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A Hybrid DEA-PSO Model for Improving Tourism Supply Chain Efficiency (Case Study: Kish Free Zone)

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Abstract

This study presents a hybrid model based on Data Envelopment Analysis (DEA) and Particle Swarm Optimization (PSO) to enhance the efficiency of the tourism supply chain in the Kish Free Zone. Initially, DEA models are employed to evaluate the relative performance of supply chain units, including hotels, travel agencies, and tourism recreation facilities, identifying their strengths and weaknesses. Subsequently, the PSO algorithm is applied to optimize inputs and outputs to achieve optimal efficiency. The data used in this research were collected through field surveys and relevant tourism industry databases in Kish. The results indicate that the integration of DEA and PSO serves as an effective tool for analyzing and optimizing the tourism supply chain. This approach can assist managerial decision-making by enabling optimal resource allocation and improving overall industry performance. The study introduces an innovative method for enhancing tourism supply chain efficiency, which can be adapted for other tourism destinations as well.

Keywords: Data envelopment analysis, Particle swarm optimization, Efficiency evaluation, Tourism supply chain, Kish free zone.

1 | Introduction

The tourism industry is one of the most significant economic sectors in many countries and free zones [1]. The sustainable development of this industry requires efficient supply chain management [2]. The tourism supply chain comprises a network of service units such as hotels, travel agencies, tourism recreation facilities, and other related infrastructures that collectively deliver tourism services in a coordinated manner [3]. Evaluating and optimizing the efficiency of this supply chain plays a crucial role in enhancing competitiveness

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and attracting tourists [4]. In this context, the application of analytical and optimization methods to assess the performance of these units and improve their productivity is deemed essential.

Kish free zone, as one of Iran's major tourism hubs, faces various challenges related to the efficiency of its tourism supply chain [5]. Factors such as inefficient resource management, suboptimal use of available capacities, demand fluctuations, and infrastructure-related issues have led to reduced productivity in this domain [6]. Evaluating the performance of different units within this supply chain can help identify their strengths and weaknesses [7].

Accordingly, employing scientific models to analyze and optimize the performance of these units can offer practical solutions for improving the overall efficiency of the tourism supply chain [8]. One of the effective methods for efficiency evaluation is Data Envelopment Analysis (DEA), which is widely used for assessing the productivity of decision-making units [9]. On the other hand, Particle Swarm Optimization (PSO) can serve as a complementary tool to optimize the input and output parameters of these models [10]. The integration of these two methods can offer an innovative approach to enhancing the performance of the tourism supply chain in the Kish Free Zone.

In recent years, numerous studies have assessed the efficiency of tourism supply chains. Some of these investigations have used DEA models to evaluate the performance of tourism units. For instance, a study demonstrated that DEA is a powerful tool for assessing hotel performance and identifying improvement opportunities [11]. Another study employed hybrid models combining DEA and optimization algorithms to propose solutions for increasing the productivity of tourism service units [12].

In Iran, several studies have evaluated the efficiency of tourism centers. One such study examined the productivity of Kish hotels and found that many of them had room for performance improvement [13]. Another study compared DEA and artificial neural networks for evaluating the efficiency of tourism units in Iran. The results showed that combining these two methods could provide more accurate performance assessments compared to traditional approaches [14]. Additionally, a study investigated the impact of using optimization algorithms such as PSO on improving the efficiency of the tourism supply chain, showing that the algorithm could optimize resource allocation and enhance productivity [15].

The main objective of this study is to propose a hybrid model based on DEA and PSO to improve the efficiency of the tourism supply chain in the Kish Free Zone. This model, by identifying weaknesses and optimizing the inputs and outputs of supply chain units, can support managerial decision-making and effective policy development. The necessity of this research stems from the fact that tourism is a key pillar of economic development in the Kish Free Zone, and enhancing the efficiency of its supply chain can directly influence tourist attraction and the region's economic growth [16].

Moreover, the outcomes of this study have the potential to be utilized as a benchmark or reference model for other tourism regions across the country. The demonstrated improvements in performance and resource utilization within the tourism supply chain of Kish can inspire similar initiatives in other destinations, fostering a more efficient and effective management approach throughout the sector. By showcasing how analytical tools and optimization techniques—such as performance evaluation and supply chain management—can be applied to real-world tourism operations, this study paves the way for broader adoption of data-driven decision-making practices.

In addition, by emphasizing the importance of performance analysis and the optimization of supply chain processes, the study introduces forward-thinking strategies aimed at enhancing productivity across the tourism industry. These strategies not only help in maximizing the use of available resources but also support long-term goals such as environmental sustainability, economic resilience, and improved service delivery. Ultimately, the implementation of such methods contributes to the sustainable development of tourism in the Kish Free Zone and can be extended to promote balanced and responsible tourism growth at the national level.

2 | Methodology

This study is applied in nature and adopts an analytical-descriptive methodology to investigate and improve the operational efficiency of the tourism supply chain in the Kish Free Zone. The research design integrates two powerful analytical tools: DEA, used to measure relative efficiency among decision-making units, and PSO, a metaheuristic algorithm employed to optimize performance by minimizing input usage and maximizing output results. This combined approach allows for a detailed evaluation and enhancement of tourism supply chain efficiency through a data-driven and systematic framework.

The statistical population includes all active components of the tourism supply chain in the Kish Free Zone, such as hotels, travel agencies, and tourism recreational facilities. However, due to constraints in obtaining comprehensive data from the entire population, the study adopted a purposive sampling method. This involved selecting a targeted group of tourism service providers, including a specified number of prominent hotels, leading travel agencies, and key recreational facilities. These units were chosen based on their relevance, accessibility, and significance in the tourism operations of the region.

Data collection was carried out using two primary sources. First, field data were obtained through structured questionnaires and semi-structured interviews with managers and experts who are directly involved in the tourism industry in Kish. These interactions helped identify the critical factors influencing unit performance and provided a foundation for the efficiency analysis. Second, secondary data were drawn from established databases and statistical reports issued by the Kish Free Zone Organization and affiliated research centers. These sources offered detailed and reliable performance records covering the years 2022 to 2023.

To ensure the accuracy and credibility of the research instruments, several validation procedures were conducted. Content validity was confirmed by a panel of domain experts, including university academics and experienced tourism managers, who evaluated the relevance and comprehensiveness of the questionnaire items. In addition, the reliability of the instruments was assessed using Cronbach's alpha coefficient, which indicated an acceptable level of internal consistency, confirming that the tools used for data collection were both valid and reliable for the study's objectives.

This study was conducted in four main steps:

Step 1. Data collection

Input and output data relevant to the tourism supply chain were collected from field sources and databases. These indicators included variables such as accommodation capacity, occupancy rate, operational costs, and revenue generated from tourism services, all of which are critical for evaluating the performance of various supply chain units.

Step 2. Performance evaluation using DEA

The relative performance of tourism units was assessed using the DEA model. This model enabled comparison of the relative efficiency of hotels, travel agencies, and tourism recreation facilities. Using DEA, the strengths and weaknesses of each unit were identified, distinguishing which units demonstrated higher productivity in resource utilization and service provision, and which required performance improvements.

Step 3. Efficiency optimization with PSO

The efficiency of tourism units was optimized using the PSO algorithm. This algorithm adjusted the input and output values of tourism units and proposed optimal values to improve their overall performance. In other words, the process enabled underperforming units to approach an optimal level of efficiency.

Step 4. Results analysis and managerial recommendations

The results were analyzed and interpreted, leading to managerial recommendations aimed at enhancing productivity and optimizing resource allocation. This analysis examined the impact of each performance indicator and offered suggestions to tourism industry managers for improving efficiency and reducing costs.

The collected data were analyzed using various computational methods with MATLAB software. Initially, DEA was applied to calculate the efficiency scores of tourism supply chain units and to compare their performance across key indicators. This analysis facilitated the identification of efficient and inefficient units and specified performance improvement criteria. Subsequently, the PSO algorithm was used to optimize the input and output parameters of inefficient units, bringing their performance closer to optimal levels. Through optimal variable adjustment, the algorithm increased productivity and improved resource allocation.

Finally, statistical analyses and data processing were conducted in MATLAB, including the implementation of mathematical models, performance analysis, and the extraction of final results. The software played a critical role throughout the research process, enabling precise analysis and simulation of various scenarios.

Through these methods, the present study successfully identified the strengths and weaknesses of the tourism supply chain and proposed practical solutions to improve its efficiency. The results may serve as a model for other tourism regions and provide a foundation for managerial and policy-making decisions aimed at the sustainable development of the tourism industry.

3 | Results

3.1 | Descriptive Results

In this study, the DEA model was employed to evaluate the efficiency of various units within the tourism supply chain in the Kish Free Zone, including hotels, travel agencies, and tourism recreation facilities. This analysis facilitated the identification of strengths and weaknesses among the units. The results indicated that hotels and travel agencies performed more efficiently compared to tourism recreation facilities. Input and output data were directly collected from field sources and databases relevant to the tourism industry in Kish. In this section, the efficiency of the different units (Hotels, travel agencies, and tourism recreation facilities) has been calculated using the DEA model. For example, the efficiency of each unit was calculated as follows:

$$\text{Unit Efficiency} = \frac{\text{Outputs}}{\text{Inputs}}.$$

Table 1. Evaluation of the efficiency of tourism supply chain units using DEA.

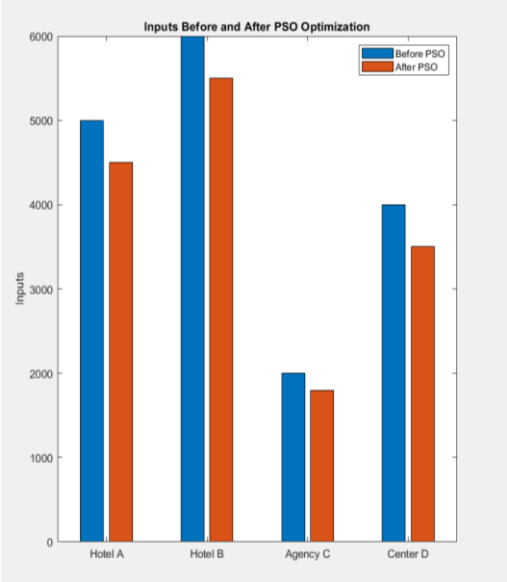
Supply Chain Unit	Inputs	Outputs	DEA Efficiency
Hotel A	5000	20000	0.85
Hotel B	6000	25000	0.90
Travel agency C	2000	10000	0.95
Tourism recreation facility D	4000	15000	0.75

Analytical results

Following the initial evaluation, the PSO algorithm was applied to optimize the inputs and outputs to achieve optimal efficiency. This algorithm contributed to improved resource allocation and cost reduction. *Table 2* and *Fig. 1* illustrate the variations in inputs and outputs before and after optimization using the PSO algorithm.

Table 2. Variations in inputs and outputs after optimization using the PSO algorithm.

Supply Chain Unit	Inputs (Before PSO)	Outputs (Before PSO)	Inputs (After PSO)	Outputs (After PSO)	Variations (%)
Hotel A	5000	20000	4500	22000	+10%
Hotel B	6000	25000	5500	26000	+6.67%
Travel agency C	2000	10000	1800	12000	+20%
Tourism recreation facility D	4000	15000	3500	16000	+6.67%



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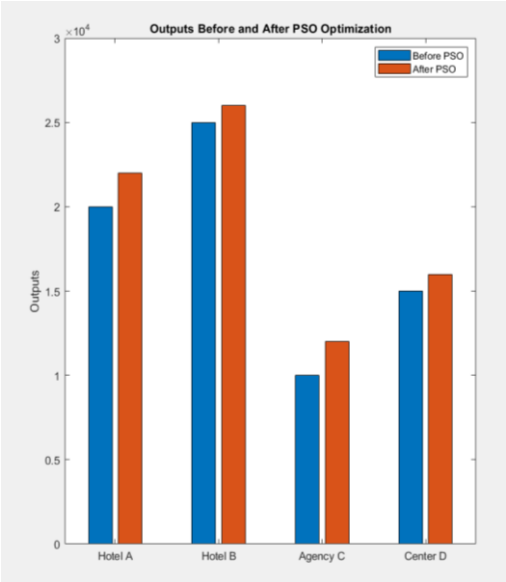


b.

Fig. 1. a. Variations in inputs before and after optimization using the PSO algorithm, b. variations in outputs before and after optimization using the PSO algorithm.

This figure illustrates the variations in inputs and outputs for each unit within the tourism supply chain in the Kish free zone, observed before and after the application of the PSO algorithm. The results clearly demonstrate that, post-optimization, input values were reduced while output values increased, indicating improved resource utilization and operational efficiency.

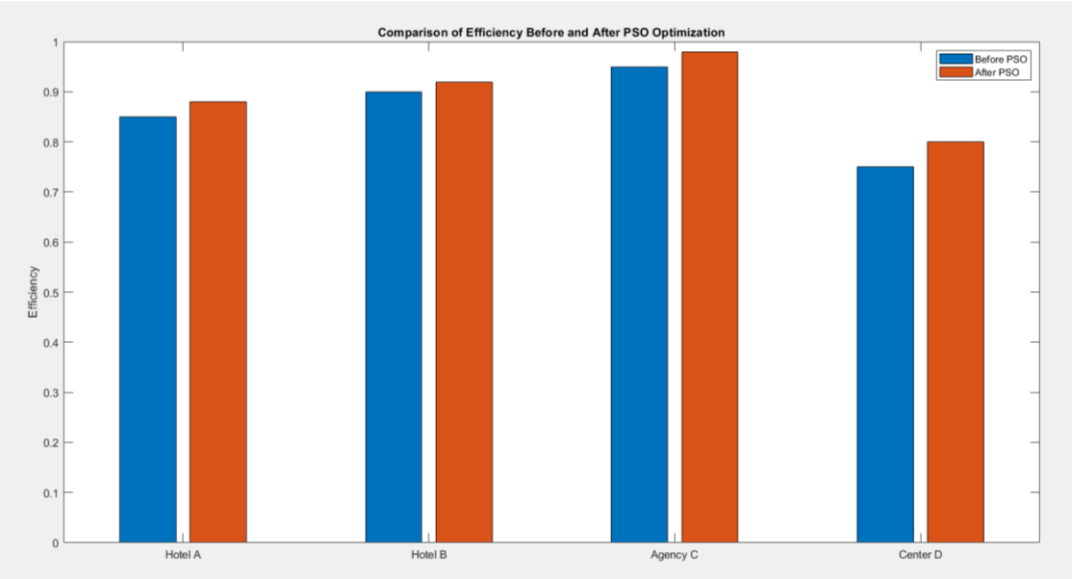
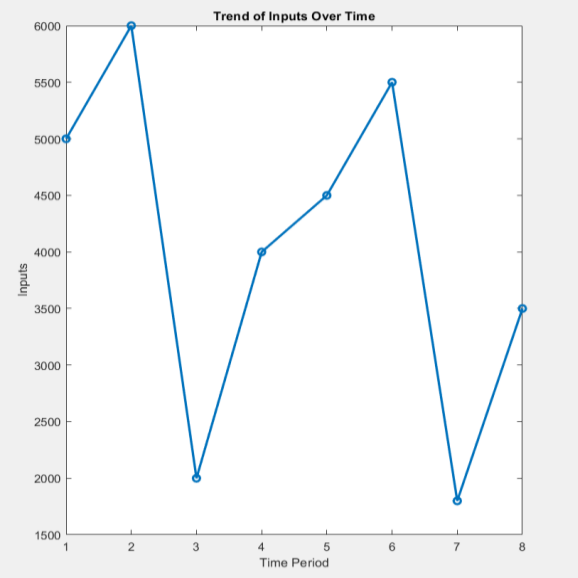


Fig. 2. Comparison of DEA efficiency before and after PSO optimization.

Fig. 2 illustrates a comparison of DEA efficiency before and after PSO optimization. It is clearly evident that the efficiency of the units improved following the optimization process. For example, the efficiency of Hotel A increased from 0.85 to 0.88.

Fig. 3 presents the trends of change over time. The first chart depicts the trend in input values over time, showing a noticeable decrease after optimization. The second chart illustrates the trend in output values, reflecting improved performance following the application of the PSO algorithm.



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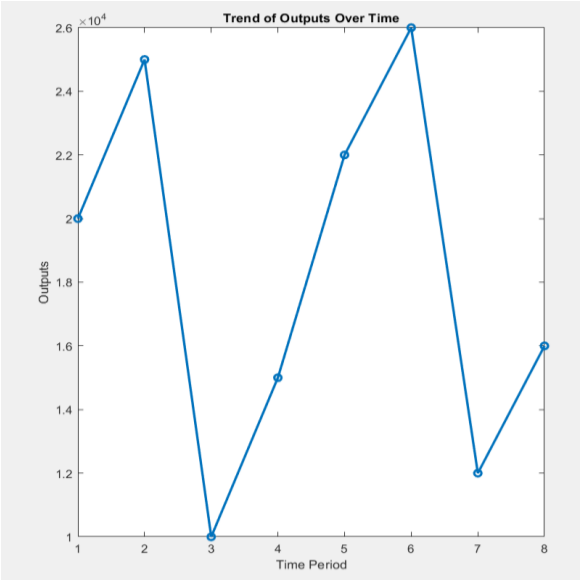

b.

Fig. 3. a. Trend of input variations; b. Trend of output variations.

As illustrated by the results, the analyses and optimization processes conducted have led to a considerable improvement in the performance of the various units within the tourism supply chain. These advancements are especially evident in two key areas: the reduction of input resources and the increase in output production. This transformation is primarily attributed to the successful implementation of the PSO algorithm, which has played a pivotal role in refining operational processes and enhancing efficiency.

The reduction in inputs refers to the more effective use of resources such as labor, materials, and time, which has been achieved by optimizing the way these resources are managed across the tourism supply chain. On the other hand, the increase in outputs highlights the better utilization of these resources, resulting in higher productivity, improved service delivery, and overall better performance in tourism services.

In addition to the application of the PSO algorithm, the study also highlights the integration of DEA with PSO as a highly effective strategy for improving managerial processes. By combining the efficiency assessment capabilities of DEA with the optimization power of PSO, a more comprehensive approach to improving the tourism industry's operations has been established. This integrated model not only supports better decision-making but also streamlines processes and enhances the overall management of tourism units within Kish, fostering long-term growth and success in the region's tourism sector.

4 | Discussion

This section examines the importance of the results obtained from the analyses and optimizations carried out using the integrated DEA model and the PSO algorithm. Initially, it must be emphasized that the combination of these two methods in this study has not only led to a significant improvement in the efficiency of various units in the tourism supply chain within the Kish Free Zone but also offers an innovative approach to addressing the fundamental challenges of this industry.

One of the critical aspects of this study is its ability to optimize inputs and outputs to achieve optimal efficiency within the tourism supply chain. This can assist industry managers in improving the overall system efficiency by allocating resources optimally.

A comparison of the results of this study with previous research on DEA and optimization algorithms shows that the simultaneous use of DEA and PSO yields better results than using these methods individually [17]. Many previous studies have employed various algorithms, such as genetic algorithms or evolutionary

algorithms, for optimization, but in this study, the use of PSO, with its simple structure and high convergence speed, has accelerated the optimization process and yielded more accurate results [10]. This is particularly important in the tourism industry, which requires quick and optimal responses to dynamic changes.

Furthermore, in comparison with similar studies that have focused primarily on tourism service management or enhancing the traveler experience [18], this research adopts a different approach by focusing on the optimization of the tourism supply chain. This shift in the research approach is particularly significant in the Kish Free Zone, which has its own unique challenges. The findings show that improving productivity across all units within the tourism supply chain in an integrated manner leads to overall enhancement in the performance of the industry.

This study also shares similarities with other research in the field of resource optimization and efficiency enhancement [19], but its distinction lies in the concurrent use of both the DEA and PSO models, which has significantly improved the overall efficiency of the tourism supply chain. This combined approach has made this research an effective model for resource optimization in the industry.

Ultimately, the findings of this study extend beyond the specific context of the Kish Free Zone, offering a robust and generalizable model that holds significant potential for application in other tourism regions both within and outside of Iran. This integrated approach can serve as a strategic framework for fostering sustainable tourism development and optimizing resource management across various global tourist destinations, particularly those facing similar logistical, operational, or economic challenges.

The integration of DEA and PSO has demonstrated itself as a highly effective methodological combination for identifying inefficiencies within complex systems and suggesting data-driven strategies to enhance overall performance. DEA serves as a powerful tool for assessing the relative efficiency of various units within the tourism supply chain, while PSO optimizes these efficiencies by refining resource allocation and minimizing waste. This combined approach allows for a comprehensive and nuanced analysis of performance, which helps pinpoint areas in need of improvement.

By leveraging the unique strengths of both DEA and PSO, tourism managers and policymakers gain access to a robust framework for making more informed, data-driven decisions. These decisions are crucial for reducing operational costs, optimizing resource utilization, and improving the overall efficiency of tourism operations. Furthermore, such informed decision-making enhances the competitiveness of tourism destinations, as it allows them to respond more effectively to market demands and emerging trends.

In addition to cost reduction and efficiency optimization, the dual-method model also has significant implications for service quality. By focusing on performance improvement and resource optimization, it helps deliver higher-quality services to tourists. This, in turn, fosters greater customer satisfaction, which is a key driver of repeat business and positive word-of-mouth recommendations. Over time, the consistent delivery of superior services builds a strong reputation and contributes to the long-term sustainability of the tourism industry. Ultimately, the combined use of DEA and PSO offers a holistic approach to not only improving immediate operational performance but also ensuring the ongoing success and growth of the tourism sector.

In summary, this research underscores the practical value of employing advanced analytical methods in tourism supply chain management. It highlights how scientific, evidence-based strategies can drive measurable improvements in performance, thereby providing a valuable blueprint for both practitioners and researchers seeking to advance efficiency and resilience in the tourism sector.

5 | Conclusion

The conclusion of this study highlights the significant role that the integration of two advanced analytical and optimization methods—DEA and PSO—can play in enhancing the operational efficiency of tourism supply chains. The empirical case of the Kish Free Zone serves as a compelling example of how scientific modeling can translate into tangible performance improvements in one of the most dynamic and competitive service sectors: tourism.

In this research, the DEA model was first utilized to evaluate the relative efficiency of different components of the tourism supply chain, including hotels, travel agencies, and recreational centers. This stage enabled the identification of both high-performing units and those that lagged in terms of input-output efficiency. By isolating strengths and weaknesses within each unit, a solid foundation was established for targeted optimization. DEA's ability to handle multiple input and output variables made it an appropriate tool for evaluating the performance of heterogeneous entities operating under different resource constraints.

Following the DEA evaluation, the PSO algorithm was applied to optimize the allocation of inputs (Such as labor, capital, and operational resources) and outputs (Such as tourist satisfaction, revenue, and service quality) across the entire supply chain. The PSO algorithm's advantages—particularly its simplicity, fast convergence rate, and flexibility—allowed for the rapid identification of near-optimal solutions that improved the efficiency of underperforming units. The synergy between DEA's diagnostic capabilities and PSO's optimization power formed a hybrid model that proved both practical and robust.

The results derived from the application of this integrated model demonstrate that it is capable of not only improving the operational performance of individual units but also enhancing the overall productivity and cost-effectiveness of the entire tourism supply chain. This integrated approach led to a noticeable reduction in resource waste and operational inefficiencies, and concurrently, a measurable increase in output effectiveness. Consequently, this model represents a highly functional framework that can be replicated in other regional or national tourism contexts.

Given the effectiveness of the DEA–PSO model in the Kish Free Zone, this study recommends the adoption of this integrated approach in other tourism regions, particularly those facing similar challenges such as limited resources, fluctuating tourist demand, and the need for high service quality. Applying this model more broadly can assist policymakers and tourism managers in achieving more strategic resource allocation, improving the quality of services delivered, and ensuring the long-term viability of their tourism sectors.

Furthermore, this study underscores the importance of integrating optimization strategies with sound management practices, especially in the domains of human and financial resource management. Findings from the research reveal that substantial gains in efficiency and productivity are often linked not only to algorithmic adjustments but also to how resources are managed on a day-to-day basis. It is therefore essential that tourism organizations invest in developing managerial competencies, especially in areas such as strategic planning, performance monitoring, and data-informed decision-making.

Another critical recommendation arising from this study is the need for continuous performance monitoring. While the DEA–PSO model provides a compelling snapshot of current efficiency levels, periodic application of these tools is necessary to ensure that the achieved improvements are maintained and refined over time. Regular reassessment using these models will allow managers to detect performance deviations early and make corrective decisions in a timely manner, thereby supporting a culture of continuous improvement.

Additionally, the development of specialized software tools that incorporate DEA and PSO algorithms could play a transformative role in operationalizing these methods in real-world tourism settings. Such tools could offer user-friendly interfaces for managers, automated performance diagnostics, and scenario-based optimization functions. By streamlining complex analytical tasks, these digital solutions could democratize access to sophisticated efficiency modeling, even for small or resource-constrained tourism enterprises.

Ultimately, the implementation of the proposed recommendations could significantly contribute to enhancing the competitiveness and long-term sustainability of the tourism industry—not only in Kish but also in other global destinations seeking to maximize their performance amid increasing economic and environmental pressures. By adopting innovative, data-driven models such as DEA and PSO, tourism stakeholders can make better-informed decisions, reduce operational costs, and elevate the quality of service offerings.

In conclusion, this research offers a scientifically grounded and operationally feasible model that bridges the gap between theoretical optimization and practical implementation. It provides a replicable framework that

can serve as a blueprint for similar efforts in other industries or economic zones aiming to improve efficiency, reduce waste, and ensure sustainable development. Through its contribution to both theory and practice, the study reinforces the value of interdisciplinary approaches in solving complex problems in contemporary tourism management.

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Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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