TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO

2-B/2014

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USE OF THE KASS PROGRAM IN SCHEDULING

ZASTOSOWANIE PROGRAMU KOMPUTEROWEGO KASS W SZEREGOWANIU ZADAŃ

A b s t r a c t

This paper presents uses for the KASS (Krzeminski Algorithm Scheduling System) program in scheduling for construction projects. The program serves as a tool for scheduling for up to a maximum of 10 work crews at 13 work sites, and then applies a **complete overhaul** in simulation. This paper describes the first version of the program released in 2012, as well as the modified version introduced in 2013.

Keywords: scheduling, construction scheduling, flow shop models

S t r e s z c z e n i e

W artykule zaprezentowane zostaną możliwości zastosowania programu KASS (Krzeminski Algorithm Scheduling System) w szeregowaniu zadań dla celów budownictwa. Program służy do szeregowania pracy maksymalnie 10 zespołów roboczych na 13 działkach z zastosowaniem przegląd zupełnego lub na 50 działkach przy zastosowaniu symulacji. Pokazana zostanie pierwsza wersja programu z roku 2012 oraz modyfikacje, jakie zostały wprowadzone w roku 2013.

Słowa kluczowe: szeregowanie zadań, harmonogramowanie budowlane, modele przepływowe

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1. Introduction

The construction scheduling problem is particularly important when a task accomplishment process is being prepared. Scheduling is a fast-growing area of scientific research in construction production engineering [11]. Methods of artificial intelligence, such as genetic algorithms, ant colony optimization algorithms, simulated annealing, neural networks have all been applied as well as fuzzy logic techniques. Elements of fuzzy logic are now being widely used in order to determine time.

This paper investigates a flow-shop scheduling problem [9, 10], which consists of having to determine the optimum working sequence for crews (known in the KASS (Krzeminski Algorithm Scheduling System program as brigades) at work spaces. The model is based on assumptions necessary for performing a sequence of technological operations, which were determined in advance and cannot be changed. For certain reasons, each crew could only work at any selected work place once, swapping shifts with another crew at an exact time. In total there are three main types of processes, one type being homogenous and heterogeneous [12]. In all of them, the same technological activities are being performed. The only difference lays in time: in heterogeneous operations it does not change linearly with the change of the work space. This is why it is essential to use advanced optimization methods in order to avoid work stoppages and minimize work time.

Scheduling is an advanced area of scientific research [8]. There are numerous models for determining the right sequence for the work at work spaces. Nevertheless, one must observe that the construction industry is a branch with only a slight repeatability of projects. Taking that into consideration, we can claim that general models which have been elaborated from models prepared for industrial purposes are often inapplicable. This is why the author aims to devise a system, which will provide specific scheduling, for construction projects.

2. Assessment criteria in scheduling

This chapter presents a set of criteria which form the basis of the the KASS program, devised for flow-shop scheduling [4]. According to the author, thanks to these criteria, scheduling is in line with construction project characteristics.

The first criterion is to select the **Shortest work accomplishment time**, in other words the shortest scheduling duration/time [1, 2]. This criterion often appears in scheduling optimization tasks. It is particularly important for the construction industry, as it determines work/ task accomplishment times. If we want to find the shortest work/ task accomplishment time for the schedule, we need to use the following equation

$$T_{\min} = \min\left(T_{nm}^{k,1}, T_{nm}^{k,2}, \ldots, T_{nm}^{k,u}\right), \tag{1}$$

where

u – stands for consecutive variants of scheduling,

T_{nm}^{k} – accomplishment time last task in chosen scheduling.

The next and one of the most important assessments, is **Crew working continuity**. Every proprietor/owner is set on having a well-qualified and harmonious team. One element that helps to achieve this goal is to ensure that workers are paid properly and it should be underlined that salaries depend on crew efficiency. It is then possible to conclude that the working continuity is very much needed in order to have a good team, which also serves to acquire harmony.

Crew working continuity may be determined by choosing the solution which has the lowest value for work stoppages. In order to use crew optimization for chosen **i-** (known as a brigade), we may do the following equation:

$$CPB_{i,\min} = \min\left\{\left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(1)}, \left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(2)}, \ldots, \left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(u)}\right\} \quad (2)$$

where:

u – stands for consecutive variants of scheduling.

It is also possible to use optimization for minimal total work stoppage time of all working brigades $CPB_{\min}$. In order to do this, we may use the following equation:

$$CPB_{\min} = \min\left\{\begin{array}{l} \left[\left(\sum_{j=1}^{m} T^{p}_{1,j} - T^{k}_{1,j-1}\right)^{(1)} + \left(\sum_{j=1}^{m} T^{p}_{2,j} - T^{k}_{2,j-1}\right)^{(1)} + \ldots + \left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(1)}\right], \\ \left[\left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(2)} + \left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(2)} + \ldots + \left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(2)}\right], \\ \left[\left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(u)} + \left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(u)} + \ldots + \left(\sum_{j=1}^{m} T^{p}_{i,j} - T^{k}_{i,j-1}\right)^{(u)}\right] \end{array}\right\} \quad (3)$$

where:

u – stands for consecutive variants of scheduling,

i – number of brigade,

j – number of consecutive workspaces.

The last criterion used in The KASS program is **Works Transition Cost** [7]. The cost consists in all kind of expenditure, not only the financial one.

Work accomplishment time may vary considerably at different work spaces. If this is the case, the scheduling model could provide an optimal sequence in relation to previously mentioned criterion, such as crew (brigade) work continuity. Nevertheless, this scheduling could be deprived of fluency in working crew transition (within workspace).

The aim of this scheduling criterion is to ensure the lowest Works transition cost [3]. To achieve that, it is necessary to form a series of cost matrices for each working crew (brigade) transition within each Works MKi and it needs to be done at the stage when the data is introduced. Matrices does not need to be symmetric, however, if crew transition is not problematic, there is no need to introduce any matrix. This is how a matrix of cost should be defined:

$$MK_i = \begin{bmatrix} 0 & k_{12} & \dots & k_{1j} \\ k_{21} & 0 & \dots & k_{2j} \\ \dots & \dots & 0 & \dots \\ k_{j1} & k_{j2} & \dots & 0 \end{bmatrix} \quad (4)$$

where:

i – stands for a number of brigade,

j – stands for a number of workspace.

When we obtain scheduling data which is consistent with the previously mentioned criteria, we can determine the working crew (brigade) KBi transition cost within a chosen work space. It is essential to choose the solution which has the lowest transition cost, according to the following equation:

$$KB_i = \min\left\{KB_i^{(1)}, KB_i^{(2)}, \dots, KB_i^{(u)},\right\} \quad (5)$$

where:

u – stands for consecutive variants of scheduling.

The above-mentioned criteria were used in the KASS v.1.0, as well as KASS v.2.0. The program has not been finished yet, which means that it does not include all of the possibilities described.

3. KASS v.1.0 program description

The KASS v.1.0 program was written in the Java programming environment. This is a program which does not require installation. It can be downloaded for free from the website www.ipb.edu.pl, in the Programs tab. The program has an interface in both Polish and English. The first version contains three criteria: Shortest work accomplishment time, Crew (brigade) working continuity and Works transition cost. It was possible to use the Shortest work accomplishment time or the Minimization of work stoppages as the main criterion, as well as the Works Transition Cost as an additional criterion. Optimization calculations are carried out using the complete overhaul. It is possible to use optimization for a maximum of 10 working crews (brigades) at 13 work spaces. The limit concerning workspace count results from current PC computing capabilities: 13 is currently the highest figure which permits a quick and efficient calculation. More information on the KASS v.1.0 program can be found on the website www.ipb.edu.pl [5, 6].

4. KASS v.2.0 program description

The KASS v.2.0 program was also written in the Java programming environment. It also has a bilingual interface, it does not require installation and it can be downloaded for free from the website www.ipb.edu.pl (This applies to both versions).

The second version of the program has a slightly different layout, but more important changes were also introduced. The program **uses** the complete overhaul, when no more than 13 work spaces are considered. If there are more work spaces, we apply a simulation. The program also provides a new criterion of optimization that takes into consideration chosen brigade's continuity of work.

To show how the program works, we will use the example of optimization for chosen task. Fig. 1 depicts the welcome window that appears after we start the program.

Fig. 1. The welcome window of the KASS v.2.0 program

After we press the button Next, we move to the next window and we need to choose workspace count (seven in this example), as well as working brigades count (two in this example).

Fig. 2. The configuration window of the KASS v.2.0 program

It is also necessary to choose an assessment criteria which will be taken into account during optimization calculations. It is possible to choose from one to four criteria (the shortest work accomplishment time, crew (brigade) working continuity counted for all crews, chosen crew (brigade) working continuity and the lowest transition cost within work spaces. In this example **shortest** work accomplishment time was chosen as the main criterion, continuity of crew (brigade) number 2 is the second criterion and the lowest transition cots the last criterion. The criteria sequence is important, as it sets its precedence. The first one will influence the most the results of optimization. The picture above depicts those criteria input window.

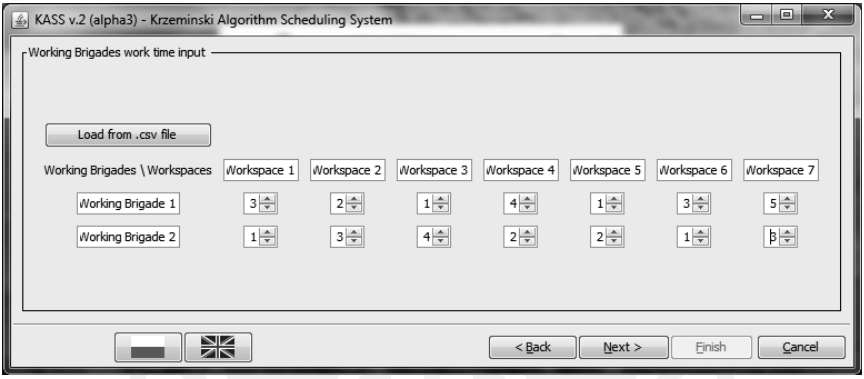

Fig. 3. The working brigades work time input window of the KASS v.2.0 program

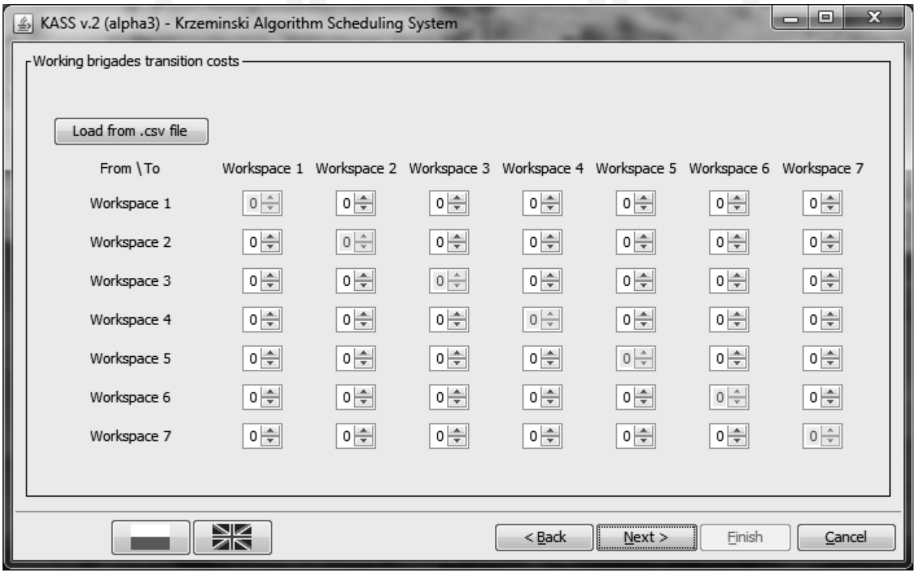

Fig. 4. The working crew (brigade) transition cost input window of the KASS v.2.0 program

After we press the button Next, we move to the working crew (brigade) work time input window. It is depicted in the Fig. 3.

The table in the Fig. 4 is a matrix of working crew (brigade) transition cost. As it was mentioned before, this matrix does not need to be symmetric. In this example, the value 0 was put in all of the fields intentionally.

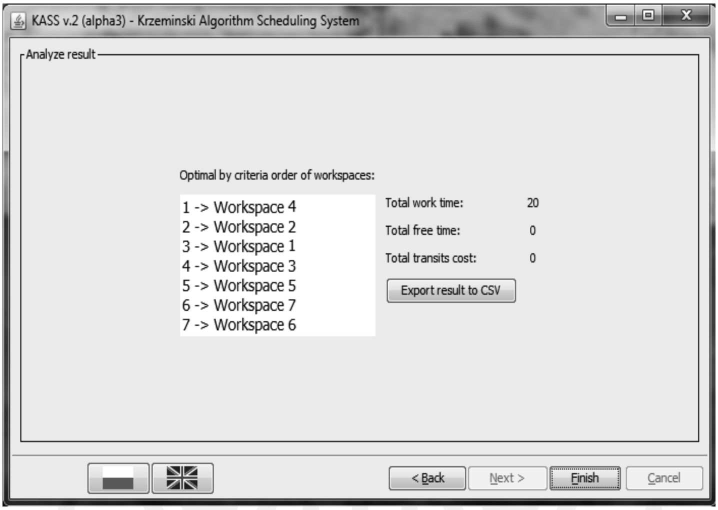

Fig. 5. The results window of the KASS v.2.0 program

Fig. 5 depicts the results. The window presents the right scheduling and it is also possible to read off data concerning total time, total crew (brigade) work stoppages, chosen crew (brigade) work stoppage and crew (brigade) transition cost.

It is also possible to save the results as *.csv files, which are readable in the Excel program among others. This is useful, because it enables the KASS v.2.0. users to work further in an easy and comfortable manner on data that were obtained

4. Conclusions

The program presented in this paper may be helpful for scheduling, when it comes to cases where there are a sequence of operations that repeat themselves at numerous work spaces.

The program allows for up to 13 work spaces using the complete overhaul application. In other scientific areas, thirteen would not be considered as a high number, however, in the construction industry this is a reasonable figure. Complete overhaul is the best optimization method. If this number were to increase, we would then apply a simulation.

The example shown in this paper proves that it pays to build this kind of program, as the results provided are better than the solution that can be obtained by using Johnson's algorithm. Time is always the same in both cases and equals 20, but when it comes to the KASS program, there are no work stoppages as a result.

The author plans to work further on the KAAS program and enlarge criteria and introduce heuristics, as well as more elaborate probabilistic versions.

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