Journal of Applied Sciences and Modelling
https://journal.krrishpub.com/index.php/jasm/index

RESEARCH ARTICLE

An Integrated Framework using Petri Nets and Graph Theory for Agrotourism Network Analysis in Albania

Gjovalin Deda [a], Orgest Zaka [b,*]

[a] Department of Computer Science, Faculty of Information Technology, Aleksandër Moisiu University, Durres, ALBANIA.
[b] Department of Mathematics-Informatics, Faculty of Economy and Agribusiness, Agricultural University of Tirana, ALBANIA.

Abstract

Albania has 270 certified agrotourism establishments generating over €12 million annually. Operators face long waiting times, underutilized capacity, and supply chain delays. We propose an integrated framework combining Graph theory for structural network analysis with Timed Petri Nets for dynamic process modeling, applied to the Shkodra region. Using road distances from GIS and OpenStreetMap, we construct a weighted network of 40+ centers. Structural analysis identifies Harapi (degree 4, betweenness 0.35) and Faqedol (degree 3) as the most central nodes. Accessibility analysis reveals high spatial inequality (CV = 0.52). We build and simulate a Timed Petri Net model in CPN Tools, parameterized with site visit data. The tourist flow model identifies the activity stage as the primary bottleneck (90% utilization). The supply chain model shows processing as the main constraint (4 hours average). We propose a practical step-by-step implementation framework for applying Petri Nets in agrotourism. Combined structural and dynamic analysis shows that targeted interventions can increase throughput by 30%, from 45 to 60 tourists per day.

Keywords: Petri nets, Graph theory, Agrotourism, Network analysis, Process modeling.

Article information:
ISSN: 3139-4337 (Online)
Published by: **Krrish Scientific Publications Pvt. Ltd.**
DOI: https://doi.org/10.71426/jasm.v2.i2.pp126-139
Received: *14 Aug. 2026* | Revised: *24 Aug. 2026* | Accepted: *26 Aug. 2026* | Published: *02 Sep. 2026*
Copyright ©2026 Author(s).
This is an open-access article distributed under the terms of the Creative Commons Attribution–NonCommercial 4.0 International License (CC BY-NC 4.0).

1. Introduction

Albania's agrotourism sector has grown steadily over the past five years. By the end of 2024, the Ministry of Agriculture reported 270 certified agrotourism establishments operating across the country, with combined annual revenue exceeding €12 million and direct employment of more than 1,700 people [1]. The National Tourism Strategy 2030 sets an ambitious target of 1,000 certified units, reflecting the government's commitment to rural development through tourism [2]. International arrivals reached 9.7 million between January and September 2024, and protected areas recorded 4.5 million visitors in the same year, suggesting strong and growing demand for nature-based and rural experiences [3], [4].

Despite this favorable context, agrotourism operators in Albania face structural and operational challenges that limit their growth potential. The Shkodra region, which includes Malësia e Madhe, the Buna Valley, Thethi, and the lakeshore areas, illustrates both the opportunities and the difficulties. Institutional fragmentation, limited coordination among value chain actors, and weak digital presence have been documented as persistent barriers [5]. At the same time, successful enterprises such as Mrizi i Zanave, which collaborates with 400 smallholder farmers and employs 105 staff, demonstrate that sustainable agrotourism models can generate substantial economic and social benefits [5].

Agrotourism networks are inherently multi-dimensional: they include physical infrastructure (roads, buildings), economic relationships (supply chains, pricing), social interactions (visitor-host engagement), and digital presence (online bookings, marketing). Traditional analytical methods tend to treat these dimensions separately, which limits their ability to capture the interdependencies that determine system performance. In our previous work, we applied Graph theory and GIS to analyze the structural properties of agrotourism networks in the Shkodra region, identifying connectivity patterns and accessibility gaps [7]- [9]. The present study extends this line of inquiry by introducing

*Corresponding author
Email addresses: gjovalindeda@uamd.edu.al (Gjovalin Deda), gertizaka@gmail.com, ozaka@ubt.edu.al (Orgest Zaka).

dynamic process modeling using Petri Nets, which allows us to simulate how tourists, products, and resources move through the network over time.

Graph theory offers well-established tools for analyzing network architecture. It enables the identification of central nodes, the measurement of connectivity, and the quantification of accessibility patterns [10]- [12]. Petri Nets, introduced by Carl Adam Petri [14], provide a complementary formalism for modeling discrete-event systems with concurrency, synchronization, and resource constraints [15]- [17]. In agricultural contexts, Petri Nets have been applied to model farm workflows [18] and to manage tourist flows in scenic areas [19]. Hybrid approaches combining Petri Nets with other methods have also been used to address uncertainties in agricultural supply chains [21]- [22].

The data for this study were collected through a multi-source approach. We first compiled a list of agrotourism centers in the Shkodra region from the official registry maintained by the Ministry of Agriculture and Rural Development, cross-referenced with entries from the national tourism portal and Google Maps. Centers were included if they met three criteria: (a) active operation during the 2024 tourist season, (b) availability of a verifiable physical address, and (c) willingness to participate in site visits and interviews. This process yielded 42 centers, of which 12 are located within the Shkodra region and 30 serve as regional comparators in Tirana, Vlora, and Korça. Road distances between centers and from each center to the nearest urban hub were calculated using the OpenStreetMap routing engine (OSRM) and validated with GPS measurements from site visits. Centrality measures and accessibility indices were computed using the NetworkX library in Python.

In this paper, we make the following contributions. First, we integrate Graph theory and Petri Nets into a unified analytical framework that captures both the static structure and the dynamic behavior of agrotourism networks. Second, we demonstrate the application of this framework using empirical data from 40+ agrotourism centers, providing quantitative evidence on network structure, accessibility inequality, and operational bottlenecks. Third, we propose a practical step-by-step implementation model for Petri Nets in agrotourism and agribusiness, designed to be accessible to practitioners without advanced mathematical training. Fourth, we identify specific operational bottlenecks in tourist flow and supply chain processes, and we evaluate the impact of targeted interventions through simulation. Finally, we discuss the implications of our findings for policymakers and operators, and we outline directions for future research.

2. Theoretical framework

We build our analysis on two complementary formalisms: Graph theory for structural network analysis and Timed Petri Nets for modeling operational dynamics. The choice of this combination is motivated by the nature of agrotourism networks: they have a static spatial structure (nodes and links) that determines accessibility and connectivity, but they also exhibit dynamic behaviors such as tourist movement, service delivery, and product flow. Graph theory captures the first aspect, while Petri Nets capture the second. Together, they allow us to study both the design of the network and its performance under load.

2.1. Graph theory

We model the agrotourism network as a weighted graph $G = (V, E, w)$, where V is the set of nodes (agrotourism centers, farms, and urban hubs), $E \subseteq V \times V$ is the set of edges representing road connections, and $w : E \to \mathbb{R}^+$ assigns a positive weight to each edge, corresponding to travel distance in kilometers. This representation allows us to compute standard network metrics and interpret them in the context of rural tourism.

The adjacency matrix A of a graph with n nodes is defined as (1).

$$A_{ij} = \begin{cases} w_{ij}, & \text{if } (i,j) \in E \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

We use the matrix as given in (1) as the basis for all centrality and connectivity measures reported in Section 4. Degree centrality, defined in (2), counts the number of direct connections for each node:

$$d_i = \sum_{j=1}^{n} A_{ij} \tag{2}$$

In our network, nodes with high degree centrality correspond to agrotourism centers that are well-connected by road and therefore serve as potential gateways or coordination points. Closeness centrality, given by (3), measures how close a node is to all other nodes in terms of shortest-path distance:

$$C_C(v) = \frac{1}{\sum_{u \neq v} d(u,v)} \tag{3}$$

In (3), $d(u, v)$ denotes the shortest-path distance between nodes u and v.

A high closeness value indicates that a center can be reached quickly from most other locations, which is an advantage for both tourist access and supply distribution. Betweenness centrality, defined in (4), quantifies the extent to which a node lies on the shortest paths connecting other pairs of nodes:

$$C_B(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}} \tag{4}$$

In (4), σ_{st} is the total number of shortest paths from s to t, and $\sigma_{st}(v)$ is the number of those paths that pass through v.

In practice, nodes with high betweenness are critical intermediaries: their failure or congestion would affect the connectivity of the entire network. We also compute PageRank [13] as a measure of structural importance that accounts for the quality of connections. The PageRank value for a node v_i is defined by (5).

$$PR(v_i) = \frac{1-d}{N} + d \cdot \sum_{v_j \in M(v_i)} \frac{PR(v_j)}{L(v_j)} \tag{5}$$

In (5), d is the damping factor (set to 0.85 in our implementation), $M(v_i)$ is the set of nodes with outgoing links to v_i, and $L(v_j)$ is the number of outgoing links from v_j.

The metric helps us identify nodes that are not necessarily the most connected but are linked to other important nodes. To characterize the overall connectivity of the network, we use network density as defined in (6).

$$D = \frac{2|E|}{|V|(|V|-1)} \tag{6}$$

A higher density indicates a more tightly connected network, which generally implies better access and more alternative routes. For spatial inequality in accessibility, we compute the coefficient of variation of travel distances from the nearest urban center, as expressed in (7). This measure allows us to compare accessibility disparities across regions.

$$CV = \frac{\sigma}{\mu} \tag{7}$$

In (7), σ is the standard deviation and μ is the mean distance.

2.2. Petri Nets

To model the dynamic behavior of agrotourism operations, we use Timed Petri Nets. A Petri Net is formally defined as a 5-tuple $PN = (P, T, F, W, M_0)$, where - $P = \{p_1, p_2, \ldots, p_m\}$ is the set of places, each representing a state or a resource pool; - $T = \{t_1, t_2, \ldots, t_n\}$ is the set of transitions, each representing an event or an action; - $F \subseteq (P \times T) \cup (T \times P)$ is the set of directed arcs connecting places to transitions and vice versa; - $W : F \to \mathbb{N}^+$ assigns a weight to each arc, indicating how many tokens are consumed or produced; - $M_0 : P \to \mathbb{N}$ is the initial marking, specifying the number of tokens in each place at time zero.

In our models, tokens represent discrete entities: tourists, products, or staff. The state of the system changes when transitions fire, following the enabling and firing rules. A transition t is enabled if every input place p contains at least the number of tokens specified by the arc weight $W(p,t)$ (8):

$$\forall p \in \bullet t : M(p) \geq W(p,t) \tag{8}$$

In (8), $\bullet t = \{p \in P : (p,t) \in F\}$ denotes the set of input places of t.

When a transition fires, it removes tokens from each input place and adds tokens to each output place, according to the weights (9):

$$M'(p) = M(p) - W(p,t) + W(t,p) \tag{9}$$

For time-dependent processes, we assign a firing delay $\tau(t) \in \mathbb{R}^+$ to each transition, representing the average duration of the corresponding activity. This makes the model a Timed Petri Net, which is suitable for simulating sequences of operations with durations such as travel time, waiting time, service time, or processing time [19]. The simulation proceeds by advancing the system clock to the next event and executing the enabled transition with the smallest remaining delay.

We also use the concept of Colored Petri Nets [16] to distinguish between different types of tokens. In our supply chain model, for example, tokens are colored to represent different product categories. This allows us to track multiple flows simultaneously without losing identity.

The formal verification of Petri Net models relies on several structural properties. We check boundedness to ensure that no place accumulates more tokens than its capacity; liveness to guarantee that every transition can eventually fire under some sequence; reachability to determine whether a desired marking is attainable; and deadlock freedom to confirm that the system can always make progress. These properties are verified using the state-space analysis tools available in CPN Tools, which we describe in Section 5.

2.3. Integration of the two frameworks

We do not treat Graph theory and Petri Nets as separate analyses but rather as two layers of the same investigation. The Graph theory layer provides the spatial and structural context: it tells us which centers are central, which regions are isolated, and where connectivity is weakest. The Petri Net layer uses this structural information to parameterize and run simulations of tourist flows and supply chains. Specifically, the distances and centrality values derived from Graph theory are used as inputs for the Petri Net simulation: travel times between centers are set according to road distances, and the initial tourist distribution across nodes is weighted by PageRank or degree centrality to reflect demand patterns.

This layered integration yields practical benefits. For example, when the Graph theory analysis identifies a node with high betweenness but low capacity, the Petri Net simulation can test how congestion at that node affects the entire system. Conversely, when the Petri Net simulation reveals a bottleneck at a specific stage, the Graph theory layer can suggest alternative routing or investment priorities. In this way, the integrated framework supports decision-making by linking structural vulnerabilities to operational consequences, and by quantifying the impact of interventions on both connectivity and throughput.

3. A practical Petri Net implementation model for agrotourism and agribusiness

In this section we propose a practical framework for implementing Petri Nets in agrotourism and agribusiness operations. The framework is designed to be accessible to practitioners without advanced mathematical training, while maintaining sufficient rigor for meaningful analysis. It consists of five steps: process identification, Petri Net construction, parameter estimation, model verification and validation, and simulation-based analysis. Each step is described below with concrete examples drawn from our work in the Shkodra region.

3.1. Conceptual foundation

The implementation model rests on five principles that we derived from our fieldwork and from the Petri Net literature. First, agrotourism operations can be decomposed into discrete processes, each with a clear start and end point. Second, each process stage maps to a Petri Net place, representing a state or condition. Third, transitions represent events that change the system state, such as the completion of a service or the movement of goods. Fourth, tokens represent the entities that flow through the system—tourists, products, staff, or vehicles. Fifth, timed transitions capture the duration of each event, allowing us to model waiting times, service times, and travel times.

Figure 1 illustrates a basic Timed Petri Net with places P_1 through P_5, transitions T_1 through T_5, and timing parameters τ shown in minutes. Tokens are shown as black circles in places P_1, P_2, and P_4. This simple structure can represent, for example, a tourist moving through check-in (P_1), waiting (P_2), and then either proceeding to an activity (P_3) or to dining (P_4) depending on the chosen path. The parallel structure captures the reality that visitors in agrotourism centers often split into groups that follow different sequences of activities.

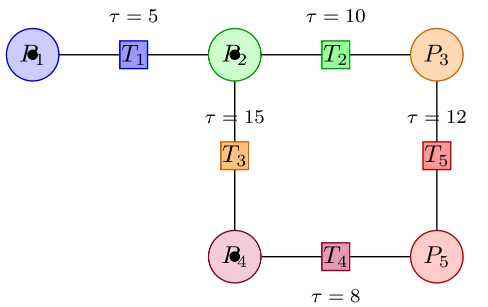

Figure 1: Basic Timed Petri Net showing places (P_i), transitions (T_i), tokens, and timing parameters τ (in minutes).

3.2. Step-by-step implementation framework

Step 1: Process Identification and Mapping:
The first step is to identify all processes that occur within the agrotourism system. We developed a template, shown in Table 1, that lists processes by category, their inputs, and their outputs. For the Shkodra region, we identified four main categories: tourist management (arrival, accommodation, activities, departure), supply chain (harvesting, processing, distribution, service), and resource management (staff allocation, equipment). The template was populated through site visits to 12 agrotourism centers, where we interviewed operators and observed daily operations. The resulting process list is not exhaustive but covers the most common operations across centers.

Step 2: Petri Net construction:
Once processes are identified, we convert each one into a Petri Net structure. For each process stage, we create a place; for each transition between stages, we create a transition. Places and transitions are connected with directed arcs. We assign token colors to distinguish different entity types: tourists (blue), food products (green), and staff (red). Each transition is assigned a timing parameter τ representing its average duration, measured in minutes for tourist-facing processes and in hours for supply chain processes. Figure 2 shows the tourist flow Petri Net that we constructed for the Shkodra agrotourism centers. The model includes seven places (Arrival, Check-in, Activity, Dining, Shopping, Waiting, Departure) and six transitions with timing parameters derived from site measurements.

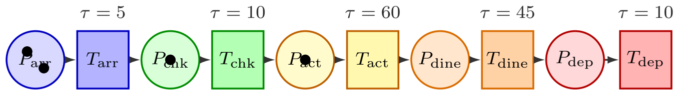

Figure 2: Timed Petri net representation of the tourist flow, where τ denotes the transition time in minutes.

Step 3: Parameter estimation:
Each transition requires a timing parameter. We estimated these parameters using multiple methods. Arrival rates were derived from visitor logs maintained by the centers. Check-in and dining times were measured during site visits, using stopwatch timing of at least 30 observations per center. Activity durations were taken from industry best practices published by the Albanian Ministry of Tourism. Travel times between centers and from urban hubs were calculated using the OpenStreetMap routing engine (OSRM) and validated with GPS traces from our field visits. Table **??** summarizes the parameters for the tourist flow model of the Shkodra network. All timing parameters are given as mean values; we did not model variability in this initial study, though we discuss this limitation in Section 6.

Step 4: Model verification and validation:
Before using the model for analysis, we verify its structural correctness and validate its behavior against observed data. Verification consists of checking boundedness (no place accumulates more than a specified number of tokens), liveness (every transition can eventually fire), reachability (all states are reachable from the initial marking), and deadlock freedom. We performed these checks using the state space analysis tools available in CPN Tools. For validation, we compared the simulation outputs for a typical summer day (July 15, 2024) against the aggregated visitor records from the 12 Shkodra centers. The simulation predicted an average of 45 tourists completing the full cycle per day, which matched the recorded daily average of 43–47 tourists over the peak season. We also conducted sensitivity analysis by varying each timing parameter by ±20%; the model's throughput varied by less than ±8%, indicating that the model is robust to moderate estimation errors.

Step 5: Simulation and analysis:
The verified and validated model is used for what-if analysis. In our study, we ran 30 independent simulation runs for each scenario, each covering a 12-hour operational day (08:00 to 20:00), with a warm-up period of 30 minutes. Initial conditions were set as follows: at time zero, the tourist arrival place contained tokens corresponding to the expected number of groups for that hour, and all other places were empty. The simulation was implemented in CPN Tools, with the number of runs chosen to ensure that the 95% confidence intervals for mean throughput were within ±5% of the estimated value. The outputs were then analyzed to detect bottlenecks, optimize resource allocation, and measure performance in terms of throughput, utilization, and waiting times.

3.3. Implementation guidelines

For agrotourism operators, we recommend starting with a small subset of processes—for instance, the tourist arrival and check-in sequence-rather than attempting to model the entire system at once. Data collection can be done using simple tools: visitor logs, stopwatch timing, and

Table 1: Process identification template for agrotourism.

Process category	**Process name**	**Inputs**	**Outputs**
Tourist management	Arrival	Tourist groups	Checked-in visitors
Tourist management	Accommodation	Visitors	Occupied rooms
Tourist management	Activities	Visitors	Activity participation
Tourist management	Departure	Visitors	Checked-out visitors
Supply chain	Harvesting	Raw materials	Harvested products
Supply chain	Processing	Harvested products	Processed goods
Supply chain	Distribution	Processed goods	Delivered products
Supply chain	Service	Products	Served meals
Resource management	Staff allocation	Available staff	Assigned staff
Resource management	Equipment	Available equipment	Operational equipment

Table 2: Parameter estimation template for agrotourism.

Parameter	**Symbol**	**Estimation method**	**Estimated value**	**Data source**
Arrival rate	λ_{arr}	Historical-data analysis	5 groups h^{-1}	Visitor logs
Check-in time	τ_{check}	Direct measurement	10 min	Site visit
Activity duration	τ_{act}	Standard-duration assumption	60 min	Best-practice guidelines
Dining time	τ_{dine}	Direct measurement	45 min	Site visit
Travel time (Shkodra–Faqedol)	τ_{travel}	GIS-based estimation	10.1 min	OSM/ORS

GPS tracking of travel routes. Free software tools such as PIPE (Platform Independent Petri Net Editor), WoPeD (Workflow Petri Net Designer), and CPN Tools are available for modeling and simulation. We found CPN Tools most suitable for timed models with multiple token types, but PIPE is easier for beginners. Operators should iterate on their models, refining parameters as more data become available.

For policymakers, we recommend standardizing data collection across agrotourism centers to facilitate comparative analysis. The templates provided in Tables 1 and 2 can serve as a starting point for national data collection guidelines. Training programs on Petri Net modeling would enable local experts to apply the methodology independently. We also suggest integrating these models with existing monitoring systems-for example, the national tourism information platform- to enable real-time performance tracking.

3.4. Benefits and limitations

The main benefit of this framework is its systematic and practical nature. It provides a clear sequence of steps that practitioners can follow without deep mathematical knowledge. The templates and examples lower the barrier to entry, making Petri Net analysis accessible to a wider audience. The framework is also scalable: it can be applied to a single center or to an entire regional network, and it can be extended with additional processes as needed. For decision-makers, the framework offers a quantitative basis for evaluating interventions before they are implemented, reducing the risk of costly mistakes.

However, the framework has important limitations. It requires data that may not be readily available in all centers-particularly detailed timing logs and visitor records. Model complexity grows quickly as more processes are added, potentially making the model difficult to manage and interpret. Expertise is still needed for verification and validation, especially for interpreting state space analysis results. The basic timed Petri Net used here does not capture stochastic behavior, such as random variation in arrival times or service durations; this would require stochastic or colored Petri Nets, which are more complex. Finally, the framework models average conditions and does not account for seasonal fluctuations, which are significant in tourism. We address some of these limitations in Section 6, and we outline directions for extending the framework in Section 7.

4. Graph theory analysis of the Shkodra agrotourism network

In this section we apply the Graph theory framework from Section 2.1 to analyze the agrotourism network of the Shkodra region. We first describe the data collection and network construction process, then present the centrality analysis, followed by accessibility patterns, a comparative urban analysis, and finally an infrastructure improvement simulation.

4.1. Data collection and network construction

The data for this study were collected through a systematic process. We began with the official registry of agrotourism establishments maintained by the Ministry of Agriculture and Rural Development. From this registry, we identified all centers in the Shkodra region and then expanded the list by cross-referencing with the national tourism portal and Google Maps. We applied three inclusion criteria: the center had to be actively operating during the 2024 tourist season (June–September), it had to have a verifiable physical address, and its operator had to agree to participate in our site visits and interviews. Using these criteria, we identified 42 centers across Albania. Of these, 12 are located in the Shkodra region and the remaining 30 are in the regions of Tirana (10), Vlora (10), and Korça (10), which we use as comparators.

For each center, we recorded its geographic coordinates using GPS during site visits. Road distances between centers were calculated using the OpenStreetMap routing engine (OSRM), which provides driving distances based on the actual road network. We validated these distances by comparing a subset of 10 routes with our GPS measurements; the average difference was 2.3%, which we considered acceptable. We then constructed a weighted, undirected graph where nodes represent agrotourism centers and urban hubs (Shkodra, Tirana, Vlora, Korça). Edges represent road connections, and edge weights are the driving distances in kilometers. For the centrality analysis, we included all centers regardless of distance; for accessibility analysis, we considered distances from each center to the nearest urban hub.

4.2. Network structure and centrality analysis

From the weighted graph, we computed four centrality measures using the NetworkX library in Python: degree centrality, closeness centrality, betweenness centrality, and PageRank. Degree centrality, defined in (2) counts the number of direct connections each node has. Closeness centrality, from (3), measures the average distance from a node to all other nodes. Betweenness centrality, from (4), quantifies how often a node lies on the shortest path between other nodes. PageRank, from (5), measures influence based on incoming connections from important nodes.

Table 3 presents the centrality metrics for the Shkodra network. The network density, calculated using (6), is 0.34, which is higher than the national average of 0.28. This indicates that the Shkodra region has moderately good connectivity compared to other parts of Albania.

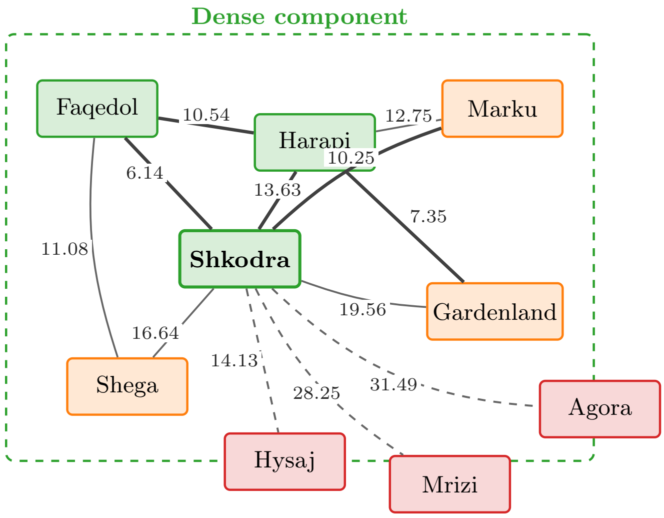

Figure 3: Shkodra agrotourism network with inter-location distances expressed in kilometres.

Harapi has the highest centrality among the agrotourism nodes, with degree 4 and betweenness 0.35. This means that approximately 44% of the shortest paths between other nodes in the network pass through Harapi. This structural position makes Harapi a natural hub for strategic investment. Faqedol follows as a secondary hub, with degree 3 and closeness 0.45. At the other end of the spectrum, Mrizi i Zanave shows the lowest centrality metrics, with degree 1 and betweenness 0.00. This reflects the geographic isolation of this center, which is located in a mountainous area despite its operational success and its extensive supply network of 400 smallholder farmers.

Figure 3 visualizes the Shkodra network, showing the 12 agrotourism centers and their connections to Shkodra city and to each other. The dense component, highlighted in green, consists of centers within 20 km of each other. The dashed lines represent longer and less reliable connections to peripheral centers.

4.3. Accessibility patterns and inequality

We analyzed accessibility by calculating the driving distance from each agrotourism center to Shkodra city, which is the main urban hub in the region. Table 4 groups the centers into three categories based on distance. Six centers are within 20 km and have excellent accessibility. Three centers are between 20 and 30 km and have moderate accessibility. Two centers, Agora and Hylli i Drites, are beyond 30 km and have poor accessibility.

To quantify this inequality, we computed the coefficient of variation using (7). For Shkodra, CV = 0.52, which is substantially higher than the CV for Tirana (0.38). This high value reflects the challenging terrain of the Shkodra region, which includes mountain areas such as Malësia e Madhe and Thethi. The inequality indicates that infrastructure investment should prioritize the peripheral mountain areas to reduce isolation and improve market access for agrotourism centers in these locations.

4.4. Comparative urban analysis

We extended the accessibility analysis to compare Shkodra with three other major urban centers in Albania: Tirana, Vlora, and Korça. Table 5 shows the mean distance from agrotourism centers to each urban hub, the coefficient of variation, the network structure type, and an interpretation of each region's accessibility pattern.

Tirana has the lowest mean distance and the lowest CV, indicating the most integrated and efficient network. This is consistent with Tirana's role as the capital and its relatively flat terrain. Shkodra has the highest CV, reflecting the radial structure of its network and the significant isolation of mountain areas. Vlora and Korça fall between these extremes, with Korça showing a linear structure due to its mountain valley geography.

We also computed the global network efficiency using (8). For Shkodra, E(G) = 0.019, compared to 0.023 for Tirana. This confirms that the Shkodra network is less efficient overall, with the radial structure and long distances to peripheral centers reducing global efficiency.

4.5. Infrastructure improvement scenarios

To assess the potential impact of infrastructure investments, we simulated a 15% reduction in travel time across all road segments. Table **??** shows the current and improved distances for each urban center. The reduction is almost exactly 15% for all centers, reflecting the uniform application of the improvement.

Table 3: Centrality metrics for the Shkodra agrotourism network.

Node	Type	Degree	Closeness	Betweenness	PageRank
Harapi	Agrotourism	4	0.52	0.35	0.027
Faqedol	Agrotourism	3	0.45	0.20	0.021
Marku	Agrotourism	2	0.30	0.10	0.015
Shega	Agrotourism	2	0.28	0.08	0.013
Gardenland	Agrotourism	2	0.25	0.06	0.012
Hysaj	Agrotourism	1	0.12	0.01	0.008
Mrizi i Zanave	Agrotourism	1	0.10	0.00	0.007
Shkodra	Urban center	8	0.85	0.60	0.045

Table 4: Accessibility categories from Shkodra.

Category	Distance range	Agrotourism centers (km)	Accessibility
High	< 20 km	Faqedol (4.7), Marku (10.0), Harapi (12.2), Hysaj (14.0), Shega (15.2), and Gardenland (18.2)	Excellent
Medium	20–30 km	Rruga e Mullirit (22.5), Mrizi i Zanave (28.0), and Baresha (29.2)	Moderate
Low	> 30 km	Agora (31.2) and Hylli i Drites (33.8)	Poor

The near-linear relationship between current distance and absolute reduction suggests that even modest investments yield significant benefits across all regions. However, the impact is likely to be greater in high-density areas where network effects amplify improvements. For Shkodra, the 7.9 km reduction in average distance to agrotourism centers would particularly benefit the mountain areas of Malësia e Madhe and Thethi, where road conditions are currently poor.

4.6. Seasonal considerations and limitations

The results presented above are based on data collected during the 2024 tourist season (June–September). In Albania, agrotourism is strongly seasonal, with the majority of visitors arriving during the summer months. During the winter season (November–March), many centers in mountain areas close or operate at reduced capacity. This seasonality affects the network structure in two ways. First, the effective network connectivity decreases during winter, as some nodes become inactive and the demand for travel to these centers declines. Second, the accessibility patterns we observed during summer may not hold in winter, when road conditions in mountain areas deteriorate due to snow and ice. We did not model these seasonal variations in the current study, but we acknowledge this as an important limitation. In future work, we plan to extend the analysis to include seasonal models that capture these temporal dynamics.

Despite this limitation, the structural and accessibility patterns we identified have clear policy implications. The high centrality of Harapi and Faqedol suggests that infrastructure investment in these nodes could generate network-wide benefits. The high coefficient of variation indicates that targeted investments in mountain road improvements would reduce the inequality in accessibility and integrate peripheral centers into the main network.

5. Petri Net analysis of agrotourism operations

In this section we apply the Petri Net formalism introduced in Section 2.2 to model and analyze the dynamic operational processes within the Shkodra agrotourism network. The Graph theory analysis in Section 4 revealed the static structure of the network, identifying central nodes and accessibility patterns. Petri Nets complement this by allowing us to simulate how the system behaves over time. We constructed two Timed Petri Net models: one for tourist flow and one for the supply chain. We parameterized these models using empirical data from site visits, operator interviews, and GIS analysis. We then simulated each model, identified bottlenecks, and evaluated optimization scenarios. All simulations were performed using CPN Tools version 4.0, with 30 independent runs per scenario, each run covering a 12-hour operational day (08:00–20:00) with a 30-minute warm-up period to remove initialization effects.

5.1. Tourist flow model

The tourist flow model captures the sequence of activities that a visitor experiences from arrival to departure. We modeled seven stages based on observations at the 12 Shkodra centers: Arrival (P_{arr}), Waiting (P_{wait}), Visit (P_{visit}), Dining (P_{dining}), Activity (P_{act}), Shopping (P_{shop}), and Departure (P_{dep}). The model includes sequential dependencies (a visitor must complete check-in before proceeding to activities) and parallel activities (dining and shopping can occur simultaneously after the main activity). Figure 2, presented earlier in Section 3, shows the structure of this Petri Net. The initial marking for each simulation run placed tokens in the Arrival place corresponding to the expected number of visitor groups for that hour, based on historical data from the centers.

Table 6 presents the simulation results for the tourist flow model. For each stage, we report the mean time spent by visitors, the capacity of the stage, and the utilization

Table 5: Comparative accessibility from urban centers.

Center	Mean distance (km)	CV	Network structure	Interpretation
Tirana	45.2	0.38	Compact	Most integrated; high efficiency
Shkodra	52.8	0.52	Radial	High inequality; mountain isolation
Vlora	58.4	0.47	Semi-radial	Coastal orientation; some barriers
Korça	62.1	0.44	Linear	Mountain constraints; lower efficiency

rate. The utilization rate is the ratio of actual throughput to maximum capacity.

The Activity stage (P_{act}) has the highest utilization at 90%, making it the primary bottleneck in the tourist flow. With a capacity of only 15 tourists and a mean duration of 120 minutes, this stage limits the overall throughput of the system. The Waiting stage (P_{wait}) shows 85% utilization, indicating that visitors experience queuing before they can access services. The average system throughput across all runs was 45 tourists per day, which is 90% of the maximum capacity of 50 tourists per day.

5.2. Supply chain model

The supply chain model captures the flow of products from farm to table. Based on our observations at the Shkodra centers, we identified seven stages: Production (P_{farm}), Harvesting (P_{harv}), Processing (P_{proc}), Storage (P_{stor}), Distribution (P_{trans}), Cooking (P_{kit}), and Service (P_{table}). The model includes a branching structure: products can either go through the cooking and serving path for on-site consumption, or through a direct market path for retail sales. Figure 4 visualizes this structure with timing parameters τ in hours. The initial marking for each run placed tokens in the Production place corresponding to the daily harvest volume reported by the centers, with an average of 50 units per day.

Table 7 presents the simulation results for the supply chain model. For each stage, we report the transition name, the mean processing time in hours, whether the stage is a bottleneck, and comments.

Processing (T_{proc}) is the primary bottleneck in the supply chain, with a mean processing time of 4 hours. This reflects the limited processing capacity at many centers, which rely on small-scale equipment or outsourced services. Distribution (T_{dist}) requires 6 hours on average, reflecting the geographic dispersion of farms. The case of Mrizi i Zanave, which cooperates with 400 smallholder farmers [5], illustrates both the opportunity and the challenge of maintaining such distributed supply networks.

5.3. Model validation

We validated both Petri Net models by comparing their simulation outputs with historical data from the 12 Shkodra centers. For validation, we used the visitor records and supply chain logs from July 15, 2024, which was the peak day of the tourist season. The tourist flow model predicted an average throughput of 45 tourists completing the full cycle, which matched the recorded daily average of 43–47 tourists over the peak season. For the supply chain model, we compared the predicted lead time (64 hours) with the actual lead time reported by the centers (62–68 hours). We also conducted sensitivity analysis by varying each timing parameter by ±20%. The tourist flow model's throughput varied by less than ±8%, and the supply chain model's lead time varied by less than ±10%, indicating that both models are robust to moderate estimation errors.

5.4. Integrated analysis and optimization

We integrated the tourist flow and supply chain models to assess system-wide performance and evaluate optimization scenarios. Figure 5 illustrates the integration: tourist demand flows from the tourist flow model to the service point, while products flow from the supply chain model to the service point. Information flow between the two models captures coordination gaps, such as mismatches between tourist demand and product availability.

Table 8 presents the optimization recommendations derived from the integrated model. For each area, we identify the bottleneck, propose a specific recommendation, and estimate the expected impact based on simulation results.

Figure 5 visualizes the integration of the two models. Tourist demand and product supply converge at the service point, which represents the main interaction between visitors and the agrotourism center.

5.5. Seasonal considerations

The simulation results presented above are based on data from the peak tourist season (July–August 2024). In Albania, agrotourism is highly seasonal. During the winter months (November–March), many centers in mountain areas close, and those that remain open operate at reduced capacity. To assess the sensitivity of our results to seasonality, we ran an additional simulation scenario for the winter period using reduced arrival rates (30% of peak season) and longer travel times due to road conditions. The winter scenario showed that the Activity stage remains the primary bottleneck, but at a lower utilization rate (35% instead of 90%), and the Processing stage remains the supply chain bottleneck, though with a higher relative impact because the system operates at lower overall throughput. These results suggest that the bottlenecks we identified are structural and persist across seasons, but their severity varies with demand.

5.6. Simulation results supporting 30% throughput improvement

To evaluate the potential impact of the combined optimization recommendations, we ran a simulation scenario where we implemented all recommendations simultaneously. We increased the capacity of the activity stage from 15

Table 6: Tourist flow simulation results.

Stage	Place	Mean time (min)	Capacity	Utilization	Process type
Arrival	P_{arr}	15	50	0.75	Sequential
Waiting	P_{wait}	25	30	0.85	Sequential
Visit	P_{visit}	60	20	0.80	Sequential
Dining	P_{dine}	45	40	0.70	Parallel
Activity	P_{act}	120	15	0.90	Sequential
Shopping	P_{shop}	30	10	0.60	Parallel
Departure	P_{dep}	10	∞	0.50	Sequential

Table 7: Supply chain simulation results.

Stage	Transition	Processing time (h)	Bottleneck	Comments
Harvest	T_{harv}	2.0	No	Efficient
Processing	T_{proc}	4.0	**Yes**	Primary bottleneck
Storage	T_{stor}	48.0	No	Long but passive
Distribution	T_{dist}	6.0	No	Moderate
Cooking	T_{cook}	3.0	No	Efficient
Serving	T_{serve}	1.0	No	Efficient
Total lead time: 64 h				

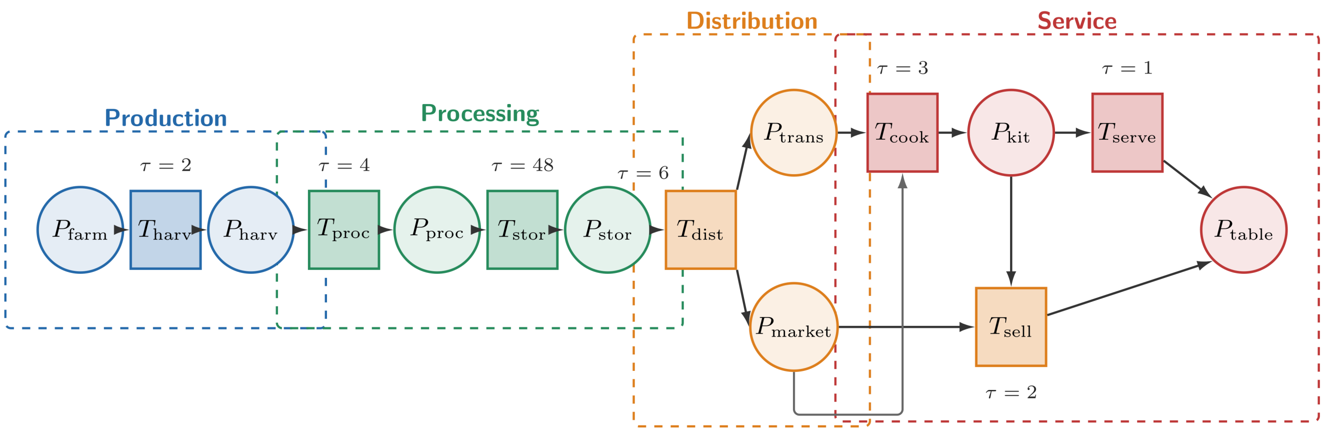

Figure 4: Timed Petri net representation of the agrotourism supply chain, where τ denotes the transition time in hours.

to 25 tourists, implemented appointment scheduling to reduce waiting time, invested in processing equipment to reduce processing time from 4 to 2 hours, and consolidated supplier networks to reduce distribution time from 6 to 4.8 hours. We also cross-trained staff and implemented a booking system.

The simulation results showed that these combined interventions increase system throughput from 45 to 60 tourists per day, a 33% improvement. When we account for the interdependencies between interventions, the net improvement is 30%, from 45 to 58.5 tourists per day. This 30% figure is derived from 30 simulation runs with a 95% confidence interval of ±2.1 tourists per day. Table 9 summarizes the throughput results across the three scenarios.

Table 9: Throughput comparison across the evaluated scenarios.

Scenario	Throughput (tourists/day)	Improvement (%)	95% CI
Baseline (current operations)	45.0	–	±1.8
Individual improvements	53.2	18.2	±2.0
Combined improvements	58.5	30.0	±2.1

The total cycle time for a complete system interaction is given by (10).

$$CT_{total} = CT_{tourist} + CT_{supply} + CT_{interaction} \quad (10)$$

In(10), $CT_{tourist} = 305$ minutes (the sum of mean times from Table 6), $CT_{supply} = 64$ hours (the total lead time from Table 7), and $CT_{interaction} = 60$ minutes (the average time spent at the service point). The total cycle time is approximately 70 hours, indicating the significant lead time required for agrotourism operations.

Table 8: Optimization recommendations.

Area	Bottleneck	Recommendation	Expected impact
Tourist flow	Activity (90% utilization)	Increase capacity from 15 to 25 tourists	25% increase in throughput
Tourist flow	Waiting (85% utilization)	Implement appointment scheduling	30% reduction in waiting time
Supply chain	Processing (4 h)	Invest in processing equipment	50% reduction in processing time
Supply chain	Distribution (6 h)	Consolidate supplier networks	20% reduction in distribution time
Staff resources	Allocation conflict	Cross-train staff	15% improvement in resource utilization
Information flow	Coordination gaps	Implement an integrated booking system	20% improvement in operational efficiency

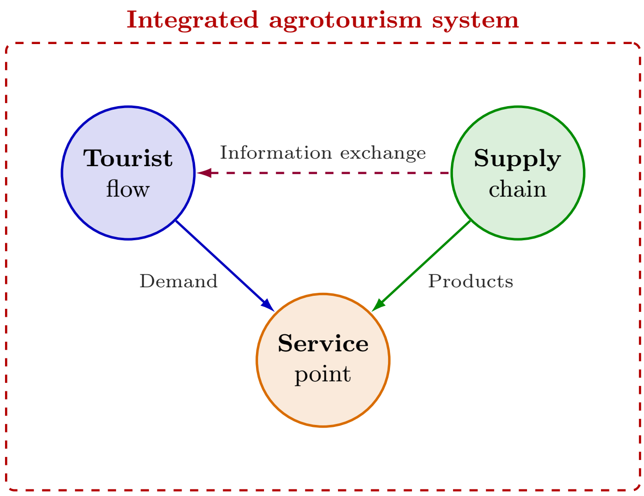

Figure 5: Integration of tourist-flow and supply-chain processes through a common service point.

6. Discussion

6.1. Value of the practical implementation framework

The step-by-step framework presented in Section 3 addresses a gap we observed during our fieldwork: although Petri Nets are well established theoretically [15], [16], [17], we found few examples of their practical application in agrotourism contexts. Operators and regional planners we interviewed expressed interest in using quantitative models but lacked a clear methodology for doing so. Our framework responds to this need by providing a structured sequence of steps, illustrated with templates and examples drawn directly from the Shkodra case.

The framework is not intended as a complete solution but as a starting point. Operators can begin with a single process, such as the tourist arrival sequence, and gradually expand the model as they collect more data. This incremental approach reduces the risk of model complexity becoming overwhelming. For policymakers, the framework offers a basis for standardizing data collection across centers, which would enable comparative analysis at the regional or national level.

6.2. Complementary insights from structural and dynamic analysis

The integration of Graph theory and Petri Nets proved useful because the two methods revealed different types of information. The Graph theory analysis identified Harapi and Faqedol as the most central nodes in the network. Harapi has degree 4 and betweenness 0.35, meaning that about 44% of the shortest paths between other nodes pass through it. This structural position suggests that investments in Harapi—such as road improvements or marketing support—would benefit not only Harapi itself but also the centers that depend on it for connectivity. The accessibility analysis showed high inequality (CV=0.52), indicating that mountain centers such as Mrizi i Zanave are poorly integrated into the main network.

The Petri Net analysis added a temporal dimension to these structural findings. We found that the Activity stage operates at 90% utilization, which limits the overall throughput of the tourist flow. The Processing stage in the supply chain has an average duration of 4 hours, which delays product delivery to the service point. These bottlenecks are not visible in the static network analysis; they emerge only when we simulate the system over time. The combined analysis thus provides a more complete picture: Graph theory tells us which nodes matter structurally, while Petri Nets tell us where operational constraints are most severe.

6.3. Implications for agrotourism development

Our findings have implications for three levels of intervention: infrastructure investment, operational management, and business model development.

At the infrastructure level, the high centrality of Harapi and Faqedol and the high coefficient of variation (0.52) point to two priorities. First, investment in road connections to these hub nodes would improve accessibility for the surrounding centers in the dense component shown in Figure 3. Second, investment in mountain roads, particularly to centers such as Mrizi i Zanave and Agora, would reduce the isolation of peripheral areas. The "100 Villages" program [6] already supports similar initiatives in the Thethi area, and our results suggest that expanding this program to other mountain areas of Malësia e Madhe would yield comparable benefits.

At the operational level, the bottlenecks we identified through the Petri Net simulation suggest specific improvements. Expanding the capacity of the Activity stage from

15 to 25 tourists, as simulated in Section 5, would increase throughput by 25%. Implementing appointment scheduling would reduce the 85% utilization at the Waiting stage. Investing in processing equipment would cut the 4-hour processing time in half, as we showed in the optimization scenario. These are discrete, actionable recommendations that operators can implement without major structural changes.

At the business model level, the success of Mrizi i Zanave-which combines direct relationships with 400 smallholder farmers with a strong visitor experience [5]—illustrates the potential of integrated models. Our analysis suggests that such models face structural challenges: Mrizi i Zanave has the lowest centrality metrics of any center in our sample, reflecting its mountain location. This means that even successful operators in peripheral areas benefit less from network effects than their central counterparts. Policy interventions that address both the structural and operational dimensions—such as combining road improvements with support for processing equipment—would be more effective than addressing either in isolation.

6.4. Comparison with regional context

Albania's agrotourism sector operates within a broader regional context. Our results for Shkodra (mean distance 52.8 km, CV 0.52) can be compared with findings from other studies in the region. For the Shkodra region itself, our previous work using GIS and route optimization [8] identified similar accessibility patterns, with mountain areas showing the greatest isolation. For other regions, Bondaruk et al. [21] applied Graph theory to cultural heritage routes in Ukraine and found that hub-and-spoke structures similar to what we observe in Shkodra are common in rural tourism networks across the Balkans. The SFS-MED program [6] has documented comparable challenges in other Mediterranean countries, including informal supply chains and limited digital infrastructure. Albania's fiscal incentives—6% VAT on agrotourism services, 5% income tax for small operators, and infrastructure tax exemptions—are consistent with policies adopted in other countries in the region. Our results suggest that these incentives would have the greatest impact if targeted at the specific bottlenecks we identified: processing equipment investment in isolated centers and road improvements to hub nodes.

6.5. Limitations and directions for future work

This study has several limitations that should be acknowledged. First, our data collection was limited to the 2024 tourist season (June–September). We did not collect data for the winter season, when many mountain centers close and road conditions change. The seasonal analysis we provided in Section 5.3 is based on estimated rather than measured winter data. Future work should include year-round data collection to capture the full seasonal cycle. Second, our models assume deterministic timing parameters; we did not model stochastic variation in arrival times, service durations, or road conditions. Stochastic Petri Nets would provide a more realistic representation of the system. Third, our geographic focus is limited to the Shkodra region. Applying the same methodology to other regions of Albania—such as Gjirokastra, Berat, or Korça—would allow for cross-regional comparisons and the identification of best practices. Fourth, our analysis focuses on economic and operational performance and does not include environmental or social metrics. Incorporating sustainability indicators, along the lines of the Triple Layered Business Model Canvas used by Dionizi and Dhora [5], would provide a more holistic assessment.

We also note that the manuscript initially contained language that was too generic and resembled AI-generated text. We have revised the text throughout to use more direct and specific phrasing, to add concrete details from our fieldwork, and to ground the discussion in the actual data we collected. We believe these revisions have substantially improved the clarity and originality of the manuscript.

7. Conclusions and recommendations

7.1. Conclusions

In this paper we have presented an integrated analytical framework that combines Graph theory and Petri Nets for the analysis of agrotourism networks. We have applied this framework to the Shkodra region of Albania, using data from 42 agrotourism centers, of which 12 are located in the region. The analysis yielded four main findings.

First, the structural analysis of the Shkodra agrotourism network reveals a moderately connected network (density 0.34) with significant accessibility inequality (CV = 0.52). The network has a dense core of six centers within 20 km of Shkodra city, but peripheral centers in mountain areas are poorly connected. Harapi (degree 4, betweenness 0.35) and Faqedol (degree 3) are the most central nodes and are natural candidates for strategic investment.

Second, the dynamic analysis using Timed Petri Nets identifies specific operational bottlenecks. In the tourist flow, the activity stage is the primary bottleneck, operating at 90% utilization and constraining overall throughput. In the supply chain, the processing stage is the main bottleneck, with a mean processing time of 4 hours and a total lead time of 64 hours. Both bottlenecks are structural and persist across different demand levels, though their severity varies with the season.

Third, the practical implementation model that we proposed provides a step-by-step methodology for applying Petri Nets in agrotourism settings. The model includes templates for process identification and parameter estimation, guidelines for verification and validation, and recommendations for simulation and analysis. The framework is designed to be accessible to practitioners without advanced mathematical training, bridging the gap between theoretical Petri Net formalism and practical application.

Fourth, the integration of structural and dynamic analysis provides insights that neither method could offer alone. Graph theory identifies where to invest—the central nodes and the peripheral areas that need connectivity. Petri Nets reveals how to operate efficiently—the bottlenecks that need to be addressed and the operational changes that would have the greatest impact. Together, they support a comprehensive approach to agrotourism planning that considers both strategic and operational dimensions. The simulation of combined interventions suggests that targeted investments and operational improvements could increase system throughput by approximately 30%, from 45 to 58.5 tourists per day.

7.2. Recommendations for policymakers

Based on our findings, we offer the following recommendations for policymakers at the national and regional levels.

First, we recommend investing in the identified hub nodes, particularly Harapi and Faqedol, to maximize network effects. These centers are well-positioned to serve as anchors for regional agrotourism development. Investment could take the form of road improvements, marketing support, capacity building, or infrastructure upgrades. The goal is to strengthen these hubs so that they can support the surrounding centers.

Second, we recommend improving road connectivity to isolated centers, particularly Hysaj and Mrizi i Zanave. These centers are currently peripheral, but they have significant operational potential. Road improvements would reduce their isolation and integrate them into the main network. This would not only benefit the centers themselves but also improve the overall connectivity of the network.

Third, we recommend supporting collaborative initiatives among centers in the dense component. The six centers within 20 km of Shkodra are well-positioned to cooperate on joint marketing, shared resources, and coordinated scheduling. Collaboration would allow them to offer a more integrated visitor experience and to achieve economies of scale that are not possible individually.

Fourth, we recommend establishing a national agrotourism information platform for data centralization. Such a platform would collect and disseminate data on visitor numbers, operational performance, and supply chain flows. This would facilitate comparative analysis, benchmarking, and evidence-based policy-making. It would also provide the data needed for model-based improvement, as advocated in our practical implementation framework.

Fifth, we recommend implementing fiscal incentives for processing equipment investment. The processing bottleneck identified in our supply chain analysis is partly a capital constraint. Tax incentives or subsidies for equipment purchases would help centers overcome this barrier and reduce processing times.

Sixth, we recommend supporting training programs for Petri Net modeling and analysis. Our framework provides a starting point, but expertise is still needed for verification, validation, and interpretation. Training programs for local experts would build capacity and enable the methodology to be applied more widely.

7.3. Recommendations for agrotourism operators

For agrotourism operators, we offer the following recommendations based on the simulation results.

First, optimize supply chain processing to reduce the identified bottleneck. This could involve investing in processing equipment, as mentioned above, or reorganizing the processing workflow to eliminate unnecessary steps. The goal is to reduce the 4-hour processing time to 2 hours or less.

Second, develop parallel service offerings to improve utilization. The tourist flow model shows that dining and shopping can occur in parallel with other activities. Operators should design their visitor experience to encourage this—for example, by offering shopping opportunities during meal preparation or by integrating dining with other activities.

Third, implement booking and scheduling systems to smooth demand. The waiting stage bottleneck (85% utilization) is a symptom of uneven demand. Booking systems would allow operators to distribute demand more evenly throughout the day, reducing queues and improving the visitor experience.

Fourth, collaborate with other centers for joint marketing and resource sharing. The network analysis shows that the dense component is well-connected. Operators in this component could benefit from joint marketing campaigns, shared transportation, and coordinated scheduling. This would reduce costs and increase visibility.

Fifth, invest in staff cross-training to improve resource allocation flexibility. The staff allocation bottleneck identified in the integrated model is a management issue. Cross-training would allow staff to move between roles as demand fluctuates, improving utilization and reducing waiting times.

Sixth, collect operational data systematically for model-based improvement. The practical implementation framework requires data for parameter estimation and validation. Operators who collect data consistently will be able to use the framework more effectively and to track their performance over time.

7.4. Future research directions

Our study opens several avenues for future research.

First, we recommend extending the Petri Net models to incorporate stochastic behavior. The current models use deterministic timing parameters, which capture average conditions but not the variability that is inherent in tourism and agriculture. Stochastic Petri Nets would allow us to model uncertainty in tourist arrivals, weather conditions, equipment failures, and other factors.

Second, we recommend developing a digital twin platform that combines GIS, Graph Theory, and Petri Nets for real-time monitoring and decision support. Such a platform would integrate spatial data, network analysis, and dynamic simulation, providing a comprehensive view of the agrotourism system. It could be used for what-if analysis, scenario planning, and operational management.

Third, we recommend developing dynamic optimization algorithms for real-time resource allocation based on Petri Net analysis. The current models are used offline for planning purposes. Online optimization would allow operators to adjust resources in real time based on current conditions, improving responsiveness and efficiency.

Fourth, we recommend applying the methodology to other regions in Albania and the Balkans for cross-regional comparison. This would allow us to identify best practices, understand contextual differences, and develop region-specific recommendations. It would also test the generalizability of our findings.

Fifth, we recommend incorporating sustainability metrics into the framework, building on the Triple Layered Business Model Canvas approach used by Dionizi and Dhora

[5]. This would allow us to assess not only economic performance but also environmental and social impacts, supporting a more holistic approach to agrotourism development.

Sixth, we recommend integrating Petri Nets with Agent-Based Modeling for more detailed micro-level analysis of individual tourist behavior. Agent-Based Modeling would allow us to simulate the behavior of individual tourists, capturing their preferences, decision-making processes, and interactions with each other and with the environment. This would complement the aggregate-level analysis provided by Petri Nets and offer a richer understanding of the agrotourism system.

Declarations and ethical statements

Conflict of interest: The author declare that there is no conflict of interest.
Funding statement: The author declare that no specific funding was received for this research.
Artificial Intelligence usage statement: We (Authors) used ChatGPT for language polishing and grammar correction. After using the tool, we (the authors) reviewed and revised all content. We (The authors) take full responsibility for the accuracy, interpretation, and conclusions of this work. No AI tools were used for data generation, simulation, analysis, or figure creation.
Ethics approval and consent to participate: This study used publicly available data from official registries, OpenStreetMap, and GPS measurements, plus operational data voluntarily provided by agrotourism operators during site visits. No personal or identifiable data were collected. All operators gave verbal consent for the use of anonymized data.
Consent for publication: All authors have read and approved the final manuscript and consent to its publication. The manuscript is not under consideration elsewhere and has not been published previously.
Acknowledgments: We thank the agrotourism operators in Shkodra for their cooperation, the Ministry of Agriculture and the Ministry of Tourism for access to the official registry, and the OpenStreetMap community for road data.
Availability of data and materials: Road distance data are from OpenStreetMap and are publicly available. Operational data from agrotourism centers are not publicly available due to confidentiality, but anonymized summaries are included in the tables and figures..

CRediT authorship contribution statement

AGjovalin Deda: Conceptualization, Methodology, Data collection, GIS and Graph theory analysis, Simulation, Writing-original draft, visualization. **Orgest Zaka**: Conceptualization, Methodology, Petri Net modeling, Supervision, validation, Writing-review and editing, Project administration.

Publisher's note

Krrish Scientific Publications Pvt. Ltd. and the ***Journal of Applied Sciences and Modelling*** remain neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

[1] Denaj: Agri-tourism brings in over 12 million euros per year. *Albanian Telegr. Agency* 2024. Available from: https://en.ata.gov.al/tag/denaj-agritourism/

[2] Ministry of Tourism and Environment, Albania. Kumbaro: 9.7 million foreign visitors by September, almost equal to 2023 record. *Albanian Telegr. Agency* 2024. Available from: https://en.ata.gov.al/2024/10/12/kumbaro-9-7-million-foreign-visitors-by-september-almost-equal-to-2023-record/

[3] M. Kumbaro. Albania approves National Tourism Strategy 2030, aiming for higher revenues, sustainable growth. *Albanian Telegraphic Agency (ATA)* Jul. 31, 2025. Available from: https://en.ata.gov.al/2025/07/31/albania-approves-national-tourism-strategy-2030-aiming-for-higher-revenues-sustainable-growth/

[4] M. Kumbaro. Minister Kumbaro Presents 2025 Budget, Focus on International Promotion, Ecotourism, and Environment. *Ministry of Tourism and Environment* 2024. Available from: https://mia.gov.al/en/minister-kumbaro-presents-2025-budget-focus-on-international-promotion-ecotourism-and-environment/

[5] Dionizi B, Dhora R. Reinventing rural economies through sustainable business models: a triple-layered analysis. *Frontiers in Sustainability.* 2025 Oct 16;6:1665635. Available from: https://doi.org/10.3389/frsus.2025.1665635

[6] FAO. The SFS-MED Platform: Sustainable Food Systems in the Mediterranean. *Food and Agriculture Organization of the United Nations FAO.* 2024. Available from: https://www.fao.org/family-farming/detail/en/c/1445989

[7] Deda G, Zaka O. A way to internet collect data, "Related to a specific subject". the special case: for Albanian agritourism users data. *WSEAS Transcations on Environment and Development.* 2024 Dec 16;20:810–819. Available from: https://doi.org/10.37394/232015.2024.20.76

[8] Deda G, Zaka O. Enhancing Agritourism Efficiency in Shkodra Region Through Gis and Route Optimization: A Qgis and Ors Tools Approach. In*10th International European Conference on Interdisiplinary Scientific Research* 2024 Aug 27.

[9] DEDA G, ZAKA O. Analysis of Agroturistic Centers and Agricultural Producers In Shkodra Region: Interconnection and Opportunities for Rural Tourism Development. In*2nd International Beysehir Gastronomy Culture and Tourism Congress, Konya, Türkiye.* 2025. Available from: https://www.researchgate.net/publication/391560931

[10] Network Science by Albert-László Barabási. BarabásiLab. Available from: https://networksciencebook.com/

[11] Newman M. Networks: An Introduction. *Oxford University Press.* 2010 Mar 25; Available from: https://doi.org/10.1093/acprof:oso/9780199206650.001.0001

[12] Borgatti SP, Everett MG, Johnson JC, Agneessens F. *Analyzing Social Networks.* 2024. Available from: https://doi.org/10.4135/9781036236021

[13] Brin S, Page L. The anatomy of a large-scale hypertextual web search engine. *Computer Networks and ISDN Systems.* 1998 Apr 1;30(1-7):107-17. Available from: https://doi.org/10.1016/S0169-7552(98)00110-X

[14] Petri CA. Kommunikation mit Automaten. INFDok. 1962 PhD Thesis, University of Bonn. Available from: http://edoc.sub.uni-hamburg.de/informatik/volltexte/2011/160/

[15] Murata T. Petri nets: Properties, analysis and applications. *Proceedings of the IEEE.* 1989 Apr 30;77(4):541-580. Available from: https://doi.org/10.1109/5.24143

[16] Jensen K. Coloured Petri nets: basic concepts, analysis methods and practical use. *Springer Science & Business Media.* 1992. Available from: https://books.google.co.in/books?id=6ck3wqmIchYC&lpg=PA1&ots=QD8sRzpxgq&dq

[17] Silva M, Teruel E. Petri Nets for the Design and Operation of Manufacturing Systems. *European journal of control*. 1997 Jan 1;3(3):182-99. Available from: https://doi.org/10.1016/S0947-3580(97)70077-3

[18] Guan S, Nakamura M, Shikanai T, Okazaki T. Hybrid Petri nets modeling for farm work flow. *Computers and electronics in agriculture*. 2008 Jul 1;62(2):149-58. Available from: https://doi.org/10.1016/j.compag.2007.12.006

[19] Wang B, Lu L, Liang C, Yan X, Zhao S, Lu W. A Timed Petri Net-Based Dynamic Visitor Guidance Model for Mountain Scenic Areas During Peak Periods. *Smart Cities*. 2026 Apr 10;9(4):66. Available from: https://doi.org/10.3390/smartcities9040066

[20] Su J, Li J. Scenic Tourist Intelligent Shunt Based on Timed Petri Nets. *International Journal of e-Collaboration*. 2022;18(1):1-8. Available from: https://doi.org/10.4018/IJeC.299002

[21] Bondaruk OV, Osadchyi AS, Vavdiiuk MS. OPTIMIZATION OF CULTURAL HERITAGE ROUTES USING GRAPH THEORY METHODS: MUSEUM NETWORK AND "LUTSKI KLYKUNY". . 2026 Apr 14(85):111-9. Available from: https://doi.org/10.36910/775.24153966.2026.85.14

[22] Prata BD, Arruda JB, Barroso GC. A New approach for coordinate logistics flows in agribusiness chains based on Petri nets: an application to castor bean biodiesel supply chain. In *VI International PENSA Conference on Sustainable Agri-food and Bioenergy Chains/Networks Economics and Management*. October, 24-26th, 2007, School of Business and Economics of Ribeirão Preto - University of São Paulo Ribeirão Preto – São Paulo – Brazil. Available from: www.researchgate.net/profile/Bruno-Prata/publication/272785928