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Evaluation of alternative strategies to meet the demand for blood and blood products

Kan ve kan ürünlerinin talebinin karşılanmasında alternatif stratejilerin değerlendirilmesi

***Yazar(lar) (Author(s))**: Rumeysa GÜNEŞ[1], Buğra AKYOL[2], Emel GÜVEN[3], Tamer EREN[4]*

ORCID[1]: 0009-0009-7479-9867

ORCID[2]: 0009-0008-4636-7584

ORCID[3]: 0000-0001-6106-9720

ORCID[4]: 0000-0001-5282-3138

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Highlights

- *Alternatives and Strategies*
- *Pythagorean Fuzzy AHP*
- *Pythagorean Fuzzy TOPSIS*
- *Donate Blood*

Graphical Abstract

In this study, alternative strategies used to meet the demand for blood and blood products were examined and alternatives and criteria were ranked using Pythagorean Fuzzy AHP and TOPSIS.

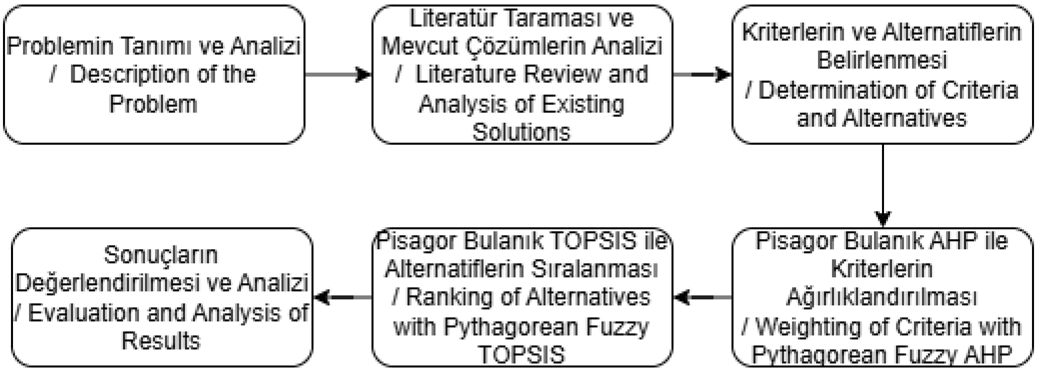

Figure. Application Flowchart

Aim

This study aims to determine the most appropriate solution by developing alternative strategies to meet the demand for blood and blood products in Türkiye.

Design & Methodology

Pythagorean Fuzzy AHP and TOPSIS were used in the solution phase of the problem.

Originality

The study evaluates alternative strategy choices in meeting the demand for blood and blood products.

Findings

As a result of the implementation, a strategic roadmap was created to increase donation amounts and maintain stock levels.

Conclusion

Within the scope of the study, alternative strategies to meet the demand for blood and blood products will be evaluated.

Declaration of Ethical Standards

Bu makalenin yazar(lar)ı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler. / The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and / or legal-special permission.

Evaluation of Alternative Strategies to Meet the Demand for Blood and Blood Products

Araştırma Makalesi / Research Article

Rumeysa GÜNEŞ[1], Buğra AKYOL[1], Emel GÜVEN[1], Tamer EREN[1*]

[1]Mühendislik ve Doğa Bilimleri Fakültesi, Endüsti Mühendisliği Bölümü, Kırıkkale Üniversitesi, Türkiye

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ABSTRACT

Blood and blood products are vital in many medical conditions. In cases such as surgical operations, cancer treatments, and accidents, successful treatment becomes difficult without blood and blood products. Therefore, blood donation is of vital importance for saving the lives of patients and for the smooth operation of the healthcare system. This study aims to determine the most appropriate solution by developing alternative strategies to meet the demand for blood and blood products in Türkiye. The study aims to establish a sustainable supply and donation management mechanism by evaluating all stages, from blood donation processes to the delivery process to hospitals, with Pythagorean Fuzzy AHP and Pythagorean Fuzzy TOPSIS methods. In the analyses based on the criteria of Sustainability, Impact Potential, Target Audience Suitability, Cost Effectiveness, Ease of Implementation, and Stakeholder Support, the highest priority was determined as sustainability, and the "Easy Accessibility" alternative stood out. This result shows the potential to increase the efficiency of donation processes with solutions such as mobile donation units and accessible locations in city centers. As a result of the study, contribution to the literature and increase social solidarity, awareness with its adaptability to regional differences and long-term effects.

Keywords: Blood and Blood Products, Pythagorean Fuzzy AHP, Pythagorean Fuzzy TOPSIS

Kan ve Kan Ürünlerinin Talebinin Karşılanmasında Alternatif Stratejilerin Değerlendirilmesi

ÖZ

Kan ve kan ürünleri birçok tıbbi durumda hayati öneme sahiptir. Cerrahi operasyonlar, kanser tedavileri ve kazalar gibi durumlarda kan ve kan ürünleri olmadan başarılı bir tedavi zorlaşır. Bu nedenle kan bağışı, hastaların hayatlarını kurtarmak ve sağlık sisteminin sorunsuz işlemesi için hayati öneme sahiptir. Bu çalışma, Türkiye'de kan ve kan ürünlerine olan talebi karşılamak için alternatif stratejiler geliştirerek en uygun çözümü belirlemeyi amaçlamaktadır. Çalışma, kan bağışı süreçlerinden hastanelere ulaştırma sürecine kadar tüm aşamaları Pisagor Bulanık AHP ve Pisagor Bulanık TOPSIS yöntemleri ile değerlendirerek sürdürülebilir bir tedarik ve bağış yönetim mekanizması kurmayı amaçlamaktadır. Sürdürülebilirlik, Etki Potansiyeli, Hedef Kitle Uygunluğu, Maliyet Etkinliği, Uygulama Kolaylığı ve Paydaş Desteği kriterlerine dayalı analizlerde en yüksek öncelik sürdürülebilirlik olarak belirlenmiş ve "Kolay Erişilebilirlik" alternatifi öne çıkmıştır. Bu sonuç, mobil bağış üniteleri ve şehir merkezlerinde erişilebilir lokasyonlar gibi çözümlerle bağış süreçlerinin verimliliğini artırma potansiyelini göstermektedir. Çalışmanın sonucunda bölgesel farklılıklara uyum sağlayabilmesi ve uzun vadeli etkileri ile literatüre katkı sağlanarak toplumsal dayanışma ve farkındalığın artırılması amaçlanmaktadır.

Keywords: Anahtar Kelimeler: Kan ve Kan Ürünleri, Pisagor Bulanık AHP, Pisagor Bulanık TOPSIS

1. INTRODUCTION

Health is an element that forms the basis of the quality of life of individuals and is also an indispensable priority for the sustainable development of societies. Blood and blood products are vital elements that must be accessed immediately when needed; otherwise, it can lead to serious and unpreventable situations such as interruption of treatments, progression of diseases, or loss of life [1].

Providing safe and demand-capable blood should be an integral part of every country's health policy. In countries with large economies, the main reasons for transfusion are complex medical and surgical interventions, trauma and accidents, malignancies, and birth complications. Pregnancy complications and childhood anemia are conditions that require blood transfusion to a large extent in middle- and low-income countries. It has been shown that more than a quarter of maternal deaths can be prevented by providing access to safe blood [2].

Blood, a limited resource that can deteriorate over time, can only be produced by the human body and there is no artificial alternative that can replace it. This situation increases the importance of blood even more. It requires that it be delivered to where it is needed as soon as possible after it is obtained through donation [3].

Blood donation has positive effects on individuals both physically and psychologically. After blood donation, the tissues and organs responsible for blood production are activated, and new blood formation is supported; thus, the renewal of blood cells is ensured. In addition, blood donation has positive effects on reducing high-fat levels in the blood. In addition, during each donation, donors' blood is tested and screened for infections that can lead

*(Sorumlu Yazar) Corresponding Author
e-posta : tamereren@gmail.com

to serious consequences, such as HIV (Human Immunodeficiency Virus), Hepatitis B, Hepatitis C, and syphilis [4]. The concept of blood donation is not limited to the health sector and technical issues in our lives, but can also be described as the result of the well-intentioned behavior of donors. In a way, donating blood can be associated with the hope of helping an organization, society, or individual or with the concept of "sacrifice" as a personality trait. For this reason, blood donation is one of the basic building blocks of the health system. [5].

Blood donation is an essential element of public health and is subject to strict standards to protect the safety and well-being of donors and recipients. The World Health Organization (WHO) recommends establishing a blood supply system that is coordinated at the national level and supported by a strong legal framework. The challenges of the pandemic have highlighted the decline in donor participation and the importance of storage technologies for the sustainability of the blood supply. Methods such as education in schools, social media campaigns, and facilitating donation experiences are essential to reach young donors. Thus, by ensuring a sustainable blood supply chain, the resilience of the health system against crises can be strengthened [6].

This study aims to determine and evaluate the most appropriate strategy by weighting the appropriate criteria in order to meet the demand for blood and blood products that may occur in Türkiye. The timely and sufficient supply of blood and blood products, which are of critical importance for the sustainability of health systems, is a strategic necessity in terms of both preserving individual quality of life and preventing public health crises. Especially in countries with high population density and diverse regional health needs, such as Türkiye, effective management of the blood supply chain is of great importance. In this context, the most appropriate strategies for meeting the demand for blood and blood products should be determined by considering variables such as the adequacy of existing donation processes, storage capacity, logistics facilities and public awareness level. This study aims to evaluate alternative strategies with a multi-criteria decision-making approach by using the Pythagorean Fuzzy AHP and Pythagorean Fuzzy TOPSIS methods in an integrated manner in order to optimize the blood and blood product supply processes in Türkiye. Thus, it is aimed to go beyond the repetition of general information and focus on the weaknesses of the blood donation system and develop a scientifically based, applicable decision support model. Since it is challenging to meet this wide range of needs, the importance of blood donors increases significantly. With this study, regular blood donation will be encouraged, and the optimization of the supply processes of blood and blood products will be provided.

The study aims to evaluate all stages, from blood donation processes to storage and delivery to hospitals, by determining appropriate criteria and alternatives and using Pythagorean Fuzzy Logic in order to optimize blood donation and product management. In addition, the study emphasizes that blood donation is an indispensable element for the health system by drawing attention to the fact that blood and blood products are a critical and continuous need. In this context, the aim is to increase the amount of donations by developing different strategies.

The study has broad effects, such as meeting the demand for blood and blood products most efficiently, increasing donation levels, keeping inventory levels at a critical threshold, reducing costs, and encouraging solidarity in society. In line with these strategies, it aims to establish a balanced donation-management mechanism on a national scale for the sustainable supply of blood and blood products by using Pythagorean Fuzzy AHP (Analytical Hierarchy Process) and Pythagorean Fuzzy TOPSIS (Technique For Order Preference By Similarity To An Ideal Solution) methods. Different criteria will be developed to increase blood and blood product donations, and appropriate alternatives will be obtained to increase donations. As a result of the study, answers will be sought to questions such as which strategy should be followed in which situation, what kind of approach should be taken regionally, and what can be done to prevent blood and blood product levels from falling below the critical threshold. Ultimately, this study aims to avoid problems such as blood and blood product waste, shortage, and critical inventory by ensuring the balance between blood and blood product demand and donation.

2. BLOOD AND BLOOD PRODUCTS

Blood has been seen as the primary symbol of health and life throughout history, and in modern medicine, it has been accepted as a vital medicine that can only be obtained from humans [5].

Blood, the only liquid tissue in our body, is pumped when it reaches the heart and continues to circulate in the veins. Blood has an essential regulatory role in order for the body to maintain its vital functions. It helps maintain the acid-base balance of body fluids, allowing cells to function under optimum conditions. It also balances the density of cell and tissue fluids, thus regulating the exchange of substances between the internal and external environments of cells. Blood keeps body temperature at a constant level, ensuring that the organism maintains a balanced temperature and that metabolic processes continue healthily. This regulatory role is of critical importance in maintaining the general health of the organism and in ensuring that systems work in harmony [7].

Blood and blood products are one of the most vital elements of modern medicine and play a critical role in healthcare. Blood plays an important role in transporting oxygen and nutrients throughout the body, removing waste products, and in the immune system's defense mechanisms [8]. In addition, different components of blood, such as plasma, platelets, erythrocytes, and white blood cells, are used as vital resources in various medical interventions. The provision of blood through donation is indispensable for the continuity of health systems. Blood and blood products are used not only in emergencies such as accidents, surgeries, and birth but also in long-term treatment processes such as cancer treatments, heart diseases, and chronic diseases [9]. Therefore, regular and sufficient blood donation is of great importance for public health. However, the supply and management of blood face many challenges. First, blood and blood products are based on a limited resource. It is necessary to continuously increase blood donations worldwide because the storage period of blood is limited, and it is not always possible to guarantee that there is enough blood [10]. In countries like Türkiye, the decrease in blood donations, especially during holiday periods or disasters, can become a critical problem. Therefore, regularizing blood donations is of great importance for the sustainability of blood inventories. The management of blood products also requires great care. Errors that may occur in the collection, processing, storage, and distribution of blood can pose vital risks [11].

For example, giving the wrong blood group can lead to serious complications in the patient. Therefore, it is essential to provide appropriate conditions during the transportation and storage of blood and blood products. In order to manage blood donations effectively, it is of great importance to develop the best inventory management strategies and to deliver blood to those in need on time and correctly.

In conclusion, blood and blood products are the cornerstones of the health system and management. Donation campaigns and public awareness activities in this area play a critical role in saving lives. Therefore, being more conscious and sensitive about blood donation as a society is extremely important for strengthening health systems.

2.1. Blood Donation Process

Blood Donation is the process of donating whole blood or at least one of the blood components. It consists of donors donating, testing the donation, storing it, and delivering it to those in need. An effective donation process includes certain steps for both the safety of the donor and the appropriate usability of the blood obtained. This process takes place in five steps: [12, 39].

1. Donation Reception: Blood donors' eligibility criteria (age, health status, disease history, etc.) are checked.

2. Blood Testing: Donated blood is tested for diseases such as HIV, hepatitis, and syphilis.

3. Separation of Blood Components: The resulting blood is separated into its basic components such as plasma, platelets, and red blood cells.

4. Storage: Blood products are stored at certain temperatures and conditions.

5. Distribution: Delivered to hospitals and health institutions.

2.2. Supply Chain Management of Blood and Blood Products

The constant need for blood and blood products necessitates effective supply chain management. Maintaining critical inventory levels and optimizing transaction costs are the main objectives of this system. The following factors shape supply chain management [13].

1. Critical Inventory Level: Because blood products have a limited shelf life, inventory levels must be constantly monitored.

2. Distribution and Access: Blood must be delivered to the areas in need and on time.

3. Donor Management: Implementation of programs that encourage donors to increase blood donation.

4. Cost Optimization: Strategies are developed to reduce storage, distribution, and testing costs.

3. LITERATURE REVIEW

Blood and blood products are vital components that are needed continuously, not in emergencies. Blood, the only liquid tissue circulating in our body, is a critical medicine for humans. Blood is divided into two parts: red and white parts. This distinction also shows that their areas of use are different. While the red parts are used in cases such as anemia and blood loss, the white parts are used in diseases such as blood diseases, cancer treatments, and AIDS [1, 7]. Therefore, blood donation and management of blood and blood products are of great importance. Blood pumped by the heart carries oxygen and nutrients to all parts of the body while also removing waste products. The components of blood that undertake this vital task and the effects of these components on human health are among the subjects that have been researched in the medical world for many years. When studies in the literature were examined, the prominent studies were compiled, and a literature review was obtained.

In their study, Koç and Kokangül [11]. analyzed the process from blood donation to testing and separation before being given to the patient, examined the distribution to the relevant health institutions, and simulated the process. Randa et al. [14] examined the blood supply process in the Central Anatolia Region and offered suggestions such as opening regional blood centers and reorganizing inventory policies. In their study, Göray and Peker [8] examined the transfusion process of blood taken from donors in detail.

Gillespie and Hillyer [15] studied the characteristics of blood donors in their studies conducted in the United States. They evaluated strategies to increase donor motivation and organize donation processes. They developed more effective blood donation methods by ensuring donor continuity. Tezcan [16], focused on transfusion complications and costs and proposed a new approach by compiling existing methods in this field. Küçüktaş et al. [17] focused on the inadequacy of access to blood and blood components at the time of need and the shortage of volunteer blood donors and made evaluations on the use of blood in clinics. Blood and blood products should be quickly provided and accessible when needed. These products consist of white blood cells, erythrocytes, plasma, and platelets, and the most needed component is erythrocytes. Şengil [18] has examined the issues of blood perishability, uncertainties in demand, and the separation of erythrocytes into different groups. In the supply process, the health status of the donor is first evaluated, and the blood taken from the donor is subjected to certain tests. In order to meet the demand for blood and blood products needed throughout Türkiye, sufficient donations must be made.

Cevizci et al. [10] discussed the psychosocial factors affecting voluntary blood donation and blood donation behavior. However, the critical inventory level is 20,000 units, and the sustainability of this level cannot be ensured. Sojka and Sojka [19] examined donors' motivations for giving and the difficulties they face when donating. While the first motivations for giving were friend influence and appeals made through the media, altruism was determined as the most common reason for continuous giving. It is emphasized that methods such as friend referral are effective for first donors, and strategies such as information and strengthening donor identity are effective for regular donors. Gökler and Boran [20] aimed to develop a stochastic inventory model that optimally estimates the demand for blood components and minimizes the costs of the blood bank.

Kaya [9] drew attention to the aim of his study, which was to determine the knowledge level and practices regarding blood and blood product transfusion and transfusion complications. 255 volunteer nurses participated in the study, and the knowledge levels of nurses regarding blood transfusion practices were evaluated. Kruskal Wallis, Mann Whitney U tests, and Spearman correlation analysis was used during the evaluation.

Höbel [21] drew attention to the direct increase in cost when blood transfusion is applied unnecessarily and to the additional cost increase in treating complications if complications develop. He aimed to examine the situations in which blood and blood product transfusions are performed in the emergency department and the factors affecting the cost for patients who receive transfusions. In the study, patient files were scanned retrospectively, and issues such as demographic characteristics of the patients, reasons for transfusion, and types were examined.

Göray and Peker [8] have been increasing the health problems that come with the increase in our country's population. The importance of blood and blood products in treating these increasing problems is too great to ignore. For this reason, they have drawn attention to issues such as giving frequent seminars, raising awareness of personnel, and developing equipment to increase the number of volunteer donors in the donation process of blood and blood products.

Kavak [22], the most critical problem in our country is not being able to provide safe blood. The inadequacy of voluntary blood donation and the wrong beliefs and attitudes of the public are the causes. They have examined the reasons that keep society away from donating and determined their level. As a result, they have reached a sufficient level of voluntary blood donation and actively achieved its sustainability by increasing the number of voluntary blood donors.

If the demand for blood and blood products cannot be met, human life is at risk, and the processes need to proceed faster than they are. Because blood is not an urgent need but a constant need, the research project to be conducted will focus on how the demand for blood and blood products can be increased. If this demand cannot be met, it is seen that the life expectancy of patients may be shortened, their quality of life may decrease, and their treatment processes may be prolonged. For this reason, the problems that may be encountered in the supply process of blood and blood products will be evaluated, and appropriate strategies will be created. In line with the plan developed, it is aimed at the person in need to easily access the product at the right time and in the right place. When the literature is examined, it has been seen that no previous study has been conducted to evaluate alternative strategies for meeting the demand for blood and blood products and to determine their effects on blood.

The study differs from the studies in the literature in terms of meeting the demand for blood and blood products and evaluating alternative strategies. It is seen that the literature focuses on issues such as blood donation processes, transfusion practices, logistics distribution, stock management and donor behaviors. However, there is no study on developing a comprehensive decision-making model for developing a holistic strategy to meet the demand for blood and blood products in a sustainable way. This study, prepared based on direct information received from the Turkish Red Crescent, offers a strategic perspective by considering not only technical processes but also socio-technical factors such as donor behavior, ease of access and sustainability. Another unique aspect of the study is that alternative scenarios are evaluated with both quantitative and qualitative data, and in this way, strategies are presented that will contribute to increasing critical stock levels as well as the level of awareness of society towards donation. The study is original in this respect and contributes to the literature. A study will be presented that will address critical inventory levels of blood demands while also creating awareness of social consciousness and solidarity.

4. METHOD

The fuzzy set theory was put forward by Zadeh [23]. The subject discussed in the study may produce different results depending on uncertain situations and scenarios. In this case, evaluations will be made by applying fuzzy logic sets. Fuzzy logic is needed to evaluate qualitative and quantitative criteria in uncertain situations where decisions cannot be made with definite values. Intuitive fuzzy sets, presented by Antanassov in 1986, are based on both the membership and non-membership degrees of an element in a fuzzy set. While the sum of the membership and non-membership degrees in classical fuzzy sets is always 1, this sum should be less than or equal to 1 in intuitional fuzzy sets. It is based on the idea that there may be a degree of hesitation in real-life examples where the non-membership degree of an element is not always equal to a 1-membership degree [24].

The strategy determination process for blood and blood products has a complex structure that includes multi-criteria decision-making dynamics and is shaped by uncertainties. In this process, there are both subjective uncertainties in the evaluations of decision makers and uncertainties arising from the nature of the criteria and alternatives. For this reason, the decision-making process is addressed within the framework of fuzzy logic. In order to evaluate the uncertainties of decision makers more accurately and effectively in the study, it was decided to use Pythagorean Fuzzy AHP and Pythagorean Fuzzy TOPSIS methods together. In this study, appropriate criteria will be determined using Pythagorean Fuzzy AHP and Pythagorean Fuzzy TOPSIS methods, and strategies suitable for these situations will be developed. The integration of Pythagorean Fuzzy AHP and Pythagorean Fuzzy TOPSIS within this specific context offers a methodological contribution by addressing the complex and uncertain nature of strategic decision-making in blood product management. This approach provides an enhanced decision-making framework that has not been extensively explored in previous studies.

interrelated groups aims to make them easier to solve. Pythagorean Fuzzy AHP offers a more realistic, more objective, and subjective approach by modeling these uncertainties [26].

The first step of the method is to determine the problem to be decided and the criteria affecting this problem. These criteria are organized in a hierarchical structure. Afterward, the relationships between these criteria and the evaluation of the alternatives according to these criteria are made. These evaluations are carried out using fuzzy numbers instead of crisp numbers. Fuzzy numbers are used to express uncertainties [27] better. For example, while it may be said that a criterion is "essential," this statement can be expressed more clearly with a fuzzy number. After this stage, the weights of the criteria are calculated using the Pythagorean theorem for each level in the hierarchy, thus determining which criterion is more important for the decision. Finally, after all the calculations, general evaluations of the alternatives are made, and as a result of these evaluations, the criteria are weighted.

The Pythagorean Fuzzy AHP stages are given below [28]:

1. Table 1 shows the descriptions of the notations used in the Pythagorean Fuzzy AHP methodology, including membership values, uncertainty levels, and the final criteria weights.

2. First, the decision problem is modeled. Target criteria and alternatives are determined. As a result of the pairwise comparison between each criterion or alternative, the matrix $A = (r_{ik})mxm$ (1) is created, and the decision matrix is obtained through the group

Table 1. Notations Used in the Pythagorean Fuzzy AHP Method

Notations	Description
$\boldsymbol{A = (r_{ik})mxm}$	Pairwise comparison matrix for criteria or alternatives
$\boldsymbol{M_{ik_L}}$	Lower membership degree of criterion i with respect to criterion k
$\boldsymbol{M_{ik_u}}$	Upper membership degree of criterion i with respect to criterion k
$\boldsymbol{V_{ik_L}}$	Lower non-membership degree of criterion i with respect to criterion k
$\boldsymbol{V_{ik_u}}$	Upper non-membership degree of criterion i with respect to criterion k
$\boldsymbol{d_{ik_L}}$	Lower difference value between two criteria
$\boldsymbol{d_{ik_u}}$	Upper difference value between two criteria
$\boldsymbol{d_L}$	Lower difference result used in multiplicative matrix calculation
$\boldsymbol{d_U}$	Upper difference result used in multiplicative matrix calculation
$\boldsymbol{s_{ik_L}}$	Lower value in the multiplicative matrix S
$\boldsymbol{s_{ik_U}}$	Upper value in the multiplicative matrix S
$\boldsymbol{h_{ik}}$	Uncertainty level between criteria i and k
$\boldsymbol{t_{ik}}$	Unnormalized weighted value for criteria pair i, k
$\boldsymbol{T = (t_{ik})mxm}$	Matrix of unnormalized weighted values
$\boldsymbol{w_i}$	Final normalized weight of criterion i

4.1. Pythagorean Fuzzy AHP Method

When making decisions, we usually encounter uncertainties and subjective evaluations rather than exact numbers [25]. Dividing these uncertainties into

evaluation of the individual opinions of the experts.

3. After the comparison matrix is created, the $D = (d_{ik})mxm$ (2) difference matrix is created using

Equations 3 and 4 when determining the differences between the two criteria.

$$d_{ik_L} = M_{ik_L}^2 - V_{ik_u}^2 \quad (3)$$

$$d_{ik_u} = M_{ik_u}^2 - V_{ik_L}^2 \quad (4)$$

4. The multiplicative matrix $S = (s_{ik})mxm$ (5) is calculated using Equations 6 and 7.

$$s_{ik_L} = \sqrt{1000^{d_L}} \quad (6)$$

$$s_{ik_U} = \sqrt{1000^{d_U}} \quad (7)$$

5. Uncertainty levels are calculated as given in Equation 8.

$$h_{ik} = 1 - \left(M_{ik_U}^2 - M_{ik_L}^2\right) - \left(V_{ik_U}^2 - V_{ik_L}^2\right) \quad (8)$$

$$H = (h_{ik})mxm \quad (9)$$

6. Unnormalized weighted values $T = (t_{ik})mxm$ (10) are calculated with Equation 11.

$$t_{ik} = \left(\frac{s_{ik_L} + s_{ik_U}}{2}\right) h_{ik} \quad (11)$$

7. The criteria weights w_i are finalized using Equality 12, and the final preference ranking is obtained.

$$w_i = \frac{\sum_{j=1}^{m} w_i}{\sum_{j=1}^{m} \sum_{j=1}^{m} w_i} \quad (12)$$

4.2. Pythagorean Fuzzy TOPSIS Method

Pythagorean fuzzy TOPSIS is a method developed by Hwang and Yoon in 1981, and it is used in multi-criteria decision-making (MCDM) problems. This method combines the Pythagorean fuzzy set theory with the traditional TOPSIS method. Pythagorean fuzzy sets allow for a more flexible representation of uncertainty and fuzziness [29]. Thus, it ranks the alternatives by evaluating their proximity to the ideal and negative ideal solutions. Areas of use include decision-making processes such as supplier selection, project evaluation, performance analysis, and strategic planning. The basic stages of Pythagorean fuzzy TOPSIS begin with the creation of the decision matrix. After determining the criteria weights, fuzzy ideal and negative ideal solutions are defined. The proximity values of the alternatives to the ideal solution are calculated, and the alternatives are ranked. This method offers an effective solution for decision problems involving uncertainty and makes the job of decision-makers easier [30].

The steps of the Pythagorean Fuzzy TOPSIS method are as follows [31]:

1. To enhance the clarity and comprehensibility of the mathematical formulations used in this study, all notations and symbols employed in the proposed Pythagorean Fuzzy TOPSIS method are summarized in Table 2. This table defines the variables, parameters, and functions involved in the construction of the decision matrix, the identification of ideal solutions, and the calculation of distances and similarity measures.

2. Decision makers evaluate criteria and alternatives.

3. The decision matrix is obtained using Equation 13.

Table 2. Notations Used in the Pythagorean Fuzzy TOPSIS Method

Notations	Description
x_i	The i-th alternative, where $i = 1,2,\dots,m$
C_j	The j-th criterion, where $j = 1,2,\dots,n$
$R = (C_j(x_i))_{mxm}$	The Pythagorean fuzzy decision matrix
V_{ik_L}	A Pythagorean fuzzy number (PFN) representing the evaluation of alternative x_i with respect to criterion C_j, where u_{ij} is the degree of membership and v_{ij} is the degree of non-membership
u_{ij}, v_{ij}	Degree of membership and non-membership for alternative x_i under criterion C_j
π_{ij}	Hesitation degree for the PFN, calculated as $\pi_{ij} = \sqrt{1 - u_{ij}{}^2 - v_{ij}{}^2}$
x^+	The ideal solution vector
x^-	The negative-ideal solution vector
$P(u_j^+, v_j^+)$	Ideal PFN for criterion C_j, where u_j^+ and v_j^+ are the maximum membership and minimum non-membership degrees among alternatives
w_j	The weight of criterion C_j
$D_{(x_i, x^+)}$	The distance of alternative x_i from the ideal solution
$D_{(x_i, x^-)}$	The distance of alternative x_i from the negative-ideal solution
$D_{max(x_i, x^+)}$	The maximum distance between alternative x_i and all negative-ideal solutions (used for normalization)
$D_{min(x_i, x^-)}$	The minimum distance between alternative x_i and all ideal solutions (used for normalization)
$\xi(x_i)$	The similarity measure (relative closeness) of alternative x_i to the ideal solution

$$R = (C_j(x_i))_{mxm} = \begin{pmatrix} P_{u_{11},v_{11}} & P_{u_{12},v_{12}} & \cdots & P_{u_{1n},v_{1n}} \\ P_{u_{21},v_{21}} & P_{u_{22},v_{22}} & \cdots & P_{u_{2n},v_{2n}} \\ \vdots & \vdots & & \vdots \\ P_{u_{m1},v_{m1}} & P_{u_{m2},v_{m2}} & & P_{u_{mn},v_{mn}} \end{pmatrix} \quad (13)$$

4. Pythagorean Fuzzy Ideal and Negative-Ideal solutions are determined by Equations 14 and 15.

$$x^+ = \{C_j, maks_i\langle s(C_j(x_i))\rangle I\ j = 1,2,\ldots,n\} = \{\langle C_1, P(u_1^+, v_1^+)\rangle, \langle C_2, P(u_2^+, v_2^+)\rangle, \ldots, \langle C_n, P(u_n^+, v_n^+)\rangle\} \quad (14)$$

$$x^- = \{C_j, min_i\langle s(C_j(x_i))\rangle I\ j = 1,2,\ldots,n\} = \{\langle C_1, P(u_1^-, v_1^-)\rangle, \langle C_2, P(u_2^-, v_2^-)\rangle, \ldots, \langle C_n, P(u_n^-, v_n^-)\rangle\} \quad (15)$$

5. For the Pythagorean Fuzzy method, the degree of hesitation is calculated as in Equation 16.

$$\pi_{ij} = \sqrt{1 - {u_{ij}}^2 - {v_{ij}}^2} \quad (16)$$

6. The distances of each alternative to the ideal solution and the negative-ideal solution are calculated using Equations 17 and 18.

$$D_{(x_i,x^+)} = \sum_{j=1}^{n} w_j d((C_j(x_i), C_j(x^+)) = \frac{1}{2}\sum_{j=1}^{n} w_j(\left|(u_{ij})^2 - (u_j^+)^2\right| + \left|(v_{ij})^2 - (v_j^+)^2\right| + \left|(\pi_{ij})^2 - (\pi_j^+)^2\right|) \quad (17)$$

$$D_{(x_i,x^-)} = \sum_{j=1}^{n} w_j d((C_j(x_i), C_j(x^-)) = \frac{1}{2}\sum_{j=1}^{n} w_j(\left|(u_{ij})^2 - (u)^2\right| + \left|(v_{ij})^2 - (v_j^-)^2\right| + \left|(\pi_{ij})^2 - (\pi_j^-)^2\right|) \quad (18)$$

7. Equation 19 calculates the relative closeness of each alternative to the ideal solution, i.e. the similarity value. The Pythagorean Fuzzy TOPSIS approach incorporates the uncertainty and hesitation in decision makers' judgments by using Pythagorean fuzzy sets, unlike the Classical TOPSIS method which is based on sharp numerical values. Pythagorean fuzzy sets extend traditional and intuitive fuzzy sets by allowing the sum of the squares of the membership and non-membership degrees to be less than or equal to one, as shown in Equation 16. This provides a more flexible framework for representing human judgment under uncertainty and results in more reliable and realistic decision-making results [33].

$$\xi(x_i) = \frac{D_{(x_i,x^-)}}{D_{max}(x_i,x^-)} - \frac{D_{(x_i,x^+)}}{D_{min}(x_i,x^+)} \quad (19)$$

8. The alternatives are ranked according to their similarity values and ends by determining the best ranking of the alternatives.

5. FINDINGS

5.1. Problem Definition

An application was carried out for the needs and supply processes of a blood donation organization providing service throughout Türkiye. Data regarding blood donations were collected and analyzed on-site. In the study, six criteria affecting the donation process were weighted with the Pythagorean Fuzzy AHP method in order to improve blood donation and inventory management processes. Then, four alternative strategies suggested to increase the donation amount were prioritized using the Pythagorean Fuzzy TOPSIS method. These methods provided more effective results in decision-making processes that included multiple alternatives and criteria. As a result of the application, a strategic roadmap was created to increase the donation amount and maintain inventory levels.

During the study, 6 experts were consulted while determining the alternatives and strategies. The experts evaluated the identified alternatives and strategies by using a group decision-making approach and provided the necessary scores for the AHP and TOPSIS methods.

The decision matrix was decided together with the group data obtained in line with the individual opinions of the experts, and the final evaluation was made using one of the multi-criteria decision-making methods. Information about the experts is shown in Table 3.

Table 3. Experts' Professions and Experience

Expert	Profession	Experience(Years)
1	Engineer-Academic	25
2	Turkish Red Crescent Employee	15
3	Engineer-Academic	10
4	Health Specialist	10
5	Engineer	2
6	Engineer	2

5.2. Criteria

The study's criteria were created after a literature review. The criteria determined to meet the demand for blood and blood products are "Target Audience Suitability (TAS)," "Impact Potential (IP)," "Cost Effectiveness (CE)," "Ease of Implementation (EI)," "Stakeholder Support (SS)," and “Sustainability (SUS)." Table 4 explains the criteria.

5.3. Alternatives

The alternatives included in the study were created after a literature review. The criteria determined to meet the demand for blood and blood products are "Awareness Campaigns (AC)," "Target Audience Oriented Approach (TAOA)," "Easy Accessibility (EA)," "Incentive and Reward System (IRS)," and “Sustainable Approach (SA)." Explanations of the criteria are given in Table 5.

Table 4. Criteria

Criteria
Target Audience Suitability (TAS): Every strategy should be shaped according to the needs and characteristics of a specific target audience. For instance, the behaviors and interests of groups such as youth, students, or professionals differ. This criterion clarifies which audience a strategy is designed for and evaluates its accessibility [33].
Impact Potential (IP): As increasing blood donation is the main goal of the project or strategy, this criterion is critical for evaluating the strategy's direct contribution to the objective. Sustainable increases in donation rates are necessary to provide lasting improvements rather than temporary solutions. This criterion considers both the short-term and long-term effects of a strategy [34].
Cost Effectiveness (CE): This criterion evaluates whether a strategy is feasible within the available budget and resources. It prioritizes strategies that have the potential to use resources more efficiently [21].
Ease of Implementation (EI): Ease of implementation facilitates quicker results by minimizing the challenges a strategy may encounter in practice. Strategies aligned with existing resources avoid additional costs and time loss. Shaping the strategy according to current capacities allows the organization to set realistic goals [35].
Stakeholder Support (SS): The support provided by various stakeholders ensures the necessary resources and logistical arrangements. Strategies that gain widespread stakeholder support lead to greater public acceptance and increased awareness. Stakeholder support plays a critical role in reaching a broader audience and ensuring the synchronized actions of different parties [36].
Sustainability (SUS): Sustainability is essential for achieving not only temporary but also consistent and widespread success. Strategies that produce long-term results continue to be effective without requiring repeated implementation. Sustainable strategies build trust within the community and encourage individuals to become regular donors. Structures that can be updated and improved quickly address deficiencies identified during the implementation process, leading to more successful outcomes [8].

Table 5. Alternatives

Alternatives
Awareness Campaigns (AC): Awareness campaigns aim not only to encourage a single donation but also to create a lasting blood donation culture and foster a mental shift in society. These campaigns focus on raising awareness about the vital importance of regular blood donation for the healthcare system. Using communication channels such as social media, television, and radio, they share impactful and informative content to increase public interest in blood donation. By emphasizing that the need for blood is continuous and that every donation can save lives, these campaigns aim to boost donation rates [8].
Target Audience-Oriented Approach (TAOA): To raise awareness about blood donation, activities are organized for specific groups such as young people, students, and employees. Regular donation events are arranged in collaboration with universities, companies, and public institutions. This approach aims to increase donation rates through campaigns tailored to the needs and habits of the target audience [37, 41].
Ease of Accessibility (EA): Blood donation centers located in city centers, hospitals, and universities are more accessible to donors. Mobile blood donation units extend services to different regions, further enhancing donors' accessibility. Online appointment systems and informational applications make the donation process more organized and user-friendly [11].
Incentive and Reward System (IRS): This system aims to encourage blood donations by offering various rewards, discounts, or gifts to donors. Special privileges are provided to regular donors to foster a long-term donor base. Additionally, institutions and employees involved in blood donation are rewarded, increasing social encouragement [38].
Sustainable Approach (SA): Regular communication and follow-up encourage donors to donate again. Feedback from donors is taken into account to improve the donation experience. Through the use of technology and innovation, the blood donation system becomes more efficient and sustainable [1,9,40].

5.4. Weighting of Criteria with Pythagorean Fuzzy AHP

First, the study determined the criteria affecting the demand for blood and blood products. The decision-makers evaluated these criteria using the linguistic variable scale in Table 6, and the decision matrix was obtained.

Table 6. Pythagorean Fuzzy AHP Linguistic Variables [38]

Linguistic Variables	Pythagorean Fuzzy Numbers			
	μ_L	μ_U	ν_L	ν_L
Absolutely Low Importance (AL)	0,9	1	0	0
Very Low Importance (VL)	0,8	0,9	0,1	0,2
Low Importance (L)	0,65	0,8	0,2	0,35
Below Average Importance (BA)	0,45	0,55	0,45	0,55
Equal Importance (EQ)	0,1965	0,1965	0,1965	0,1965
Average Importance (A)	0,45	0,55	0,45	0,55
Above Average Importance (AA)	0,35	0,45	0,55	0,65
High Importance (HI)	0,2	0,35	0,65	0,8
Very High Importance (VH)	0,1	0,2	0,8	0,9
Absolutely High Importance (AH)	0	0	0,9	1

In the decision matrix obtained by jointly determining the decision makers in Table 7, the Pythagorean fuzzy AHP formulas were applied, respectively, and the criteria weights shown in Table 8 were obtained.

Table 7. Pythagorean Fuzzy AHP Decision Matrix

Decision Variables	TAS	IP	CE	EI	SS	SUS
TAS	EQ	L	VL	L	A	AA
IP	HI	EQ	VL	L	A	HI
CE	VH	HI	EQ	AA	HI	VH
EI	HI	AA	L	EQ	AA	HI
SS	HI	AA	A	L	EQ	HI
SUS	L	L	VL	L	L	EQ

Table 8. Pythagorean Fuzzy AHP Criteria Weights

Criteria	Criteria Weights
SUS	0,3299230
TAS	0,2825416
IP	0,2255435
SS	0,0765230
EI	0,0714041
CE	0,0140647

When the criteria weights are examined, it is seen that sustainability is the most important criterion. The other criteria are Target Audience Suitability, Impact Potential, Stakeholder Support, and Ease of Implementation, and the lowest criterion weight is Cost Effectiveness. The sustainability criterion, being the highest weighted criterion, is due to the importance of the continuity of the work being done. Blood and blood products are needed not only today but also at all times. Therefore, the strategies to be implemented should also support sustainability.

5.5. Ranking of Alternatives with Pythagorean Fuzzy TOPSIS

The alternatives selected for the study were ranked using the Pythagorean Fuzzy TOPSIS method to find suitable alternatives and strategies. Using the Linguistic Variable values seen in Table 9, decision-makers evaluated all alternatives, and the decision matrix was obtained.

The decision matrix created by the decision makers based on the Pythagorean fuzzy linguistic variables in Table 9 is presented in Table 10. The linguistic variables in this table were determined through the joint evaluation process of a group of six experts.

In this study, AHP and TOPSIS methods were used in an integrated manner. First of all, the criterion weights were obtained with the Pythagorean Fuzzy AHP method. These weights were directly used in the Pythagorean Fuzzy TOPSIS method stage, which was created based on the decision matrix. In particular, in equations 17 and 18, where the distances of the alternatives to the positive ideal solution and the negative ideal solution were calculated, the weights in Table 8 obtained for each criterion were included in the formula as a multiplier. Thus, the total distance of each alternative was weighted to reflect the relative importance of the relevant criterion in the decision process. Thanks to this integration, the criterion priorities determined with the AHP method were directly reflected in the TOPSIS ranking structure, and a more consistent and reliable multi-criteria decision-making model was obtained.

Table 9. Pythagorean Fuzzy TOPSIS Linguistic Variables [28]

Linguistic Variables	Pythagorean Fuzzy Numbers	
	u	v
Extremely Low (EL)	0,1	0,99
Very Little (VL)	0,1	0,97
Small (S)	0,25	0,92
Medium Small (MS)	0,4	0,87
Medium (M)	0,5	0,8
Medium-High (MH)	0,6	0,71
High (HI)	0,7	0,6
Very High (VH)	0,8	0,44
Extremely High (EH)	0,1	0

Table 10. Pythagorean Fuzzy TOPSIS Decision Matrix

Strategies	TAS	IP	CE	EI	SS	SUS
AC	MH	HI	HI	M	HI	MH
TAOA	EH	HI	MS	HI	HI	HI
EA	HI	VH	M	VH	S	HI
IRS	MH	VH	VH	MS	HI	MH
SA	S	M	HI	M	HI	EH

The reason why the similarity values (Table 11) in the Pythagorean Fuzzy TOPSIS results appear as negative is primarily due to the structure of the similarity coefficient formula used in the method. In this approach, the similarity value is calculated as the difference between the normalized distance to the negative ideal solution and the normalized distance to the positive ideal solution.

In the ranking obtained as a result of Pythagorean Fuzzy TOPSIS, the highest alternative was found to be Easy

Table 11. Pythagorean Fuzzy TOPSIS Ranking of Alternatives Results

Ranking	Alternatives	$\xi(x_i)$
1	EA	-0,042238668
2	IRS	-1,953568302
3	AC	-2,749455546
4	TAOA	-6,187218481
5	SA	-12,19330967

Accessibility. Then, the alternatives are an Incentive and Reward System, Awareness Campaigns, Target Audience Approach, and Sustainable Approach. The process of reaching the donor while donating blood is the most critical process experienced in order to meet the blood demand. The donor must have easy access to blood banks, hospitals, or mobile donation points. For this reason, it is seen that it is determined as the most crucial alternative in the ranking. With the incentive and reward system strategy, the motivation of the donor to donate blood can be supported, and donation rates can be supported to the same extent.

5.6. Sensitivity Analysis

In order to evaluate the consistency of the obtained model, a sensitivity analysis was conducted. For the sensitivity analysis study, 15 different scenarios were created by pairwise swapping the weights of the six criteria used in the model. The criteria used in the study were labeled as shown in Table 12 for the sensitivity analysis calculations.

Table 12. Criteria and Labels

Criteria	Label
TAS	C1
IP	C2
CE	C3
EI	C4
SS	C5
SUS	C6

Initially, the weight of criterion C1 was replaced with that of C2, and the resulting change in the ranking was recorded. Subsequently, all possible pairwise combinations of the criteria were evaluated in sequence, and rankings were obtained for each scenario. Following these changes, the sensitivity of the criteria was analyzed using the Pythagorean Fuzzy TOPSIS method. The results of the sensitivity analysis are presented in Table 13.

There was no significant change in the rankings after the combinations created. The EA alternative was ranked first in 8 out of 15 combinations. In addition, the SA alternative came last in all except the 12th scenario. Similarly, the TAOA alternative was ranked 4th except for the 1st, 3rd, 4th and 12th scenarios. It was observed that the current ranking was ranked the same in 6 scenarios out of 15 scenarios. It was observed that there were some changes in the rankings of the other alternatives except for the TAOA and SA alternatives. However, these changes were not at a level that would create major differences. Most of them were due to the change of place with the previous value as a result of the combination.

As a result of the sensitivity analysis performed, it was observed that there were no major changes in the rankings of the alternatives when the 15 different scenarios created were examined. This supports the consistency and reliability of the obtained model. In particular, the fact that the EA alternative was ranked first in 8 out of 15 scenarios shows that this alternative stands out as the primary choice even with different criterion weights. Similarly, the fact that the SA alternative is ranked last except for one scenario (scenario 12) reveals the relative weakness of this alternative.

The fact that the TAOA alternative is mostly ranked fourth and that this position changes only in a few scenarios shows that the place of this alternative in the ranking is relatively stable. On the other hand, although some position changes were observed in other alternatives except EA, these changes were generally in the form of replacing the alternative in the previous place and their effect on the results was limited. This also reveals that the changes made in the criterion weights did not fundamentally affect the general structure of the model.

Table 13. Sensitivity Analysis

Sensitivity Analysis			*Ranking*				
			1	**2**	**3**	**4**	**5**
Scenario	***0***	***Current Ranking***	***EA***	***IRS***	***AC***	***TAOA***	***SA***
	1	**C1-C2**	AC	TAOA	EA	IRS	SA
	2	**C1-C3**	IRS	AC	EA	TAOA	SA
	3	**C1-C4**	EA	TAOA	IRS	AC	SA
	4	**C1-C5**	IRS	AC	TAOA	EA	SA
	5	**C1-C6**	EA	IRS	AC	TAOA	SA
	6	**C2-C3**	IRS	EA	FK	TAOA	SA
	7	**C2-C4**	EA	AC	IRS	TAOA	SA
	8	**C2-C5**	IRS	EA	AC	TAOA	SA
	9	**C2-C6**	EA	IRS	AC	TAOA	SA
	10	**C3-C4**	EA	IRS	AC	TAOA	SA
	11	**C3-C5**	EA	IRS	AC	TAOA	SA
	12	**C3-C6**	IRS	AC	EA	SA	TAOA
	13	**C4-C5**	EA	IRS	AC	TAOA	SA
	14	**C4-C6**	EA	IRS	AC	TAOA	SA
	15	**C5-C6**	IRS	AC	EA	TAOA	SA

As a result, the findings obtained with the sensitivity analysis show that the model is usable in the decision-making process and that the decision structure maintains its stability under different criterion weightings. This supports the reliability of the Pythagorean Fuzzy TOPSIS method used.

6. DISCUSSION AND CONCLUSION

Blood donation is undeniably essential for human life. Regular donations should be made, and the demand for blood should be met at any time when needed. The study aims to increase the blood inventory level and meet the demands by developing strategies and alternatives that will meet the demand for blood and blood products. In light of information received from blood donation centers in Ankara and expert opinions, appropriate criteria and alternatives were determined, and evaluations were made according to the needs. The study covers the whole of Türkiye, and the application stages can be applied to all regions.

The study aims to facilitate access to blood and blood products and develop strategies to increase blood donations. This study was evaluated in a fuzzy environment, and criteria were determined using Pythagorean fuzzy methods. In the study, six experts participated in the evaluation process of the determined alternatives and strategies. Utilizing a group decision-making approach, the experts individually assessed the options and assigned scores required for the AHP and TOPSIS methods. Based on the aggregation of their individual inputs, a collective decision matrix was formed, and the final assessment was carried out using a selected multi-criteria decision-making method. Alternatives were listed. When the criteria weights were taken into consideration, the criterion with the highest weight was the Sustainability criterion. This criterion measures the strategy's potential to create a permanent, not temporary, difference by targeting long-term and continuous blood donation rates instead of short-term successes. Strategies that offer structural solutions to increase donation habits, rather than one-time campaigns, produce both effective and long-term results.

The prioritization of sustainability reflects a broader health policy objective, which is to ensure resilient and adaptive donation systems that can endure public health crises or systemic disruptions. Thus, the findings not only support theoretical strategy models but also offer practical input for policy-makers aiming to enhance health system continuity.

Dizer and Demirpek [34] stated in their studies that the decrease in blood supply is due to reasons such as difficulties in finding donors and reaching blood collection units, fears about infectious diseases, reluctance of donation teams, and the spread of panic regarding the risk of infection in society. In disaster situations such as pandemics, the preparation of blood supply plans and the protection of the reliability and suitability of blood should be the main goal. A sudden increase in blood demand or a decrease in blood support can seriously affect the blood banking system. Insufficiency of blood donors, interruptions in blood collection processes, or a combination of both situations can cause disruptions in the blood supply system.

Gasparovic Babic et al. [6] emphasized in their studies that in order to encourage blood donation, the behavior and motivations of donors must first be understood, and a sustainable blood donation strategy can be achieved in this way. These programs support the resilience and continuity of the health system and monitor donor health. They state that while technological developments improve blood supply, the effects of crises such as the aging population and COVID-19 have reduced donation rates. Therefore, they emphasize that education, awareness campaigns, and modern technologies should be used to gain young generations and retain regular donors.

In this context, our findings reinforce the importance of integrating behavioral and sociocultural dimensions into donor strategies. While structural accessibility is a foundational component, success also depends on understanding and addressing motivational drivers, regional differences, and public perception—an approach consistent with recent international literature.

The literature has examined similar strategies for blood and blood products. Still, no study has been encountered that aims to increase the demand by examining blood and blood products with criteria and alternatives determined from a particular general perspective. The conditions and difficulties in the transfusion process are generally addressed in blood and blood products, and this study will contribute to the literature in meeting the demand for blood products.

The criteria considered in the study are target audience suitability, impact potential, cost-effectiveness, ease of implementation, stakeholder support, and sustainability. It was observed that the criterion with the lowest weight was cost-effectiveness. This criterion aims to establish a meaningful balance between the increase in the number of donations and the cost spent. In cases where strategies need to be implemented with limited budgets and resources, cost-effectiveness plays an important role in terms of sustainability and the long-term continuity of projects. However, it can be concluded that other criteria have priority over cost criteria because cost-effectiveness is a criterion based on the analysis of environmental impacts and donor profiles for collecting blood donations.

The alternatives determined for the study are Awareness Campaigns, Target Audience Focused Approach, Easy Accessibility, Incentive and Reward System, and Sustainable Approach, and the alternative that came out on top was Easy Accessibility. Locating blood donation centers in city centers, hospitals, and universities ensures that donors can easily reach these points. The dense population and transportation networks in city centers prevent loss of time for donors and speed up the donation process. The fact that mobile blood donation units go to different regions makes access even more straightforward. Mobile units allow reaching various segments of society, especially in remote settlements. Since mobile units can provide service in a particular region for a short time, they offer a practical solution for those who want to donate. Providing easy accessibility will play a critical role in increasing the continuity and regularity of blood donation. This result is an indication that it is essential to provide suitable conditions and environments for donors to donate. Therefore, the process by which institutions and organizations that collect donations reach donors should be managed healthily as a priority.

To implement this strategy effectively, health authorities and policymakers should prioritize establishing permanent and mobile donation units in densely populated areas, integrate digital appointment systems, and develop regional transportation supports that facilitate access to donation centers. Additionally, collaborating with universities, public institutions, and private sector actors may further enhance regional outreach and participation.

The alternative to the incentive and reward system comes second. The volunteering of the donor is essential in increasing blood donation. Working on incentive and reward systems by considering criteria such as donor profile, cultural factors, and regional factors will have a positive effect on increasing blood donation. Moreover, aligning these systems with public health objectives—such as ensuring equity and long-term donor retention—can help integrate these strategies into broader healthcare planning frameworks.

All determined strategies and criteria and the situations experienced and possible to be experienced during the blood donation process were evaluated, and applicable results were presented. These findings provide important implications for health policy, particularly in guiding national and regional strategies to promote voluntary and regular blood donations. The prioritization of easy accessibility aligns with the growing emphasis in health systems on equity and availability of essential health services. Although the study presents strong methodological insights, it is important to acknowledge certain limitations. The research is based on expert evaluations and regional inputs from Ankara, which may limit its generalizability. Future studies could broaden expert diversity and consider dynamic simulation-based modeling to assess strategy impacts under different crisis scenarios.

The data obtained for this study, the criteria examined, and the alternatives selected are adaptable to all regions and are expected to offer a scalable solution. In this context, the ability to apply the model in regions with different socioeconomic and demographic characteristics significantly increases the study's practical value. Furthermore, these adaptable strategies will not only help increase the number of donors but also strengthen societal awareness and responsibility regarding blood donation.

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DECLARATION OF ETHICAL STANDARDS

This article do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Rumeysa GÜNEŞ: Performed the experiments, analysed and wrote the manuscript of the results.

Buğra AKYOL: Performed the experiments, analysed and wrote the manuscript of the results.

Emel GÜVEN: Performed the experiments, analysed and wrote the manuscript of the results.

Tamer EREN: Supervised in this research and wrote the manuscript.

CONFLICT OF INTEREST

There is no conflicts of interest in this study.

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