hydrorobot          | 6.00   | 3.00       | 3.00                    | 1.00       | 2.00     | 4.00       | 19.00       |
| Chemical            | 1.00   | 0.25       | 0.16                    | 0.50       | 1.00     | 0.50       | 3.41        |
| Ultrasonic          | 2.00   | 0.25       | 0.20                    | 0.25       | 2.00     | 1.00       | 5.70        |
| Total               |        |            |                         |            |          |            | 66.09       |

Further, the sums are normalized so that their sum of the line in turn equals 1. To do this, divide the sum of each row by 66.09 (the sum of the last column, i.e., the sum of the lowercase sums themselves) and build the ranking of alternatives to the formula:

$$R = \frac{\sum m}{S}$$  \hspace{2cm} (1)

- \(R\) – normalized value;
- \(\sum m\) – the sum of each row;
- \(S\) – sum of string amounts.

Table 3. Ranking of alternatives for the production

| Methods             | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic | Line amount |
|---------------------|--------|------------|-------------------------|------------|----------|------------|-------------|
| Manual              | 1.00   | 0.25       | 0.16                    | 0.16       | 1.00     | 0.50       | 0.05        |
| Mechanized          | 4.00   | 1.00       | 0.33                    | 0.33       | 0.25     | 4.00       | 0.15        |
| Technological explosion | 6.00   | 3.00       | 1.00                    | 4.00       | 6.00     | 5.00       | 0.38        |
| Hydrorobot          | 6.00   | 3.00       | 3.00                    | 1.00       | 2.00     | 4.00       | 0.29        |
| Chemical            | 1.00   | 0.25       | 0.16                    | 0.50       | 1.00     | 0.50       | 0.05        |
| Ultrasonic          | 2.00   | 0.25       | 0.20                    | 0.25       | 2.00     | 1.00       | 0.09        |
| Total               |        |            |                         |            |          |            | 1.00        |

In the Saaty process, the normalized amounts obtained in this way are accepted as estimates of alternatives according to the production criterion per 1 m³. It is worth noting that these estimates reflect only the point of view of a particular DM.

A similar analysis is carried out according to other criteria of comparison: duration and noise impact.

The duration is calculated similarly to the development by constructing a matrix and bringing it into decimal form:
Table 4. The pairwise comparison of alternatives methods for the duration

| Methods       | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic |
|---------------|--------|------------|--------------------------|------------|----------|------------|
| Manual        | 1/1    | 1/5        | 1/10                     | 1/5        | 1/1      | 1/4        |
|               |        | 1          | 0.2                      | 0.1        | 0.2      | 1          |
| Mechanized    | 5/1    | 1/1        | 1/4                      | 0.25       | 1/2      | 4/1        |
|               |        | 5          | 1                        | 0.25       | 0.5      | 4/1        |
| Technological | 10/1   | 4/1        | 1/1                      | 5/1        | 8/1      | 5/1        |
| explosion     |        | 10         | 4                        | 1          | 5        | 8          |
| Hydrorobot    | 5/1    | 2/1        | 1/5                      | 0.2        | 1/1      | 4/1        |
|               |        | 5          | 2                        | 0.2        | 1        | 4/1        |
| Chemical      | 1/1    | 1/4        | 1/8                      | 0.12       | 0.25     | 1/1        |
|               |        | 1          | 0.25                     | 0.12       | 0.25     | 1          |
| Ultrasonic    | 4/1    | 1/4        | 1/5                      | 0.2        | 0.33     | 2/1        |
|               |        | 4          | 1/4                      | 0.24       | 0.33     | 0.5        |

Further, the sums are normalized so that their sum of the line in turn is equal to 1. To do this, divide the sum of each row by 75.1 (the sum of the last column, i.e. the sum of the lowercase sums themselves) and build the ranking of alternatives:

Table 5. Summarizing alternative lines

| Methods       | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic | Line amount |
|---------------|--------|------------|--------------------------|------------|----------|------------|-------------|
| Manual        | 1      | 0.2        | 0.1                      | 0.2        | 1        | 0.25       | 2.75        |
| Mechanized    | 5      | 1          | 0.25                     | 0.5        | 4        | 4          | 14.75       |
| Technological | 10     | 4          | 1                        | 5          | 8        | 5          | 33          |
| explosion     |        |            |                          | 1          | 4        | 3          | 15.2        |
| Hydrorobot    | 5      | 1          | 0.25                     | 0.2        | 1        | 4          | 3            |
| Chemical      | 1      | 0.25       | 0.12                     | 0.25       | 1        | 0.5        | 3.12        |
| Ultrasonic    | 4      | 0.25       | 0.2                      | 0.33       | 0.5      | 1          | 6.28        |

Total 75.1

Table 6. Ranking of alternatives by duration

| Methods       | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic | Line amount |
|---------------|--------|------------|--------------------------|------------|----------|------------|-------------|
| Manual        | 1      | 0.2        | 0.1                      | 0.2        | 1        | 0.25       | 0.04        |
| Mechanized    | 5      | 1          | 0.25                     | 0.5        | 4        | 4          | 0.20        |

5
### Table 6. Ranking of alternatives by duration - continued

| Methods          | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic | Line amount |
|------------------|--------|------------|-------------------------|------------|----------|------------|-------------|
| Technological explosion | 10     | 4          | 1                       | 5          | 8        | 5          | 0.44        |
| Hydrorobot       | 5      | 2          | 0.2                     | 1          | 4        | 3          | 0.20        |
| Chemical         | 1      | 0.25       | 0.12                    | 0.25       | 1        | 0.5        | 0.04        |
| Ultrasonic       | 4      | 0.25       | 0.2                     | 0.33       | 0.5      | 1          | 0.08        |

Total 1.00

A similar calculation is carried out for noise exposure, however, in this case, the ranking is made from the reverse, since the least value is obtained by the method that has the least noise impact.

### Table 7. The pairwise comparison of alternatives methods for noise impact

| Methods          | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic |
|------------------|--------|------------|-------------------------|------------|----------|------------|
| Manual           | 1/1    | 1          | 3                       | 6/1        | 1/2      | 0.5        | 1/5         |
| Mechanized       | 1/3    | 0.33       | 1                       | 3/1        | 1/3      | 0.33       | 1/4         |
| Technological explosion | 1/6    | 0.16       | 1/4                     | 1/1        | 1/5      | 0.2        | 1/8         |
| Hydrorobot       | 2/1    | 2          | 3/1                     | 5/1        | 1/1      | 1/4        | 0.25        |
| Chemical         | 5/1    | 5          | 4                       | 8/1        | 4/1      | 1/1        | 1/2         |
| Ultrasonic       | 4/1    | 4          | 4                       | 6/1        | 3/1      | 2/1        | 1/1         |

In this case, the ranks are put down in such a way, where 1/10 is the strongest source of noise exposure, and 10 is the weakest source of noise exposure, otherwise the results are not correct.

### Table 8. Sum lines of alternatives for the development

| Methods          | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic | Line amount |
|------------------|--------|------------|-------------------------|------------|----------|------------|-------------|
| Manual           | 1      | 3          | 6                       | 0.5        | 0.2      | 0.25       | 10.95       |
| Mechanized       | 0.33   | 1          | 3                       | 0.33       | 0.25     | 0.25       | 5.16        |
| Technological explosion | 0.16  | 0.25       | 1                       | 0.2        | 0.12     | 0.16       | 1.89        |
| Hydrorobot       | 2      | 3          | 5                       | 1          | 0.25     | 0.33       | 11.58       |
| Chemical         | 5      | 4          | 8                       | 4          | 1        | 0.5        | 22.5        |
| Ultrasonic       | 4      | 4          | 6                       | 3          | 2        | 1          | 20          |

Total 72.08
### Table 9. The ranking of the alternatives according to the noise impact

| Methods                  | Manual | Mechanized | Technological explosion | Hydrorobot | Chemical | Ultrasonic | Line amount |
|--------------------------|--------|------------|-------------------------|------------|----------|------------|-------------|
| Manual                   | 1      | 3          | 6                       | 0.5        | 0.2      | 0.25       | 0.15        |
| Mechanized               | 0.33   | 1          | 3                       | 0.33       | 0.25     | 0.25       | 0.07        |
| Technological explosion  | 0.16   | 0.25       | 1                       | 0.2        | 0.12     | 0.16       | 0.03        |
| Hydrorobot               | 2      | 3          | 5                       | 1          | 0.25     | 0.33       | 0.16        |
| Chemical                 | 5      | 4          | 8                       | 4          | 1        | 0.5        | 0.31        |
| Ultrasonic               | 4      | 4          | 6                       | 3          | 2        | 1          | 0.28        |
| **Total**                | 1.00   |            |                         |            |          |            |             |

Similar to the calculation of pairwise alternatives, the specific weights of each of the comparison criteria can be obtained.

### Table 10. Pairwise comparison of criteria

| Criteria                  | Production | Duration | Noise impact |
|---------------------------|------------|----------|--------------|
| Production                | 1/1        | 3/1      | 6/1          |
| Duration                  | 1/3        | 1/1      | 2/1          |
| Noise impact              | 1/6        | 1/2      | 1/1          |

### Table 11. The summation of the rows of criteria

| Criteria                  | Production | Duration | Noise impact | Line amount |
|---------------------------|------------|----------|--------------|-------------|
| Production                | 1          | 3        | 6            | 10          |
| Duration                  | 0.33       | 1        | 2            | 3.33        |
| Noise impact              | 0.16       | 0.5      | 1            | 1.66        |
| **Total**                 |            |          |              | 14.99       |

### Table 12. Ranking criteria for the comparison

| Criteria                  | Production | Duration | Noise impact | Line amount |
|---------------------------|------------|----------|--------------|-------------|
| Production                | 1          | 3        | 6            | 0.67        |
| Duration                  | 0.33       | 1        | 2            | 0.22        |
| Noise impact              | 0.16       | 0.5      | 1            | 0.11        |
| **Total**                 |            |          |              | 1.00        |
Table 13. Comparison of alternatives taking into account the calculated specific weight of the criteria.

| Criteria          | Production | Duration | Noise impact |
|-------------------|------------|----------|--------------|
| Manual            | 0.05       | 0.04     | 0.15         |
| Mechanized        | 0.15       | 0.20     | 0.07         |
| Technological explosion | 0.38   | 0.44     | 0.03         |
| Hydorobot         | 0.29       | 0.20     | 0.16         |
| Chemical          | 0.05       | 0.04     | 0.31         |
| Ultrasonic        | 0.09       | 0.08     | 0.28         |

By calculating the specific weight of each criterion, you can determine a rational method of dismantling a building or structure, taking into account its features.

3. Results and discussions

According to the results of the calculation of the ranking of the comparison criteria, the output parameter is 0.67 of the total weight, which is 307% more than the calculated duration criterion and 610% more than the obtained noise exposure value.

According to the distribution of weights and ranks, the technological explosion has a weight of 0.38 of the total volume and is the most rational method of dismantling under given conditions.

4. Conclusions

To choose the most effective method of dismantling, a lot of tools are used: from a simple calculation of the working time of the mechanisms to a detailed study and interconnection of the dismantling processes into the one united system. Comparison of methods of dismantling buildings using the analytical hierarchical Saaty process is a convenient tool for selecting a method of dismantling, because you can compare not only the aggregated indicators, but also divided into several types of criteria, which increases the accuracy of this comparison.

In this topic, a comparison of dismantling methods according to 3 enlarged criteria: production per 1 m$^3$, duration of work and noise exposure. The first step of this procedure is to bring the pairwise comparison to one, the proportion of which shows its superiority or insufficient advantage over another alternative. Further, the specific weight of the criterion is calculated, according to which the DM compares the obtained pairwise alternatives.

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