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SELECTION OF OPTIMAL CENTRAL PROCESSING UNIT USING THE PSI METHOD

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Abstract: *Modern business strongly relies on the use of information and communication technologies. So, choosing the right technical equipment is extremely important because the right one influences the timely execution of business tasks. Various conflicting criteria impact the decision about equipment selection which justifies the application of Multiple-Criteria Decision-Making (MCDM) as a convenient tool for the optimization of this kind of decision process. This paper proposes the application of the Preference Selection Index (PSI) method to settle the appropriate processing unit (CPU). Five alternative CPUs are compared against four criteria which include: core numbers, virtual cores (threads), operating frequency, and price. The results that came from using the PSI method favor the* CPU_3 *– AMD Ryzen 5 5600 as the most compatible for the end-user in the present case. The obtained results proved the applicability of the PSI method because it facilitated the decision process and define the best solution regarding the given conditions.*

Keywords: *Central processing unit / MCDM / PSI method.*

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INTRODUCTION

A central processing unit (CPU), also known as a processor, is the main component of a computer that performs the majority of the processing tasks. The CPU is composed of an Arithmetic Logic Unit (ALU) to execute operands, a small memory in the form of registers (RF) to store temporary data, and two large size memories operating as instruction and data caches (Bindal, 2019). It is responsible for executing instructions and controlling the other components of the computer. The CPU receives input from the user and other devices, processes the input according to a set of instructions, and produces output that is displayed or stored for future use. Older generations of processors had only one core and therefore could only be dedicated to performing one function at a time. Today, processors have from 2 to 18 cores, and server processors can have more than said 18 cores, which allow us to smoothly perform multiple functions, programs at the same time. Simplified, one core works on one task, while the others work on other functions, which gives the assumption that the more core a processor has, the more efficient – faster it is. Most of today's processors have the possibility of multithreading (Hyper-threading), which allows one processor core to be virtually divided into two or more cores, and we call such virtual cores threads. Due to the principle of virtual cores, we enable the user to perform multiple processes at a time without losing the efficiency of his computer.

Among the hardware components, the CPU is the most important, and is capable of managing all hardware units (Tan et al., 2015). The processor is an important component of a computer because it is responsible for executing instructions and controlling the other components of the computer. The processing power of the CPU determines the speed and efficiency of the computer, and therefore, it is important to choose the optimal processor to ensure that the computer can handle the tasks and workloads required by the user. Moreover, since power density issues limit the increase of the clock frequency, manufacturers have turned to adding more cores to their processors (Papadrakakis et al., 2011).

A processor with a high number of cores and threads, as well as a high operating frequency, can provide the necessary processing power to handle complex tasks and improve the overall performance of the computer. There may be conflicts between the criteria when making a decision on which processor to choose. For example, a processor with a higher number of cores and threads may have a higher price and operating frequency compared to a processor with fewer cores and threads. In this case, the decision-maker must weigh the importance of each criterion and determine the optimal trade-off between the criteria to make the best decision. Multiple-Criteria Decision-Making (MCDM) methods can help to resolve these conflicts by providing a systematic and objective way to evaluate and compare the processors based on multiple criteria.

MCDM belongs to the field of the operation research and implies the process of selecting one alternative from a set of available alternatives (Mardani et al., 2015). These methods facilitate the process of solving a number of problems when there are more mutually conflicting criteria (Zavadskas & Turskis, 2011). The authors have been proposed many different MCDM approaches with one common goal – to enable finding of the optimal solution/alternative in an efficient way. These field includes the well-known and proved methods such as Analytic Hierarchy Process – AHP (Saaty, 1994), the Technique for Order of Preference by Similarity to Ideal Solution – TOPSIS (Hwang & Yoon, 1981), Visekriterijumska Optimizacija I Kompromisno Resenje – VIKOR (Opricović, 1986), The outranking approach and the foundations of ELECTRE methods (Roy, 1990), as well as the recently proposed approaches such as the integrated simple Weighted Sum Product method – WISP (Stanujkic et al., 2021), the Comprehensive Distance Based Ranking – COBRA (Krstić et al., 2022), and the Compromise Ranking of Alternatives from Distance to Ideal Solution – CRADIS (Puška et al., 2022). All the introduced methods have been used for making a different kinds of business decisions, and one of them is certainly the IT equipment selection.

Selecting the best piece of technical equipment, in this instance the processor, is one of the key issues. For every organization, choosing the right IT equipment is an essential choice since it may have a big impact on the effectiveness and performance of the company. According to a study published Nor & Jabar (2006), multi-criteria decision making (MCDM) methods can be effectively used to evaluate and compare different IT equipment options, taking into account factors such as cost, performance, reliability, and maintenance requirements. These methods can help organizations to make informed, data-driven decisions that align with their goals and objectives. In the context of IT equipment, processors are a particularly important consideration. The performance of a processor can have a significant impact on the overall performance of the system, so it is important to choose a processor that is suitable for the intended use case. According to a review published Tzeng & Tsao (2011), MCDM methods can be used to evaluate different processor options in terms of factors such as speed, power consumption, and price. Organizations may select processors that provide the best performance and value for their unique needs by taking these considerations into account. Overall, the adoption of MCDM techniques may be a useful tool for choosing the proper IT hardware, including CPUs. Organizations are able to reach their objectives and optimize the return on their investments by methodically analyzing and contrasting various choices.

In this paper, we will use MCDM to make an objective decision regarding the best/optimal choice of processors from the available alternatives. To make this decision, we will use the Preference Selection Index method (PSI method) (Maniya & Bhatt, 2010) to evaluate and compare five alternative processors based on their price, number of cores, number of threads, and operating frequency. By using the PSI method, we can derive the criteria weights and combine them with the attributes' quality of the alternatives to determine the composite score for each processor and ultimately select the best option. To present the applicability of the proposed approach, the paper is organized as follows: in Section 2 the proposed methodology is presented; Section 3 contains the numerical example; at the end, the conclusion is presented.

METHODOLOGY

The PSI method was proposed by Maniya and Bhatt (2010) and it is based on the principle of relative preference, where the alternatives are compared to each other in pairs, and the relative preference between the alternatives is used to derive the criteria weights and calculate the composite score for each alternative. This method is a useful tool for decision-makers because it provides a systematic and objective way to evaluate and compare alternatives based on multiple criteria. It can help to resolve conflicts between the criteria and provide a clear and transparent basis for making decisions. Additionally, the PSI method is flexible and can be applied to a wide range of decision-making problems in different fields.

The computational procedure of PSI method contains the following steps**Error! Bookmark not defined.**:

Step 1. The decision-maker must first define the set of alternatives and the criteria that will be used to evaluate the alternatives. The criteria should be chosen based on their relevance to the decision-making problem, and the decision-maker should assign a relative importance or weight to each criterion.

Step 2. Evaluate the alternatives and construct initial decision-making matrix D, as follows:

$$D = \left[x_{ij}\right]_{mxn}, \tag{1}$$

where xij denotes ratings of the alternative I in relation to criterion j, m is the number of alternatives and n is the number of criteria.

Step 3. Construct the normalized decision matrix in which the elements of the matrix are calculated as follows:

$$r_{ij} = \frac{x_{ij}}{x_{ij}} \text{ for maximization criteria,} \tag{2}$$

$$r_{ij} = \frac{x_{ij}}{x_{ij}} \text{ for minimization criteria.} \tag{3}$$

Step 4. Calculate preference variation value in relation to each criterion as follows:

$$\chi_j = \sum_{i=1}^{m}\left(r_{ij} - \bar{r}_j\right)^2, \tag{4}$$

where $\bar{r}_j$ denotes the mean value of normalized ratings of criterion j and it is determined as follows:

$$\bar{r}_j = \frac{1}{m}\sum_{i=1}^{m} r_{ij}. \tag{5}$$

Step 5. Calculate deviation in the preference variation value as follows:

$$\Omega_j = 1 - X_j. \tag{6}$$

Step 6. Determine the criteria weights using the following equation:

$$w_j = \frac{\Omega}{\sum_{i=1}^{n}\Omega_j}. \tag{7}$$

Step 7. Calculate the preference selection index of alternatives as follows:

$$S_i = \sum_{j=1}^{n} r_{ij} w_j. \quad (8)$$

Based on the preference selection index values of the alternatives, determine the complete ranking order of alternatives. The alternative which has the largest preference selection index represents the best ranked alternative.

RESULTS

The PSI method was utilized in this research to assess five CPUs and identify the best choice. These options were chosen because they were significant to the current decision-making issue and they are presented in **Table 1**.

Table 1. *Alternative CPUs*

Alternative	CPU Name
CPU_1	i3-10100
CPU_2	Pentium G74000
CPU_3	AMD Ryzen 5 5600
CPU_4	i7-11700
CPU_5	i5-10400

Source: Author

The given alternative CPU_S were evaluated against four evaluation criteria presented in **Table 2**.

Table 2. *Evaluation criteria*

Alternative	Criteria	Explanation
NC	The number of cores	A CPU core is an independent processing unit which can carry out operations and make computations within a Central Processing Unit (CPU).
VC	Virtual cores (threads)	A virtual core, also referred to as a hyper-thread or logical core, is a technology that enables a single physical CPU core to appear to the operating system as two or more logical cores, enhancing the CPU's overall performance and efficiency by enabling it to switch between various threads more quickly.
OF	Operating frequency	The number of cycles per second that a CPU (Central Processing Unit) can perform is known as operating frequency, sometimes known as clock speed, and is normally measured in Hertz (Hz).
PR	Price	The performance of the CPU, the number of cores it contains, its clock speed, and the brand and reputation of the manufacturer are just a few variables that might affect a CPU's pricing and the end users budget.

Source: Author

Table 3 contains the initial data about chosen alternatives referred to the considered criteria.

Table 3. *Initial data*

	NC	VC	OF	PR
CPU_1	4	8	3.6	16000
CPU_2	2	4	3.7	12500
CPU_3	6	12	3.5	30000
CPU_4	8	16	2.5	48000
CPU_5	6	12	2.9	20000

Source: https://gigatron.rs/

Because the initial data is in different units, the normalization procedure is performed by using Eq. (2) and (3). The obtained results are presented in **Table 4**.

Table 4. *Normalized decision-making matrix*

	NC	VC	OF	PR
CPU_1	0.7813	0.5000	0.5000	0.9730
CPU_2	1.0000	0.2500	0.2500	1.0000
CPU_3	0.4167	0.7500	0.7500	0.9459
CPU_4	0.2604	1.0000	1.0000	0.6757
CPU_5	0.6250	0.7500	0.7500	0.7838

Source: Author

The mean value of normalized ratings ($\bar{r}_j$) was defined by using Eq. (5), and by applying Eq. (4) the preference variation values (χ_j) were calculated (**Table 5**). Also, by using Eq. (7) and (8), the deviations in the preference variation (Ω_j), and finally criteria weights (w_j) were determined and presented in **Table 5**.

Table 5. *The criteria weights*

	NC	VC	OF	PR	Σ
$\bar{r}_j$	0.6167	0.6500	0.6500	0.8757	
χ_j	0.3410	0.3250	0.3250	0.0783	
Ω_j	0.6590	0.6750	0.6750	0.9217	2.9307
w_j	0.2249	0.2303	0.2303	0.3145	1.0000

Source: Author

The results of the PSI criteria weights calculation showed that criterion NC – The number of cores had a weight of 0.2249, criterion VC – Virtual cores (threads) had a weight of 0.2303, criterion OF – Operating frequency had a weight of 0.2303, and criterion PR – Price had a weight of 0.3145. This indicated that criterion PR – Price was the most important criterion in the decision-making process, followed by criteria VC – Virtual cores (threads) and OF – Operating frequency, and then criterion NC – The number of cores.

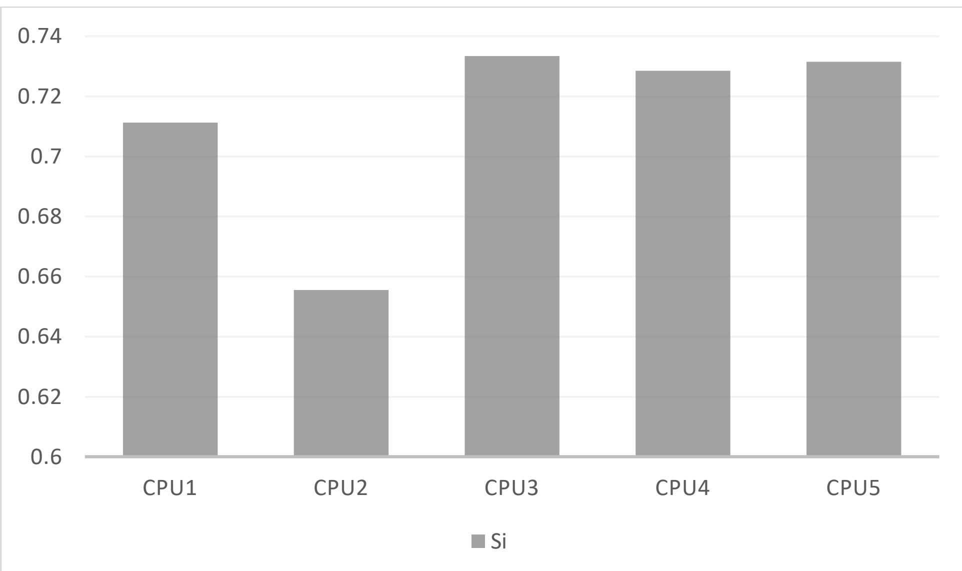
The preference selection index (S_i) was determined for all alternative CPUs with the help of Eq. (9). Regarding these values, the final ranking order of the alternatives involved in the decision-making was determined. **Table 6** and **Figure 1** illustrates the obtained results. It is important to note that a CPU with multiple physical cores can run multiple threads simultaneously, while a CPU with virtual threads can execute multiple threads more efficiently by dividing the task of a single physical core into multiple virtual cores.

Table 6. *Preference selection index – final rank of alternatives*

	NC	VC	OF	PR	S_i	RANK
CPU_1	0.1757	0.1152	0.1152	0.3060	0.7120	4
CPU_2	0.2249	0.0576	0.0576	0.3145	0.6545	5
CPU_3	0.0937	0.1727	0.1727	0.2975	0.7367	1
CPU_4	0.0586	0.2303	0.2303	0.2125	0.7317	3
CPU_5	0.1405	0.1727	0.1727	0.2465	0.7325	2

Source: Author

Figure 1. *Final ranking of the alternative CPUs*



Source: Author

The results of the PSI indicated that alternative CPU_3 – AMD Ryzen 5 5600 was the best/optimal choice based on the criteria and their weights, followed by alternative CPU_5 – i5-10400, alternative CPU_4 – i7-11700, alternative CPU_1 – i3-10100, and alternative CPU_2 – Pentium G74000. The best alternative was the processor AMD Ryzen 5 5600 with the highest number of cores, threads, and operating frequency, and the lowest price. This processor had a composite score that was higher than the other alternatives, indicating that it was the most optimal choice based on the criteria and their weights. The second optimal decision in this research was the CPU_5, which represents an equivalent of AMD processor in Intel terms. Intel core i5-10400 has the same number of cores and virtual threads as its AMD counterpart, but in term of base clock speed is slower. Moreover, AMD's Ryzen processors have excellent compatibility with faster DDR4 memory, further enhancing overall system performance. Even if the number of virtual cores is higher in CPU_4 – i7-11700 example, the base core, or a singular one, does not have enough strength, which we can see in the frequency column in CPU_3 – AMD Ryzen 5 5600 which doesn't have enough virtual cores, but beats CPU^4 in overall frequency, which determinates how fast a task can be accomplished.

CONCLUSION

In this research, the PSI method was applied to evaluate and compare four alternatives for selecting the most optimal processing units. The alternatives were evaluated based on the criteria of core numbers, virtual cores (threads), operating frequency, and price. The results of the PSI Method showed that the best alternative was the alternative CPU_3 – AMD Ryzen 5 5600, the processor with the highest number of cores, threads, and operating frequency, and the lowest price. The AMD brand of processors is known to be cheaper options then their concurrent processors at Intel, but that doesn't make them automatically as processors that can't be used efficiently. In this study, we concluded that from a range of Intel processors the best outcome was the alternative known as CPU_3 or AMD Ryzen 5 5600.

The PSI method provided a clear and transparent basis for making the decision on which processor to choose. The method helped to resolve conflicts between the criteria and provide a systematic and objective evaluation of the alternatives. It allows decision-makers to make informed and objective decisions based on multiple criteria and their relative importance or significance. Overall, the PSI method is a useful tool for decision-makers because it provides a systematic and objective way to evaluate and compare alternatives based on multiple criteria. Determination of the criteria weights based on the input data removes the bias of decision-makers from the decision process. Besides, the application of the PSI method is very easy which enables its use by the decision-makers that are not familiar with the MCDM field.

The presented research has limitations, too. The criteria on which the evaluation and selection of the optimal CPU were based are very scarce. It is necessary to involve a few more criteria in the decision-making process to obtain more relevant and reliable results. It would be very interesting if the objective-subjective approach is utilized. Namely, by combining the subjective and objective MCDM methods to define the criteria weights, they will be more realistic because they would illustrate the standpoints of the decision-makers as well. Finally, the application of the appropriate extension of the PSI or other relevant MCDM method would lead to results that take into account the vagueness of the environment. But, besides all the limitations the PSI method proved its applicability and usability in the case of the CPU selection.

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