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# Quantitative Analysis of Peri-Urbanization: Developing a Peri-Urban Index for Medium-Sized Cities Using the Analytic Hierarchy Process—A Case Study of Yozgat, Turkey

**Begüm Demiroğlu İzgi**

Department of Architecture, Yozgat Bozok University, 66200 Yozgat, Türkiye; begum.demiroglu@bozok.edu.tr; Tel.: +90-3542421001

**Abstract:** The rapid development of urbanization necessitates effective analytical methods to address its complexities. Peri-urbanization, the expansion of settlement boundaries and urban spread, is a critical aspect of this phenomenon. This study introduces a quantitative method to analyze peri-urbanization, providing a peri-urban index (PUI) for medium-sized cities based on peri-urban dynamics. Utilizing the analytical hierarchy process (AHP), the weight values of influencing dynamics are calculated, establishing a peri-urban scale (PUS) ranging from one to five based on rural and urban characteristics. Applied to a medium-sized case study city, the method assesses the peri-urbanization from 2007 to 2022. Four main dynamics—socio-demographics, economic-employment, land use-accessibility, and building-texture patterns—and fourteen sub-dynamics were identified and weighted using AHP. The city's PUI values over different years reveal a 41.6% increase, indicating significant peri-urbanization. This quantitative approach, which innovatively integrates multiple numerical analysis methods, not only highlights the peri-urbanization trends of the city but also provides a comparative analysis framework for other cities. The method's ability to track changes over time and compare different urban areas supports the development of sustainable urbanization strategies, ensuring balanced growth and resource allocation. This method offers urban planners, policymakers, and architects a powerful tool to manage and guide future urban expansion effectively through interdisciplinary collaboration.

**Keywords:** peri-urbanization; urban expansion; analytical hierarchy process (AHP); sustainable urbanization; quantitative analysis

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**Citation:** Demiroğlu İzgi, B. Quantitative Analysis of Peri-Urbanization: Developing a Peri-Urban Index for Medium-Sized Cities Using the Analytic Hierarchy Process—A Case Study of Yozgat, Turkey. *Sustainability* **2024**, *16*, 6002. https://doi.org/10.3390/su16146002

Received: 8 June 2024
Revised: 11 July 2024
Accepted: 12 July 2024
Published: 14 July 2024



## 1. Introduction

Peri-urbanization is a concept that describes transitional zones around urban centers where urban and rural characteristics intermingle. These areas are spatially and structurally dynamic, characterized by complex social and economic dynamics. The peri-urban interface, located between fully urbanized land and predominantly agricultural areas, features mixed land uses and indistinct inner and outer boundaries. These zones experience rapid population growth and significant changes in land use, driven by the outward expansion of urban centers. As cities expand, peri-urban areas shift and grow, facing pressures on natural resources, changing labor market opportunities, and evolving patterns of land use. This phenomenon underscores the constantly evolving nature of peri-urban regions and the dynamic transformations occurring within these areas [1].

Terminologies such as peri-urbanization, ex-urbanization, displaced urbanization, anti-urbanization, hidden urbanization, counter-urbanization, and rurbanization are utilized to define the cities or surrounding regions affected by urbanization processes [2–7]. The terms 'peri-urban' and 'peri-urbanization' are often characterized by broad and ambiguous definitions, particularly when describing areas undergoing recent urban transformation in developing countries [5]. This ambiguity presents challenges in assessing and managing the social, economic, and environmental dimensions of rapid changes occurring in these regions. In developed industrial or post-industrial societies, peri-urban areas are recognized as zones of social and economic transition and spatial restructuring. Conversely, in newly industrialized and developing countries, the peri-urban landscape is associated with irregular urban expansion and urban sprawl [8].

### 1.1. Dynamics and Impacts of Peri-Urbanization

Peri-urbanization refers to the process by which rural areas on the outskirts of established cities acquire a more urban character in physical, economic, and social terms, often in a fragmented manner. Since the mid-20th century, this concept has been utilized in Western Europe and North America to understand the morphological changes and social transformations occurring in settlement areas expanding outward from urban centers. This process encompasses rapid social changes, as small agricultural communities are compelled to adapt swiftly to an urban or industrial way of life [9].

Understanding the impact of urban transformation processes on peri-urban areas facilitates a better comprehension of the social and economic dynamics within these regions. Urban transformation processes have led to the fragmentation of previously continuous agricultural lands in peri-urban areas and increased distances between agricultural landscapes and human interventions [10]. Changing employment patterns and rising mobility demands in post-industrial societies have significantly altered urban forms, especially concerning the transportation infrastructure [11]. Industrialization has transformed urban landscapes, including roads, parks, open spaces, squares, and buildings, a transformation often referred to as peripheralization or peri-urbanization [11]. These processes illustrate how peri-urbanization operates as an integral part of broader urban transformation dynamics (Figure 1).

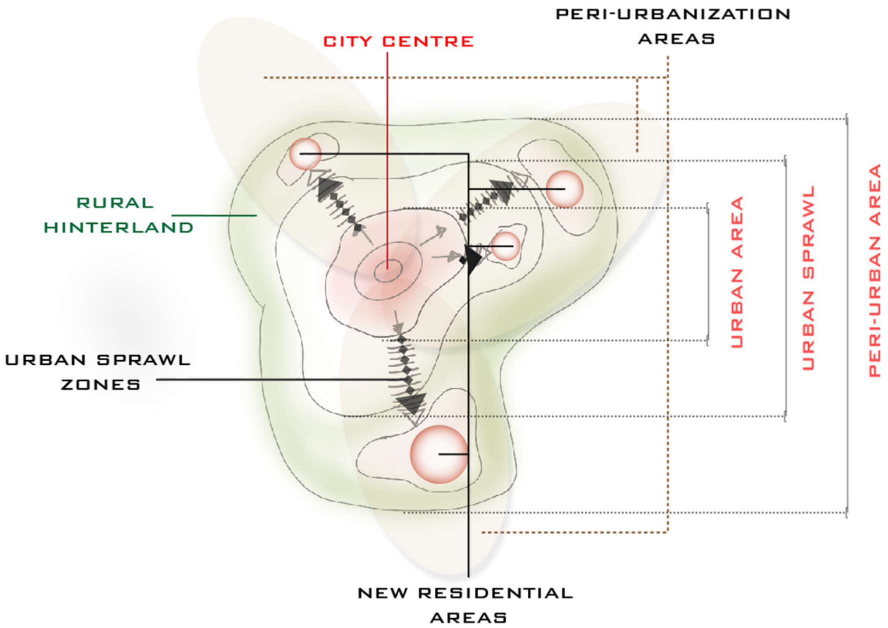


**Figure 1.** Illustration of the peri-urbanization process between urban and rural settlement areas. The arrows represent the spread area of the expanding new settlements.

Urbanization has not only progressed in industrial centers but has also extended towards rural settlement areas. In this context, peri-urbanization is a dynamic process occurring in transitional zones between urban and rural areas, encompassing the formation of new regional areas, urban expansion, and the integration of rural areas with urban functions. This process plays a significant role in regional planning and socio-economic policy reforms by generating new regional identities and functions, as observed in the case of Germany [12]. The dynamic change and transformation processes within peri-urban areas are crucial in understanding their various social, economic, and environmental dimensions.

Similarly, in many developing countries, peri-urban areas serve as transitional zones where traditional agricultural practices intersect with new urban developments. These regions often feature informal settlements and mixed land uses due to rapid urban expansion and the lack of formal planning [13]. In contrast, peri-urban areas in developed countries may include suburban developments, industrial zones, and green belts designed to limit urban sprawl. European peri-urban areas typically consist of low-density residential areas, commercial developments, and green belts aimed at controlling urban growth [14]. These hybrid zones, containing a mix of rural and urban characteristics, hold strategic importance in the planning and policy development processes. These different applications and strategies provide examples of how peri-urbanization is shaped and managed according to local conditions.

The various applications of peri-urbanization necessitate evaluating the impacts of urban expansion within a broader context. Peri-urbanization transforms rural areas surrounding cities into complex structures affected by urbanization. Common features of these areas include low population density, scattered settlements, high dependency on transportation, fragmented communities, and a lack of spatial management. These areas often form multifunctional regions with various forms and functions, highlighting spatial and socio-economic changes occurring in transitional zones between rural and urban areas. Examples of peri-urban regions include Hangzhou (China), known for rapid urbanization and high population growth; Koper (Slovenia), emphasizing social cohesion; Montpellier (France), recognized for strategies to protect green spaces and control urban sprawl; Warsaw (Poland), dealing with urban sprawl and uncontrolled growth; and Leipzig-Halle (Germany), focusing on ecosystem services [15]. These examples illustrate how peri-urban areas can be managed and analyzed through different strategies and approaches.

The interactions between rural and urban areas are critical for understanding the dynamics of peri-urbanization processes. Numerous studies have been conducted across various disciplines in the field of peri-urbanization [2,3,11,16–18]. The ecological, economic, and social functions of the urban environment affect both urban and rural areas. The artificial distinction between 'urban' and 'rural' contributes to the complexity of definitions [2]. Studies have explored the transitory nature of rural areas based on criteria such as transportation systems, economic, demographic, social, and cultural impact, and attraction factors [19]. The more fluid growth of the urban boundary has transformed the dynamics of urban and rural areas into an ambiguous form. The interface between urban and rural areas serves as a space where urban infrastructure, housing, industry, public and semi-public facilities, and transportation networks are anticipated to expand [3]. The rapid expansion of urban extensions into settlements with an agricultural economy creates informal settlement patterns. Carrilho [17] argued that the hybridization and diversification of people, space, landscape, economy, and institutions in peri-urban informal settlements require a different approach in planning and governance, examining the boundaries and outcomes of peri-urbanization dynamics with a pragmatic approach. Mustak et al. [3] discussed urbanization in accordance with the rural–urban fringe (RUF) definition, identifying settlements between agricultural and urban societies and analyzing them based on the categories of urban fringe, rural fringe, and urban shadow. Mitchell [16] identified three sub-categories of anti-urbanization: self-sufficient lifestyle, migration to improve quality of life, and comfort-oriented retirement migration. Additionally, under these subheadings, he classified the anti-urban movement.

### 1.2. Concept and Characteristics of Peri-Urbanization

Morphological parameters are crucial for understanding peri-urbanization processes and the interaction, change, and abstract and concrete layers of change between urban and rural areas. Hillier et al. [20] emphasized that urban form is the result of the interaction between human activities and the built environment, which over time shapes the form, highlighting the importance of understanding the dynamic nature of urban morphology and the relationship between the built environment and social practices. Settlements are shaped not only by physical formations but also by socio-economic factors [4]. Urbanization includes not only physical changes in settlements and land use but also functional and lifestyle changes that may not be immediately visible. These socio-economic changes significantly impact population characteristics such as income levels, education standards, job opportunities, and land use interests in surrounding rural areas [21].

Alongside these concrete parameters, abstract parameters have also been frequently addressed within the relevant context. Many researchers have analyzed the ambiguous transition and intermediate state between urban and rural areas in terms of abstract and concrete dynamics. Settlement morphologies and users are significant determinants in defining a region. Bryant et al. [22] provided examples of defining and researching rural areas based on the proximity to and accessibility of urban areas, presenting various geographical influence zones. Antrop [23] highlighted the historical development and spread of urbanization and its impact on accessibility, landscape dynamics, and the relationship between urban and rural areas.

Peri-urbanization should be examined as a process rather than a static outcome or phenomenon. Defining this process and understanding its self-fulfilling elements necessitate a process-oriented analysis. Factors such as the relocation of services and industries, part-time agriculture, second homes, and retirement migration are recognized as significant drivers of urbanization outside traditional urban centers [21]. Allen [2] considers peri-urban dynamics as an area where three systems—agricultural system, urban system, and natural resource system—continuously interact in social, economic, and environmental terms. Madsen [21] conducted peri-urban analysis in 22 dynamic titles and their sub-dynamics by identifying the drivers and characteristics of urbanization in categories of social structure, labor market, and agricultural structure.

While definitions may be similar, different peri-urbanization processes can be discussed for each settlement pattern. Analyzing the local nature and changes in settlement morphologies is essential for this purpose. Understanding the impact of morphological parameters on peri-urban areas necessitates a localized process of settlements. Localizing a settlement requires a simultaneous semantic action where the evolving settlement pattern over time is evaluated through a subjective analysis of the settlement morphology dynamics. This approach not only identifies changing settlement dynamics but also provides an effective tool for understanding transformations in settlement identity. The relationship between historically persistent elements and building type and urban fabric over time is evaluated using two analytical methods.

The morphological analysis of urban texture is a fundamental tool for understanding the dynamic nature of settlements. Numerous interdisciplinary studies have analyzed urban texture. The results of these studies have revealed different dynamics depending on the researcher and the sample area. These dynamics have been grouped under tangible and intangible elements (social, cultural, economic, land, streets, buildings, roads, etc.) that constitute urban texture [20,24–29]. Levy [11] advocates the necessity of researching morphological transformations, particularly the shift from a closed structure to an open, fragmented peri-urban texture, and the need for new analytical tools to understand the components and formation processes of modern urban texture. Al-Saaidy [30] examined these processes by comparing critical points among three urban morphology approaches (British, Italian, and French). Quantitative and qualitative analytical methods can be used to scientifically identify the push and pull forces of morphological dynamics, guiding appropriate steps for settlement development and transformation decisions [31]. The evaluation and examination of morphological dynamics can be subjective and variable depending on the studied area. Wang and Yuan [32] used methods of statistical analysis, spatial analysis, and data visualization analysis to examine the spatial distribution of rural settlement morphogenesis.

### 1.3. Methodological Approach and Case Study

As evidenced by the comprehensive literature reviews, morphological analyses of urban and rural settlements have been extensively conducted in numerous studies. In these analyses, the dynamics are usually clearly selected, and morphology–typology schools and regionally specialized type–morphology dynamics are frequently used for morphological layer studies. However, concepts such as which morphological dynamics to use and how to compare these dynamics hierarchically in simultaneous semantic analyses of the spread of peri-urban urban extensions into rural areas remain unclear. Furthermore, there is a gap in the literature regarding the calculation of a settlement's peri-urbanization level. This study proposes an analysis method based on the dynamics used in peri-urban morphology studies to fill this gap. Using this method, the peri-urban index (PUI) of medium-scale settlements can be calculated, determining the degree of peri-urbanization of the settlement. The peri-urban index calculated with the proposed method allows for the analysis of changes in the degree of peri-urbanization of medium-scale settlements over the years and the comparison of different settlements in terms of peri-urbanization.

In this study, the proposed peri-urban index was applied to a medium-scale city. First, peri-urban dynamics were identified, and those dynamics were hierarchically ranked and weighted using the AHP method. Then, the data range for each dynamic was normalized and scaled between 1 and 5. Finally, the PUI value of the sample city for different years was calculated, and the changes in the level of peri-urbanization of the city were analyzed.

This study contributes to a comprehensive understanding of the effects of change and transformation by creating an intersection point between urban disciplines and architecture. It offers an interdisciplinary perspective necessary for systematically understanding and managing past, present, and future urban movements. Additionally, it emphasizes the importance of sustainability in urban planning and highlights future research directions that underscore the need for balanced growth and resource-efficient urban development.

## 2. Peri-Urbanization Dynamics

Cities have been analyzed by different researchers with different methods and these analyses have been categorized according to different parameters.

Madsen et al. [21] conducted a study analyzing the dynamics of urbanization in rural areas using a two-stage multivariate analysis. The variables used in this study are grouped under three main categories: social structure, labor market, and agricultural structure. Figure 1 illustrates the relationships between rural–urban parameters and the results are categorized based on whether the region is classified as rural or urban. This division into three main categories aims to provide a comprehensive understanding of how different combinations of these structural parameters contribute to the transformation of areas into peri-urban regions (Figure 2).

The social structure includes demographic and socio-economic variables such as age, income level, and education status, while the labor market focuses on employment sectors and types of employment. The agricultural structure encompasses variables related to farming types and livestock concentration. These three main categories offer a detailed framework to better understand the complexity and diversity of the urbanization processes in rural areas. Each category examines the interaction of rural areas with urban areas and the impact of these interactions on the socio-economic structure of rural areas [21].

Mustak et al. [3] conducted a comprehensive analysis of peri-urbanization covering two different categories: primary and secondary factors. The author carefully categorized the primary factors, which include accessibility, light, non-agricultural workers, population density, percentage of urban land, and gender ratio.

Allen [2] conducted a comprehensive analysis examining the dynamics of population size, resident population density, infrastructural characteristics, administrative boundaries, and economic activities to distinguish rural areas from their urban counterparts and delineate their boundaries. Furthermore, in the context of the peri-urban definition of land use, Adams and Mortimore [18] included urban accessibility, household characteristics, income diversity, proximity to markets, availability of farm labor, and non-farm employment dynamics.

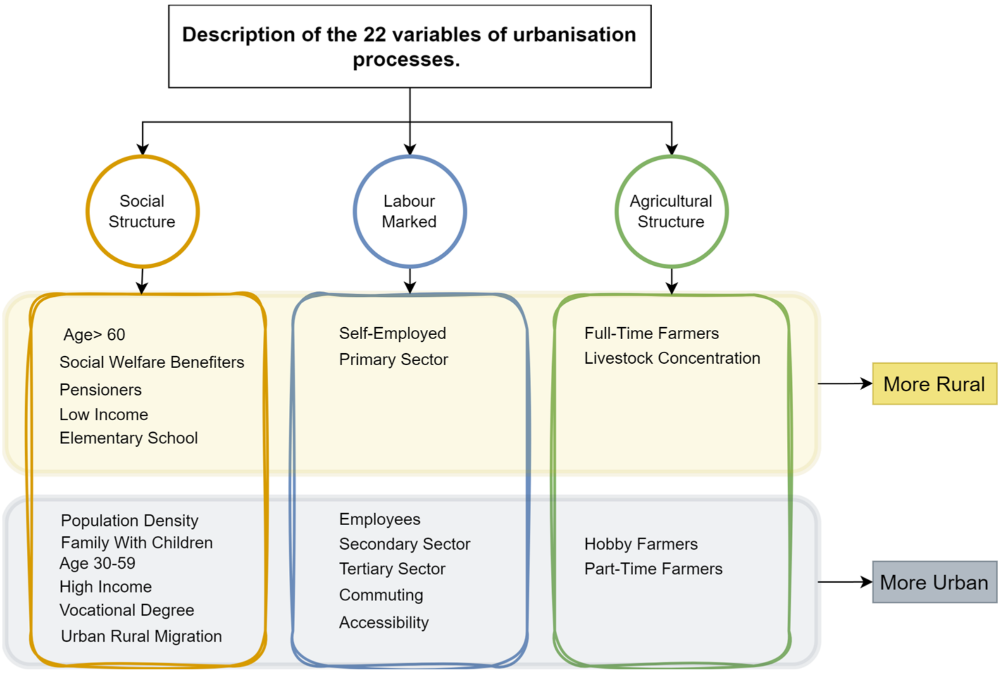


**Figure 2.** Rural–urban parameters.

An additional analytical approach is adopted by rural–urban fringe (RUF) dynamics, which analyzes the urban environment by considering parameters such as outward urban expansion, land use changes, demographic transformations, economic activity, infrastructure development, and environmental considerations.

Urban morphology studies have been conducted across disciplines and supported by many schools and researchers. Pioneering research on urban morphology and parameterization has been carried out by reputable institutions such as the School of Morphology, Chicago School, Los Angeles School, English School, Frankfurter School, Delft School, and Italian School. Among these, the British, Italian, and French schools stand out due to their widely adopted methods in urban morphology studies. Although urban morphology has been studied from different perspectives, analyses typically fall under the categories of historical geographical approach, architectural approach, and typo-morphological approach. The basic elements of the urban built environment include land, buildings, built parcels, and streets. Morphogenetic studies conducted by researchers such as Conzen [26] have investigated the evolution and stratification of building parameters, parcels, and built parcels. Conzen's analysis focuses on urban form, taking into account parameters such as urban plan/ground plan (e.g., area, avenue, street, building parcel, built parcel), building fabric, and land-building use. Xu et al. [31], in their stratification analysis, used a multiple decision-making approach to investigate study areas, considering location, landform, and socio-economic criteria as the primary topics. Secondary sub-headings include distance to the city, distance to roads, distance to water sources, land slope, land appearance, land type, population density, and annual per capita income.

In his morphological approach, Muratori described architecture as an organism and argued that structures that integrate with existing urban mechanisms should ensure the continuity of the organism. Historical stratification and historical structure gain importance in this perspective. Muratori's analysis of organicity covered five groups: sometimes sequential, systematically serial, episodically organic, episodically organic, and purely organic. Cataldai et al. [25] adopted the Muratori framework in its morphological approach and used parameters such as type, typology, structure, texture, sequence, and serial processual typology in its analysis.

Levy [11] introduced the concept of the rural–urban or traditional–modern urban phenomenon, which he associated with the reflections of the post-industrial employment model. Urban mobility resulting from this pattern has a significant impact on the transportation infrastructure in particular. The upward trajectory of population growth requires the development of roads and the provision of parking spaces within the pre-existing urban fabric. Moreover, as one moves away from the city center, new architectural structures, roads, and structural innovations emerge and spread, challenging the dominant urban form. Levy [11] argued that the interrelationships between existing morphological dynamics in settlements located within the peripheral rural–urban transition are differentiated. The morphological parameters that change/transform in such a morphological formation are provided in Table 1.

**Table 1.** Morphological transformations in pre- and post-peri-urbanization phases according to [11].

| Transforming Morphological Parameters | Pre-Peri-Urbanization | Post-Peri-Urbanization |
| --- | --- | --- |
| Road and Traffic Configurations | Streets, boulevards, lanes, intersections, and corners | Peripheral roads, urban highways, side roads, exits, junctions, and roundabouts |
| Pedestrian and Public Spaces | New public squares | Elevated walkways, platforms, and shopping centers |
| Commercial Areas | Large stores, market streets, and covered markets | Supermarkets and shopping malls |
| Green Spaces and Play Areas | Parks and gardens | Lawns and playgrounds |
| Residential and Building Arrangements | Individual units and blocks | Towers and linear buildings |
| Housing Developments | Garden city | New private housing estates |

Table 2 provides a chronological synthesis of the key studies on peri-urbanization and urban morphology, highlighting the parameters, dynamics, and methodologies employed by various scholars. The early research primarily focused on the interaction between spatial organization and functional integration, employing spatial and empirical analyses. Subsequent studies expanded to include agricultural intensification, socio-economic systems, and land use changes within peri-urban interfaces, utilizing case studies, fieldwork, and the literature reviews. The investigation of urban morphology and modern urban fabric brought a conceptual and empirical perspective, emphasizing the structural elements of urban environments. The analysis of counter-urbanization and rural–urban interactions introduced qualitative approaches to understand demographic shifts and lifestyle changes. Historical and spatial analyses have been pivotal in examining landscape transformations and urbanization processes over time. Typomorphological studies have provided insights into the typological and structural dynamics of urban forms. Comparative analyses of different urban morphology schools further enriched the understanding of urban structures and functions. The use of multivariate and GIS analyses facilitated the exploration of social structures, labor markets, and agricultural dynamics. Recent advances in geospatial techniques and the AHP method have enhanced the delineation and classification of rural–urban fringes. Quantitative and spatial analyses have been instrumental in identifying the driving forces behind urban growth and development trends. Lastly, the focus on sustainability, hybridization, and informal settlements underscored the complexity of social dynamics in peri-urban areas. This comprehensive review encapsulates the diverse methodological approaches and thematic focus areas that have shaped the current understanding of peri-urbanization and urban morphology.

**Table 2.** Chronological overview of peri-urbanization and urban morphology studies: parameters, dynamics, and methods.

| Researcher | Parameters/Dynamics | Method |
|---|---|---|
| Hillier et al. [20] | Building function, spatial organization, integration values, control values | Spatial analysis, empirical study |
| Adams and Mortimore [18] | Agricultural intensification, labor flexibility, grazing resources, field location | Case study, empirical fieldwork, interviews |
| Levy [11] | Urban morphology, modern urban fabric, elements of urban fabric (parcels, streets, buildings, open spaces) | Typological analysis, morphological examination, and diachronic approaches. |
| Allen [2] | Environmental planning, peri-urban management, socio-economic systems, land use change | Case study analysis, literature review |
| Mitchell [16] | Counter-urbanization, migration patterns, rural–urban interaction, self-sufficient lifestyle, migration to improve quality of life, comfort-oriented retirement migration | Empirical analysis, qualitative research |
| Antrop [23] | Landscape change, urbanization process, accessibility, transportation networks | Historical analysis, spatial analysis |
| Cataldai et al. [25] | Typology, urban form, structure, texture, sequence, serial processual typology | Typomorphological analysis, historical analysis |
| Al-Saaidy [33] | Urban form, structure, function, British, Italian, French schools of urban morphology | Comparative analysis, literature review |
| Madsen et al. [21] | Social structure, labor market, agricultural structure | Multivariate analysis, GIS analysis |
| Mustak et al. [3] | Rural–urban fringe, urbanity index, classification based on geospatial techniques. | Geospatial techniques, AHP method |
| Xu et al. [31] | Rural spatial morphology, driving factors, evolution trends, development. | Quantitative analysis, spatial analysis, ANP, ArcGIS. |
| Carrilho and Trindade [17] | Sustainability, hybridization and diversification, informal settlements, social dynamics | Qualitative systematic literature review and meta-analysis/meta-synthesis. |
| Wang and Yuan [32] | Morphological characteristics, spatial distribution, rural settlement morphogenesis | Spatial analysis, statistical analysis |

## 3. Methodology

This study introduces a method aimed at quantitatively examining peri-urbanization. The proposed approach entails calculating a peri-urban index (PUI) specifically tailored for medium-sized cities, relying on the dynamics of peri-urbanization. These dynamics are evaluated for their impact using the analytical hierarchy process (AHP), assigning weight values, and then applying a peri-urban scale (PUS) ranging from one to five based on the rural and urban characteristics of each dynamic. In this section, the determination of peri-urban dynamics, the AHP method, scaling of dynamics, and PUI calculations are presented. A schematic view of the applied methodology is illustrated in Figure 3.

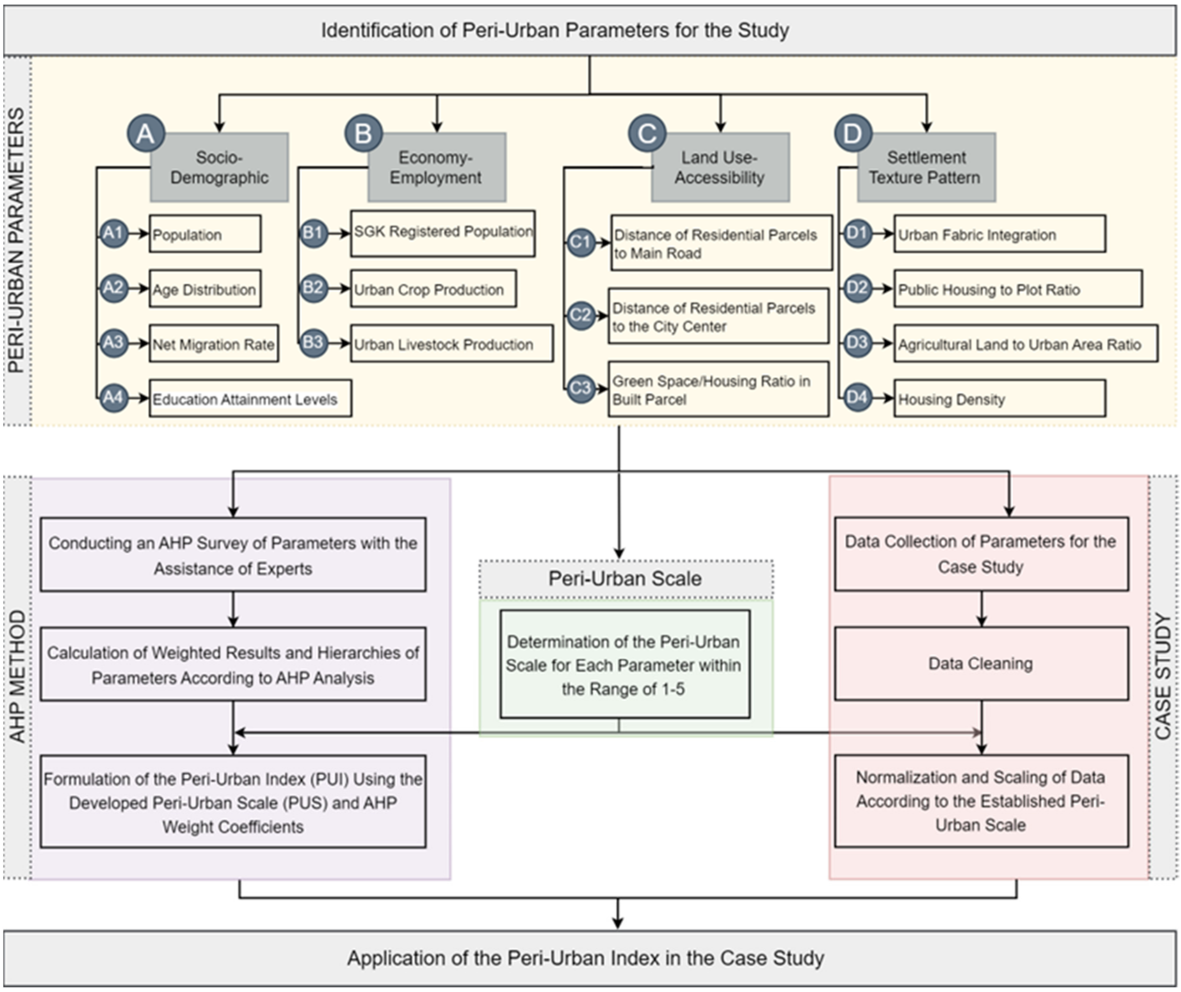


**Figure 3.** Flowchart of the methodology.

### 3.1. Determination of Peri-Urban Dynamics

The existing literature shows that various researchers from different disciplines have used different criteria derived from the same analytical framework for both morphology analysis and urbanization environment analysis. In the current research, the peri-urban parameters were carefully identified in the light of these collective studies, with considerable emphasis on the interdisciplinary factors that serve as a nexus between research on morphology and peri-urban dynamics. The dynamics and reasons for selection examined by Madsen et al. [21] in their peri-urban study and the AHP methodology of Xu et al. [31] also guided the process of identifying and analyzing the dynamics in this study. However, it is worth noting that this study has the potential to evolve into a more comprehensive form depending on factors such as research scale, sample size, and the diversification or expansion of the dynamics examined. However, a rigorous and thoughtful process guided the selection of dynamics identified from the literature, with careful consideration of the inherent challenges and limitations of empirical data collection, as well as the complex interplay of geographic dynamics in the study area.

In this study, the selection of indicators for analyzing peri-urban dynamics was carefully guided by both theoretical frameworks and empirical findings from previous studies. The chosen indicators encompass socio-demographic, economic–employment, land use-accessibility, and settlement texture pattern dimensions, reflecting a comprehensive approach to capturing the multifaceted nature of peri-urban areas.

In order to analyze peri-urbanization in medium-sized cities, the dynamics to be used in this study were handled by selecting four main (primary) headings: Socio-Demographic

(A), Economy–Employment (B), Land Use–Accessibility (C), and Building–Texture Patterns (D). Sub-driving force headings of each heading were created and categorized.

The socio-demographic indicators (A), such as population, age distribution, net migration rate, and education attainment levels, were selected due to their critical role in understanding the demographic shifts and human capital variations in peri-urban regions. These indicators are well-documented in the literature for their impact on urban–rural interactions and have been validated by studies like those of Adams and Mortimore [18] and Madsen et al. [21].

Economic–employment indicators (B), including SGK-registered population, urban crop production, and urban livestock production, were integrated to highlight the economic activities and employment patterns that drive peri-urban growth. Allen [2] and Mustak et al. [3] have emphasized these factors as essential for understanding the economic base and resilience of peri-urban areas.

Land use-accessibility indicators (C), such as the distance of residential parcels to main roads and city centers, and the green space/housing ratio, were chosen to capture the spatial dynamics and accessibility challenges within peri-urban settings. The importance of these indicators is supported by Antrop [23] and Xu et al. [31], who have demonstrated their relevance in urban planning and environmental sustainability.

Lastly, building–texture pattern indicators (D), including urban fabric integration, public housing to plot ratio, agricultural land to urban area ratio, and housing density, were included to understand the morphological and structural transformations in peri-urban areas. Studies by Hillier et al. [20] and Cataldai et al. [25] have provided substantial evidence on the significance of these parameters in analyzing urban form and spatial organization.

The selected primary and secondary dynamics are capable of capturing the peri-urbanization processes of the settlements over time. However, each sub-dynamic has been categorized on a peri-urban scale of 1–5 based on the criteria, ranges, or percentages of rural and urban characteristics, and numerical assessments are expressed in a tertiary ranking on this scale. As urbanization increases, peri-urbanization follows an increasing parallelism. In this context, the parameters have the same scale value in the peri-urban chart (Table 3).

**Table 3.** Peri-urban scale.

| Rank | Characteristics |
|---|---|
| 1 | Very Few Peri-Urban Characteristics |
| 2 | Few Peri-Urban Characteristics |
| 3 | Moderate Peri-Urban Characteristics |
| 4 | Many Peri-Urban Characteristics |
| 5 | Very Many Peri-Urban Characteristics |

### *3.2. AHP Methodology*

The analytic hierarchy process (AHP) has emerged as a powerful and widely adopted research method for decision making and prioritization in complex systems. Developed by Saaty [33], the AHP provides a systematic approach to structuring and analyzing complex problems by decomposing them into a hierarchical structure of criteria and alternatives. This method effectively addresses problems by having decision makers evaluate and assign relative importance to various criteria and sub-criteria and then prioritize alternatives according to the hierarchical importance of the criteria using Saaty's 1–9 scale (Table 4).

**Table 4.** Saaty's 1–9 scale.

| Scale | Description |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance |
| 5 | Strong importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2, 4, 6, 8 | The importance between each of the above two scales |

In the AHP method, decision makers assign numerical values, known as pairwise comparison judgments, to assess the relative importance of criteria and alternatives at different levels of the hierarchy. These judgments are based on the subjective evaluations of decision makers and can be obtained through surveys or expert opinions. Through a series of pairwise comparisons, a set of priority weights is derived that reflects the relative importance of the criteria and alternatives. AHP also includes a consistency check to ensure the reliability and validity of the judgments provided by decision makers.

In this analytical approach, pairwise comparisons are expressed by a matrix. To ensure consistency, the diagonal values of the comparison matrix representing the comparisons of criteria among themselves are set to 1, indicating that they are of equal importance. To assess the existence of consistency, a validation method using the consistency ratio (CR) test is used. The pairwise comparison matrix is defined as:

$$B = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{bmatrix}_{nxn} = \left[b_{ij}\right] \quad i, j = 1,\ 2,\ ..,\ n \tag{1}$$

Here, $n$ represents the number of criteria used in the evaluation, $i$ and $j$ represent criteria used in the evaluation, and $bij$ indicates the degree of importance of criterion $i$ with respect to criterion $j$. To express the importance of criterion j with respect to $i$, the transformation is applied as follows:

$$b_{ji} = \frac{1}{b_{ij}} \tag{2}$$

$$B' = \begin{bmatrix} 1 & b_{12} & \dots & b_{1n} \\ \frac{1}{b_{12}} & 1 & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ \frac{1}{b_{1n}} & \frac{1}{b_{2n}} & \dots & 1 \end{bmatrix}_{nxn} \tag{3}$$

In order to calculate the weights of the criteria, the row products ($v_j$) of each criterion in the matrix are calculated with the following equation:

$$v_j = \prod_{i=1}^{n} B'_{ij} \tag{4}$$

The next step is to calculate the nth order root of each product column. The order root of each product column is calculated as follows:

$$w_j = \sqrt[n]{v_j} \tag{5}$$

To calculate the weight, each nth order root is divided by the sum of the nth order roots. The weight is calculated with the following formula:

$$W_j = \frac{w_j}{\sum_{k=1}^{n} w_k} \tag{6}$$

To assess the consistency of the factors, consistency index ($CI$) eigenvalue ($\lambda$) and consistency ratio ($CR$) values are calculated. To find the eigenvalue, first all columns of the $B'$ matrix are summed with the following formula:

$$c_j = \sum_{i=1}^{n} b_{ij} \quad (7)$$

The sum of each column is multiplied by the previously calculated weighting ($W_j$) and the sum of the multiplied values is calculated. The following formula is used for this process:

$$\lambda_{max} = \sum_{j=1}^{n} W_j \times c_j \quad (8)$$

The consistency index ($CI$) is calculated as follows:

$$CI = \frac{\lambda_{max} - (n-1)}{n} \quad (9)$$

The $CI$ value obtained after these steps is used for the consistency check in the AHP method. A lower $CI$ value indicates a higher consistency between the criteria.

The last step in the consistency calculation, the consistency ratio ($CR$) value, is calculated together with the random value index ($RI$), which provides reference values. The $RI$ value for the method is calculated by taking into account the fixed value ranges corresponding to the number of criteria as specified in the Table 5.

$$CR = \frac{CI}{RI} \quad (10)$$

**Table 5.** Random value index.

| *n* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| *RI* | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

If the consistency ratio ($CR$) < 0.10, the decision maker's pairwise comparisons are relatively consistent. If the consistency ratio ($CR$) > 0.10, the decision maker should consider re-evaluating their pairwise comparisons—the source(s) of the lack of consistency should be identified and resolved and the analysis redone.

### *3.3. Development of a Peri-Urban Scale*

Population (A1)

The population variable serves as a threshold value widely employed by many countries in defining rural and urban settlements [34–36]. This identification parameter is also adopted by organizations such as the OECD and Eurostat. The OECD [37] delineates rural and urban areas at national, regional, and local levels, establishing a typology classification based on NUTS definitions. In Turkey, urban settlements are defined with a lower population limit of 20,000, which forms the basis of this study. Demography varies across countries, leading to differing settlement definitions.

In the methodology of this study, the sample area comprises a medium-sized city, and there have been no significant changes in urban demographics over the years. Therefore, the population scale is categorized on a scale of 1–5 through a review of the existing literature. Metropolitan and rural scales are excluded from the evaluation due to their deviation from the current sample area's limitations. The parameter for small and medium-sized cities is assessed by extending the range [38,39]. The peri-urban scale for population change is presented in Table 6.

**Table 6.** Classification of urban sizes based on population with detailed subcategories for cities and corresponding peri-urban scale.

| Population | Classification | Peri-Urban Scale |
|---|---|---|
| 10,000–19,000 | Village/Town | - |
| 20,000–29,000 | Lower small-sized city | 1 |
| 30,000–39,000 | Medium small-sized city | 1 |
| 40,000–49,000 | Upper small-sized city | 1 |
| 50,000–59,000 | First Degree Lower medium-sized city | 2 |
| 60,000–69,000 | Second Degree Lower medium-sized city | 2 |
| 70,000–79,000 | First Degree Medium medium-sized city | 3 |
| 80,000–89,000 | Second Degree Medium medium-sized city | 3 |
| 90,000–99,000 | Third Degree Medium medium-sized city | 4 |
| 100,000–299,000 | Medium medium-sized city | 4 |
| 300,000–399,000 | Lower Upper medium-sized city | 5 |
| 400,000–499,000 | Upper Upper medium-sized city | 5 |
| 500,000–999,000<br>1 million + | Metropol | - |

Age Distribution (A2)

This dynamic aims to examine the demographic effects of peri-urbanization by analyzing changes across different age groups. The population composition of settlements is often interpreted in terms of the labor force, with rural areas typically having a higher proportion of elderly residents, while urban areas tend to have a younger population due to employment opportunities and urbanization.

The World Health Organization's 5-group age scale, which categorizes individuals by age, serves as the value scale for this parameter. The index range below is derived from the age ranges provided by the Turkish Statistical Institute (TurkStat). Table 7 below illustrates this scale.

**Table 7.** Age classification and corresponding peri-urban scale.

| Age | Peri-Urban Scale |
|---|---|
| 0–14 | 5 |
| 15–34 | 4 |
| 35–49 | 3 |
| 50–64 | 2 |
| 65+ | 1 |

Net Migration Rate (A3)

The role of migration rates in the dynamics of peri-urbanization is multifaceted and can be analyzed from various perspectives. In this study, migration rates are examined in terms of their spatial dynamics, particularly how they influence population density and settlement patterns within a given region. A high migration rate in a region often leads to concentrated population growth in urban areas, resulting in increased construction pace in residential areas, heightened infrastructure demands, and potentially amplified environmental impacts. These circumstances are reflected by higher values on the peri-urbanization scale. Conversely, regions with low migration rates may experience more controlled expansion of settlements, potentially resulting in lower environmental impacts and a more distinct rural character. In such cases, peri-urbanization is characterized by lower values on the scale.

Net migration rate data are sourced from TurkStat and scaled within the peri-urban scale, with the lowest value representing a net migration rate of 50% equating to 1, and the highest value representing a net migration rate of −50% equating to 5.

Education attainment levels (A4)

Urban areas with high levels of education are typically characterized by dense populations and well-developed infrastructure, whereas areas with lower levels of education may exhibit limited infrastructure. Additionally, education level directly correlates with factors such as employment opportunities, social development, and quality of life. In this context, evaluating education levels within the peri-urban scale can help determine the degree of peri-urbanization of settlements; regions with higher education levels generally receive higher rankings, while regions with lower education levels may rank lower. Assuming that education levels increase with urbanization and decrease in rural areas, the scale is standardized between 1 and 5 and presented in Table 8.

**Table 8.** Classification of education attainment levels and their corresponding peri-urban Scale.

| Education Attainment Levels | Peri-Urban Scale |
|---|---|
| Illiterate | 1 |
| Primary and Secondary Education and Equivalent | 2 |
| High School and Equivalent Graduation | 3 |
| Higher Education Graduation | 4 |
| Master's Degree and Above | 5 |

SGK-Registered Population (B1)

This parameter, reflecting the Social Security Institution of Turkey (SGK)-registered population in settlements, serves as a significant indicator of economic and social structure, labor force status, and quality of life within a region. A high SGK-registered population is typically concentrated in urban areas, reflecting the economic dynamics of these regions. It also plays a crucial role in determining labor force potential and employment opportunities, thereby influencing the level of development and living standards in urban areas.

Regions with a low SGK-registered population often exhibit a more rural character and may be considered economically weaker. Evaluating the SGK-registered population within the peri-urban scale can serve as a pivotal criterion for determining the level of peri-urbanization in settlements. Regions with high SGK-registered populations are generally regarded as more developed and peri-urbanized, while those with low SGK-registered populations may receive lower rankings.

For this parameter, the ratio of SGK-registered population to total population is used as the scale value. The index range of the parameter is determined based on the provinces in Turkey with the highest and lowest SGK rates. Accordingly, 15% and below equates to 1, while 35% and above equates to 5.

Urban Crop Production (B2)

Crop production serves as a vital measure reflecting a region's agricultural potential, productivity, and environmental sustainability. The regions with high crop production potential are typically situated in rural areas with agriculture-based economies, where agricultural activities are paramount. Agriculture holds significant economic and social importance in these regions, playing a pivotal role in local economic revitalization.

Conversely, regions with low crop production potential may exhibit a more urban character, with agriculture playing a less significant economic role. Evaluating the crop production parameter within the peri-urban scale can serve as a crucial criterion for determining the level of peri-urbanization in settlements.

The scale range for this parameter is based on the provinces in Turkey with the highest and lowest crop production ton/decare ratios. Accordingly, if the ratio is 1, the parameter scale is assigned a value of 1, whereas if the ratio is 0, the parameter scale is assigned a value of 5.

Urban Livestock Production (B3)

Regions with high livestock production potential are typically found in rural areas, where agriculture is a dominant economic sector. In these regions, livestock production plays a crucial role in stimulating the local economy and boosting agricultural income.

Conversely, regions with low livestock production potential tend to exhibit a more urban character, with livestock production being less economically significant in urban areas. Evaluating the livestock production parameter within the peri-urban scale can serve as a key criterion for determining the level of peri-urbanization in settlements. Regions with high livestock production potential generally possess more advanced agricultural infrastructure and animal husbandry techniques, reflecting a less peri-urban and more rural characteristic in the peri-urbanization process.

The scale range for this parameter is based on the provinces in Turkey with the highest and lowest livestock/hectare ratios. Accordingly, if this ratio is 2 or above, the scale value is assigned a value of 1, whereas if it is 0, the scale value is assigned a value of 5.

Distance of Residential Parcels to Main Road (C1)

Peri-urbanization is characterized by the rapid development of alternative housing patterns along or near the main road axis of urban areas. As the population grows and the demand for new settlements increases, cities expand towards their peripheries. This expansion results in new settlement areas being established further away from the main road as existing settlements expand along the road.

The scale for this parameter is based on the distance of residential parcels to the main road. It is scaled as 1 for distances of 1 km and below, and 5 for distances of 5 km and above, taking into account the average size of medium-sized urban settlements.

Distance of Residential Parcels to the City Center (C2)

The trend of moving away from the city center over time is a prominent characteristic of urban fringing. The gradual relocation of residential building-built parcels away from the city center not only signifies the city's expansion but also indicates a shift away from urban amenities, leading to the creation of new centers as residential areas disperse. In this context, the movement of residential settlements away from the center reflects the peri-urban growth in a direct manner. In areas with a low peri-urban indicator, housing tends to be situated closer to the city center, whereas in areas with a high peri-urban indicator, housing is typically located further away from the city center.

The scale for this parameter ranges from 1 for distances of 1 km and below to 5 for distances of 10 km and above, taking into consideration the average size of medium-sized urban settlements.

Green Space/Housing Ratio in Built Parcels (C3)

In areas with a high peri-urban indicator, there is typically an increase in building density and a decrease in the ratio of housing to green space within the built parcel. This suggests that settlements become more densely populated and congested, with fewer environmental areas. Conversely, regions with lower peri-urban indicators may exhibit lower building density and a higher ratio of housing to green space within the built parcel.

Within the same urban settlement boundary, a continual increase in the built ratio results in a decrease in green space. Consequently, as the ratio increases, peri-urbanization decreases, whereas as when the ratio decreases, peri-urbanization increases, under the assumption that urbanization leads to increased peri-urbanization.

The scale for this parameter ranges from 1 if the ratio is 60% and above, to 5 if the ratio is 10% and below, considering the average size of medium-sized urban settlements.

Urban Fabric Integration (D1)

This parameter pertains to the expansion of building areas on the same surface area with increasing urbanization, leading to growth towards the fringe areas that characterize peri-urbanization. Consequently, existing settlement boundaries are compressed due to intensified construction, resulting in increased construction in more distant parts of the city.

This parameter is calculated as the ratio of built-up parcel area to urban area. Considering the average growth percentages of medium-sized urban settlements in Turkey, the index range is scaled as 1 for 0.5% and below, and 5 for 5% and above.

Public Housing to Plot Ratio (D2)

One of the key indicators of rising urbanization is the expansion of public housing construction. State-sponsored public housing has emerged as a response to the increasing housing demands of the growing urban population. The Housing Development Administration of Turkey (TOKİ) buildings, prevalent in nearly every city across Turkey, have been developed for this purpose.

In this parameter, the increase in TOKİ constructions is evaluated in relation to the parcel size of the settlement. It is calculated as the ratio of the TOKİ settlement area to the total housing parcel area of the city. An increase in this ratio signifies a higher density of public housing (TOKİ) within the settlement, indicating an increase in peri-urbanization. Conversely, a decrease in this ratio indicates a reduction in peri-urbanization.

Considering the TOKİ areas in medium-sized urban settlements in Turkey, the scale range for this parameter is set as 1 for ratios of 1% and below, and 5 for ratios of 5% and above.

Agricultural Land to Urban Area Ratio (D3)

Agriculture is considered the primary economic component of rural settlements. However, with increasing urbanization, the transformation of geographical areas into residential textures leads to a reduction in agricultural land. Consequently, the ratio of agricultural land to the city center within the same urban area becomes a key indicator of urbanization trends.

As urbanization intensifies and agricultural areas diminish, the settlement gradually extends towards the fringes of the city center. A decrease in this ratio signifies an increase in peri-urbanization, while an increase indicates a decrease in peri-urbanization.

The scale for this parameter is determined based on the provinces with the highest and lowest proportions of agricultural land in Turkey. A ratio of 0.6 and above is scaled as 1, indicating lower peri-urbanization, whereas a ratio of 0 is scaled as 5, indicating higher peri-urbanization.

Housing density (D4)

The expansion of housing areas within a settlement signifies an increase in urbanization, driven by the growing population's demand for housing and access to urban amenities. Once the central business district (CBD) areas reach structural saturation, residential construction tends to extend towards the outskirts of the city, leading to urban fringe development and peri-urbanization.

In peri-urbanization, housing expansion beyond the central areas is also influenced by urban dwellers' preference for living outside the city center, often seeking low-rise or garden housing options.

This parameter is calculated as the ratio of housing parcel area to built-up area. Considering the typical housing parcel sizes in medium-sized urban settlements in Turkey, the index range is scaled as 1 for ratios of 10% and below, and 5 for ratios of 80% and above.

### *3.4. Peri-Urban Index Formulation*

Multiple methods are proposed for analyzing settlement patterns. Among these, the AHP method is employed to establish a hierarchy among selected dynamics through expert opinions and to determine their weight values. The dynamics chosen for settlement analysis are then scaled to fit within a standardized range of 1–5. While both methods can be used independently to analyze the peri-urban process or status of settlement textures, combining them yields a mathematical peri-urban index.

To calculate the peri-urban index (PUI), the following formula is proposed, utilizing the weight values of parameters obtained from AHP and the scale of selected peri-urban dynamics together.

$$PUI = \sum_{i=1}^{n} W_i \left( \sum_{j=1}^{m} w_{ij} P_{ij} \right) \quad (11)$$

where $n$ is the number of primary dynamics; $W_i$ is the weight value of each primary dynamic obtained from AHP; m is the number of secondary dynamics; $w_{ij}$ is the weight value of each secondary dynamic obtained from AHP; and $P_{ij}$ is the peri-urban scale (PUS) of each secondary dynamic.

Given that the PUS values vary across different ranges for each dynamic, normalization and scaling are necessary when incorporating them into the peri-urban index (*PUI*) calculation. Normalization is a commonly used scientific method for comparing data with different scales, allowing all data to be expressed within a similar range. The following formulas are utilized for normalization and scaling:

$$\overline{N} = \frac{n - n_{min}}{n_{max} - n_{min}} \quad (12)$$

$$P = (\overline{N} * 4) + 1 \quad (13)$$

where $\overline{N}$ represents the normalized data value; $n_{max}$ and $n_{min}$ denote the highest and lowest values in the data, respectively; and P corresponds to the scaled dynamic value within the range of 1–5.

## 4. Results

The results of this study are presented in three main sections. The first section details the outcomes of the AHP, the second section evaluates the application of peri-urban dynamics through a case study, and the third section presents the calculations and findings of the developed peri-urban index as applied to the case study.

### *4.1. AHP Results*

This study analyzed four primary (main) and a total of fourteen secondary (sub) parameters. The first main parameter, Socio-Demographic (A), includes four sub-parameters: A1—population, A2—age distribution, A3—net migration rate, and A4—Education attainment levels. The second main dynamic, Economy–Employment (B), includes three sub-parameters: B1—SGK-registered population, B2—urban crop production, and B3—urban livestock production. The third main dynamic, Land Use–Accessibility (C), consists of three sub-parameters: C1—distance of residential parcels to main road, C2—distance of residential parcels to the city center, and C3—green space/housing ratio in built parcels. Finally, the fourth main dynamic, Settlement Texture Pattern (D), consists of four sub-parameters: D1—urban fabric integration, D2—public housing to plot ratio, D3—agricultural land to urban area ratio, and D4—housing density.

The parameters were evaluated by 27 architecture and urban planning academicians who are experts in their fields. The evaluation of the parameters was conducted using the AHP method in the form of pairwise comparisons. All responses provided in the questionnaire were assessed for consistency using matrices created by pairwise comparisons. The responses with a consistency ratio of <0.10 were selected to determine their weights. Based on these data, the weighted values of each dynamic were calculated, and their averages were ranked.

The weighted hierarchical ranking of the parameters according to the AHP results is presented in Figure 4. Among the primary parameters, Land Use–Accessibility (C) is the most significant, while Socio-Demographic (A) is the least significant, ranked as C > B > D > A. For the secondary parameters within Socio-Demographic (A), education attainment levels (A4) hold the highest importance, and age distribution (A2) holds the lowest, with the ranking A4 > A3 > A1 > A2 (Figure 4b). Similarly, within Economy–Employment (B), SGK-registered population (B1) is the most critical, and urban livestock production (B3) the least, ranked B1 > B2 > B3 (Figure 4b). For Land Use–Accessibility (C), the distance of residential settlement parcels to the city center (C2) is the most important, and the Distance of Residential Parcels to Main Roads (C1) is the least, ranked C2 > C3 > C1 (Figure 4b). Lastly, within Settlement Texture Pattern (D), urban fabric integration (D1) is the most significant, while public housing to plot ratio (D2) is the least, ranked D1 > D3 > D4 > D2 (Figure 4b).

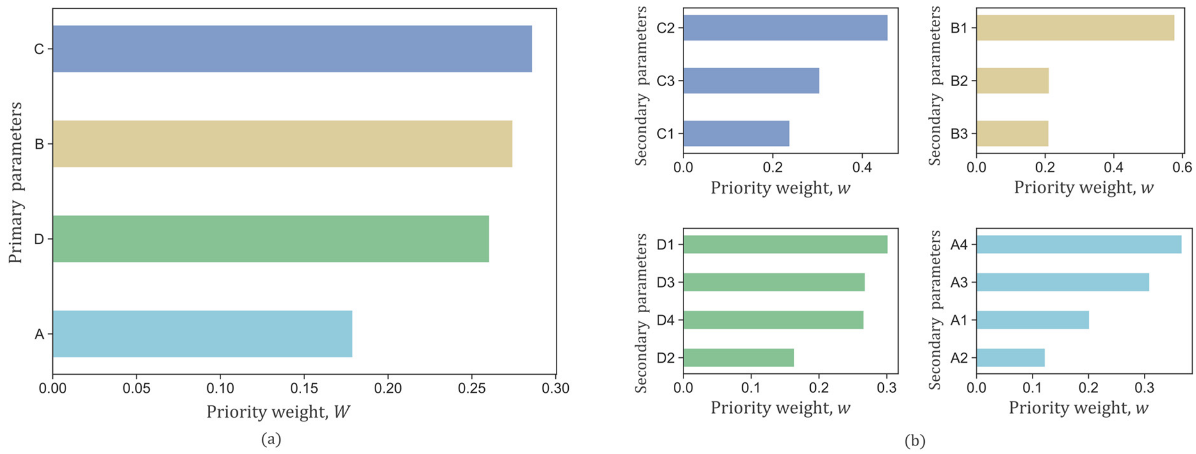


**Figure 4.** The results of the AHP hierarchical ranking of parameters. (**a**) primary parameters, (**b**) secondary parameters.

### 4.2. Peri-Urban Dynamics Evaluation for Case Study

In this study, Yozgat province in Turkey was chosen as the case study (Figure 5). Yozgat boasts a rich historical background, having been inhabited by numerous civilizations including the Hittites, Phrygians, Medes, Persians, Romans, and the Byzantine Empire [40]. This historical trajectory extends back to the pre-Republican era and continued to evolve through the end of the 17th century, eventually shaping its present-day urban structure.

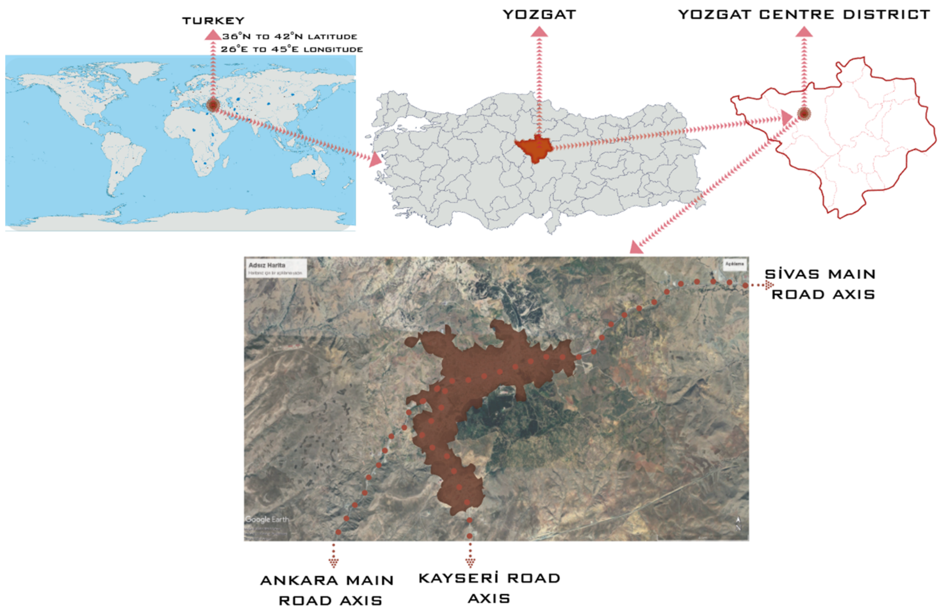


**Figure 5.** Yozgat province in Turkey.

When examining the historical context of Yozgat, the city is primarily characterized by traditional Anatolian structures, primarily mosques and marketplaces. However, over time, factors such as technological advancements and increasing population have significantly altered the urban morphology and identity. Particularly, developments during the Republican era have led to the emergence of symbolic structures like the clock tower, which have bestowed a new identity upon the city [40].

The city center, primarily the business district, initially formed around the clock tower and the Çapanoğlu Mosque, expanded northeastward in subsequent years along Lise Avenue and Fuar Avenue. During this expansion process, the increase in public and commercial buildings played a significant role alongside the integration of the city park and recreational area (Figure 6).


**Figure 6.** Illustration of central Yozgat highlighting the CBD areas, major streets, and landmarks.

The urban sprawl of Yozgat has occurred along five main axes. Starting from the city center, new settlement areas have formed along the Yozgat–Sivas highway (A), Yozgat Central–Kentpark axis (B), Yozgat–Çorum axis (C), Yozgat–Ankara highway (D), and Yozgat–Kayseri axis (E). In this sprawl process, the limiting effect of natural factors such as topographic structure and Çamlık National Park has been significant (Figure 7).


**Figure 7.** Illustration of urban growth axes in Yozgat city center.

The expansion and evolution of the main road axes in the city center have been strengthened through fostering relationships with neighboring municipalities. New dynamics such as the university campus area and the expansion process along the road corridor have played a significant role in the city's development.

As a result, the Yozgat region has become a focal point with semi-rural and semi-urban characteristics. While rural economic activities such as agriculture and animal husbandry are prevalent in the city center and its surroundings, there exists a distinct urban economic structure in both the public and private sectors. This indicates that despite not being industry-focused, the city has developed in harmony with both urban and rural economic aspects.

Data for the selected Yozgat province was provided by TurkStat and the Yozgat Municipality. Since the oldest available data for the relevant city was from 2007 in the TurkStat database, the analysis timeline started from the year 2007.

Socio-Demographics (A)

The socio-demographic changes in Yozgat over the years are presented in Figure 8. When examining the parameter of population change (A1) (Figure 8a), it is observed that the population of the city center increased from 72,183 in 2007 to 92,643 in 2022. The PUS values for this dynamic are noted as 3 between 2007 and 2014, 3.5 between 2015 and 2017, and 4 after 2017. It can be concluded that the population in the city is increasing and urbanization is growing in parallel.

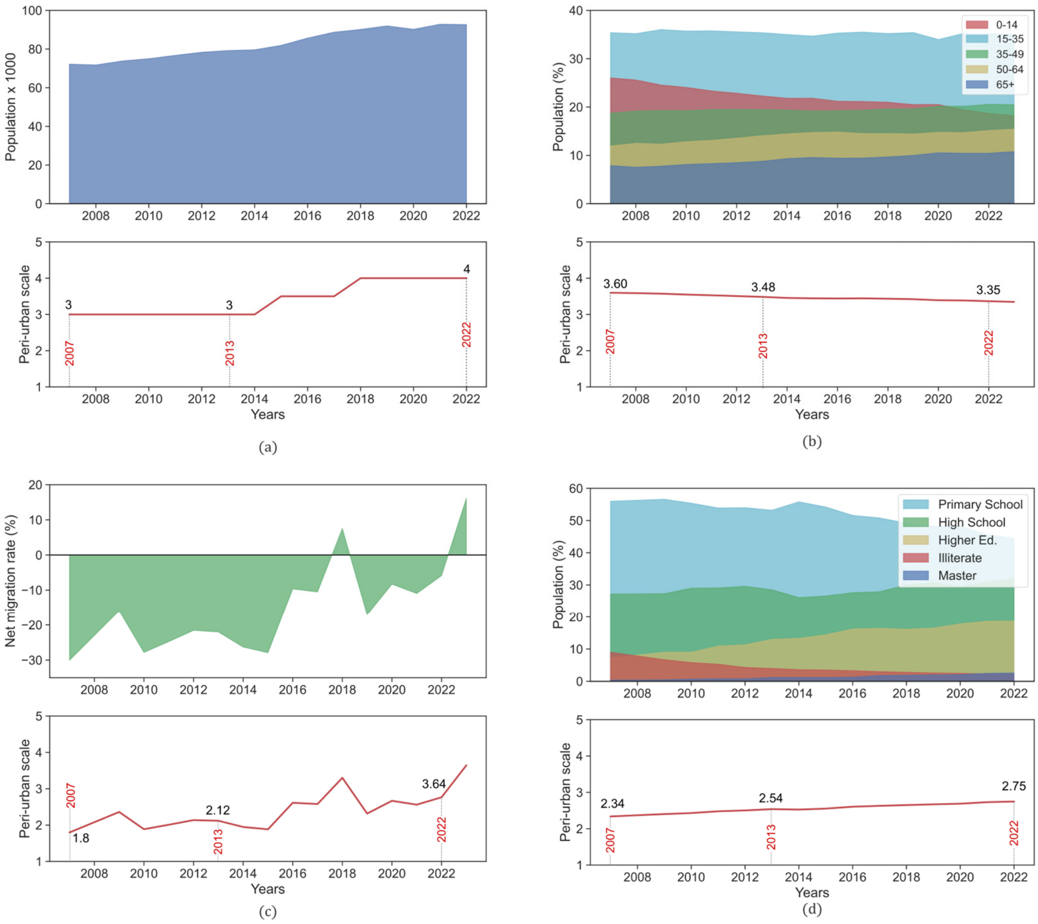


**Figure 8.** Changes in socio-demographic dynamics over the years. (**a**) Population; (**b**) age distribution; (**c**) net migration rate; (**d**) education attainment levels.

Figure 8b illustrates the changes in age groups as proportions of the total population. Regarding the age distribution (A2) parameter, it is observed that the proportion of the 0–14 age group within the total population has decreased over the years. While there has not been much change in the 15–35 age group, a slight increase in the proportion of the population aged 35 and above is observed. Despite minimal changes, the PUS value has decreased from 3.60 in 2007 to 3.36 in 2022.

The change in net migration rate (A3) over the years is presented in Figure 8c. It is observed that until 2018, the net migration rate of the city was negative, indicating that the migration it received was less than the migration it gave out. In 2018, there was a short period where the migration received exceeded the migration given, resulting in a briefly positive net migration rate. Although the overall net migration rate of the city briefly decreased after 2018, it returned to a positive value in 2022. This trend is also reflected in the total increase in the PUS value due to net migration rate.

The last sub-parameter under the Socio-Demographic heading, education levels (A4), is presented in Figure 8d. As the illiteracy rate is generally decreasing, there is also an overall increase in education levels over the years. The proportion of individuals with higher education increased from 7.3% in 2007 to 18.7% in 2022, and the proportion of individuals with a Master's degree increased from 0.4% in 2007 to 2.6% in 2022. This result has raised the PUS value of the relevant parameter from 2.34 in 2007 to 2.75.

Economy–Employment (B)

The change in Economy–Employment (B) of Yozgat, the selected sample area, over the years is depicted in Figure 9. When analyzing the SGK-registered population (B1) parameter, it is observed that it was 12% in 2007 and increased to 23% by 2022 (Figure 9a), indicating a general upward trend. Concurrently, the peri-urbanization score (PUS) for this parameter rose from 1.26 in 2007 to 2.69 in 2022.

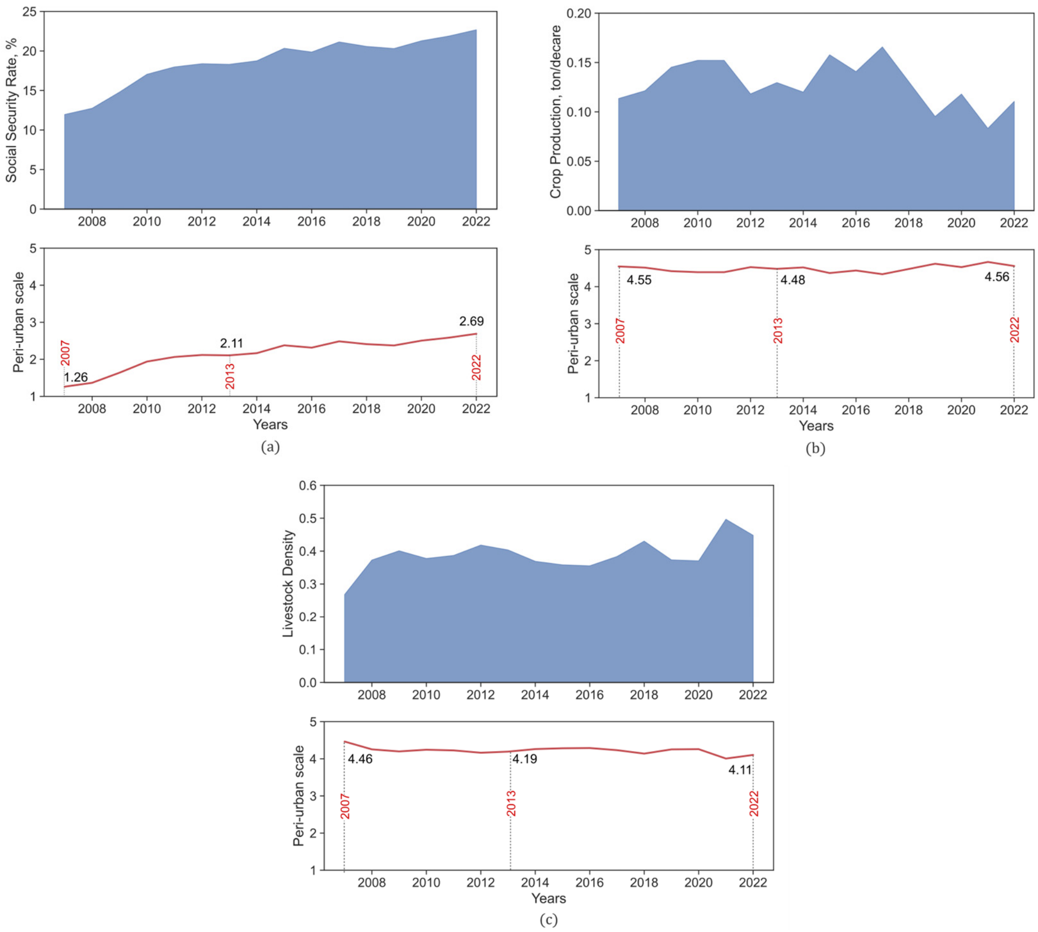


**Figure 9.** Economy–employment (B) dynamic changes over the years. (**a**) SGK-registered population; (**b**) urban crop production; (**c**) livestock density.

The urban crop production (B2) parameter is illustrated in Figure 9b, showing minimal changes in total production over the years. Although the crop production rate remained at 0.11 from 2007 to 2022, with slight fluctuations in intermediate years, the PUS value remained constant at 4.55. Consequently, there has been no substantial alteration in the quality of peri-centralization within the city over the years regarding this parameter.

The livestock density (B3), the final sub-parameter of Economy–Employment (B), is presented in Figure 9c. Similar to the crop production parameter, there is a minimal change observed over the years, albeit a decrease in the PUS value from 4.46 in 2007 to 4.10 in 2022. This decline is primarily attributed to the increase in the livestock density value post 2020. As with crop production, this parameter, crucial to the rural economy, is anticipated to be inversely proportional to urbanization. Hence, it can be inferred that there has been a slight decline in the quality of peri-centralization within the city over the years concerning this parameter.

Land Use–Accessibility (C)

The evolution of Land Use–Accessibility (C) in Yozgat over the years is depicted in Figures 10 and 11. Data from the Yozgat Municipality were utilized for this parameter, with records available for the years 2007, 2013, and 2022. Secondary parameter calculations for parameter C were conducted using vector maps, GIS, and CAD programs.

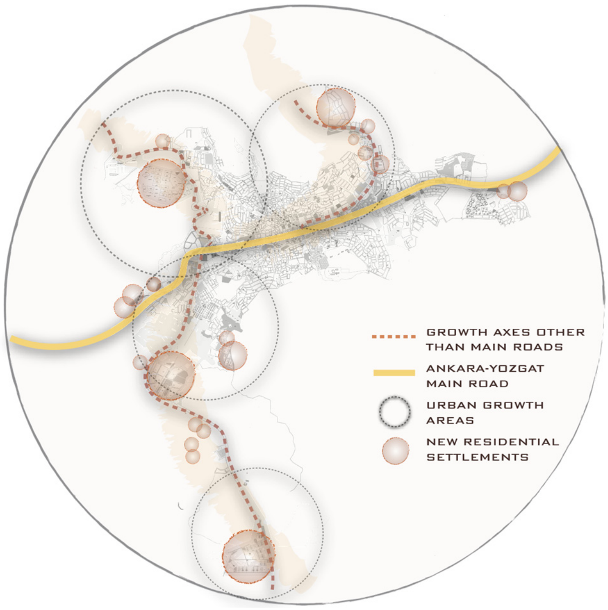


**Figure 10.** Selected axes for the distance of residential parcels to main road (C1) parameter.

In this study, the peripheral regions around Yozgat city center were delineated along five primary axes: (A) Yozgat–Sivas main road axis, (B) Yozgat–Kentpark road axis, (C) Yozgat–Çorum road axis, (D) Yozgat–Ankara main road axis, and (E) Yozgat–Kayseri road axis. For the distance of residential parcels to main road (C1) parameter, the Ankara–Yozgat main arterial road was chosen as the reference route. Along this main artery, axes A and D intersect; thus, calculations for parameter C1 were based on the distances from settlements along the three designated axes, as depicted in Figure 10. The calculation method involved determining the straight-line distance from the midpoint of the farthest settlement block/parcel to the main road along the three axes for the specified years. The numerical results are presented in Figure 11a. Assuming that an increase in distance to the main road within urban settlements signifies a shift towards the city's periphery, it is observed that there was minimal change in these distances between 2007 and 2013. However, between 2013 and 2022, the city expanded further away from the main road. The peri-urbanization scores (PUS) for this parameter was 1.61, 1.58, and 4.34 in 2007, 2013, and 2022, respectively, indicating rapid peri-urbanization between 2013 and 2022.

The analysis of the distance of residential parcels to the city center (C2) parameter was conducted based on the five peri-urban extensions of residential settlements in the central district of Yozgat. The distances to key landmarks in what was considered to be the central business district (CBD) of the city—Çapanoğlu Mosque, Clock Tower, Kentpark, and Lise–Fuar Street axes—were measured along the vehicular transportation route.

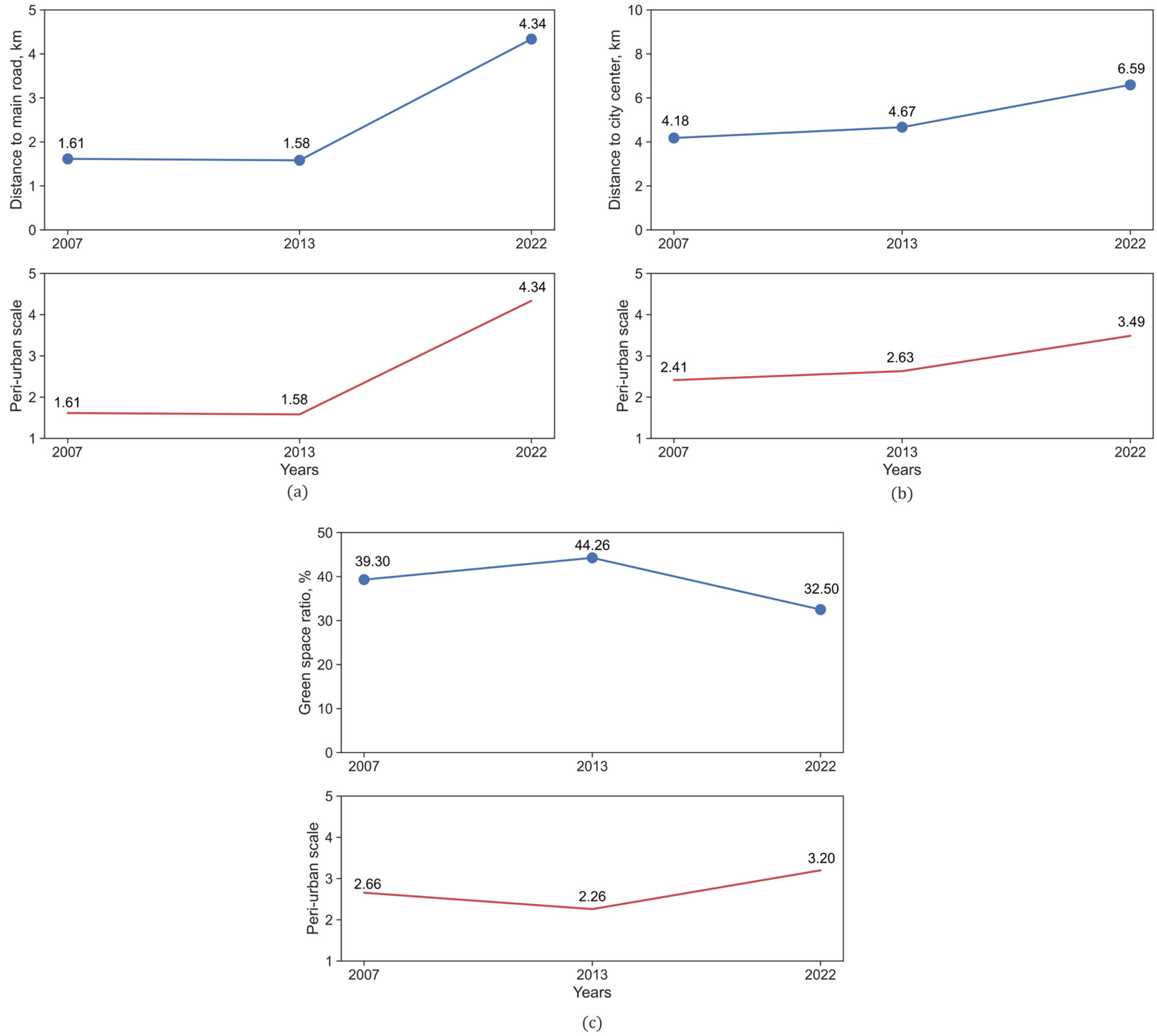


**Figure 11.** Land use–accessibility (C) dynamics over the years. (**a**) Distance of residential parcels to main road; (**b**) distance of residential parcels to the city center; (**c**) green space/housing ratio in built parcels.

Using GIS and CAD programs, the settlement textures in the sample area were identified, and the distances from the midpoint of residential parcels to the CBD midpoint along the road track were measured for the five urban settlement fringes identified in Figure 7, as shown in Figure 11b. The calculation involved measuring the distance from the midpoint of each residential parcel to the CBD midpoint and taking the weighted average of changes along the A–E road axes for the years 2007, 2013, and 2022.

The location of settlements further from the city center signifies an increase in the peri-urbanization index. As peri-urbanization progresses, the distance to the city center generally increases. The weighted average distance to the city center was 4.2 km in 2007, 4.7 km in 2013, and 6.6 km in 2022. The peri-urbanization score (PUS) values for the parameter were calculated as 2.41, 2.63, and 3.49, respectively.

Thus, it is evident that from 2007 to 2022 the distance of settlements from the city center gradually increased, and the pericentric nature of the settlement expanded proportionally.

The green space ratio values, the final secondary parameter of the Land Use–Accessibility (C) parameter, are depicted in Figure 11c. Within this parameter, it is observed that the green space ratio within the same settlement boundary was 39.3% in 2007, increased to 44.3% in 2013, and decreased to 32.5% in 2022. The fluctuation in the green area ratio within the same settlement area can be interpreted as a consequence of overall urban development, where increased built-up areas result in a reduction in green spaces within parcels. In this context, the peri-urbanization score (PUS) values for the respective years were calculated as 2.66, 2.26, and 3.20, respectively. Despite a slight decrease in the PUS values from 2007 to 2013, the values between 2013 and 2022 indicate a decline in green area texture within the built environment, signaling an increase in urbanization intensity.

Settlement Texture Pattern (D)

The change in the settlement texture pattern (D) of Yozgat, which was selected for the sample area, over the years is given in Figures 12 and 13. In the D parameter, data obtained from Yozgat Municipality were used and data for 2007, 2013, and 2022 were available from these numerical data. All secondary parameter calculations of the D parameter were performed by means of vector maps, GIS, and CAD programs. The urban fabric integration (D1) parameter shows the ratio of the number of building plots–parcels within the borders of Yozgat central district to the surface area of Yozgat central district, the density of construction, and the integration of the structure in the existing texture (Figure 13a). This ratio was calculated as 0.58% for 2007, 1.04% for 2013, and 1.11% for 2022. It is seen that there is a continuous increase in the percentage ratios over the years. However, the PUS values of the relevant years were calculated as 1.07, 1.48, and 1.54, respectively, close to the lower bar of the peri-urban scale. As this ratio increases, peri-urbanization will increase and as the ratio decreases, peri-urbanization will decrease. Although the overall PUS values of the D1 parameter are low, the increase over the years emphasizes the increase in the peri-urbanization rate of the city according to the relevant parameter.

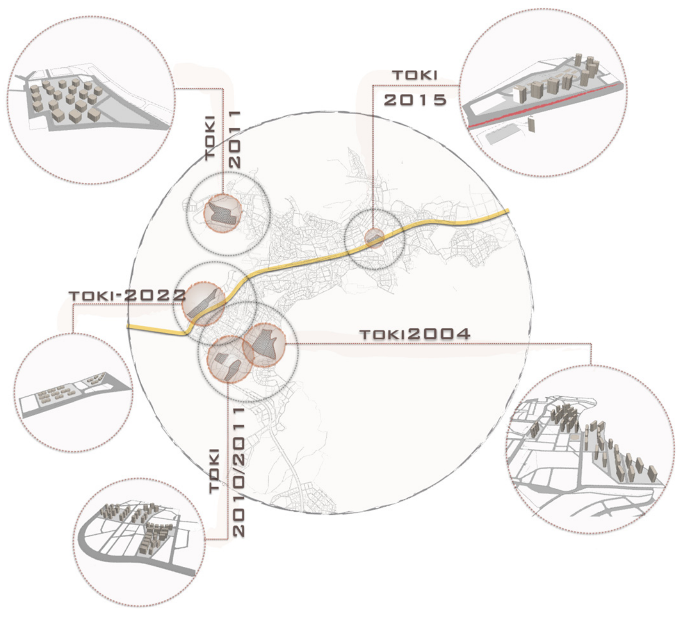


**Figure 12.** Locations and construction years of TOKİ settlements in Yozgat city center.

The public housing to plot ratio (D2) parameter calculates the ratio of public housing parcel area to the Yozgat central district housing parcel area, as shown in Figure 13b. The rates for the D2 parameter were 2.74% in 2007, 3.22% in 2013, and 3.67% in 2022, indicating an increase over the years. The corresponding peri-urbanization score (PUS) values for the parameter are 2.74, 3.22, and 3.67. The rise in the rate of public housing construction by TOKİ within the study area suggests that the city's housing demand is being addressed with governmental support, contributing to the continuous expansion of the city. Furthermore, as illustrated in Figure 12, the predominance of TOKİ settlements in the fringe areas of the city is a significant factor driving peri-urbanization within Yozgat.

The agricultural land to urban area ratio (D3) parameter for the sample area indicates a decline over the years, as illustrated in Figure 13c. Between 2007 and 2013, there was a notable decrease, which continued, albeit to a lesser extent, between 2013 and 2022. The ratio of agricultural land area to urban area in the city was calculated as 55% in 2007, 40% in 2013, and 39% in 2022. While agricultural areas do exist in small quantities within city centers, they are predominantly situated farther away from the center. The reduction in agricultural areas signifies the city's expansion from the center towards the outskirts. The peri-urbanization score (PUS) values for the D3 parameter were calculated as 1.33, 2.34, and 2.42 for the corresponding years. The increase in PUS values suggests that agricultural land in the city center have been supplanted by residential and urban developments, indicating a rise in urbanization intensity, which could directly impact peri-urbanization.

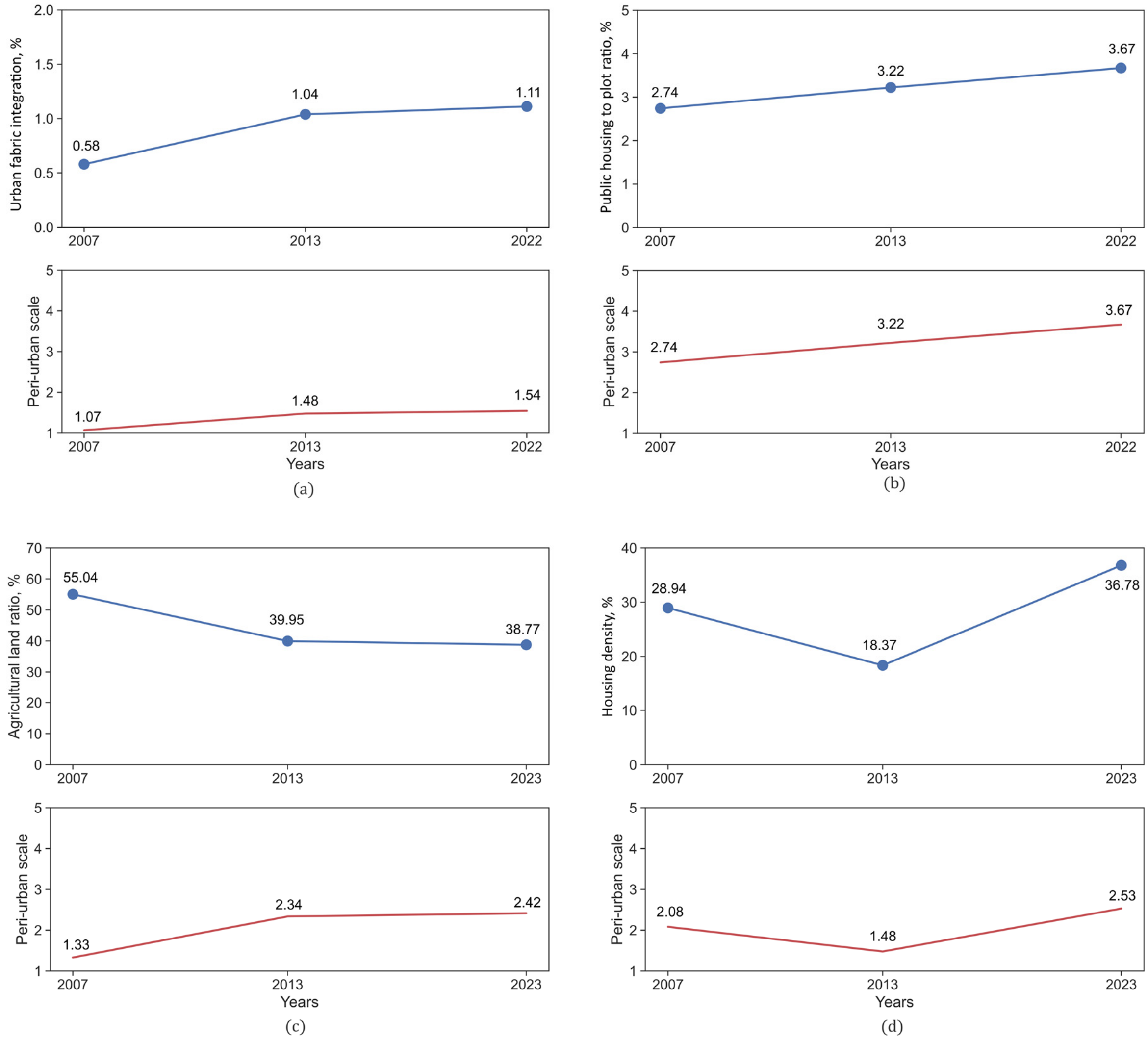


**Figure 13.** Change in settlement texture pattern (D) dynamics over the years. (**a**) Urban fabric integration; (**b**) public housing to plot ratio; (**c**) agricultural land to urban area ratio; (**d**) housing density.

The housing density (D4) values, the last secondary parameter of the Settlement Texture Pattern (D) parameter, are presented in Figure 13d. This parameter calculates the ratio of Yozgat housing parcel area to the Yozgat center built-up block-parcel area, indicating the extent of housing parcel increase within the city center boundaries. The ratio was calculated as 28.94% in 2007, 18.36% in 2013, and 36.78% in 2022. Notably, there was a percentage decrease between 2007 and 2013. However, this decrease reflects a change in rate, rather than a decrease in actual housing construction. In reality, the housing parcel area increased between 2007 and 2013; however, the percentage calculation shows a decrease due to a comparatively greater increase in the built block-parcel area in Yozgat center in 2013.

The denominator used in the calculation accounts for this discrepancy; since the built-up built parcel area of Yozgat center changed less in 2022 compared to 2007–2013, and the housing parcel area of Yozgat increased more, the difference widened accordingly. Based on these calculations, the peri-urbanization score (PUS) values were found to be 2.08, 1.48, and 2.53.

### *4.3. Peri-Urban Index Calculation for Case Study*

The parameter data collected for the sample area were calculated according to the determined peri-urbanization score (PUS) value range and are presented in Table 9 for the years 2007, 2013, and 2022. Additionally, the AHP results are provided in Table 10. Using the values from these tables, the peri-urbanization index (PUI) was calculated for the sample city using the method presented in Equation (11). The change in PUI between 2017 and 2022 is illustrated in Figure 14.

**Table 9.** Case study (Yozgat) PUS values for investigated dynamics.

| | *p* Values (PUS) | | |
|---|---|---|---|
| **Secondary Parameters** | **2007** | **2013** | **2022** |
| A1 | 3 | 3 | 4 |
| A2 | 3.597 | 3.484 | 3.345 |
| A3 | 1.798 | 2.12 | 3.64 |
| A4 | 2.338 | 2.54 | 2.75 |
| B1 | 1.262 | 2.11 | 2.69 |
| B2 | 4.55 | 4.48 | 4.56 |
| B3 | 4.46 | 4.19 | 4.11 |
| C1 | 1.614 | 1.58 | 4.33 |
| C2 | 2.412 | 2.63 | 3.49 |
| C3 | 2.656 | 2.26 | 3.2 |
| D1 | 1.07 | 1.48 | 1.54 |
| D2 | 2.74 | 3.22 | 3.67 |
| D3 | 1.33 | 2.34 | 2.42 |
| D4 | 2.082 | 1.48 | 2.53 |

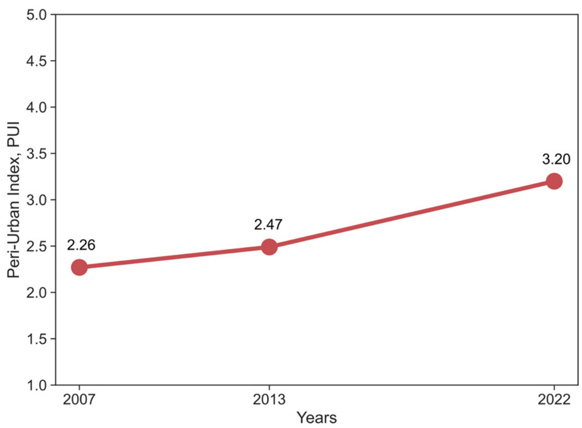


**Figure 14.** Changes in peri-urban index over the years for Yozgat.

**Table 10.** AHP results for investigated dynamics.

| Primary Parameters (W) | |
|---|---|
| A | 0.179 |
| B | 0.274 |
| C | 0.286 |
| D | 0.260 |
| Secondary Parameters (w) | |
| A1 | 0.202 |
| A2 | 0.123 |
| A3 | 0.309 |
| A4 | 0.367 |
| B1 | 0.578 |
| B2 | 0.212 |
| B3 | 0.211 |
| C1 | 0.238 |
| C2 | 0.457 |
| C3 | 0.305 |
| D1 | 0.302 |
| D2 | 0.164 |
| D3 | 0.268 |
| D4 | 0.266 |

As depicted in the figure, the PUI value for Yozgat, the sample city, has shown a consistent increase over the years. In 2007, the PUI value was 2.26, which increased to 2.47 in 2013 and further to 3.20 in 2022. The rate of increase in the PUI index between 2007 and 2022 was 41.6%.

The proposed PUI calculation method demonstrates that a quantitative assessment of peri-urbanization in a medium-sized city can be conducted based on numerical data, enabling a comprehensive evaluation of urban development dynamics over time.

- Step 1: Calculation of Weighted Averages for Secondary Parameters;

The weighted averages for the secondary parameters are calculated for each year using the secondary parameter weights ($w$) and values ($P$).

$$A_{\ year} = w_{A1}P_{A1,year} + w_{A2}P_{A2,year} + w_{A3}P_{A3,year} + w_{A4}P_{A4,year} \tag{14}$$

For example, for the year 2007, the parameter $A$ is calculated as follows:

$$A_{\ 2007} = (0.202 \times 3) + (0.123 \times 3.597) + (0.309 \times 1.798) + (0.367 \times 2.338) = 2.459 \tag{15}$$

This calculation is repeated for parameters B, C, and D.

- Step 2: Calculation of Weighted Averages for Primary Parameters

The weighted averages for primary parameters are calculated for each year using the primary parameter weights ($W$) and the previously calculated secondary parameter weighted averages.

$$PUI_{\ year} = W_A A_{year} + W_B B_{year} + W_C C_{year} + W_D D_{year} \tag{16}$$

For example, for the year 2007:

$$PUI_{\ 2007} = (0.179 \times 2.459) + (0.274 \times 2.631) + (0.286 \times 2.296) + (0.260 \times 1.682) = 2.26 \tag{17}$$

This calculation is repeated for the years 2013 and 2022.

## 5. Discussion

The findings of this study underscore the significance of the peri-urban index (PUI) as a novel numerical method for analyzing peri-urban dynamics in medium-sized cities. By examining socio-demographic, economic, and land use data, this study demonstrates how PUI can effectively evaluate urban development and peri-urbanization processes.

In medium-sized cities, an increase in the net migration rate signifies enhanced urban opportunities and improved quality of life. This trend indicates a shift in settlement preferences and population dynamics, driven by the attractiveness of urban amenities and employment prospects. The rise in educational attainment levels further supports urban development by contributing to a more skilled labor force. Higher education levels are often associated with better job opportunities, which in turn stimulate economic growth and urbanization.

The demographic shift towards an increasing working-age population and a declining proportion of young people under 14 years old indicates a more economically productive population structure. These changes enhance the labor market and support economic growth, which in turn fuels urbanization and the expansion of peri-urban areas.

As urbanization progresses, there is a notable decline in traditional rural economic activities such as agriculture and livestock production. This shift reflects the transition of medium-sized cities from rural-based economies to urban-centric economies. The increase in the number of formally employed individuals highlights the growing opportunities and the strengthening of the labor market necessary for sustaining urban development. These economic dynamics contribute significantly to the acceleration of peri-urbanization.

The increase in distance to main roads within urban settlements suggests an outward expansion of cities. This pattern is characteristic of peri-urban growth, where peripheral areas become more integrated into the urban fabric. The growing distance of residential parcels from the city center further supports the trend of peri-urbanization. As settlements expand outward, the core urban areas become less dense, and new residential zones develop in the outskirts. This model is indicative of a growing city adapting to increasing population and urban demands.

Fluctuations in the green space ratio within residential areas reveal the impact of urban development on environmental parameters. In medium-sized cities, the preservation of green spaces is a critical component of sustainable urban planning. The decline in green space ratios highlights the pressure of urbanization on open areas and underscores the need for strategic planning to balance development with environmental conservation.

Urban fabric integration in medium-sized cities is a vital indicator of peri-urbanization. The gradual integration of new urban structures into the existing fabric is crucial for maintaining urban coherence and ensuring sustainable development. The rise in the public housing to plot ratio reflects the governmental efforts to meet the housing demand, contributing to the expansion of peri-urban areas. Public housing projects, particularly those located in the city's fringe areas, play a significant role in driving peri-urbanization.

The decrease in the agricultural land to urban area ratio illustrates how urban development encroaches on traditionally rural zones. As agricultural lands are converted into residential and urban spaces, the peri-urban nature of these cities becomes more pronounced. Changes in housing density demonstrate the rapid expansion of residential areas, indicating a dynamic urban growth model that requires strategic planning to manage urban sprawl effectively.

The upward trend in the peri-urban index (PUI) highlights the increasing peri-urbanization in medium-sized cities over time. The PUI serves as a quantitative tool to assess urban expansion and the dynamics of urban development. The use of PUI in medium-sized cities provides urban planners and policymakers with a valuable metric for understanding and managing urban growth.

### 5.1. Originality and Contributions

This paper presents a comprehensive and innovative methodological framework for understanding peri-urbanization processes. By integrating the AHP and the PUS, this approach develops a novel method for quantitatively assessing peri-urbanization. The developed PUI is a unique tool designed to determine the level of peri-urbanization in medium-sized cities and allows for the comparative analysis of different urban and rural settlements. PUI provides a useful indicator for monitoring urban growth and sprawl dynamics, and supports data-driven decision-making for urban planners and policymakers. This study adds new insights to the urban development literature by emphasizing the critical role of land use and accessibility in shaping peri-urban areas. Furthermore, the proposed methodology and the practical applicability of PUI provide a scientific basis for urban management and policy-making processes, with significant contributions to future research and local government policies.

### 5.2. Limitations and Future Work

Despite the comprehensive nature of this study, several limitations exist. The AHP method serves as the primary research method of this paper and can be utilized to assess urban development. However, it is particularly important to explain and emphasize that this method is highly dependent on the subjective judgments of the evaluators. The reliability of the AHP method can be enhanced by including more experts, as data from a limited number of experts may affect the generalizability of the results. The data are limited to those data obtained from TurkStat and the Yozgat Municipality. Additionally, the municipality data, which correspond to the built parameters and form the basis for this issue, cover only a three-year period. Future research can address these limitations by utilizing larger and longer-term data sets. Additionally, the PUI methodology can be tested by adapting it to different urban and rural contexts to determine PUS ranges in these settings. Customizing the selected parameters according to local conditions can increase the flexibility and applicability of the methodology. More detailed local studies and long-term data analyses will facilitate a deeper understanding of peri-urbanization processes. Within this framework, this study can contribute to the development of more comprehensive and data-driven approaches to urban management and planning, providing a robust scientific basis for the sustainable management of urban sprawl.

## 6. Conclusions

This study aimed to provide a comprehensive analysis of both abstract and concrete parameters characterizing the macroform of urban architecture, particularly focusing on cities and their peri-urbanization processes through the integrated application of quantitative methods. Urban environments are dynamically shaped by the interplay of social and structural elements, which continuously influence each other. Key factors such as social structure, education, economy, settlement patterns, and architectural integrity function as fundamental components of urban systems.

In this research, the parameters shaping the urban environment were categorized under four primary dimensions: Socio-Demographic (A), Economy–Employment (B), Land Use–Accessibility (C), and Settlement Texture Pattern (D). Each primary dimension includes various secondary (sub) parameters, with a total of 14 secondary parameters selected for detailed examination. Each secondary parameter was assigned a PUS value (1–5) based on qualitative assessments reflecting their proximity to or distance from peri-urban characteristics. The second methodological step involved determining the weighted hierarchies of all parameters using the AHP. Expert academics with qualifications in urban and architectural fields provided pairwise comparisons for the primary and secondary categories, resulting in weighted values for each parameter. Using the PUS values and AHP weights of the dynamics, a peri-urbanization index (PUI) calculation is proposed. The key findings from the analysis are summarized as follows:

- Importance of Primary Parameters: According to the AHP results, among the four primary parameters, the highest weight value was attributed to the "Land Use-Accessibility" (C) parameter, whereas the "Socio-Demographics" (A) parameter holds the lowest weight.
- Significant Secondary Parameters: The AHP analysis reveals that the secondary parameters with the highest weight values are A4, B1, C2, and D1. These parameters are identified as education levels (A4), registered population with social security (B1), distance of residential parcels from city center (C2), and urban tissue integration (D1).
- Weighted Comparisons: When calculating the weighted percentages of the secondary parameters, the registered population with social security (B1) parameter has the highest weight, while the age distribution (A2) parameter holds the lowest weight.
- Determination of PUS Values: The PUS value range for each secondary parameter has been determined through the literature reviews, ensuring qualitative consistency. PUS values allow for a clearer evaluation of the impacts of different parameters on peri-urbanization processes and enable standardization in the assessment of various medium-sized urban areas.
- Development of PUI: By integrating AHP weights and PUS values, a peri-urbanization index (PUI) calculation method has been developed for medium-sized urban settlements. This index provides urban planners and policymakers with a quantitative tool to evaluate and compare peri-urbanization processes, serving as a strategic instrument for monitoring and managing urban sprawl and development dynamics.
- Case Study Application: The proposed PUI method has been tested through a case study, yielding significant results over time. The case study demonstrated the practical applicability and validity of the PUI method, underscoring the importance of such quantitative methods in assessing and managing peri-urbanization processes.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Ethics committee permission was obtained to conduct an online AHP survey exclusively with experts. Only information about the survey results was obtained from the participants, without collecting any personal information. This study was approved by the Ethics Committee of YOZGAT BOZOK UNIVERSITY (12/38, 20 March 2024).

**Informed Consent Statement:** This study involved a survey conducted with experts using the analytic hierarchy process (AHP) method. No personal data were collected during the survey. Therefore, written informed consent for publication is not applicable.

**Data Availability Statement:** The data presented in this study are available upon request.

**Conflicts of Interest:** The author declares no conflicts of interest.

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