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# Evaluating Infrastructure Project Priorities in Kuwait Using AHP

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## Abstract

Effective infrastructure planning is essential for sustainable national development, especially in resource-constrained environments like Kuwait. This study applies the Analytic Hierarchy Process (AHP) to evaluate and prioritize infrastructure projects based on expert judgments. Four major project types were assessed—Highway Network Expansion, Desalination and Water Infrastructure, Smart Energy Grid Modernization, and Coastal and Recreational Zone Revitalization—using criteria including economic impact, technical feasibility, social benefit, and environmental sustainability. A structured questionnaire was administered to 30 experts, and the results were processed using AHP methodology, including consistency checks. The findings revealed that economic impact was the most influential criterion (weight = 0.35), followed by technical feasibility and social benefit (0.25 each), with environmental sustainability being least prioritized (0.15). Desalination and Water Infrastructure ranked highest overall, reflecting the strategic importance of water security in Kuwait. The study confirms AHP as an effective decision-support tool for infrastructure planning and offers a localized prioritization framework that can inform public policy and investment strategies across the Gulf region.

**Keywords;** Infrastructure Planning; Project Prioritization; Analytic Hierarchy Process (AHP); Kuwait.

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## Introduction

Infrastructure development plays a pivotal role in driving economic growth, enhancing public services, and improving overall quality of life (Hoedemaekers, 2024). For countries like Kuwait, where infrastructure investment forms a core component of long-term national development strategies, the ability to prioritize projects effectively is essential. However, with finite financial and environmental resources, decision-makers are often confronted with the challenge of selecting among multiple high-impact projects across sectors such as transportation, energy, water, and urban development.

Globally, multi-criteria decision-making (MCDM) tools—particularly the Analytic Hierarchy Process (AHP)—have been widely applied to improve transparency and objectivity in infrastructure planning (Rane, Achari & Choudhary, 2023). These approaches enable the integration of technical, economic, social, and environmental factors into a coherent framework for project ranking.

Existing research in the Kuwaiti context has largely focused on evaluating individual infrastructure challenges (e.g., solid waste management or megaproject complexity), without offering a systematic, multi-criteria model for ranking national infrastructure priorities. Moreover,

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few studies have incorporated localized expert input to reflect Kuwait’s specific development needs, constraints, and policy objectives.

To address this gap, the present study aims to develop a context-sensitive AHP framework for prioritizing infrastructure projects in Kuwait. By drawing on expert judgments from civil engineers, urban planners, and policymakers, the research seeks to identify the most critical projects based on criteria such as economic impact, technical feasibility, social benefit, and environmental sustainability. The findings are expected to support more structured, evidence-based decision-making for infrastructure planning in Kuwait and offer a replicable model for other Gulf countries.

## Literature review

As Oswald Beiler and Treat (2015) noted, the increasing risks of climate change have amplified the need for sustainable transportation planning. Their research emphasizes the role of Geographic Information Systems (GIS) and Analytic Hierarchy Process (AHP) in prioritizing transportation infrastructure, incorporating environmental, economic, and societal sustainability metrics. Their integrated GIS-AHP framework facilitated the identification and weighting of relevant factors through expert pairwise comparisons, culminating in a Project and Location Prioritization Index (PLPI). A case study in Philadelphia demonstrated the model's applicability, which aligns closely with the methodological goals of the present study in Kuwait.

Aboushady and El-Sawy (2013) proposed a qualitative assessment framework for identifying sustainability indicators that influence infrastructure construction in Egypt. Their study used AHP to rank these indicators through expert surveys, highlighting how early prioritization improves project planning in developing countries. This framework, adaptable across national contexts, offers useful parallels to the Kuwaiti infrastructure landscape, particularly in the methodological use of expert judgment and hierarchical modeling.

As Belay et al. (2022) emphasized, effective decision-making in infrastructure projects requires a structured evaluation of critical success factors. Applying AHP within the Ethiopian construction industry, they established interdependent relationships among decision criteria like consultant competency and financial strength. Their multi-criteria approach highlights how stakeholder-based judgments can improve project planning, similar to the expert-driven model used in the Kuwaiti context.

Marcelo et al. (2015) developed the Infrastructure Prioritization Framework (IPF), a decision support tool that integrates social, environmental, and financial-economic dimensions into project assessment. Designed for government application, IPF promotes systematic infrastructure decision-making under resource constraints. The flexibility of this model—evident in its applications in Vietnam and Panama—

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demonstrates the global relevance of AHP-like frameworks for infrastructure prioritization.

In the Brazilian context, Quadros and Nassi (2015) utilized AHP to assess transportation infrastructure investment priorities by categorizing criteria into logistical, economic, social, and environmental domains. Through expert comparisons, they found “reduction of transportation costs” to be the most influential criterion, a finding that reinforces the weight assigned to economic impact in infrastructure decisions—mirrored in the weighting structure of the Kuwaiti study.

Bošnjak and Jajac (2023) proposed a hybrid AHP-TOPSIS model to improve infrastructure maintenance prioritization, accommodating stakeholder perspectives while enabling sensitivity testing. Their approach illustrates how financial limitations can be rationally addressed using structured decision tools. This is particularly relevant in Kuwait, where resource allocation efficiency remains central to project evaluation.

Khan et al. (2022) addressed the lack of localized sustainability frameworks for Gulf urban infrastructure projects. Using AHP to derive the weights of sustainability indicators from expert input, they proposed a hierarchically coordinated model tailored to the Gulf context. This study directly complements the current research, which also considers environmental sustainability and regional expertise in its evaluation.

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As Amponsah (2013) indicated, prioritizing road infrastructure requires an integrated consideration of social, legal, environmental, economic, political, and technological (SLEEPT) criteria. By structuring decision-making with AHP and employing software like Expert Choice, Amponsah showcased how agencies can systematize infrastructure planning—a process reflected in the structured decision model of the present Kuwaiti study.

AlKheder et al. (2025) examined the complexity of megaprojects in Kuwait, particularly the Shadadiyah university campus, using both AHP and fuzzy AHP methods. Their results demonstrated the importance of technological and goal-related complexities in influencing project feasibility. The dual-method approach and focus on local infrastructure contexts provide valuable insights for the current research on prioritizing national infrastructure initiatives.

Lastly, Alsulaili et al. (2024) explored municipal solid waste (MSW) management in Kuwait using AHP combined with genetic algorithms. Their focus on multiple criteria—including safety, air, and water pollution—underlines the role of environmental factors in infrastructure-related decision-making. Their work reinforces the applicability of AHP in diverse infrastructure domains, from waste to transportation, within Kuwait's development framework.

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While numerous international studies have demonstrated the effectiveness of the Analytic Hierarchy Process (AHP) in prioritizing infrastructure and construction projects—especially in contexts like transportation planning (Oswald Beiler & Treat, 2015), sustainable development (Aboushady & El-Sawy, 2013), and infrastructure complexity (AlKheder et al., 2025)—there remains a significant gap in localized applications of such frameworks within the Gulf region, particularly Kuwait. Although some regional efforts (e.g., Khan et al., 2022; Alsulaili et al., 2024) have adapted AHP to evaluate urban sustainability and waste management, these models u lack a comprehensive focus on multi-sectoral infrastructure priorities involving critical national projects such as transportation networks, water infrastructure, energy modernization, and coastal development.

Furthermore, existing prioritization models frequently emphasize either technical or environmental aspects in isolation, without integrating economic, social, and environmental factors simultaneously within a structured decision-making model rooted in expert judgment. In the context of Kuwait, no prior study has systematically ranked infrastructure projects using a customized, expert-driven AHP framework that aligns with national development goals and local planning constraints.

This research, therefore, fills a clear gap by developing and applying a tailored AHP-based prioritization model that incorporates localized expert

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input and multi-criteria analysis to identify and rank infrastructure priorities in Kuwait. The study not only responds to the need for context-specific decision tools but also offers a replicable framework for public policy and investment planning across the Gulf region.

## Methodology

The present study employs a descriptive, decision-oriented research design to evaluate infrastructure project priorities in Kuwait. The methodology consists of two primary phases. In the first phase, a group of experts—including civil engineers, urban planners, and policymakers—were surveyed to gather their assessments of key criteria influencing infrastructure development. In the second phase, the Analytic Hierarchy Process (AHP) was applied to structure and analyze these expert judgments, enabling the prioritization of infrastructure projects based on weighted criteria such as economic impact, technical feasibility, social benefit, and environmental sustainability.

## Study Tool

The primary tool used in this study was a structured AHP-based questionnaire, developed based on a review of relevant literature and aligned with best practices in multi-criteria decision-making. The questionnaire was designed to collect expert judgments on the relative importance of predefined criteria for infrastructure project evaluation. These criteria were

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derived from prior studies and included dimensions such as economic impact, technical feasibility, social benefit, and environmental sustainability. Experts were asked to perform pairwise comparisons among these criteria and among the proposed infrastructure projects under each criterion, in accordance with the standard AHP methodology.

The final version of the questionnaire was validated for clarity and content by academic and professional experts in civil engineering and infrastructure planning. Their feedback helped ensure that the tool was contextually appropriate and methodologically sound for evaluating project priorities in Kuwait.

**Sample and Population**

The study population comprised professionals actively involved in infrastructure planning and development in Kuwait, including civil engineers, urban planners, and policymakers. A purposive sample of 30 experts was selected to participate in the study, representing a cross-section of public and private sector stakeholders with direct experience in infrastructure decision-making. The sampling technique employed was convenience sampling, focusing on individuals with demonstrated expertise and availability to provide informed judgments through the AHP-based questionnaire.

## AHP Approach

The Analytic Hierarchy Process (AHP) was employed to systematically prioritize infrastructure projects in Kuwait by evaluating them against multiple decision criteria. AHP provides a structured framework capable of integrating both qualitative judgments and quantitative analysis in complex, multi-criteria decision-making contexts.

The following steps were undertaken to compute the relative weights of each criterion and alternative project:

### Structuring the AHP Hierarchy Model

This initial phase involved constructing the AHP hierarchy model, which comprised three levels: the overarching goal (prioritizing infrastructure projects), the decision criteria (e.g., economic impact, technical feasibility, social benefit, and environmental sustainability), and the alternative infrastructure projects being considered. The goal was placed at the top level of the hierarchy, followed by the criteria at the intermediate level, and the project alternatives at the bottom level, as illustrated in Figure 1.

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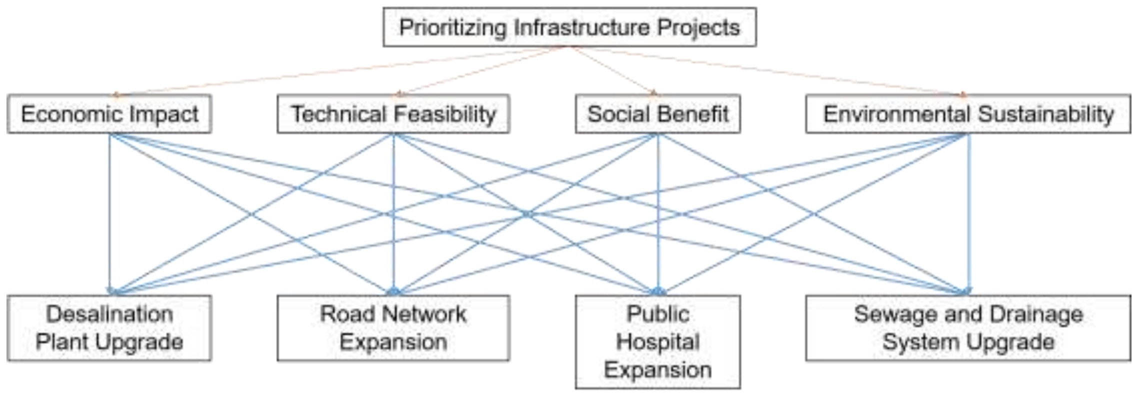


*Figure 1: The AHP hierarchy model*

**Development of the Pairwise Comparison Matrix**

In this phase, a pairwise comparison matrix was constructed to evaluate the relative importance of the selected infrastructure projects under each decision criterion. Experts were asked to compare the projects two at a time based on their professional judgment. Each comparison was assigned a numeric rating using the AHP fundamental scale (e.g., 1, 3, 5, 7, 9) to reflect the degree of preference. Intermediate values such as 2, 4, 6, and 8 were used for moderate judgments between the standard scale points. When one project was preferred less than the other, its position in the matrix was assigned the reciprocal value (e.g., 1/3, 1/5). A value of 1 was assigned when a project was compared with itself, ensuring consistency in the matrix structure (Onder & Dag, 2013).

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## Development of the Normalized Matrix

Once the pairwise comparison matrix was established, each element in the matrix was normalized by dividing it by the sum of its respective column. This transformation converts the values into a comparable scale across all criteria, ensuring that the matrix is suitable for weight derivation. This method follows standard AHP normalization procedures as outlined by Saaty (1980) and further discussed by Ishizaka and Labib (2011).

## Calculation of the Priority Vector

The priority vector was derived by calculating the mean of each row in the normalized matrix. This vector represents the relative weights or importance levels of each infrastructure project under a given criterion. The arithmetic mean method used here is a common and validated approach in AHP applications, as supported by Vaidya and Kumar (2006).

## Consistency Ratio Calculation

To ensure the reliability of expert judgments, a consistency check was performed. The process began by computing the weighted sum vector through multiplying each element in the pairwise matrix by the corresponding priority vector value, then summing the results across each row. Each row's weighted sum was then divided by its respective priority vector value to compute an estimate of $\lambda_{max}$ (maximum eigenvalue). The Consistency Index (CI) was calculated using the formula:

$$CI = (\lambda_{max} - n)/(n - 1)$$

Subsequently, the Consistency Ratio (CR) was computed as:

$$CR = \frac{CI}{RI}$$

Where RI represents the Random Consistency Index, dependent on the matrix size. Table 1 below outlines standard RI values, as referenced by Saaty and Vargas (2012) and empirically confirmed by Aguarón and Moreno-Jiménez (2003).

***Table 1: Average random consistency index (RI) as a function of pair –wise comparison matrix size***

| **Size of matrix** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|
| **RI** | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

A CR value less than 0.10 was considered acceptable, indicating consistent judgments (Saaty, 1980).

## Formation of the Final Priority Matrix

Following the consistency check and derivation of individual priority vectors, all results were aggregated into a comprehensive priority matrix. This matrix summarized the final priority scores of the infrastructure projects under each criterion, providing a clear basis for project ranking.

This step is in line with practices outlined in multi-criteria decision-making literature, such as Ishizaka and Nemery (2013) and Wang et al. (2009).

## Results

This section presents the outcomes of the Analytic Hierarchy Process (AHP) applied to prioritize infrastructure projects in Kuwait. The results were derived by integrating expert judgments across four evaluation criteria: economic impact, technical feasibility, social benefit, and environmental sustainability.

## Criteria Weighting

The first step involved calculating the relative weights of the decision criteria based on expert pairwise comparisons. Table 2 presents the final weights. The economic impact criterion received the highest weight (0.35), followed by technical feasibility and social benefit (0.25 each), while environmental sustainability was considered the least influential (0.15).

***Table 2: Criteria Weights***

| Criteria | Weight |
|---|---|
| Economic Impact | 0.35 |
| Technical Feasibility | 0.25 |
| Social Benefit | 0.25 |
| Environmental Sustainability | 0.15 |

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## Normalized Scores by Criterion

Experts evaluated four proposed infrastructure projects under each criterion. The normalized scores are shown in Table 3. These scores represent the relative performance of each project within a given criterion, adjusted to ensure comparability.

***Table 3: Normalized Project Scores by Criterion***

| Project Description | Economic Impact | Technical Feasibility | Social Benefit | Environmental Sustainability |
|---|---|---|---|---|
| **Highway Network Expansion** | 0.40 | 0.30 | 0.25 | 0.10 |
| **Desalination and Water Infrastructure** | 0.30 | 0.40 | 0.25 | 0.20 |
| **Smart Energy Grid Modernization** | 0.20 | 0.20 | 0.35 | 0.30 |
| **Coastal and Recreational Zone Revitalization** | 0.10 | 0.10 | 0.15 | 0.40 |

For example, the Highway Network Expansion project received the highest score (0.40) under the economic impact criterion, reflecting its anticipated role in improving logistics and trade connectivity. Meanwhile, the Coastal and Recreational Zone Revitalization project scored highest

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under environmental sustainability (0.40), but lower in economic and technical criteria.

### Weighted Scores by Criterion

Next, the normalized scores were multiplied by the corresponding criterion weights to determine each project's weighted contribution to the overall decision (Table 4). This step captures how each criterion influences the final prioritization.

***Table 4: Weighted Scores by Criterion***

| Project Description | Economic Impact | Technical Feasibility | Social Benefit | Environmental Sustainability |
|---|---|---|---|---|
| **Highway Network Expansion** | 0.1400 | 0.0750 | 0.0625 | 0.0150 |
| **Desalination and Water Infrastructure** | 0.1050 | 0.1000 | 0.0625 | 0.0300 |
| **Smart Energy Grid Modernization** | 0.0700 | 0.0500 | 0.0875 | 0.0450 |
| **Coastal and Recreational Zone Revitalization** | 0.0350 | 0.0250 | 0.0375 | 0.0600 |

This table highlights how projects that performed well in high-weight criteria gained higher cumulative scores. For instance, the Desalination and Water Infrastructure project performed well under both economic impact

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and social benefit—criteria with significant weights—leading to a high overall score.

**Final Project Prioritization**

Finally, the weighted scores were summed across all criteria to produce a single priority score for each project. The resulting rankings are presented in Table 5.

***Table 4: Final AHP Project Prioritization***

| Project Description | Final Priority Score | Rank |
|---|---|---|
| **Highway Network Expansion** | 0.2925 | 2 |
| **Desalination and Water Infrastructure** | 0.2975 | 1 |
| **Smart Energy Grid Modernization** | 0.2525 | 3 |
| **Coastal and Recreational Zone Revitalization** | 0.1575 | 4 |

Desalination and Water Infrastructure received the highest priority score (0.2975), reflecting its strategic importance for water security and societal well-being, while Highway Network Expansion followed closely (0.2925), benefiting from strong economic and technical ratings. Smart Energy Grid Modernization achieved a moderate score (0.2525), with high marks for environmental sustainability but lower feasibility ratings. Coastal and Recreational Zone Revitalization ranked lowest (0.1575), due to limited perceived economic and technical benefits. All pairwise comparison matrices passed the consistency check (Consistency Ratio < 0.10), confirming the internal reliability of expert judgments.

## Discussion

The findings of this study provide valuable insights into the prioritization of infrastructure projects in Kuwait using the Analytic Hierarchy Process (AHP). The application of expert judgments across four criteria—economic impact, technical feasibility, social benefit, and environmental sustainability—produced a structured and quantifiable ranking of four proposed projects. The top-ranked project was Desalination and Water Infrastructure, followed closely by Highway Network Expansion, Smart Energy Grid Modernization, and lastly Coastal and Recreational Zone Revitalization.

The highest weight was assigned to economic impact (0.35), aligning with global findings that emphasize the economic return on infrastructure investments as a primary decision driver. This mirrors the results of Quadros and Nassi (2015), who found that "reduction in transportation costs" was the most influential criterion in Brazil's infrastructure planning. Similarly,

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Marcelo et al. (2015) noted that economic and financial considerations often dominate infrastructure decision-making, especially in resource-constrained environments.

The relatively high weights for technical feasibility (0.25) and social benefit (0.25) suggest that Kuwaiti experts value both engineering viability and societal utility, consistent with findings from Belay et al. (2022), who emphasized consultant competency and stakeholder input as crucial for project success in Ethiopia. These insights validate the integration of multiple perspectives in infrastructure planning, as also advocated by Bošnjak and Jajac (2023) in their hybrid AHP-TOPSIS model.

The lowest weight was assigned to environmental sustainability (0.15), indicating a lesser emphasis on ecological considerations in Kuwait's infrastructure prioritization. This finding contrasts with studies like Oswald Beiler and Treat (2015) and Khan et al. (2022), where environmental metrics, such as climate vulnerability and urban resilience, played a more central role. While this may reflect contextual realities in Kuwait, it also signals a potential gap in long-term sustainability planning that future policy agendas could address.

The top-ranked project, Desalination and Water Infrastructure, reflects expert recognition of Kuwait's pressing water security challenges. Its strong performance under both economic and social benefit criteria is consistent with findings from Khan et al. (2022), who emphasized water infrastructure

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as a critical priority in Gulf States. Moreover, its environmental impact score, while moderate, suggests growing awareness of sustainability concerns, aligning partly with the frameworks developed by Alsulaili et al. (2024) in Kuwait's waste management sector.

The Highway Network Expansion project, ranked second, performed exceptionally well under economic impact, reinforcing the nation's need to enhance trade and logistics infrastructure. This echoes the work of Amponsah (2013), who stressed the integration of transportation systems based on social and economic alignment using AHP.

The third-ranked Smart Energy Grid Modernization scored highest in environmental sustainability but lower in technical feasibility and economic return. This tradeoff mirrors global findings on energy infrastructure, as highlighted by Marcelo et al. (2015), where environmentally sound projects may struggle to gain prioritization unless accompanied by strong economic justification.

Lastly, the Coastal and Recreational Zone Revitalization project, though rated highly under environmental sustainability, suffered from low scores in economic and technical dimensions. This suggests that aesthetic or ecological projects may be underappreciated in expert evaluations unless they are clearly tied to economic development or risk mitigation strategies.

The robustness of expert judgments in this study—evidenced by Consistency Ratios (CR) below 0.10, confirms methodological validity and aligns with best practices outlined by Saaty (1980) and Ishizaka and Labib (2011). The reliability of these inputs enhances the credibility of the resulting prioritization framework.

Moreover, the integration of expert views across government and private sectors enhances the contextual relevance of the model, supporting AlKheder et al. (2025)'s call for locally adapted AHP frameworks in Kuwait's megaprojects.

## Conclusion

This study demonstrates the utility of the Analytic Hierarchy Process (AHP) in systematically evaluating infrastructure project priorities within the Kuwaiti context. By incorporating expert assessments across multiple criteria—economic impact, technical feasibility, social benefit, and environmental sustainability—a comprehensive prioritization framework was developed. The results highlight the centrality of economic considerations in infrastructure planning, with Desalination and Water Infrastructure emerging as the top priority due to its critical relevance to national water security and societal well-being.

The findings align with global research emphasizing the practicality of AHP in decision-making for infrastructure projects while also exposing a

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regional tendency to deprioritize environmental sustainability. This suggests a need for policy initiatives that more explicitly integrate long-term ecological concerns into project evaluation frameworks.

Importantly, this study fills a significant gap in the Gulf region's infrastructure literature by providing a replicable, context-sensitive AHP model grounded in localized expert input. The model can assist policymakers, planners, and stakeholders in making transparent, evidence-based investment decisions that align with Kuwait’s development goals. Future research may consider integrating additional methods such as Fuzzy AHP or GIS tools to further enhance model robustness and responsiveness to dynamic planning needs.

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