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TRANSPORTATION OPTIMIZATION WITH EXCEL SOLVER

Nenad Kostić[1], Nenad Petrovic[2], Nenad Marjanović[3], Jelena Petrović[4]

Abstract: This article is dedicated to transportation efficiency and the related problems. Its main goal is to analyse the effects that optimization can have on transportation efficiency and its ecological performances. This problem essentially refers to determining the most lucrative maximum quantity of commodity that can be loaded in a transportation vehicle. We used evolutionary algorithm in Excel solver to observe three different case studies. In all case studies a loading capacity of a transportation vehicle is limited and different constraints are set on an allowed and a required number of parcels to be transported. Moreover, the packages to be loaded on the given vehicle are divided into three categories based on their weight and price. The results obtained through this analysis indicate that the optimization can result in significant logistic, economic, and ecological effects. The optimization leads to maximum utilization of available loading capacities and maximum profit. When conducted in such a manner, transportation of goods becomes more efficient and thus environment-friendly. Furthermore, the model developed here is general in its nature so it can be employed to solve any transportation problem of the similar nature with minimum adjustments. Thus, it can find a wide-spread practical application.

Key words: ecology, efficiency, excel solver, optimization, transport problem

1 INTRODUCTION

By concurrently striving to facilitate the negative effects and to generate as many positive ones as possible, the global market has been constantly posing new challenges to engineers. Among all negative effects, the main focus of the market is to increase their profit and reduce their current costs. From an engineering point of view,

[1] PhD, Nenad Kostić, University of Kragujevac Faculty of Engineering, Kragujevac, Serbia, nkostic@kg.ac.rs
[2] PhD, Nenad Petrović, University of Kragujevac Faculty of Engineering, Kragujevac, Serbia, npetrovic@kg.ac.rs (CA)
[3] PhD, Nenad Marjanović, University of Kragujevac Faculty of Engineering, Kragujevac, Serbia, nesam@kg.ac.rs
[4] MSc, Jelena Petrović, University of Kragujevac Faculty of Engineering, Kragujevac, Serbia, jelenapetrovic4b@gmail.com

costs are tightly knit to efficiency, degree of utilization, quality, etc. Hence, these must be improved in order to generate more profit.

Transportation efficiency is seen today as one of the most massive and widespread problems that has to be tackled. Consequently, it can be observed as one of the most demanding engineering challenges. The transportation problems include, inter alia, transport organization and management, packaging and loading goods, cost analyses, energy savings, and environmental impact. They also pose huge challenges for researchers.

The topic of transport logistics is nowadays the main focus of a large number of researchers and this field of study has been expanding rapidly. The roots of the transportation problems spread across different areas. The problem of goods packaging [1-3], for instance, is one of the most complex challenges. Moreover, transmission optimization designs and the positioning of transmission elements are compatible with transportation problems [4,5]. In order to solve such complex issues, it is necessary to apply optimization methods since without optimization, it is impossible to reach high-quality solutions today. One of the most important and widespread methods is the Genetic algorithm [6,7]. Excel is the most frequent software used for solving complex problems via optimization. It includes the Evolutionary algorithm [8] which relies on the principles of the genetic algorithm.

This paper aims at providing the mathematical model for solving one of the most widespread transportation problems – efficient organization. We use the software solution and the methods which are frequently used for the optimization of such complex problems nowadays. However, this general mathematical model is used here to measure the effects in three specific scenarios in order to prove its effectiveness in different circumstances. The primary goal in doing so is to identify the impact of the optimal transport organization and the benefits that can be thus achieved. Moreover, the model can be adapted to solve any problem of the similar nature.

2 DEFINING A PROBLEM

The transportation problem can be viewed as the issue of how to provide the optimal utilization of transportation capacities. For transportation to be as efficient as possible, the main task is to organize it in a way that allows economic benefits. In other words, loading capacities should be fully utilized. Packages, however, differ in both their masses and prices. In order to find the best loading solutions for every given scenario, we must use good mathematical optimization models.

The objective function in this model is the profit maximization while the main constraint is a transportation capacity. It is adopted here as 20t in all case studies. The additional constraint adopted in case studies is the mass of parcels to be loaded on a transportation vehicle. A number of packages refers to a minimum and a maximum number of parcels that ought to be transported.

In this general mathematical model, it is possible to define the objective function as presented in the Equation 1:

$$\sum_{i=1}^{n} p_i \cdot x_i \qquad (1)$$

, where *p* stands for profit and *x* stands for a number of packages of a given type.

In the Equation 2, *m* stands for a mass of each package while *w* is the total transportation capacity that cannot be surpassed:

$$\sum_{i=1}^{n} m_i \cdot x_i \leq w \tag{2}$$

There are certain constraints concerning the variables. The variables *x*, as stated above, represent numbers of parcels of a given type. A minimum number that must be transported (size *a*), as well as the total availability of packages (size *b*), must be defined for each type of packages. This is shown is the Equation 3:

$$a \leq x_i \leq b \tag{3}$$

The value of x_i must be a positive integer number, as defined in the Equation 4:

$$x_i \geq 0 - integer. \tag{4}$$

Due to the limited capacity of a transportation vehicle, packages weights must be taken into consideration. In addition to specific masses, packages have different prices. Since the main goal is to optimize profits, packages should be selected and loaded in a way that will enable highest possible profits.

2.1 Excel solver – Evolutionary algorithm

This paper uses Excel solver. The optimization Evolutionary algorithm belongs to the group of heuristic optimization algorithms and relies on the principles of the Genetic algorithm. This software solution is chosen here due to its commercial availability and its wide-spread application, as well as its good performances.

Evolutionary algorithm can be used to solve complex optimization problems with constraints [8]. The user interface requires users to define an objective function, constraints, and variable constraints, as shown in Figure 1.

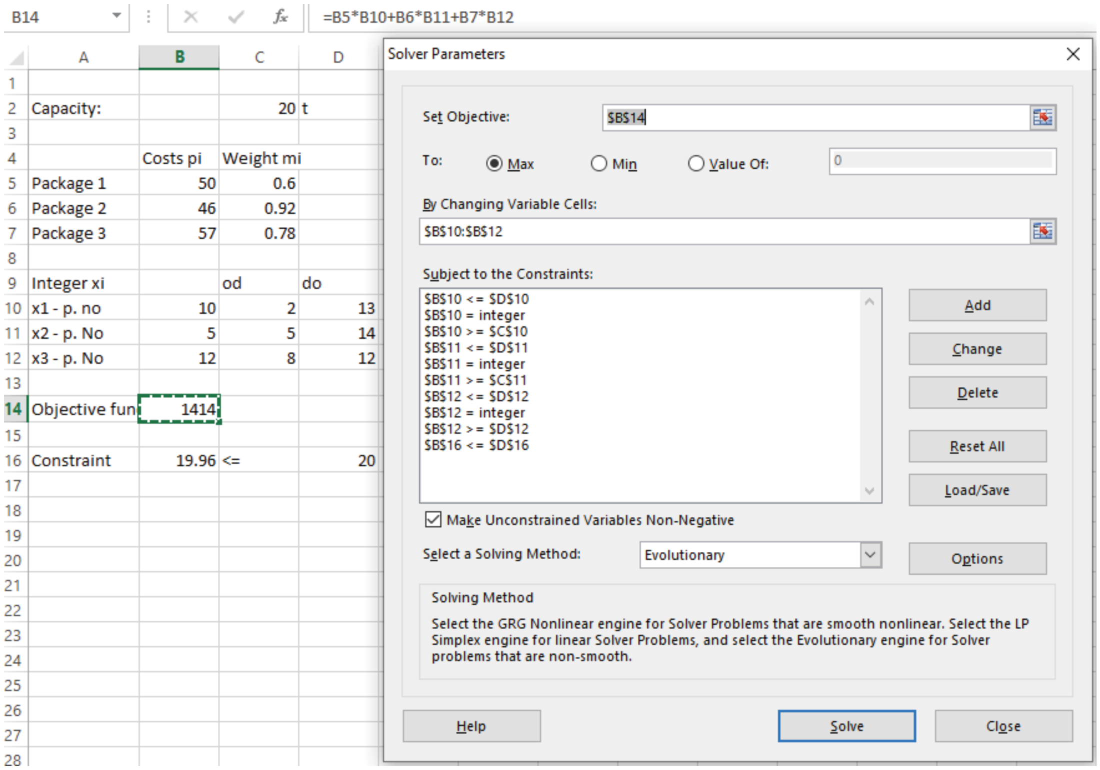

Figure 1. *User interface for an optimization configuration*

Evolutionary algorithm can be set based on the nature of a problem that is to be solved in a given situation. The general settings are presented in Figure 2.

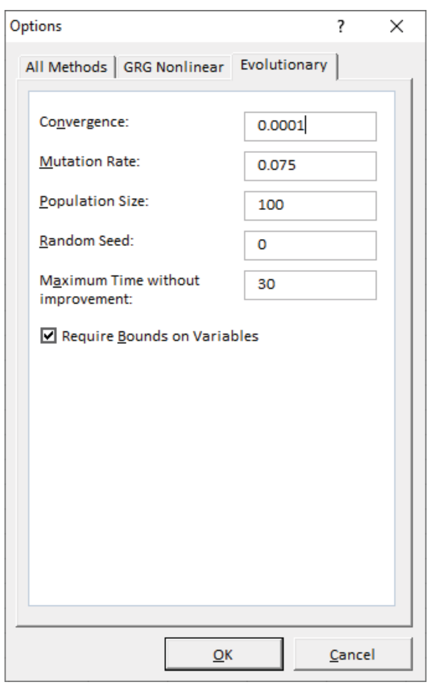

Figure 2. *Evolutionary algorithm settings*

This software provides operational security and precise solutions. It is user-friendly and very efficient in practical applications.

2.2 Case studies

For the sole purpose of verifying the results, three case studies are presented here with specific quantitative values. The main constraint is the maximum transportation capacity that is adopted here as 20t in all case studies. The same three types of packages are used. Their masses and prices are presented in Table 1.

Table 1. *Types of packages with their weights and prices*

	Package price – p_i	Package weight – m_i (t)
Package 1	50	0.6
Package 2	46	0.92
Package 3	57	0.78

The mathematical model for this specific problem can be presented as follows (Equations 5 and 6):

$$p_1 \cdot x_1 + p_2 \cdot x_2 + p_3 \cdot x_3 \tag{5}$$

$$m_1 \cdot x_1 + m_2 \cdot x_2 + m_3 \cdot x_3 \leq 20 \tag{6}$$

Case study 1 determines the optimal selection of parcels to be loaded in order to enable the highest profit when the adopted transportation capacity is fully occupied. Case study 2 determines the optimal selection of packages when there are constraints on the maximum number of packages (of all three types). Case study 3 evaluates the maximum and the minimum number of parcels of each type that ought to be loaded and transported. The optimization objective for the case studies is to generate as much profit as possible.

In Case study 1, the variables that define the number of parcels from three different package categories must be higher than zero which indicates that the given type exists. These values are integer numbers and there are no constraints in terms of the maximum number. In other words, it is possible to use as many packages as necessary despite their mass or price. The range for the variables in Case study 1 can be presented by the Equations 7:

$$\begin{gathered} x_1 \geq 0 \\ x_2 \geq 0 \\ x_3 \geq 0 \end{gathered} \tag{7}$$

The range for the variables in Case study 2 can be presented with the Equations 8. In this case, the maximum number of packages from the given categories is defined based on their hypothetical availability.

$$\begin{gathered} 0 \leq x_1 \leq 13 \\ 0 \leq x_2 \leq 14 \\ 0 \leq x_3 \leq 12 \end{gathered} \tag{8}$$

In Case study 3, the minimum numbers are also given in addition to the maximum ones. The minimum numbers are the numbers of packages of each type that have to be transported. The values for the variables can be presented by the Equations 9:

$$\begin{aligned} 2 \le x_1 \le 13 \\ 5 \le x_2 \le 14 \\ 8 \le x_3 \le 12 \end{aligned} \tag{9}$$

The values used here are hypothetical and arbitrarily selected because the goal of this paper is to demonstrate the practical application of the optimization model in different circumstances. This is most efficiently achieved by using specific values. The model developed here is flexible in terms of the number of variables and constraints so it can be easily applied to all similar transportation problems.

3 RESULTS

Excel solver and Evolutionary algorithm are used for the optimization in all case studies. The results indicate that high performances of transportation can be accomplished with this methodology. The transportation capacities can be employed to the maximum degree with the highest possible profit, while the costs are minimized and negative ecological impacts facilitated.

Figure 3 shows the number of parcels from three different package categories in all case studies.

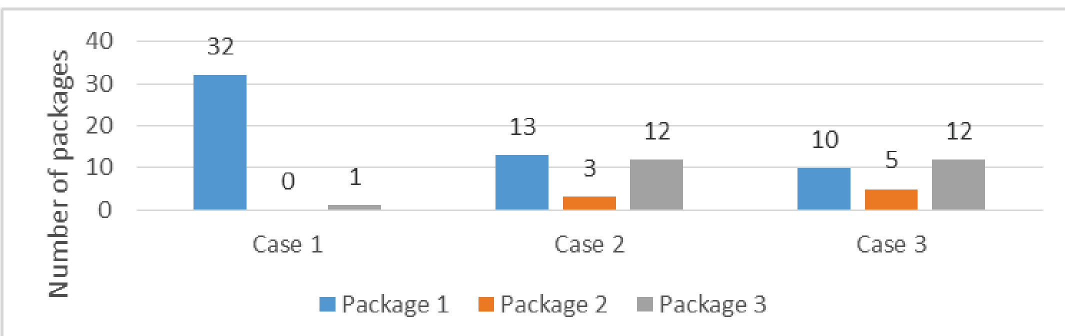

Figure 3. *The number of parcels from each category*

Case study 1 demonstrates that when there are no limitations in quantity of specific packages types that ought to be transported, the optimal model is to load 32 parcels of the Type 1, 0 parcels of the Type 2, and 1 parcel of the Type 3. The same values obtained for Case study 2 are 13, 3, and 12, respectively. In case of the third scenario tested here, those values are 10, 5, and 12, respectively. The economic indicators, i.e. the positive financial effects obtained by optimization are presented in Figure 4.

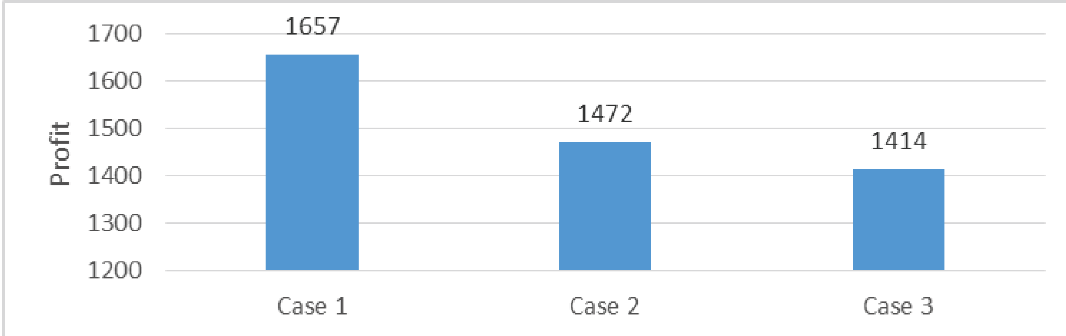

Figure 4. *The estimated profit*

It is evident from the figure above that the most profit is generated with the first scenario. This is not surprising taking into consideration that in this case there are fewest constraints. The second and the third tested scenarios follow in this particular order. The maximum difference between these case studies amounts to 15%, depending on the number of limitations. The results also indicate that there are differences in terms of the level of utilization of the given loading capacity, but they are slight – less than 0.5%. In general, the utilization of the loading capacity in all tested cases can be considered as very high (ranging from 19.92t to 19.98t). The obtained values are presented in Figure 5.

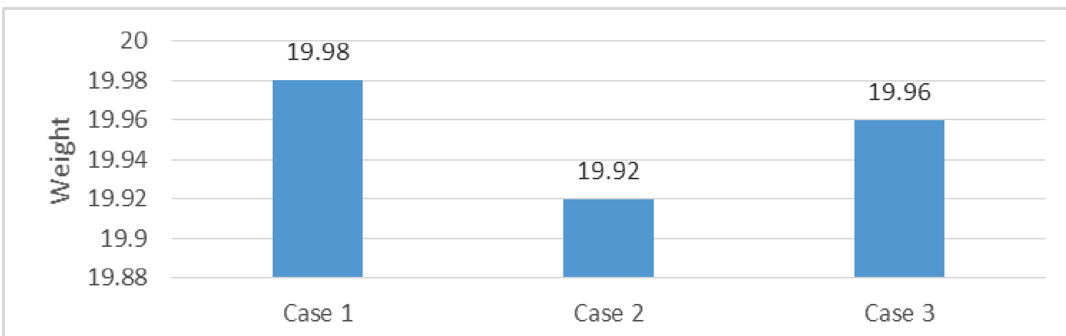

Figure 5. *The total mass of transported parcels – occupancy of the transporting capacities*

This problem is practically oriented. It is crucial for the organization of parcel-loading and transportation itself. The results obtained in this research verify the optimization model developed here by demonstrating that it helps accomplish maximum utilization of available loading capacities and maximum value of goods in different pre-set conditions. The effects of optimization are logistic, economic, and ecological. These are the main goals of the transport optimization.

4 CONCLUSION

This study focused on solving the complex problem of transportation optimization. The optimization was conducted in Excel solver via its Evolutionary optimization algorithm. With the set objective function (i.e. maximum profit), one can determine a quantity and a type of packages that can be transported in the most efficient way when the loading capacity is limited. The mathematical model developed here is general in its nature so it can be applied to all similar transportation problems.

The paper presents the results obtained for three case studies. The results indicate that the optimization can lead to maximum profit. The differences across tested scenarios amount to 15% depending on the number of different constraints. These limitations also impact the choice of packages to be loaded. The optimization also allowed the transportation capacities to be used to the maximum degree. The total capacity of a transportation vehicle in case studies was adopted as 20t, and the occupancy for different scenarios varied from 19.92t to 19.98t.

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