Journal of Process Management and New Technologies
www.japmnt.com ISSN: 2334-735X (Print) ISSN: 2334-7449 (Online)
Vol. 10, Issue 1-2, 2022, pp. 115-124

DETERMINING CRITERIA WEIGHTS FOR VEHICLE TRACKING SYSTEM SELECTION USING PIPRECIA-S

Ahmet AYTEKİN[1*]

[1] *Department of Business Administration, Faculty of Economics and Administrative Sciences, Artvin Çoruh University, Hopa, Artvin, Turkey, ahmetaytekin@artvin.edu.tr*

Abstract: *Vehicle tracking systems are generally used to determine the location of vehicles, monitor them, and guide them when appropriate. This study aims to define the criteria that logistics companies consider when selecting a vehicle tracking system, as well as the relative importance of these criteria. PIPRECIA-S, a multi-criteria decision analysis method, was used in this context. According to the analysis results, the most important criterion in the selection of a vehicle tracking system is real-time tracking of the vehicle's location. When it comes to selecting a vehicle tracking system, logistics firms should prioritize instant vehicle tracking, compliance with local rules, compatibility with new technologies and software, quality certification, and compatibility with external systems-devices over other criteria. Other important criteria to consider when selecting a vehicle tracking system are system maintenance and technical support, providing statistical data collection and effective reporting, allowing the vehicle to be diverted, comprehension, simplicity of implementation and visual geo-information presentation for users, design and quality of hardware, system cost, communication infrastructure, and reducing the operating costs of companies. Also, when developing vehicle tracking systems, system developers can prioritize the aforementioned criteria.*

Keywords: *Vehicle Tracking System, Multi-Criteria Decision Analysis, PIPRECIA, PIPRECIA-S*

Original scientific paper
Received: 28.05.2022
Accepted: 17.06.2022
Available online: 22.06.2022

1. Introduction

Vehicle tracking systems are technologies used by logistics and supply chain companies to track their fleets of vehicles and are considered an integral part of the vehicles. It was stated that vehicle tracking systems were used for the first time in the maritime sector (Lee et al., 2014). With the rapid advancement of technology in all areas of life, the automatic vehicle tracking system has been employed in a variety of ways to monitor and display vehicle locations. A system, as it is well known, is a union of interrelated components assembled for a specific purpose. A vehicle tracking system, in general, consists of three components; a data management center, a vehicle, and a user. Satisfying the user's preferences, understanding the system, processing the data, and using the information produced are all important aspects of what people expect from a vehicle tracking system. The data management center is the component that monitors the vehicle and collects and processes data. The data management center houses the geographic information

[*] Corresponding author

system, in-vehicle equipment, and server computer. The vehicle itself, which is the subject of location determination, tracking, and routing, is the component that activates the vehicle tracking system. Components can also be classified as a processor, a memory, a GPS (Global Positioning System) module, a GSM (Global System for Mobile Communications) module, and an operating system. Due to the inability to detect real-time vehicle location and the lack of a warning system, various difficulties are encountered in vehicle tracking and warning. The most widely used technology for vehicle tracking and regular vehicle tracking is GPS. The vehicle tracking system's purpose is to manage and control the transport services by using a GPS transceiver to determine the vehicle's current location (Dukare et al., 2015). In this context, the tracking system attached to the vehicle ensures that data obtained from a device that determines the vehicle's instant location is sent to the central server and processed in the center. With vehicle tracking systems, logistics firms can obtain access to critical data such as the exact location and speed of the vehicles in their fleets (Arslan et al., 2016; Doğru et al., 2006; Lee et al., 2014).

Vehicle tracking systems, depending on their application areas, are defined as systems that determine the location of vehicles, monitor them, and guide them as needed. At this point, it is stated that vehicle tracking systems are used to prevent theft, security, speed control, efficient operation of smart transportation systems, and fleet tracking. Also, vehicle tracking systems are used in a variety of vehicles, including school buses, taxis, courier vehicles, bus fleets, ships, transport vehicles, and planes (Dandıl & Demir, 2020; Doğru et al., 2006).

Logistics companies use information technologies in their services for a variety of reasons, including providing information and customer satisfaction, sustaining competitive advantage, providing complete management of transportation processes, and realizing integration within the framework of e-commerce. It was stated that information technologies benefit transportation by reducing travel times, lowering costs, optimizing route planning, ensuring safety, increasing speed, and providing flexibility. Furthermore, information systems improve order fulfillment speed, warehouse process efficiency, marketing and financial performance. In this context, companies benefit greatly from the usage of vehicle tracking systems to follow the locations of vehicles and cargoes in real time (Çağlar, 2014).

The study will use the literature and expert assessments to determine effective criteria in the selection of vehicle tracking systems. The criteria will then be weighted using experts' assessments. The obtained evaluations will be analyzed within the multi-criteria decision model to determine the importance levels of the criteria. As a result, in the field of logistics and supply chain, a decision model for the selection and evaluation of vehicle tracking systems will be developed.

2. Literature review

The majority of studies on vehicle tracking systems have focused on system development. Table 1 lists prominent studies from the literature.

Table 1. Literature Review for Vehicle Tracking Systems

Author(s)	Application(s) & Key Findings
Tekin et al. (2005)	The use of information technologies by logistics companies was investigated. When compared to the previous three years, the use of vehicle tracking systems increased among the companies participating in the study during the year the research was conducted.
Doğru et al. (2006)	Vehicle tracking system structure, components, maps, and design are examined.

Küçüksille and Kuşcu (2010)	Using pocket computers and GPS systems, an online vehicle tracking system was designed. Also, the mapping infrastructure of Microsoft Virtual Earth and Google Maps is used in the system.
Maurya et al. (2012)	The researchers aimed to develop a low-cost and effective vehicle tracking system that includes GSM and GPS technologies.
Ghaffari et al. (2014)	A fleet vehicle tracking system was developed using GIS, GPS, and GPRS. The system also has a web-based user interface.
Çağlar (2014)	The role of information technologies in ensuring customer satisfaction in logistics companies has been investigated. According to findings, logistics companies make the most use of vehicle tracking systems in terms of information systems. Furthermore, it has been stated that the use of information systems improves the service quality of companies and the satisfaction of their customers.
Lee et al. (2014)	A vehicle tracking system that can be integrated with smartphones and includes GPS, GSM / GPRS technologies was developed.
Arslan et al. (2016)	A microprocessor, GSM module, GPS modular, and the Linux operating system were used to develop an embedded vehicle tracking system.
Poyraz and Sevgen (2017)	Vehicle tracking system performance was investigated in the context of graphics cards with various GPUs.
Khin and Oo (2018)	A vehicle tracking device was developed using an Arduino Uno R3, a SIM800A module, and a NEO 6M GPS module.
Dandıl and Demir (2020)	An instantaneous velocity measurement and tracking system were developed using GSM/GPRS and GPS technologies. The developed system, according to the findings, has an absolute average error of 1.51 km/h and provides advantages in terms of functionality, cost, and features.
Raad et al. (2021)	The purpose of the study was to develop a low-cost vehicle tracking system that could be used to track school buses using the internet of things.
Tamilvizhi et al. (2021)	The development of a cloud-based vehicle tracking system was completed. The device was thought to deliver vehicle speed and position data to passengers in vehicles and those waiting for vehicles in smart cities.
Rahunathan et al. (2022)	The usage of LoRa (long range) wireless telecommunication wide area network in vehicle tracking systems was investigated in off-grid and non-internet environments. According to the findings, a vehicle can be tracked over a short distance using LoRa.
Shibghatullah et al. (2022)	The accuracy of time estimation was emphasized for vehicle tracking systems. An Android vehicle tracking application has been developed in this context, with different versions for the driver and the user.

Table 1 shows how technology advancements are quickly incorporated into vehicle tracking systems. In this context, vehicle tracking systems must be upgraded to keep up with technological advancements. One recent example is the integration of cloud technology with vehicle tracking systems. For vehicle tracking system developers, studies in the literature indicate the importance of building systems that are compatible with current technologies. Furthermore, it can be said that new technologies are quickly accepted in the logistics industry.

As mentioned in the previous section, the PIPRECIA-S (Simplified PIPRECIA), an extension of the PIPRECIA (Pivot Pairwise Relative Criteria Importance Assessment) method, will be used to weight the criteria. Table 2 summarizes the literature on the PIPRECIA method.

Table 2. Literature Review for the PIPRECIA method

Author(s)	**Application(s)**
Stevic et al. (2018)	For the application of barcode technology in the warehouse system, Fuzzy PIPRECIA was used to assess the SWOT dimensions and the sub-criteria within these dimensions.
Stanujkic et al. (2018)	The weight values of the criteria to be used in the evaluation of the hotel websites were determined using PIPRECIA.
Đalić et al. (2020)	The weights of the criteria to be considered in the selection of green suppliers were determined using Fuzzy PIPRECIA.
Vesković et al. (2020)	Fuzzy PIPRECIA was used to determine the importance levels of criteria in the selection of reach stackers.
Jaukovic Jocic et al. (2020)	PIPRECIA was used to determine the weights of the criteria to be considered in the e-Learning course selection problem.
Ulutaş et al. (2020)	The weights of the criteria to be considered in the selection of personnel were determined via Gray PIPRECIA.
Blagojević et al. (2020)	Fuzzy PIPRECIA was used to determine the weights of the output criteria to measure the efficiency of rail transport sections in terms of safety and risk management.
Tomašević et al. (2020)	Fuzzy PIPRECIA was used to determine the weights of the criteria for High-Performance Computing implementation.
Nedeljković et al. (2021)	Fuzzy PIPRECIA was used to determine the weights of the criteria in the problem of selecting one of the rapeseed varieties.
Özdağoğlu et al. (2021)	Fuzzy PIPRECIA was used to determine the weights of the criteria in the Truck Tractor Selection problem.
Stevic et al. (2022)	The weight values of the criteria were determined using Fuzzy PIPRECIA in the assessment of causes of delays in road construction projects.

Table 2 shows that PIPRECIA is used to solve problems in a variety of fields. However, it has been observed that Fuzzy PIPRECIA is preferred more widely. PIPRECIA-S will be used in this study to reflect expert evaluations as accurately and effectively as possible.

3. PIPRECIA-S

To determine the subjective weight values of the criteria, Stanujkic et al. (2017) developed the PIPRECIA (Pivot Pairwise Relative Criteria Importance Assessment) method. PIPRECIA is similar to the SWARA (Stepwise Weight Assessment Ratio Analysis) method in many ways. The most significant difference between PIPRECIA and the SWARA method is that there is no need to determine the rank order of importance of all criteria. PIPRECIA, like SWARA, compares different criteria in each pairwise comparison. As previously stated, this situation creates difficulties for evaluators who are experts or decision makers. PIPRECIA-S (Simplified PIPRECIA), an extension of PIPRECIA developed by Stanujkic et al. (2021), eliminates the aforementioned difficulty and makes all comparisons with a specified criterion. This specified criterion can be the decision problem's first criterion (Stanujkic et al., 2021).

The PIPRECIA-S method will be used in this study due to the convenience it provides in comparisons. The process steps of PIPRECIA-S are defined below (Stanujkic et al., 2021):

Step 1. Determine the criteria: The criteria to be considered in the decision problem solution are determined. The criteria can be determined using literature and/or expert opinions.

Step 2. Determine the importance levels of the criteria: The criteria to be taken as a basis for comparisons are determined. The first criterion (C_1) can be designated as the base criterion for ease of implementation. The pairwise comparison expressed in Eq. (1) is used to determine the importance levels of the criteria except for the first criterion. In this context, each criterion (C_j) is compared to C_1 in pairs.

$$S_j = \begin{cases} > 1 & , \quad C_j > C_1 \\ 1 & , \quad C_j = C_1 \\ < 1 & , \quad C_j < C_1 \end{cases} \tag{1}$$

The relative importance of the criteria to one another can be expressed as a percentage. In this case, if the C_j criterion is more important than C_1, the importance value is greater than one and less than two. If the C_1 criterion is more important than the C_j criterion, the importance value is expressed as less than 1 and greater than 0. If the C_1 and C_j criteria are equally important, then a value of 1 is assigned. $s_1 = 1$ is assigned as a result of the evaluations for C_1.

Step 3. Calculate the k_j values: The k_j values are calculated using Eq. (2).

$$k_j = \begin{cases} 1 & , \quad j = 1 \\ 2 - s_j & , \quad j > 1 \end{cases} \tag{2}$$

Step 4. Calculate the q_j values: The q_j values are calculated using Eq. (3).

$$q_j = \begin{cases} 1 & , \quad j = 1 \\ \frac{q_{j-1}}{k_j} & , \quad j > 1 \end{cases} \tag{3}$$

Step 5. Obtain the criteria weight values: The criteria weight values are calculated using Eq. (4), where $0 \leq w_j \leq 1$ and $\sum_{j=1}^{n} w_j = 1$.

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_j} \tag{4}$$

As a result, the process of determining the weight values of the criteria is finished.

4. Results

The PIPRECIA-S method was used in the study to determine the weights of the criteria. PIPRECIA-S has several advantages, including the ability for experts to express their opinions in a comprehensible manner and the ability to assess the importance of criteria with fewer comparisons than methods based on pairwise comparisons in the literature, such as AHP and BWM.

Before determining the weight values of the criteria, the procedure of defining the criteria was completed. For this purpose, a comprehensive list of criteria for the selection and evaluation of vehicle tracking systems was created using the literature. At this point, studies on system selection in various fields and sectors were also used. The comprehensive list of criteria is presented below.

- Ease of use and customization of the interface (Ertek & Aba, 2012; Ghaffari et al., 2014; Karabıyık & Gündoğmuş, 2018; Koçak, 2003; Yaldır & Polat, 2016)
- Comprehension, simplicity of implementation, and visual presentation of geo-information for users (Ghaffari et al., 2014; Karabıyık & Gündoğmuş, 2018; Yaldır & Polat, 2016)
- Compliance with local legislation (speed limits, etc.) and effective warnings when necessary (Koçak, 2003)

- Reducing the operating costs of companies owing to the system (Karabıyık & Gündoğmuş, 2018)
- Communication infrastructure (Ghaffari et al., 2014)
- System cost (Ghaffari et al., 2014; Haddara, 2018; Karabıyık & Gündoğmuş, 2018; Koçak, 2003; Yaldır & Polat, 2016; Yeşilyurt et al., 2019)
- Design and quality of hardware (Ghaffari et al., 2014)
- The software's design and inclusion of current technologies (Ghaffari et al., 2014; Yeşilyurt et al., 2019)
- Providing system training and consulting (Koçak, 2003)
- The system supplier's reliability and reputation (Haddara, 2018; Koçak, 2003)
- Having a quality certificate (Ertek & Aba, 2012)
- Real time location tracking of vehicles (Dandıl & Demir, 2020; Ghaffari et al., 2014)
- Allowing the vehicle to be diverted (Dandıl & Demir, 2020; Ghaffari et al., 2014)
- Providing statistical data collection, and effective reporting (Karabıyık & Gündoğmuş, 2018; Koçak, 2003; Yaldır & Polat, 2016; Yeşilyurt et al., 2019)
- System maintenance and technical support (Haddara, 2018; Yaldır & Polat, 2016; Yeşilyurt et al., 2019)
- The system's operating costs and sustainability (Karabıyık & Gündoğmuş, 2018)
- Adaptability to new technologies and updates (Yaldır & Polat, 2016)
- Data confidentiality and security (Haddara, 2018; Yaldır & Polat, 2016; Yeşilyurt et al., 2019)
- Integration of external systems and/or devices (phone, tablet, computer) (Dandıl & Demir, 2020; Ertek & Aba, 2012; Haddara, 2018; Karabıyık & Gündoğmuş, 2018; Yaldır & Polat, 2016)

The experts consulted live and work in Turkey. The first expert consulted for the study's criteria evaluation received a logistics undergraduate education and has worked in a logistics company's vehicle tracking system department for more than five years. The second expert has over ten years of experience and works as a field manager of operations in the transportation department of a logistics company. The third expert is an academic who works in the undergraduate logistics management department of a university and has studied GIS (Geographic Information System). The expert working on the vehicle tracking system made the first assessments on the long list of criteria. Some of the criteria were eliminated following the expert's recommendations, and the criteria listed in Table 3 were formed. The importance levels of the criteria were determined in the second stage using PIPRECIA-S by the assessments of three experts. Table 3 displays the S_j values that indicate the importance levels of the criteria.

Table 3. The S_j Values of Criteria According to Experts' Evaluations

Notation	**Criteria**	S_j			
		Expert 1	**Expert 2**	**Expert 3**	**Geo. Mean**
C1	Real time location tracking of vehicles	10	80	35	30,37
C2	Comprehension, simplicity of implementation, and visual presentation of geo-information for users	30	85	40	46,72
C3	Compliance with local legislation	15	90	15	27,26
C4	Reducing the operating costs of companies owing to the system	10	100	25	29,24
C5	Communication infrastructure	10	85	30	29,43
C6	System cost	15	90	20	30,00

C7	Design and quality of hardware	15	100	50	42,17
C8	Having a quality certificate	15	100	25	33,47
C9	Allowing the vehicle to be diverted	20	90	35	39,79
C10	Providing statistical data collection, and effective reporting	20	80	40	40,00
C11	System maintenance and technical support	20	100	50	46,42
C12	Adaptability to new technologies and updates	15	100	45	40,72
C13	Integration of external systems and/or devices	10	80	35	30,37

The S_j values determined based on expert assessments were used to calculate the k_j values. Then, q_j values were calculated, followed by w_j values and the processes for determining the weights of the criteria were completed. The weight values of the criteria are shown in Table 4.

Table 4. The Criteria Weights

Criteria	k_j	q_j	w_j	Rank
C1	1.0000	1.0000	0.1199	1
C2	1.6963	0.5895	0.0707	9
C3	1.5328	0.6524	0.0782	2
C4	1.7274	0.5789	0.0694	13
C5	1.7076	0.5856	0.0702	12
C6	1.7057	0.5863	0.0703	11
C7	1.7000	0.5882	0.0705	10
C8	1.5783	0.6336	0.0759	4
C9	1.6653	0.6005	0.0720	8
C10	1.6021	0.6242	0.0748	7
C11	1.6000	0.6250	0.0749	6
C12	1.5358	0.6511	0.0780	3
C13	1.5928	0.6278	0.0752	5

The most important criterion in vehicle tracking system selection, according to the PIPRECIA-S results in Table 4, is "real time location tracking of vehicles." In terms of importance, "compliance with local legislation" is the second most important criterion. This reveals that for logistics companies, a vehicle tracking system that includes instant vehicle tracking and warnings in accordance with local regulations is preferable. The criteria were ranked in order of importance as follows: C1>C3>C12>C8>C13>C11>C10>C9>C2>C7>C6>C5>C4.

Conclusion

Vehicle tracking systems make fleet management much easier for logistics companies. Furthermore, as technological advancements continue, vehicle tracking system features transform, as do the expectations placed on these systems. The study's aim in this context was to determine the most effective criteria for selecting vehicle tracking systems, as well as the relative importance of these criteria. As a result, the criteria to be considered in the development of the vehicle tracking system for system developers and the criteria to be considered in the vehicle tracking system for logistics companies were defined.

The literature and the assessments of vehicle tracking system experts working in the logistics sector were used to define the criteria. To determine the importance levels and weights of the criteria, the PIPRECIA-S method was used. According to the analysis results, the most important criterion in the selection of a vehicle tracking system is real-time tracking of the vehicle's location. This is a predictable outcome. Because the primary development goal of vehicle tracking systems is to track vehicle locations in real time. The second most important criterion is that vehicle tracking systems are compatible with local legislation and can provide warnings when necessary. Given that logistics companies primarily operate on an international scale, this feature is critical for both companies and vehicles. The third most important criterion is that the vehicle tracking system be compatible with new technologies and updates. This criterion is directly related to the service life of the vehicle tracking system. It is critical for logistics companies to use their vehicle tracking systems effectively and for as long as possible, as well as to carry out software updates perfectly. Other important criteria in the selection of a vehicle tracking system are "having a quality certificate", "integration of external systems and/or devices", "system maintenance and technical support", "providing statistical data collection, and effective reporting", "allowing the vehicle to be diverted", "comprehension, simplicity of implementation, and visual presentation of geo-information for users", "design and quality of hardware", "system cost", "communication infrastructure", and "reducing the operating costs of companies owing to the system".

In general, logistics companies should prioritize instant vehicle tracking, compliance with local regulations, compatibility with new technologies and software, quality certification, and integration with external systems/devices when selecting a vehicle tracking system. Similarly, developers of vehicle tracking systems can design a system by prioritizing the aforementioned criteria. In the companies where the experts whose opinions are consulted in this study, various vehicle tracking systems are used. Besides, these companies rely on a single vehicle tracking system. As a result, the study was unable to conduct a comparative analysis of the performance of vehicle tracking systems. In the future, researchers may be able to overcome the aforementioned limitation and use a multi-criteria decision model to analyze the performance of vehicle tracking systems. Furthermore, performance analysis can be generated using GIS data from vehicle tracking systems or operational costs on system setup.

References

Arslan, S., Gündüzalp, M., & Türk, E. (2016). Gömülü sistem bir araç takip sistemi uygulaması. National Conference on Electrical, Electronics and Biomedical Engineering (pp. 447-451), ELECO 2016, Bursa.

Blagojević, A., Stević, Ž., Marinković, D., Kasalica, S., & Rajilić, S. (2020). A novel entropy-fuzzy PIPRECIA-DEA model for safety evaluation of railway traffic. *Symmetry*, 12(9), 1479. https://doi.org/10.3390/sym12091479

Çağlar, B. (2014). Lojistik işletmelerinde bilişim teknolojilerinin kullanımı, müşteri memnuniyeti ve işletme performansı ilişkisi: Bir araştırma. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 32, 41–55.

Dandıl, E., & Demir, E. (2020). Gerçek Zamanlı Araç Hız Ölçümü ve Takip Sistemi Tasarımı. *Journal of the Institute of Science and Technology*, 10(1), 13–27. https://doi.org/10.21597/jist.590782

DJalić, I., Stević, Ž., Karamasa, C., & Puška, A. (2020). A novel integrated fuzzy PIPRECIA–interval rough SAW model: Green supplier selection. *Decision Making: Applications in Management and Engineering*, 3(1), 126–145. https://doi.org/10.31181/dmame2003114d

Doğru, A. Ö., Uluğtekin, N., & Çelik, R. N. (2006). Araç takip sistemleri ve harita. *Jeodezi ve Jeoinformasyon Dergisi*, 94, 19–25.

Dukare, S. S., Patil, D. A., & Rane, K. P. (2015). Vehicle tracking, monitoring and alerting system: A review. *International Journal of Computer Applications*, 119(10), 39-44.

Ertek, G., & Aba, B. (2012) *Lojistik bilişim sistemleri (logistics information systems)*, Uluslararası Lojistik, Anadolu Üniversitesi Yayınları, Açıköğretim Fakültesi Yayını No: 1593. Eds. Bülent Çatay and Gürkan Öztürk.

Ghaffari, S., Miman, M., & Küçük, L. (2014). Nakliyat araçları için bir araç takip sistemi. III. Ulusal Lojistik ve Tedarik Zinciri Kongresi (pp. 393-399), Trabzon.

Haddara, M. (2018). ERP systems selection in multinational enterprises: A practical guide. *International Journal of Information Systems and Project Management*, 6(1), 43–57. https://doi.org/10.12821/ijispm060103

Jaukovic Jocic, K., Jocic, G., Karabasevic, D., Popovic, G., Stanujkic, D., Zavadskas, E. K., & Thanh Nguyen, P. (2020). A novel integrated piprecia–interval-valued triangular fuzzy aras model: E-learning course selection. *Symmetry*, 12(6), 928. https://doi.org/10.3390/sym12060928

Karabıyık, B. K., & Gündoğmuş, M. E. (2018). Üniversitelerde bilgi sistemi seçim kriterlerinin SWARA yöntemi ile ağırlıklandırılması: Ampirik bir çalışma. *İşletme Bilimi Dergisi*, 6(1), 59–85. https://doi.org/10.22139/jobs.379695

Khin, J. M. M., & Oo, N. N. (2018). Real-time vehicle tracking system using Arduino, GPS, GSM and web-based technologies. *International Journal of Science and Engineering Applications*, *7*(11,433-436).

Koçak, A. (2003). Yazılım seçiminde Analitik Hiyerarşi Yöntemi yaklaşımı ve bir uygulama. *Ege Academic Review*, 3(1), 67–77.

Küçüksille, E., & Kuşçu, Ö. (2010). Mobil cihazlar ile çevrimiçi araç takip sistemleri. *Tübav Bilim Dergisi*, 3(1), 45–50.

Lee, S., Tewolde, G., & Kwon, J. (2014). Design and implementation of vehicle tracking system using GPS/GSM/GPRS technology and smartphone application. 2014 IEEE World Forum on Internet of Things (WF-IoT), 353–358. https://doi.org/10.1109/WF-IoT.2014.6803187

Maurya, K., Singh, M., & Jain, N. (2012). Real time vehicle tracking system using GSM and GPS technology-an anti-theft tracking system. *International Journal of Electronics and Computer Science Engineering*, V1N3-1103.

Nedeljković, M., Puška, A., Doljanica, S., Virijević Jovanović, S., Brzaković, P., Stević, Ž., & Marinkovic, D. (2021). Evaluation of rapeseed varieties using novel integrated fuzzy PIPRECIA–Fuzzy MABAC model. *Plos One*, 16(2), e0246857. https://doi.org/10.1371/journal.pone.0246857

Özdağoğlu, A., Öztaş, G. Z., Keleş, M. K., & Volkan, G. (2021). An integrated PIPRECIA and COPRAs method under fuzzy environment: A case of truck tractor selection. *Alphanumeric Journal*, 9(2), 269–298. https://doi.org/10.17093/alphanumeric.1005970

Poyraz, Y., & Sevgen, S. (2017). GPU programlama tekniği ile yüksek performanslı araç takibi. *Bilişim Teknolojileri Dergisi*, 10(3), 255–261. https://doi.org/10.17671/gazibtd.331036

Raad, M. W., Deriche, M., & Sheltami, T. (2021). An IoT-based school bus and vehicle tracking system using RFID technology and mobile data networks. *Arabian Journal for Science and Engineering*, 46(4), 3087–3097. https://doi.org/10.1007/s13369-020-05111-3

Shibghatullah, A. S., Jalil, A., Abd Wahab, M. H., Soon, J. N. P., Subaramaniam, K., & Eldabi, T. (2022). Vehicle tracking application based on real time traffic. *International Journal of Electrical and Electronic Engineering & Telecommunications*, 11(1).

Stanujkic, D., Karabasevic, D., & Cipriana, S. (2018). An application of the PIPRECIA and WS PLP methods for evaluating website quality in hotel industry. *Quaestus*, 12, 190–198.

Stanujkic, D., Karabasevic, D., Popovic, G., & Sava, C. (2021). Simplified Pivot Pairwise Relative Criteria Importance Assessment (Piprecia-S) Method. *Romanian Journal of Economic Forecasting*, 24(4), 141-154.

Stanujkic, D., Zavadskas, E. K., Karabašević, D., Smarandache, F., & Turskis, Z. (2017). The use of Pivot Pair-wise Relative Criteria Importance Assessment method for determining weights of criteria. *Romanian Journal of Economic Forecasting*, 20(4), 116-133.

Stević, Ž., Bouraima, M. B., Subotić, M., Qiu, Y., Buah, P. A., Ndiema, K. M., & Ndjegwes, C. M. (2022). Assessment of causes of delays in the road construction projects in the Benin Republic using Fuzzy PIPRECIA method. *Mathematical Problems in Engineering*, *2022*. https://doi.org/10.1155/2022/5323543

Stević, Ž., Stjepanović, Ž., Božičković, Z., Das, D. K., & Stanujkić, D. (2018). Assessment of conditions for implementing information technology in a warehouse system: A novel fuzzy PIPRECIA method. *Symmetry*, 10(11), 586. https://doi.org/10.3390/sym10110586

Tamilvizhi, T., Surendran, R., & Krishnaraj, N. (2021). Cloud Based Smart Vehicle Tracking System. International Conference on Computing, Electronics & Communications Engineering (ICCECE), 1–6.

Tekin, M., Zerenler, M., & Bilge, A. (2005). Bilişim teknolojileri kullanımının işletme performansına etkileri: Lojistik sektöründe bir uygulama. *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi*, 4(8), 115–129.

Tomašević, M., Lapuh, L., Stević, Ž., Stanujkić, D., & Karabašević, D. (2020). Evaluation of criteria for the implementation of high-performance computing (HPC) in Danube Region countries using fuzzy PIPRECIA method. *Sustainability*, 12(7), 3017. https://doi.org/10.3390/su12073017

Ulutaş, A., Popovic, G., Stanujkic, D., Karabasevic, D., Zavadskas, E. K., & Turskis, Z. (2020). A new hybrid MCDM model for personnel selection based on a novel grey PIPRECIA and grey OCRA methods. *Mathematics*, 8(10), 1698. https://doi.org/10.3390/math8101698

Vesković, S., Milinković, S., Abramović, B., & Ljubaj, I. (2020). Determining criteria significance in selecting reach stackers by applying the fuzzy PIPRECIA method. *Operational Research in Engineering Sciences: Theory and Applications*, 3(1), 72–88. https://doi.org/10.31181/oresta2001072v

Yaldır, A., & Polat, L. Ö. (2016). Çok kriterli karar verme teknikleri İle elektronik belge yönetim sistemi seçimi. *Mehmet Akif Ersoy Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 8(14), 88–108. https://doi.org/10.20875/sb.56729

Yeşilyurt, B., Karakuş, K., Gür, Ş., & Eren, T. (2019). Çok ölçütlü karar verme yöntemleri ile hastane bilgi yönetim sistemleri için paket programı seçimi. *Başkent Üniversitesi Ticari Bilimler Fakültesi Dergisi*, 3(1), 1–21.

© 2022 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).