Turk. J. Fish.& Aquat. Sci. 24(SI), TRJFAS27101
https://doi.org/10.4194/TRJFAS27101

RESEARCH PAPER

Turkish Journal of FISHERIES and AQUATIC SCIENCES

Shaping the Future of Turkish Polar Research Activities: Organizational Priorities

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How to Cite

Oktar, Ö., Özsoy, B. (2025). Shaping the Future of Turkish Polar Research Activities: Organizational Priorities. *Turkish Journal of Fisheries and Aquatic Sciences, 24(SI), TRJFAS27101.* https://doi.org/10.4194/TRJFAS27101

Article History
Received 21 November 2024
Accepted 19 December 2024
First Online 23 December 2024

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Keywords
Analytic Network Process
ANP
Decision Support Tool
Management

Abstract

This study aims to identify the key organizational priorities for a Polar Research Institute in Türkiye, employing the Analytic Network Process (ANP) as a decision-support tool. Through a survey of experts, this study gathers insights on various relevant criteria to inform the institute's strategic focus. The analysis highlights that scientific research should be the central mission of the Polar Research Institute, supported by strong logistical infrastructure. Additionally, the findings emphasize the critical importance of postgraduate programs as a key human resource first degree sub-criteria for advancing polar research. Based on these results, the study proposes essential considerations for the future development of the Institute's organizational design, ensuring that it effectively supports the strategic research goals of Türkiye's Polar Program. Scientific research in the polar regions has much to say globally about the past, present, and future-especially climate change. While the first Turkish researcher conducted studies in Antarctica in 1967, it was not until 2017, during the Turkish Presidency, that the formal National Polar Research Program was established. While priority research areas are outlined in the program's strategy document, the organizational structure of the Polar Research Institute has not yet been fully aligned with these priorities.

Introduction

The topic of organizational design is foundational in the study of organizations, primarily because an organization can adapt to environmental changes by modifying its design (Lawrence & Lorsch, 1967). Additionally, research suggests that changes in organizational design can positively impact performance (Burton & Obel, 1984). From a practical standpoint, recommendations for establishing goal-oriented organizational structures to enhance performance are especially relevant (Ansoff & Brandenburg, 1971).

The literature offers numerous, and sometimes inconsistent, definitions of organizational design, encompassing elements such as formal structure and task differentiation (Mintzberg, 1983), informal networks (Krackhardt & Stern, 1988), degree of hierarchy, coordination processes (Salancik & Pfeffer, 1978), and information processing features or costs (Carley, 1990). Although computational and mathematical approaches to organizational studies are often overlooked in traditional organizational theory, they have nonetheless played a significant role in advancing the field. Computational and mathematical organization theory is an interdisciplinary field that seeks to develop and test organizational theories through formal modeling. This perspective views organizations as systems of task-oriented, socially embedded, technologically connected, and continuously evolving processes and intelligent, adaptive agents (Carley, 1995). Organizational behaviors are considered to be both influenced by and influential upon the organization's position within its external environment. A novel analytical approach in

organizational structure utilizes the "metamatrix" framework, which provides a comprehensive method for representing and analyzing organizational data~~. This~~ (Maupin et al., 2020; Nuhodzic et al., 2010; Carley, 2002; Saaty, 1996). According to Carley & Kamneva, this framework builds on recent network-centric approaches to organizational structure, integrating ideas from information processing theory and operations research.

According to the metamatrix approach of Carley & Kamneva, organizations are conceptualized as sets of elements within five primary categories: personnel, information, resources, tasks, and organizations. Organizational structure is defined by these elements and the pairwise relationships among them. Central to the metamatrix approach is the analysis of these relationships. The Analytical Network Process (ANP) and Analytical Hierarchy Process (AHP) are both widely used multi-criteria decision-making (MCDM) methods, and each offers distinct advantages for addressing challenges in polar regions. AHP is particularly suited for problems with a well-defined hierarchical structure, such as determining optimal locations for polar research stations or prioritizing environmental protection initiatives. (Coronado-Hernandez et al., 2020; Yavaşoğlu et al., 2019; Xiaoping, Haiyan & Xi, 2014). Also risk-assessment is one of the most popular research field that AHP or ANP is applied (Tseng & Cullinane, 2018, Şahin & Kum, 2015; Peilong et al., 2021).

A systematic optimization approach, supported by Analytical Network Process (ANP) metrics, was employed to identify a design that aligns with an ideal structure (Saaty, 1996; Carley & Kamneva, 2004). By integrating ANP into the design of such networks, organizations can enhance their capability to operate efficiently under the unique constraints of these environments (Moradian et al., 2019). Consequently, the synergy between ANP and organizational design offers valuable insights for managing the complexities ~~of~~such as polar operations.

ANP supports collaborative, multi-perspective decision-making necessary in today's complex environments. It provides a structured framework for discussion, addressing both abstract and tangible components of each major decision, and encourages participation to resolve conflicts through deliberation and consensus-building (Reale et al., 2017).

Participants in ANP can work collaboratively, with a facilitator recording decisions in real time, or participate remotely by completing surveys to express individual judgments. Responses are then aggregated using the geometric mean to form a single, collective judgment within the model.

~~The Analytical Network Process (ANP) and Analytical Hierarchy Process (AHP) are both widely used multi-criteria decision-making (MCDM) methods, and each offers distinct advantages for addressing challenges in polar regions. AHP is particularly suited for problems with a well-defined hierarchical structure, such as determining optimal locations for polar research stations or prioritizing environmental protection initiatives. (Coronado-Hernandez et al, 2020, Yavaşoğlu et al, 2019, Xiaoping, Haiyan and Xi,2014). Also risk-assessment is one of the most popular research field that AHP or ANP is applied (Tseng and Cullinane, 2018, Şahin and Kum, 2015, Peilong et al, 2021).~~ Institutional-level polar research activities in Türkiye began with the establishment of Istanbul Technical University Polar Research and Application Center (ITU PolReC). ITU PolReC is Türkiye's first academic unit dedicated to polar research. ITU PolReC represented the Turkish Polar Research Program for 4 years, organized polar expeditions, funded projects, and represented it at international meetings. In 2019, the Polar Research Institute (KARE) was established ~~under~~within TÜBİTAK Marmara Research ~~Center~~Centre (MAM) and assigned as the representative of the Turkish Polar Research Program (TÜBİTAK, 2019). The fact that the Turkish Polar Program is run by an institution that is at an equal distance to the entire research community in Türkiye has been an important transition. Among countries engaged in polar research, coordination, decision-making, and budgetary units are tailored to align with national structures and are frequently adapted to reflect current changes.

Although both ITU PolReC and KARE work to advance Türkiye's interests, they currently lack sufficient authority, responsibility, and policy-making capacity to operate effectively. A preliminary examination of polar research units in other countries indicates that these units are organized differently across their domestic systems, with each organizational model offering distinct advantages and disadvantages.

Determining an effective organizational structure for polar research is critical due to the unique challenges posed by these regions, such as extreme environmental conditions, logistical constraints, and the need for multidisciplinary collaboration. This study aims to identify key priorities for a Polar Research Institute in Türkiye, using the Analytic Network Process (ANP) as a decision-support tool and considering various relevant criteria. Surveys were prepared and completed by national and international experts with experience in the field of polar research. The primary aim of this study is to identify and define the organizational priorities of the Polar Research Institute, with a particular focus on the key factors that contribute to its operational success and research effectiveness. By analyzing the responses from a diverse range of stakeholders, this study highlights the core strategic elements essential for the institute's continued growth and contribution to polar research. The study offers a comprehensive framework for understanding the internal and external factors that influence the institute's mission, including human resources, research infrastructure, international collaborations, and governance structures. Although, there are several studies ~~applied~~applying ANP or AHP to define organizational performance criteria or defining priority focus areas, this study will be a unique one by

defining organizational structure for a Polar Research Institute.

Materials & Methods

The studies conducted by KARE have identified five main areas of focus: scientific research, logistics, human resources, national coordination and international coordination. Problems that will provide the most critical data/input for preparing the surveys were identified by examining these five categories. The hierarchy of the surveys was developed in alignment with the ANP-related literature review. Once the hierarchy is established, it is necessary to calculate the degree of relative importance of each criterion in comparison to the others. Participants determine the importance levels between criteria based on a 1-9 scale. Sub-criteria were defined through personal experience of the authors.

The online questionnaire link was sent to national and international polar research experts which are representing national polar program in Antarctic Treaty Meetings (ATCM), Council of Managers of National Antarctic Programs (COMNAP), Scientific Committee on Antarctic Research (SCAR), International Arctic Scientific Council (IASC) or people in charge of management of polar affairs in their respective institutions. Demographic questions, which are not mandatory for the survey, are mostly filled out by the participants. According to 35 valid ~~response~~responses, 7 Turkish participants were followed by 4 participants from the Republic of Korea. ~~1~~10 participants from 9 different European countries took part in the survey. Also South American and Asian participants responded the questionnaire. The comprehensiveness of the questionnaire is not defined only by the countries~~,~~ but also ~~profession~~by the professions of the participants, which were grouped ~~in 4~~into four categories, namely: the first group consists of high-level administrative duties within polar ~~program,~~programs, the second group includes logistics ~~manager~~managers of polar ~~program,~~programs, the third group involves international affairs, and the last group comprises researchers. 12 participants are belong to the first group followed by 10 participants from international affairs, 7 logistics managers and 6 researchers.

Questionnaire was formed ~~in 1ka.si website which is~~on an open-source ~~application that enables services for~~ online ~~surveys. The development takes place at the Centre for Social Informatics, at the Faculty of Social Sciences, University of Ljubljana (1ka.si, 2024).~~web survey platform (1KA Web Surveys). For the evaluation of the questionnaires, SuperDecisions, ~~developed by Thomas L. Saaty, along with MS Excel and R software, were utilized. The Super Decisions is~~ a free educational decision support software that implements the AHP and ANP~~. The SuperDecisions is the only free educational software that implements AHP and ANP and was developed by the team of the creator of the method, Thomas Saaty (superdecisions.com~~, were utilized along with Microsoft Excel (Super Decisions, 2024).

The ANP method, which was explained by Saaty et al. (2013) consists of four main stages, namely defining the objective and constructing the model, forming the pairwise comparison matrix and calculating the eigenvector, calculation of the weighted supermatrix, and ranking the alternatives and selecting the best alternative. In the first step, criteria and alternatives are identified. Criteria that are interrelated are grouped within the same set, and the same process is applied to alternatives. Subsequently, interactions and dependencies between these sets are established, creating a network structure. In the second step, criteria and alternatives are subjected to pairwise comparisons with interactive criteria and alternatives. The ANP method uses the 1-9 scale, also employed in the AHP method, for these comparisons. If the consistency ratio calculated in the pairwise comparisons is below 0.10. the evaluations are deemed sufficient. Criteria with no interactions are assigned a zero value in the matrix, thus allowing the eigenvector to be calculated. The eigenvectors are then placed in the columns of the matrix to form the unweighted supermatrix.

$$A = (a_{ij})_{n\times n} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}$$

The third step involves creation of a new matrix by multiplying the values in the unweighted supermatrix by the weights of the sets to which they belong. This resulting matrix is referred to as the weighted supermatrix. If the columns of the weighted supermatrix do not sum to one, a normalization process is applied to ensure that each column sums to one. To equalize priorities, the supermatrix is raised to a high power. The resulting matrix is called the limit supermatrix. Finally, the final priorities of the alternatives and criteria are calculated. Final priorities are obtained by normalizing

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Table 1. Priority Vectors Calculated for General Criteria of Polar Research Using Four Different Methods

Criteria	Method I	Method II	Method III	Method IV
Scientific Research	0.309	0.386	0.341	0.345
Logistical Capabilities	0.337	0.276	0.311	0.313
Human Resources	0.161	0.125	0.146	0.143
National Level of Unit	0.107	0.107	0.108	0.105
International Relations	0.086	0.106	0.094	0.094
	N:28	CR: 0.050		

each set, thus determining the priorities of both the criteria and the alternatives.

The best method for calculating relative importance in the pairwise comparison matrix is Saaty's eigenvector method, where the eigenvector is calculated using the following formula:

$$W_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{j=1}^{n} aij}$$

~~Also 3~~Additionally, three different calculations defined by Topçu~~,~~ (2010) were used for the eigenvector to ~~make~~facilitate the comparison~~. In~~ since in Saaty's method inconsistency ratio was high in 3 criteria comparisons. The comparisons of all different methods showed linear similarity. All results ~~were given~~are provided in the ~~related~~relevant sections of this study. Table 1 presents the priority vectors calculated using four different methods, with Method IV representing Saaty's eigenvector approach. In subsequent sections, only the results from Method IV, the most well-known and widely used method in the literature, are evaluated, while the results of all methods are listed ~~which is the most known and used method in the literature.~~.

After calculating the eigenvector and determining the relative importance levels of the criteria, the next step is to calculate the consistency ratio (CR) of the comparison matrix. The purpose of this calculation is to assess whether the participant was consistent in making comparisons between criteria. The CR is expected to be less than 10% (Saaty, 2013).

In the final stage of the ANP method, the problem must be solved. It is important to note that this study does not delve into the evaluation of specific alternatives or potential matches between the identified priorities and the institute's future strategies. Instead, the focus remains on determining the relative importance of various organizational components that are fundamental to the Polar Research Institute's operations. The assessment of these ~~components~~criteria is a crucial first step in the broader process of strategic planning.

Results

General Overview

In the general overview, participants were asked to prioritize five main criteria~~.~~ given in Figure 1. The number of participants is denoted by N and consistency ratio is indicated by CR. In this study, the CR of 0.10 or below is considered acceptable for continuing the analysis, as demonstrated by Saaty (2012). Participants evaluated the relative importance of five primary criteria relevant to the design of a research unit, each comprising specific sub-criteria~~.~~, namely:

a. Scientific Research
b. Logistic Capabilities
c. Human Resources
d. The National Level of the Unit
e. International Relations

Scientific Research focused on the unit's ability to conduct research through project execution, securing funding, and supporting long-term monitoring activities. Logistics Capabilities encompassed aspects of infrastructure, operational planning, and budget management. Human Resources addressed the development of postgraduate education, training, awareness programs, and employment opportunities. The National Level of the Unit considered the unit's position within the public hierarchy, its organizational

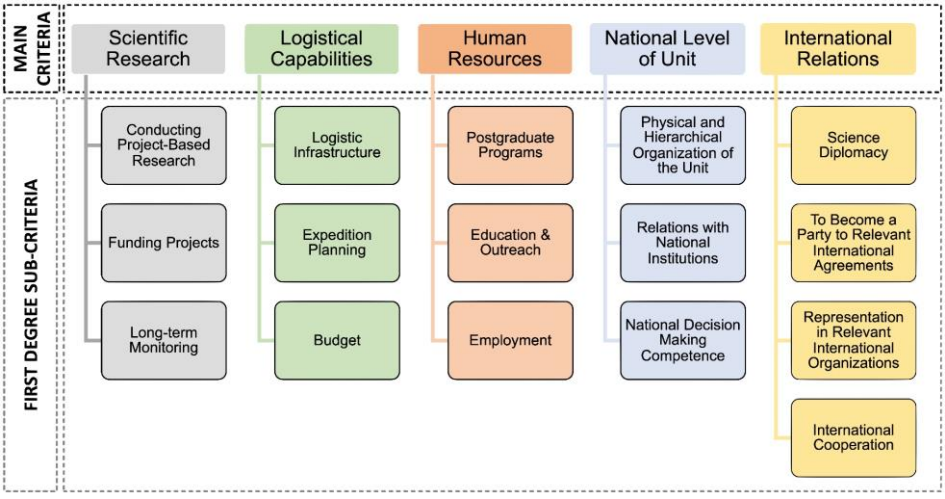

Figure 1. Hierarchy of main and first degree sub-criteria.

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structure, and its decision-making authority. Finally, International Relations emphasized the unit's engagement in international cooperation, science diplomacy, and adherence to international agreements. These criteria collectively aimed to comprehensively assess the factors influencing the unit's effectiveness.

The hierarchy of the criteria ~~is~~are divided in 3 groups. The main five criteria ~~was~~were mentioned in the previous section of this study. In the second level criteria participants were asked to compare "conducting project based research, "funding projects" and "long term monitoring" under scientific research criterion; "logistics infrastructure", "expedition planning" and "budget" under logistical capabilities; "postgraduate programs", "education and outreach activities" and "employment" under human resources; "physical and hierarchical organization of the unit", "relations with national institutions" and "national decision making competence" under national level of the unit and "science diplomacy", "to become a party to relevant agreements", "representation in relevant international organizations" and "international cooperation" under international relations criterion. Each second degree criteria is also evaluated with third degree sub-criteria. However, third degree sub-criteria comparisons are not showed in tables, where the explanations were given.

The analysis results indicate that the Polar Research Institute should prioritize scientific research, followed by enhancing logistical capabilities which is shown in Table 1. The priority analysis for the Polar Research Institute highlights scientific research as the most critical criterion, with a calculated priority vector of 0.345. This underscores the central role of research in polar studies, reflecting its importance in advancing scientific knowledge and addressing global challenges such as climate change. Logistical capabilities, with a priority vector of 0.313, emerge as the second most important factor, emphasizing the necessity of robust infrastructure and operational support to facilitate field research in the demanding conditions of polar regions.

Human resources ranks third with 0.143, showcasing the need for skilled personnel, postgraduate programs, and effective staffing to sustain the institute's long-term objectives. The national level of unit follows, with a priority vector of 0.105, highlighting the influence of national-level decision-making, institutional structure, and partnerships in shaping the institute's strategy and operations. Finally, international relations is assigned a priority vector of 0.094, reflecting the significance of science diplomacy, global collaborations, and adherence to international treaties in ensuring the institute's alignment with global standards and its participation in the broader polar research community. These priority vectors collectively provide a roadmap for the institute to allocate resources and align its efforts effectively.

Scientific Research

In this section, ~~four different~~one first degree sub-criteria and 3 second degree sub-criteria questions were used to compare ~~23~~3 first degree and 20 second degree sub-criteria in groups. In the first question, the consistency ratio exceeded the defined threshold of 0.10. However, this inconsistency is attributed to the limited number of criteria, where results clearly favor Project-Based Research in Table 2.

Conducting project-based research (0.550) is identified as the highest priority in Table 2, reflecting the institute's strong focus on research projects that are structured, time-bound, and goal-oriented. This aligns with the institute's need to address specific research questions and achieve targeted outcomes through well-funded and organized projects. Following closely is funding projects (0.411), which is essential for supporting the financial infrastructure necessary to carry out high-quality research. Adequate funding ensures that the institute can maintain its operations, secure the required resources, and attract top-tier researchers, thereby strengthening its scientific capacity. In contrast, long term monitoring is ranked lower in priority but still holds significance. Long-term monitoring (0.138) is crucial for tracking changes over time, particularly in the polar regions where environmental shifts and climate change are of increasing concern. While vital, the relatively lower priority of this criterion suggests that project-based research and immediate funding are seen as more critical in the short term, with long-term monitoring being integrated into broader research strategies as a secondary concern. Together, these priorities highlight the Polar Research Institute's strategic emphasis on project-focused research and securing the necessary funding to drive its scientific and operational goals, while also recognizing the importance of sustained monitoring efforts for long-term research outcomes.

The priority vector calculated for conducting project-based research criteria reflects the strategic priorities of the Polar Research Institute in enhancing its research capacity and international collaboration.

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Table 2. Scientific Prioritization on How Research Should Be Conducted by Polar Research Institute

Criteria	Method I	Method II	Method III	Method IV
Conducting Project-Based Research	0.397	0.430	0.414	0.550
Funding Projects	0.394	0.357	0.373	0.411
Long Term Monitoring	0.210	0.212	0.213	0.138
	N: 32	CR: 0.291*		

* The consistency ratio exceeded the defined threshold of 0.10. However, this inconsistency is attributed to the limited number of criteria

Utilizing national funds (0.191) is the highest priority, signifying the importance of securing financial support from domestic sources to sustain research activities. Following closely is research infrastructure of the unit (0.137) and experienced and competent researchers (0.135) in the unit which underscores the need for a capable unit equipped and crewed with critical research abilities. Conducting projects with international partners, conducting projects with national partners, utilizing international funds and logistics capabilities of the unit were also listed respectively (Table S1).

The priority vector calculated for funding projects criteria reveals the Polar Research Institute's emphasis on efficient project management, resource allocation, and access to essential infrastructure for conducting high-quality research. Project budget is the highest priority, reflecting the importance of securing adequate financial resources to support the entire lifecycle of research projects, from initial planning to fieldwork and data analysis. This aligns with earlier discussions on the significance of funding, both national and international, in facilitating polar research. Number of expedition participation per project follows closely, underscoring the importance of active participation in expeditions to gather firsthand data and enhance the institute's presence in the polar research community. They followed by project duration, field work time per expedition, research vessel existence, research station existence and access to data respectively (Table S2).

Table S1. Comparison of sub-criteria for project-based research

Criteria	Method I	Method II	Method III	Method IV
Utilizing National Funds	0.191	0.194	0.193	0.191
Utilizing International Funds	0.111	0.107	0.108	0.111
Conducting Projects with National Partners	0.119	0.120	0.116	0.119
Conducting Projects with International Partners	0.123	0.125	0.121	0.123
Research Infrastructure of the Unit	0.137	0.136	0.138	0.137
Experienced and Competent Researchers in the Unit	0.135	0.130	0.136	0.135
Relevance of the Research Topic to the National Strategy	0.091	0.089	0.096	0.091
Logistics Capabilities of the Unit	0.093	0.099	0.092	0.093
	N: 29	R: 0.039		

Table S2. Comparison of funding mechanisms of the polar research unit

Criteria	Method I	Method II	Method III	Method IV
Project Duration	0.142	0.158	0.142	0.142
Number of Expedition Participation	0.160	0.173	0.156	0.160
Project Budget	0.269	0.265	0.264	0.269
Field Work Time per Expedition	0.127	0.113	0.126	0.127
Research Vessel Existence	0.117	0.109	0.118	0.117
Research Station Existence	0.106	0.101	0.110	0.106
Access to Data	0.079	0.082	0.085	0.079
	N: 29	R: 0.073		

Table S3. Disciplines to be prioritized for long-term monitoring

Criteria	Method I	Method II	Method III	Method IV
Meteorology	0.263	0.268	0.266	0.264
Earth Sciences	0.232	0.211	0.220	0.225
Remote Sensing	0.179	0.160	0.174	0.170
Oceanography	0.176	0.190	0.179	0.182
Ecosystem	0.151	0.171	0.161	0.160
	N: 23	R: 0.097		

Table 3. Logistics General Overview

Criteria	Method I	Method II	Method III	Method IV
Logistic Infrastructure	0.459	0.431	0.440	0.587
Expedition Planning	0.217	0.210	0.217	0.140
Budget	0.324	0.360	0.343	0.380
	N: 33	R: 0.292		

* The consistency ratio exceeded the defined threshold of 0.10. However, this inconsistency is attributed to the limited number of criteria

Meteorology emerges as the highest priority on long term monitoring, reflecting the importance of studying weather patterns and climate dynamics in the polar regions, which are key to understanding broader global climate systems. Earth sciences which includes GNSS and seismometer follows closely as a priority, underscoring the significance of studying geological and physical processes in the polar regions, which contribute to the understanding of Earth's history and environmental changes. Oceanography, remote sensing and ecology followed them respectively (Table S3).

Logistics

Logistics is a critical component of polar research across multiple dimensions. Three first degree sub-criteria were considered under logistics: infrastructure, planning, and budget/financial considerations. The consistency ratio exceeded the defined threshold of 0.10. However, this inconsistency is attributed to the limited number of criteria, where results clearly favor of infrastructure shown in Table 3.

Logistic infrastructure (0.587) emerges as the highest priority, reflecting the critical need for well-established infrastructure, including research stations, vessels, and field equipment, to support fieldwork in the challenging polar environment. The prioritization of budget (0.380) underscores the importance of securing adequate financial resources to cover all aspects of polar research, including logistical needs, research equipment, and personnel. This corresponds to earlier findings emphasizing the significance of project funding and the need for national and international financial support to sustain the institute's activities. Lastly, expedition planning (0.140) is also a key criterion, although it is ranked lower in priority compared to infrastructure and budget. Effective planning is essential for coordinating the complex logistics involved in polar expeditions, including transportation, crew management, and research objectives (Table ~~S4~~3).

The evaluation of logistical infrastructure for a Polar Research Institute reveals significant disparities in the priority vectors assigned to various elements, emphasizing their relative importance to the institute's operations. Research stations emerge as the most critical ~~component~~second degree sub-criteria, with a priority vector of 0.275, reflecting their central role in supporting sustained scientific activities and providing a base for long-term research initiatives in polar regions. Research vessels, with a priority of 0.232, rank as the second most important, underscoring their essential function in enabling mobility, marine research, and access to remote polar areas. Communication infrastructure, automated measurement systems,

Table S4. Comparison of infrastructures in polar regions

Criteria	Method I	Method II	Method III	Method IV
Research Station	0.275	0.318	0.270	0.275
Research Vessel	0.232	0.221	0.224	0.232
Communication İnfrastructure	0.139	0.116	0.137	0.139
Automated Measurement Systems	0.120	0.097	0.127	0.120
Warehouse in Gateway	0.067	0.065	0.070	0.067
Air Vehicles	0.057	0.058	0.061	0.057
Land Vehicles	0.051	0.058	0.053	0.051
Marine Vehicles	0.058	0.068	0.058	0.058
	N: 28	R: 0.055		

Table S5. Comparison of logistic planning elements

Criteria	Method I	Method II	Method III	Method IV
Shipping Processes	0.295	0.307	0.302	0.302
Mobility Processes	0.191	0.172	0.187	0.184
Cold Climate Gear	0.145	0.146	0.145	0.145
Medical Checkups	0.263	0.264	0.259	0.261
Pre-Expedition Trainings	0.106	0.111	0.108	0.109
	N: 24	R: 0.025		

Table S6. Budget and Administrative Processes

Criteria	Method I	Method II	Method III	Method IV
Amount of Budget	0.518	0.575	0.542	0.551
Validity Period of the Budget	0.247	0.198	0.228	0.227
Ease of Purchasing Processes	0.146	0.119	0.134	0.127
Distribution of Budget Expenditure Types	0.088	0.108	0.097	0.095
	N: 26	R: 0.052		

warehouse facilities in gateway cities, air vehicles, marine vehicles, and land vehicles follow respectively. (Table S4).

In the comparison of expedition planning elements, shipping and cargo processes were identified as the most important (0.302), followed by medical check-ups (0.261). The mobility of the research crew, cold climate gear and pre-expedition trainings follow respectively. (Table S5).

The amount of the budget allocated for logistics was highly prioritized (0.551). Additionally, participants emphasized the importance of the budget's validity period (0.227), noting that a longer budget duration could facilitate more advanced planning and contribute to the success of polar research operations. Ease of purchasing processes and distribution of budget expenditure types follow respectively. (Table S6)

Human Resources

A polar program cannot be sustained without a stable and skilled human resources base. The authors identified three first degree sub-criteria for the human resources componentcriteria: postgraduate programs, education and outreach activities, and the employees of the Polar Research Institute. As presented in Table 4, postgraduate programs were highly prioritized by survey participants, followed by employment, which aligns with the results of other questions. Consistency in the evaluation of these three criteria waswere also found to be high and was accepted as such.

When participants were asked to evaluate postgraduate programs, the curriculum of the program was identified as the highest priority (0.225). The authors believe that the multidisciplinary nature of polar research explains the emphasis on the program's curriculum. Additionally, it is important that alumni of the program are readily employed by the institute (0.176). Demand for the program, scholarship opportunities, field work opportunities and academician expertise follow respectively. (Table S7).

Participants were asked to evaluate education and outreach activities. Formal education curricula should incorporate information related to polar regions (0.187). Additionally, visual materials, such as documentaries, were prioritized by participants to enhance outreach to the general public (0.169). Museums and science centers were also considered important for effective outreach (0.155). Organizing/participating in seminars, panels and school visits, social media visibility, project competitions, organizing festivals, opening booths at

Table 4. Key Human Resources Elements of a Polar Research Institute

Criteria	Method I	Method II	Method III	Method IV
Postgraduate Programs	0.488	0.473	0.477	0.707
E&O	0.230	0.218	0.227	0.154
Employment	0.282	0.309	0.296	0.285
	N: 32	R: 0.299*		

* The consistency ratio exceeded the defined threshold of 0.10. However, this inconsistency is attributed to the limited number of criteria

Table S7. Comparison of criteria of a postgraduate program under Polar Research Institute

Criteria	Method I	Method II	Method III	Method IV
Curriculum of Program	0.225	0.233	0.228	0.225
Demand for the Program	0.174	0.180	0.166	0.174
Employment of Alumni	0.176	0.1612	0.178	0.176
Scholarship Opportunities	0.170	0.167	0.167	0.170
Field Work Opportunities	0.140	0.138	0.142	0.140
Academician Expertise	0.116	0.120	0.120	0.116
	N: 26	R: 0.071		

Table S8. Comparison of criteria for education and outreach activities

Criteria	Method I	Method II	Method III	Method IV
The Presence of Polar Regions in Formal Education Curricula	0.187	0.207	0.184	0.187
Documentary and Other Visual Materials	0.169	0.169	0.166	0.169
Organizing Festivals	0.087	0.085	0.086	0.087
Establishing Museum and Science Center	0.155	0.148	0.152	0.155
Project Competitions	0.092	0.085	0.094	0.092
Social Media Visibility	0.105	0.098	0.113	0.105
Organizing/Participating in Seminars, Panels and School Visits	0.115	0.112	0.118	0.115
Art Contests	0.040	0.044	0.040	0.040
Opening Booths at Different Events	0.050	0.052	0.049	0.050
	N: 23	R: 0.044		

different events and art contests followed respectively. (Table S8).

The number of researchers is identified as the most critical criterion for employment (0.268), underscoring the central role of research personnel in driving the institute's scientific endeavors as it is shown in. This is closely followed by the number of technical staff (0.240), reflecting the importance of technical expertise in supporting the institute's infrastructure and research activities. The number of administrative staff, project-based staff hiring opportunity, ease in hiring, the station/ship crew hiring and part-time staff hiring followed respectively. These priorities suggest that, while a well-rounded staffing approach is necessary, the emphasis should be placed on researchers and technical staff to support the core activities of the Polar Research Institute. (Table S9).

National Level

The national level of the Polar Research Institute plays a significant role in shaping decision-making processes, influencing both the power dynamics and the physical and hierarchical organization of the unit. Through the ANP, the interdependencies between various criteria, such as the institute's relationship with national institutions and its decision-making competence at the national level, can be systematically evaluated in Table 5. The integration of these factors within the ANP framework allows for a comprehensive assessment of how national-level decisions impact the operational structure and effectiveness of the institute. This process highlights the importance of national decision-making competence, as it directly affects the allocation of resources, the prioritization of research initiatives, and the overall governance of the institute.

The physical and hierarchical organization of the institute emerges as the highest priority (0.605), indicating that the internal structure and organization of the institute are critical to its functionality and effectiveness. This is followed by relations with national Institutions (0.254), highlighting the importance of external collaborations and partnerships in facilitating the institute's operations and research initiatives. Finally, national decision-making competence while still significant (0.208), is deemed less critical compared to the other two criteria, suggesting that while national-level decision-making influences the institute, the structural and relational aspects take precedence in determining its overall success. These priority values offer valuable insights into the key drivers of the Polar Research Institute's strategic planning and operational effectiveness. Consistency in the evaluation of the three criteria was also found to be high and was accepted as such.

Table S9. Comparison of criteria for employees of Polar Research Institute

Criteria	Method I	Method II	Method III	Method IV
No. of Researchers	0.268	0.303	0.271	0.268
No. of Technical Staff	0.240	0.203	0.238	0.240
No. of Admin. Staff	0.115	0.105	0.114	0.115
Project-Based Staff Hiring Opportunity	0.104	0.107	0.102	0.104
Ease in Hiring	0.108	0.111	0.107	0.108
Station/Ship Crew Hiring	0.114	0.115	0.115	0.114
Part-time Staff Hiring	0.052	0.058	0.053	0.052
	N: 24	R: 0.065		

Table 5. Criteria for national level of Polar Research Institute

Criteria	Method I	Method II	Method III	Method IV
Physical and Hierarchical Organization of the Unit	0.440	0.450	0.442	0.605
Relations with National Institutions	0.310	0.283	0.299	0.254
National Decision Making Competence	0.250	0.267	0.259	0.208
	N: 33	R: 0.210*		

* The consistency ratio exceeded the defined threshold of 0.10. However, this inconsistency is attributed to the limited number of criteria

Table S10. Physical and hierarchical level of Institute

Criteria	Method I	Method II	Method III	Method IV
Decision-making Powers of the Manager	0.314	0.354	0.314	0.314
Coordination of Public Institutions	0.174	0.165	0.165	0.174
Distribution of Responsibilities and Authorities within Unit	0.217	0.199	0.212	0.217
Establishing Scientific Working Groups	0.140	0.123	0.144	0.140
Physical Infrastructure of Unit (Building, Laboratory, etc.)	0.103	0.100	0.110	0.103
Geographical Location of the Unit	0.052	0.059	0.055	0.052
	N: 33	R: 0.070		

The decision-making powers of the manager emerges as the highest priority (0.314) under physical and hierarchical organization of the institute, emphasizing the central role of leadership in guiding the institute's strategy and ensuring effective decision-making. This is followed by the distribution of responsibilities and authorities within the unit (0.217), underscoring the importance of clear organizational roles and authority structures in facilitating smooth operations. Coordination of public institutions, establishing scientific working groups, physical infrastructure of the unit, geographical location of the unit follow respectively. (Table S10).

Universities and research institutions are identified as the most critical (0.264) under relations with national institutions, reflecting the essential role of academic and research collaborations in advancing polar research. This is followed by the Ministry of Science and Technology (0.214), highlighting the importance of governmental support in facilitating scientific advancements and funding. The Ministry of Foreign Affairs also plays a significant role (0.171), indicating the importance of international relations and diplomatic efforts in polar research initiatives. The Presidency, Head of State, Ministry of Education, private sector, Ministry of Defense and Ministry of Maritime Affairs, Transport, and Fisheries followed respectively. (Table S11).

Participation of public institutions in decision making is identified as the most significant factor (0.259) under national decision making competence, highlighting the critical role of public institutions in influencing the institute's priorities and ensuring alignment with national policies. Closely following is the manager's position in the public hierarchy (0.249), emphasizing the importance of the managerial role and the decision-making power held by the institute's leadership within the broader public administration framework. The unit's board of directors, board of ministry representatives, decisions of the board of scientific/academic advisors follow respectively. (Table S12).

International Relations

Almost half of the duties of a polar research institute is related with international affairs. Science diplomacy emerges as the highest priority (0.375) in Table 6, reflecting the significant role that diplomatic efforts in science play in facilitating global collaboration and advancing the institute's research agenda. This is followed by the criterion "to become a party to relevant international agreements" (0.255), highlighting the importance of formalizing the institute's participation in international treaties and agreements that govern polar research and environmental protection.

Table S11. Comparison of polar research unit's relations with national institutions criteria

Criteria	Method I	Method II	Method III	Method IV
Universities and Research Institutions	0.264	0.300	0.264	0.264
Ministry of Foreign Affairs	0.171	0.152	0.169	0.171
Min. of Science and Technology	0.214	0.210	0.209	0.214
Presidency, Head of State	0.130	0.107	0.135	0.130
Private Sector	0.054	0.054	0.054	0.054
Min. of Defense	0.047	0.050	0.048	0.047
Min. of Education	0.075	0.077	0.076	0.075
Min. of Maritime Affairs, Transport, Fisheries	0.045	0.051	0.045	0.045
	N: 26	R: 0.037		

Table S12. Comparison of criteria for national decision-making competence for the polar research unit

Criteria	Method I	Method II	Method III	Method IV
Participation of Public Institutions in Decision Making	0.245	0.277	0.261	0.259
Manager's Position in the Public Hierarchy	0.260	0.231	0.252	0.250
Unit's Board of Directors Decisions	0.220	0.204	0.210	0.212
Decisions of the Board of Ministry Representatives	0.157	0.156	0.156	0.155
Decisions of the Board of Scientific/Academic Advisors	0.118	0.134	0.121	0.125
	N: 23	R: 0.057		

Table 6. Comparison of criteria respect to international relations

Criteria	Method I	Method II	Method III	Method IV
Science diplomacy	0.369	0.381	0.373	0.375
To Become a Party to Relevant International Agreements	0.270	0.236	0.255	0.255
Representation in Relevant International Organizations	0.174	0.171	0.172	0.172
International Cooperation	0.186	0.211	0.199	0.198
	N: 30	R: 0.043		

International cooperation is considered essential (0.198), reflecting the importance of bilateral and multilateral collaborations in achieving comprehensive and impactful polar research outcomes. Finally, representation in relevant international organizations is also a key factor (0.172), emphasizing the need for the institute's active involvement in global forums where policy and research agendas related to polar regions are discussed. These priorities demonstrate the critical role of international relations and global partnerships in supporting the Polar Research Institute's research objectives and ensuring its alignment with global scientific and environmental standards.

International representation is identified as the highest priority (0.404) under science diplomacy criteria, emphasizing the importance of the institute's visibility and influence within the global research community. The number and quality of academic publications (0.256) is also a significant factor, highlighting the importance of producing high-quality research that contributes to the scientific community and elevates the institute's academic reputation. International accessibility of scientific data follows (0.222), underscoring the need for open access to polar research data, facilitating global collaboration and transparency in scientific endeavors. This supports the institute's efforts in becoming a party to international agreements and contributing to the global body of knowledge. Presenting recommendations to international organizations with scientific data (0.118) reflects the institute's role in providing evidence-based policy recommendations to international bodies, further strengthening its global influence and aligning with the previous emphasis on international representation and cooperation. (Table S13).

The priority vector calculated for various international treaties and agreements highlights their significance in shaping the Polar Research Institute's participation in global governance and environmental protection efforts. The Antarctic Treaty (AT) emerges as the highest priority (0.456), reflecting its foundational role in regulating activities in Antarctica, particularly in terms of scientific research and environmental protection. The Protocol on Environmental Protection to the Antarctic Treaty is another critical agreement (0.201), emphasizing the protection of the Antarctic environment, which is central to the institute's mission of conducting sustainable and environmentally responsible research. The UN Convention on the Law of the Sea, The Svalbard Treaty and the Conservation of Antarctic Marine Living Resources follow respectively. (Table S14).

ATCM and CEP is identified as the highest priority (0.383) under representation in relevant international organizations, reflecting the significance of the Antarctic Treaty Consultative Meeting (ATCM) and the Committee for Environmental Protection (CEP) in guiding policies and regulations for scientific research and environmental protection in Antarctica. This aligns with the previously discussed focus on science diplomacy and international cooperation, as these bodies facilitate collaborative efforts among signatory nations to uphold

Table S13. Comparison of criteria respect to science diplomacy for the polar research unit

Criteria	Method I	Method II	Method III	Method IV
International Representation	0.373	0.428	0.405	0.404
International Accessibility of Scientific Data	0.233	0.208	0.218	0.222
Number and Quality of Academic Publications	0.280	0.240	0.254	0.256
Presenting Recommendations to International Organizations with Scientific Data	0.114	0.124	0.124	0.118
	N: 22	R: 0.059		

Table S14. Comparison of criteria respect to agreements for the polar research unit

Criteria	Method I	Method II	Method III	Method IV
Antarctic Treaty (AT)	0.432	0.477	0.445	0.456
Svalbard Treaty	0.089	0.094	0.090	0.092
UN Convention on the Law of the Sea	0.167	0.146	0.168	0.162
The Protocol on Environmental Protection to the AT	0.226	0.191	0.209	0.201
Cons. of Antarctic Marine Living Res.	0.087	0.092	0.089	0.087
	N: 23	R: 0.057		

Table S15. Comparison of criteria representation criteria for the polar research unit in relevant international organizations

Criteria	Method I	Method II	Method III	Method IV
ATCM and CEP	0.383	0.436	0.377	0.383
Scientific Organizations	0.240	0.205	0.232	0.240
Organizations Related to Marine Living Resources	0.125	0.107	0.124	0.125
Logistics Organizations	0.130	0.115	0.134	0.130
Regional Organizations	0.066	0.067	0.072	0.066
Arctic Council	0.057	0.070	0.060	0.057
	N:23	R: 0.075		

Table S16. Comparison of criteria with respect to international cooperation criteria for the polar research unit

Criteria	Method I	Method II	Method III	Method IV
Joint Scientific Research	0.342	0.380	0.342	0.342
Joint Logistics Operations	0.218	0.183	0.216	0.218
Sharing Infrastructure	0.179	0.166	0.178	0.179
Expert/Staff Exchange	0.106	0.101	0.107	0.106
Exchange of Experience/Know-How	0.092	0.099	0.093	0.092
Organizing Joint Seminars/Workshops etc.	0.063	0.071	0.064	0.063
	N: 20	R: 0.043		

the principles of the Antarctic Treaty. Scientific organizations such as SCAR and IASC follow closely (0.240), underscoring the importance of academic and research networks in advancing the institute's scientific agenda and fostering global collaboration in polar research. Logistics organizations, organizations related to marine living resources, regional organizations and the Arctic Council follow respectively. (Table S15).

Joint scientific research is the highest priority (0.342) under international cooperation, reflecting the essential role of collaborative research initiatives in expanding the institute's scientific reach and fostering international cooperation. This aligns with previous discussions on science diplomacy and international cooperation, as joint research projects help strengthen the institute's position within the global scientific community. Joint logistics operations is also highly prioritized (0.217), underscoring the importance of shared resources and logistics in facilitating field operations in polar regions, where operational challenges are significant. The ability to coordinate logistics with other institutions enhances efficiency and reduces operational costs, which is critical for the success of polar research missions. Sharing infrastructure, expert/staff exchange, exchange of experience/know-how and organizing joint seminars/workshops ~~follows~~follow respectively. (Table S16).

Discussion

Polar Research Units are formed with different organizational structure and hierarchy in different countries. While ~~military is more dominant~~logistics and management are predominantly provided by armed forces in ~~some of the~~certain cases, ~~others are well developed~~other programs rely on their own resources to sustain research~~-~~-driven ~~programs~~initiatives. Even though the size and investment to a polar program depends of the national policy, almost all polar research institutes have similar national and international duties.

The analysis of the strategic priorities for a Polar Research Institute, as derived from participant responses and prioritization through Saaty's eigenvector method, reveals several critical insights into the institute's operational and research needs. The prioritization of scientific research, particularly project-based initiatives, highlights the importance of focused and well-funded research endeavors that can address the pressing scientific questions in polar regions. The survey results underscore the central role of both national and international funding, with an emphasis on collaboration through partnerships. This reflects the growing trend towards multinational and cross-disciplinary research efforts, which are essential for tackling complex and large-scale polar research projects. The ability to attract and manage diverse funding sources not only enhances the institute's capacity to undertake ambitious projects but also strengthens its role within the global research community.

The emphasis on research infrastructure and logistical capabilities aligns with the unique challenges of conducting research in polar regions, where harsh environmental conditions and remoteness pose significant barriers to research operations. The need for a well-equipped infrastructure, including research stations, vessels, and specialized staff, is crucial for the successful execution of polar expeditions. Additionally, the importance of experienced researchers and technical staff highlights the necessity of maintaining a skilled workforce capable of navigating these challenging environments.

The focus on human resources, particularly postgraduate programs, demonstrates a forward-thinking approach to capacity-building within the institute. The integration of multidisciplinary curricula in postgraduate programs is essential for developing expertise in the various scientific domains that polar research encompasses, from oceanography to meteorology and earth sciences. The fact that the recruitment of graduates into the institute is a high priority further emphasizes the importance of a sustainable workforce that is both highly skilled and familiar with the specific demands of polar research.

From an organizational standpoint, the prioritization of the institute's physical and hierarchical structure, along with strong relations with national institutions, highlights the importance of effective governance and internal coherence. A well-organized and clear decision-making framework is critical for efficient operations and ensuring that research objectives are met. The recognition of leadership roles and the clear distribution of responsibilities underscores the necessity of strong managerial capacity in guiding the institute's research agenda and facilitating smooth collaboration with external stakeholders.

National collaborations, particularly with universities and research institutions, alongside

governmental agencies, are seen as vital in supporting the institute's scientific endeavors. The involvement of these entities is crucial not only for securing funding and resources but also for ensuring alignment with national policies and strategic objectives. While the private sector and other ministries play supportive roles, their involvement is less central, suggesting that the focus of the Polar Research Institute remains firmly rooted in academic and governmental collaboration.

Finally, the emphasis on international relations and scientific diplomacy underscores the global nature of polar research. The institute's participation in international treaties, agreements, and scientific forums is pivotal for advancing its research objectives and ensuring that its work aligns with global environmental standards and policies. By engaging with international organizations, the institute can foster collaboration, gain access to global resources, and contribute to the shaping of international policies concerning polar regions.

Considering all prioritization and combining the experiences and expertise of the authors, it is clear that polar research institute should operate state of art infrastructure which should include stations and vessels to support comprehensive and sustainable polar research. Also, high the institute's funding mission and running a postgraduate program seems crucial. However, there is no known example of institution as a national focal point and offers postgraduate programs in Türkiye. Further studies by the authors will evaluate this outcome including national legislation and suggest solutions.

Comparing national level of the institute criteria, it was prioritized that the institute should be defined with a higher hierarchy in the governmental system with a high rank manager/director. The Turkish Polar Program accelerated after the Presidency of the Republic of Türkiye's auspices. Combining both outcomes, authors believe that Polar Research Institute's direct connection with Presidency office would fulfill the priorities. When the international examples are evaluated, it could be seen that similarly structured institutes such as British Antarctic Survey are known with their success and capabilities. Also polar research institutes under ministries could be defined as a high rank hierarchy while they are mostly known with their successful works, such as Spanish Polar Committee, Korea Polar Research Institute, National Centre for Polar and Ocean Research (India), Chilean Antarctic Institute, Argentine Antarctic Institute. Authors would like to emphasize that, defining the optimum polar research unit is needed further studies which should include national legislation, operation of international polar research units, research institutions in Türkiye, not only in in theory but also including practices.

Conclusion

The findings from the survey provide valuable insights into the strategic priorities for a Polar Research Institute, emphasizing the multifaceted nature of its operations. Scientific research, supported by strong financial and collaborative frameworks, is at the core of the institute's mission. The prioritization of research infrastructure, experienced human resources, and logistical capabilities highlights the institute's commitment to conducting high-quality research in the challenging polar environments. Furthermore, the strong focus on postgraduate education and the recruitment of skilled personnel ensures the sustainability of the institute's workforce, which is crucial for long-term success.

Effective governance, clear organizational structures, and robust relationships with national institutions form the foundation for the institute's operational success. By strengthening partnerships with universities, research institutions, and key governmental agencies, the institute can ensure that its research aligns with national priorities and enjoys the necessary support. The importance of international collaboration, particularly through science diplomacy and adherence to international agreements, also emerged as a central theme, reflecting the global scope of polar research and the need for coordinated efforts to address environmental and scientific challenges.

In summary, the Polar Research Institute should prioritize strengthening its infrastructure, securing diverse funding sources, and fostering international collaborations. The establishment of long-term planning processes, supported by stable and flexible funding mechanisms, is essential for ensuring the success and sustainability of the institute's scientific endeavors. By focusing on these strategic priorities, the institute will be well-positioned to contribute to advancing knowledge in polar research and supporting global environmental sustainability efforts.

Future research will extend this analysis by evaluating the specific alternatives and potential matches that align with the defined organizational priorities. This will be accomplished through a comprehensive domestic survey targeting the Turkish Polar Community, which will provide a more detailed understanding of how the identified priorities can be translated into actionable strategies. The results of these future studies will offer valuable insights into the practical implications of these priorities and help refine the Polar Research Institute's organizational framework, ensuring that its strategic direction is closely aligned with the needs and expectations of its stakeholders.

Ethical Statement

Not applicable.

Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contribution

Ö.O and B.Ö developed the theoretical formalism of the study. Ö.O performed the analytic calculations and drafted the manuscript. Both Ö.O and B.Ö. contributed to the final version of the manuscript.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to acknowledge the assistance of ChatGPT, a language model developed by OpenAI, for providing support in translating and language improvements during the course of this study. We also would like to thank to Dr. Atilla Yılmaz and Cpt. Doğaç Baybars Işıler for their valuable comments and support.

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Biçimlendirilmiş: Yazı tipi: +Gövde (Calibri), 9 nk

Biçimlendirilmiş: Yazı tipi: +Gövde (Calibri), 9 nk, Yazı tipi rengi: Otomatik, Desen:Yok