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Architectural Evaluation of Settlement Morphologies for Self-Sufficient Temporary Shelters in Hot-Arid Regions

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Abstract Temporary shelter settlements in hot arid regions frequently endure far beyond their intended lifespan, yet their spatial and environmental performance remains weakly theorized in architectural research. Existing studies predominantly address the design of individual temporary shelter units (TSUs), with limited attention to how settlement-scale morphology shapes thermal comfort, infrastructural efficiency, and socio-spatial cohesion. To address this gap, this study develops a settlement-level evaluation framework to compare two self-sufficient configurations suited to Jordan's desert context: a Dispersed Modular Settlement and a Clustered Compact Settlement. The framework adapts established TSU performance indicators to the settlement scale and applies expert-based weighting through the Analytical Hierarchy Process. Sixteen specialists in architecture, engineering, and planning validated the criteria and completed pairwise comparisons. Model performance was assessed using weighted composite scoring, z-score normalization, inter-criteria correlation analysis, confidence interval estimation, and sensitivity testing. The results demonstrate a statistically robust advantage for the Clustered Compact Settlement across sustainability, technical, and social dimensions. This configuration achieves superior thermal moderation, more efficient renewable energy and utility integration, reduced infrastructural redundancy, and enhanced opportunities for communal interaction. Non-overlapping 95 percent confidence intervals and stable outcomes under ±10 percent weighting variations confirm result reliability. By integrating desert microclimate principles with multi-criteria decision analysis, this study offers a transferable, evidence-based framework for designing resilient, sustainable, and self-sufficient temporary settlements in arid environments.

Keywords Shelter Settlements, Settlement Morphology, Desert Architecture, Microclimate Design, Arid Environments, AHP Analysis

1. Introduction

There are growing architectural and environmental challenges to temporary settlement in hot-arid landscapes, with increasing climatic extremes, prolonged displacement, and broader environmental demands in many hot-arid environments. Although temporary shelter units (TSUs) are generally designed as small-scale, fast-moving solutions, in practice, they can evolve into long-term, living environments [1]. Yet architectural studies and humanitarian practice have historically focused on TSUs as objects more than components of larger spatial systems; settlements provide logistical needs but are exposed, socially fragmented, and operationally inefficient [2]-[5].

While much research on desert architecture and micro-climate design has made great advances, it is rarely used for temporary settlement planning. Modern, historic, and contemporary studies of hot-arid architecture clearly suggest that spatial configuration, characterized by compact clustering, courtyard typologies, shading patterns, and airflow-oriented circulation, can contribute significantly to reducing heat gain and enhancing environmental resilience [6]-[10]. Research on simulation studies further evidences that clustered and courtyard-like morphologies mitigate radiant heat and improve outdoor thermal performance more reliably than linear or grid-shaped processes [11],[12]. Although humanitarian TSU missions are largely undervalued due to the priorities of speed and logistics over environmental responsiveness, settlement morphology remains largely underdeveloped in the context of temporary shelter planning.

Aside from environmental performance, settlement morphology can be understood as a climate adaptation mechanism within socio-technical systems. Thermal moderation is influenced by space, along with infrastructure redundancy, energy integration, water autonomy, and social resilience. In this sense, morphology is a strategy for adaptive infrastructure that balances extreme climatic stress with long-term viability. The use of the adaptation and resilience lens to frame settlement design further enhances its relevance to broader climate-responsive planning discourses.

This lack of settlement-scale architectural thinking stems from Jordan, where hot, desert environments, fragile infrastructure for services, and persistent displacement have created a long-standing demand for TSUs in remote deserts. Despite the lack of focus on how TSUs interact in environmental, social, and operational terms, previous research on deplorability, materiality, unit flexibility, or envelope performance has been relegated to some areas in fewer studies about how whole settlements behave in socially and operationally effective ways. In the past, planning research often relied on urban, infrastructural, or public-health perspectives, but architectural questions about spatial form, micro-climate generation, shading network, and environmental behavior were mostly unexplored.

In addressing this critical gap, this paper investigates two different settlement configurations that are both architectural and environmentally related: Clustered Compact Settlement, which aggregates units in shaded and interconnected micro-climates, or Dispersed Modular Settlement, which distributes units across larger terrain to maximize autonomy and logistical convenience. This analysis uses findings from temporary shelter literature of Kronenburg [2], UNHCR [4], desert micro-climate literature of Fathy [6], Givoni [7], and Brown & DeKay [9], in addition to spatial morphology theory of Rashid [13].

A framework of multi-criteria is developed by Aghamolaei et al. [14], which includes environmental performance, technical feasibility, and social utility. A collection of weighted indicators through experts, factor analysis, AHP computation, and statistical normalization is assembled to facilitate the assessment.

This framework is suitable for the hot arid desert climate of Jordan and can be calibrated to other extreme environments that have climatic severity, infrastructure vulnerability, and population displacement. However, the portability of weights to criteria and performance may need to be adjusted in other contexts that have different wind patterns, different governance capabilities, different cultural settlement patterns, and different resource availability.

This investigation is guided by three research questions:

RQ1: How does settlement-scale spatial configuration influence the environmental, social, and technical performance of temporary shelter environments in hot-arid climates?

RQ2: Which settlement morphology offers the highest potential for achieving self-sufficiency, climatic responsiveness, and operational efficiency under desert conditions?

RQ3: What architectural criteria emerge as most critical for guiding the design of resilient, sustainable temporary settlements in Jordan’s desert context?

By shifting analysis from the unit level to the settlement level, this study directly addresses the gaps identified in the literature and introduces an architectural planning framework capable of supporting more context-responsive, climatically adaptive, and socially coherent temporary environments in hot-arid regions.

2. Literature Review

2.1. Temporary Shelter Architecture and Settlement Research

During the temporary shelter architecture period, specific units have traditionally been prioritized for technical and structural performance, especially for fast deployment, portability, modularity, and material efficiency [2],[3]. Humanitarian practice follows the same pattern; UNHCR guidelines [4] and Makadi et al. [5] focus on safety and minimum habitability, with a focus on logistical and structural demands rather than performance at the architectural or settlement level.

This approach has been the best known for the deployment of effective, technically efficient shelter models, but frequently exposing them to environmental, social vulnerability, and spatially disadvantaged models.

While the literature readily endorses the notion that ‘temporary’ settlements often become long-term inhabited landscapes, it has only partially shifted in these cases to examine the spatial and environmental performance of these settlements. The design of camp settlements is typically driven by planning, infrastructure, or public health principles, Santamouris [15], but architectural questions about morphology, microclimatic behavior, or spatial resilience are not sufficiently explored in the study of camps. Even research on TSU sustainability, adaptability, or self-sufficiency [16],[17] is predominantly concentrated on the unit scale and rarely extends the analysis to spatial configuration.

In terms of resilience, this unit-centric approach fails to explore the role of settlement form as an adaptive system. Climate resilience theory focuses on the interaction between built form, networks of infrastructure, and social organization as socio-technical systems. The spatial arrangement of temporary settlements is not simply spatial; morphology is also structurally related to redundancy, energy flow, and management of collective resources. The absence of a settlement-scale architectural thought, therefore, presents not only a spatial gap, but also a systems-level vulnerability in climate-exposed environments.

Hence, this literature provides valuable insights into the properties of TSUs, but also does not yet provide a coherent architecture that should reflect settlement-level design. As climate change increases environmental pressures and displacement becomes increasingly common worldwide, the gap in shelter architecture has become particularly important.

2.2. Desert Architecture and Micro-Climate Design Principles

The hot-arid climate is subject to intense environmental stress, high solar radiation, low humidity, high diurnal thermal fluctuation, and dust-laden winds that direct the architecture of buildings and settlements [7],[10]. In these contexts, traditional desert architecture responds with the use of a variety of spatial strategies, including shaded courtyards, compact settlement clustering, careful orientation, thick envelopes, and narrow circulation paths that provide shading and air flow in desert environments [6],[8],[9],[18]. These approaches show the stark dependence of climate performance in desert environments on settlement scale, not building techniques. These current simulation results are consistent with the finding that courtyard or clustered morphologies function better than dispersed linear or grid models to mitigate surface heat, wind direction changes, and outdoor thermal comfort with changes in surface heat distribution. Space configuration can also affect the characteristics of airflow, shading systems, dust control, and solar access and result in microclimates that increase or reduce environmental stress [19].

These spatial logics are increasingly conceived as passive adaptive infrastructure in the discourse of climate adaptation today. Compact clustering reduces the amount of surface area exposed, improves mutual shading, and supports shared energy systems that act as a collective buffer against climatic extremes. Thus, the vernacular morphology of deserts offers a transferable adaptation pathway that is compatible with environmental moderation and efficiency.

The desert architectural concepts are practically unavoidable in temporary settlement planning, but only very marginally significant in practice. The function and environmental relations of vernacular deserts in the present TSU configuration are not connected to clustering, courtyard logic, or micro-climate optimization, but are minimal, if not substantially functional and environmental associations between vernacular deserts and the actual TSU configuration. Such a disconnect suggests that the emergence of knowledge of desert design lies in the domain of temporary shelter settlements.

2.3. Spatial Morphology and Environmental Behavior in Temporary Settlements

The change in settlement morphology has significant implications for circulation, safety, social interaction, climate, and environmental behavior. Space syntax and other concepts describe relationships between spatial patterns, movement patterns, and social dynamics in spatial theory [13],[20]. This view indicates that temporary environmental performance is not measured on the scale of individual units.

However, morphological models were used in temporary shelter situations. The grid configurations, for instance, are clear and easily deployed; they produce large open surfaces with exposed heat-stained surfaces. This linear configuration is clear, although it funnels the wind, increasing exposure, and exposes it, reducing dust and heat irritants.

The configuration of the courtyard is more favorable for shade and comfort, although it demands a planned path with proper phasing. Cluster or organic configurations have advantages, although they rarely confront conventional humanitarian logistics. Radial configurations have centralizing and congestive potential, although they may have congestion or overexposure if properly guided.

Empirical observations of informal or refugee settlements reveal that people normally modify the space configuration as they cluster the structures, add shading devices, or develop informal courtyards to address environmental irritants [21]. This behavior highlights the distinction between a formal planning model and the environmental reality of desert settlements. These adaptive changes illustrate the role of morphology as a resilient dynamic mechanism. The focusing and shading changes reflect new self-organization in response to environmental stress, furthering the argument that settlement form should be proactively designed as an adaptive system rather than reactively modified.

The literature posits that morphology plays an essential role in environmental and social performance, but systematic empirically tested comparisons of settlement typologies for hot-arid environments are relatively underdeveloped, even largely undeveloped.

2.4. Identified Gaps and Theoretical Positioning of This Study

Three interrelated gaps emerge in architectural, environmental, and humanitarian research. First, there are no models for temporary structures of architecture at the settlement scale. Most TSU studies focus on unit design and the spatial, climatic, and social implications of settlement morphology are not fully addressed. Secondly, while several decades of data on desert architecture have long been devoted to modeling temporary settlements, micro-climate strategies are often limited for use in planning temporary settlements, and TSUs are frequently deployed in arid environments. Third, there are no multi-criteria evaluation models that can compare settlement configurations with expert-derived architectural, technical, environmental, and social characteristics related to desert environments.

Another conceptual issue is the lack of integration of settlement morphology into climate adaptation and resilience models. While environmental logic is provided by the literature on desert architecture and practical criteria are provided by humanitarian research, few papers distill them into a single socio-technical evaluation system, which could guide adaptive settlement design under extreme climatic stress.

This study begins to place itself at the intersection of these gaps as it introduces a settlement-level assessment model from architectural theory, desert micro-climate theory, and spatial morphology. The framework uses TSU indicators as planning criteria in settlement scale planning, adds climatic design logic to assessment of spatial form, and produces comparative analyses of different settlement typologies utilizing expert-weighted multi-criteria assessment. It thus contributes to the architectural structure a system of preparing environmentally oriented, socially coherent, and feasible temporary settlements in hot-arid regions.

The study provides a conceptual framework for the planning of temporary shelter in relation to a wider theoretical framework of architecture geared toward resilience, focusing on settlement morphology as an adaptive infrastructure rather than simply a formal choice.

3. Methodology

3.1. Research Design and Conceptual Orientation

The present research utilizes a mixed sequential approach, which takes into account both qualitative and quantitative aspects, in order to assess the viability of alternative self-sufficient settlements. A program of temporary shelter units has been created with the help of tools created based on the development of a multi-stage assessment process, defined based on technical, social, and sustainability aspects. These constructs were conceptualized at the settlement level, specifically for the assessment of space, infrastructure, environment, or social aspects.

This research has been constructed around the northern desert of Jordan, specifically the Mafraq Governorate, as well as the refugee camps of Al-Zaatari, established in 2012, Al-Azraq, established in 2014, and Mrajeeb Al Fhood, established in 2013. These settlements are subsistence climatic communities with high solar radiation, significant diurnal temperature variations, low humidity, and dust exposure. The population density in these camps is generally between 12,000 and 24,000 people per square kilometer, usually more than the need for them to be. This contextual reality provides a real-world basis for measuring settlement morphology under high environmental and infrastructural stress.

Direct field observations were also performed in the Mafraq and Wadi Rum deserts, in addition to literature-based construct derivation. Seven cases were randomly identified in a TSU. Other changes included the addition of photovoltaic panels, shading devices over glazing, secondary PVC roof layers to counter heat gain, reduced opening dimensions, stabilization on concrete or steel bases, and auxiliary units for larger spaces. These field observations helped to contextualize indicators and confirm the utility of thermal, infrastructural, and socio-spatial performance criteria.

3.2. Derivation and Structuring of Evaluation Criteria

The evaluation criteria used for this study were derived from a broad set of indicators already used for self-sufficient shelters. These indicators comprised more than 100 items and included environmental comfort, material performance, spatial logic, resource systems, social engagement, and technological sufficiency. The indicators were assigned new categories that would be used to translate to a unit-level design into a settlement-scale assessment. In addition, site selection, utilities, heat energy influx, renewable resource integration, spatial clustering, community involvement, and sanitation infrastructure parameters were revised with the aim of representing collective performance rather than isolated dwelling characteristics.

The contextualization stage included three levels of sampling methods. First, twelve civil, mechanical, and architectural engineers participated in facilitated focus group discussions on developing climate-relevant indicators for desert conditions. Second, 755 practicing engineers participated in a Likert scale survey of 84 contextualized measures. To ensure statistical representativeness, Cochran’s equation was used to determine sample size. Third, sixteen academic architectural design professors conducted pairwise comparisons with the Analytic Hierarchy Process (AHP).

EFA was used to statistically separate the 84 contextualized indicators into 41 significant indicators grouped into seven thematic dimensions. This reduction ensured the validity of constructs and minimal redundancy before hierarchical weighting (see Figure 1).

This analysis of theme's overlap, contextual relevance, and climate applied thematic value to a comprehensive definition of possible criteria to compare alternative settlement models, resulting in the identification of the appropriate criteria to compare with other settlement models (see Figure 2).

Figure 1. The contextualized constructs boundary diagram

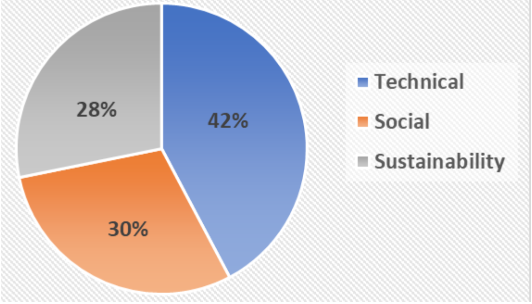

Figure 2. A pie chart shows the frequency distribution contextualized percentage of the technical, social, and sustainable based on Focus group data. Source (Author's elaboration)

The use of expert input ensures that the criteria reflect modern practice in desert architecture, renewable systems, and community-based planning in arid environments.

Proxy measures of social performance, including spatial cohesion, communal access, safety guidelines, and service integration, were applied by experts. These indicators are architectural and planning performance indicators, although research may expand this framework with resident surveys or post-occupancy behavioral mapping to further social validation.

3.3. Expert Engagement and Contextual Validation

Expert involvement was critical to determining if the results of shelter-derived indicators may transfer to settlement-scale evaluation. The architectural, civil, environmental, and planning professionals were interviewed to define acceptable criteria and ensure contextual validity with Jordan's desert landscapes. The scholars discussed the theoretical framework and accepted sustainability in off-grid settlements, and wished to include the broad points of settlement-wide elements such as road hierarchy, public facilities spread, shading networks, communal typologies, and interurban autonomy.

Sixteen of the AHP participants had studied or applied construction in the desert, off-grid infrastructure systems, or temporary settlement planning. In both cases, the pairwise tests were conducted according to the Saaty 1–9 scale, and all of the matrices had a Consistency Ratio (CR) less than 0.10, which made expert judgments valid within the institution.

This process allowed us to make sure that analytical limits are not just extrapolated from unit scale, but are an understanding of settlement morphology useful for extreme desert environments.

3.4. Analytical Hierarchy Process for Prioritizing Criteria

The Analytical Hierarchy Process (AHP) was used to determine how each evaluation criterion had relative priority over each of the other evaluation criteria. AHP is suited to complex decision-making issues because it can articulate multiple decision-making situations, such as difficult cases in which quantitative reasoning and qualitative judgment are needed. Comparative analysis was carried out in order to determine the significance of the criteria in relation to the theme categories. The comparison was based on the Saaty scale, as presented in Figure 3, and a standard range of intensity of importance.

Figure 4 presents the AHP workflow that was applied for this research. The steps of hierarchy building, pairwise comparison, consistency checking, and weight extraction were applied. All these matrices were within the acceptable consistency ratio of 0.10 to ensure that there is no room for unreliable information in the experts' decisions. The weights obtained in the global weights section of Figure 4 show that there is a hierarchy of priorities where sustainability and resource independence have the highest priority, followed by technical feasibility and socio-spatial factors.

3.5. Selection and Conceptualization of Settlement Models

The studies used two general self-sufficient settlement models, dispersed modular settlement and clustered compact settlement, as criteria for evaluating weighted parameters. It is either a mixture of autonomous water systems, renewable energy infrastructure, or climate-sensitive spatial organization. The first model emphasizes functional flexibility and convenience of expansion, while the second emphasizes thermal resilience and communal compactness. These models represent not just extensive design proposals but analytical tools in which weighted criteria can be applied comparatively.

These two configurations are used as analytical models to identify morphological effects under similar environmental conditions. In practice, there are hybrid, incrementally densifying settlement forms, or typologies, but the present study evaluates key spatial performance principles using controlled comparative typologies.

[illegible]	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slighity favor one element over another
5	Strong Importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, it dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation

2,4,6,8 can be used to express intermediate values

Figure 3. Saaty numerical scale for pairwise comparison [22]

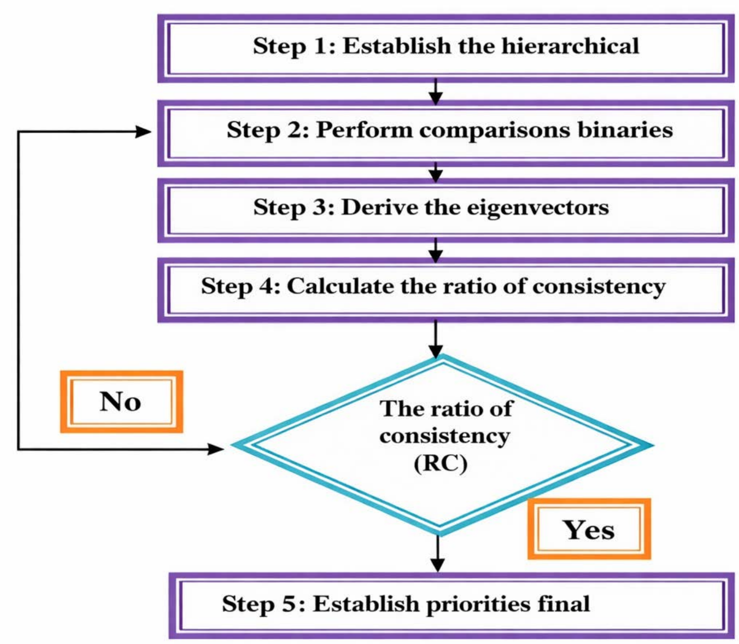

Figure 4. AHP workflow used for settlement criteria prioritization [23]

3.6. Comparative Evaluation Procedure

Each settlement model was assessed against the criteria hierarchy using overall performance scoring based on expert assessment, climate analysis, and spatial simulation. Technical feasibility, micro-climatic behavior, urban self-sufficiency, and cultural appropriability were assessed. Scores were measured relative to the weighted Analytic Hierarchy Process (AHP) weights for each model to obtain a composite performance index. This index makes comparisons for the model most suitable for Jordan's desert terrain easier and supports a hypothesis for the best model for use in desert.

Assessment of environmental performance is a criterion-based process, based on the theory of desert architecture, observation of existing TSUs, and experts. While computational simulations such as CFD or ENVI-met were not used in this study, the empirical field observations and camp performance statistics provide contextual calibration of the evaluation model. Simulation modeling may also be applied to further quantify airflow, shading, and thermal stress differentials across morphologies in the future.

3.7. Ethical Considerations and Research Validity

The research is based on the general ethical principles of academic ethics, informed consent for experts, the guarantee of anonymity, and the absence of identification of the information provided in the presentation of the data. Validity was enhanced by the use of methodological triangulation, the examination of the results of the surveys, and the application of known methods for the analysis of the statistics and the decision-making. The methodology applied can be adjusted for the application of the criteria and the weighting system to other types of climates and settlements.

The use of field observations, reduction of statistical indicators, and expert hierarchical weighting enhances construct validity and contextual reliability. But longitudinal monitoring of implemented settlements could provide future validation.

4. Results

AHP analysis hierarchically weighted criteria were used to evaluate the two proposed settlements. The model rankings were modeled to achieve stabilization through normalized weight aggregation, z-score transformation, cluster correlation testing, and sensitivity analysis. The two models were evaluated: the Dispersed Modular Settlement and the Clustered Compact Settlement.

The statistical analysis used expert weights and model performance scores to determine the best configuration for Jordan's desert environment. Expert assessment was also used in performance evaluation, as were field observations of TSU adaptations and documented environmental constraints in northern Jordanian desert settlements.

4.1. Reliability and Consistency of the AHP Model

The internal consistency of the AHP survey responses was also tested before they were applied. Each criteria matrix was coded with a λ max and CR values. C was in the range of 0.03 to 0.08 in all seven criteria and was less than the acceptable level of 0.10 in all seven criteria, and showed evidence that expert judgments were reliable (see Table 1).

Table 1. AHP Reliability Statistics

Category	λ_max	CI	CR	Interpretation
Technical Indicators	6.42	0.084	0.07	Acceptable consistency
Sustainability Indicators	5.21	0.052	0.04	High reliability
Social Indicators	6.11	0.074	0.06	Acceptable consistency
Overall Criteria Matrix	7.89	0.148	0.08	Strong internal consistency

The results validate the use of global weights for subsequent analysis.

4.2. Weighted Performance Scores of the Settlement Models

The standard criteria for performance of each settlement model were climate, infrastructure efficiency, and socio-spatial function. Composite scores were calculated using (see Table 2):

$$Score\_model = \sum(W\_i \times P\_i) \quad (1)$$

Where W_i is the global weight and P_i is the model's performance score for indicator i.

Table 2. Weighted Performance Scores

Criteria Category	Dispersed Settlement	Compact Settlement
Technical	0.74	0.81
Sustainability	0.61	0.83
Social	0.53	0.71
Composite Weighted Score	**0.63**	**0.78**

The compact settlement demonstrates superior aggregate performance, especially in sustainability indicators with the highest global weights.

This performance pattern is consistent with observations from the field in desert thermal storage units, where residents often employed shading augmentation, spatial consolidation, and energy integration strategies to mitigate thermal stress. It is observed that informal clustering and shading retrofits function as adaptive strategies, enhancing the sustainability performance of compact morphology.

4.3. Z-Score Normalization for Cross-Model Comparison

To compare the models on a standardized metric, their category scores were converted to z-scores (see Table 3):

$$\boldsymbol{z = (x - \mu) / \sigma} \quad (2)$$

Where x is the category score, μ is the mean across the two models, and σ is the standard deviation.

Table 3. Z-Score Comparison

Category	Dispersed Model (z)	Compact Model (z)
Technical	−0.49	+0.49
Sustainability	−1.22	+1.22
Social	−1.13	+1.13

The standard deviations for the compact and dispersed models are positive in all performance dimensions, while the standard deviation is negative in both cases.

The largest standard deviation is among sustainability performance (±1.22) and suggests the most significant differential impact is morphological compactness in resource-constrained desert conditions. This suggests that spatial consolidation improves the efficiency of infrastructure and microclimate buffering beyond technical or reinventive social dimensions.

4.4. Inter-Criteria Correlation Matrix

Pearson correlation coefficients were calculated to compare the technical, social, and sustainability aspects of scoring measures with scores (see Table 4).

Table 4. Correlation Matrix

Criteria	Technical	Social	Sustainability
Technical	1.00	0.71	0.82
Social	0.71	1.00	0.76
Sustainability	0.82	0.76	1.00

Technical and sustainable parameters have the strongest correlation, r = 0.82, and are strongly influenced by infrastructural logic and resource independence in desert settlement design.

This correlation is consistent with the assumption that settlement morphology is not a performance metric but rather a complex socio-technical system. Technical configuration affects energy integration, utility efficiency, and efficiency of collective resources.

4.5. Confidence Interval Estimation for Expert Scores

Expert-assigned performance scores were evaluated to estimate confidence intervals (CI) at a 95 percent confidence level using (see Table 5):

$$CI = \bar{x} \pm 1.96 \times (s / \sqrt{n}) \quad (3)$$

Where s is the standard deviation and $n = 16$ experts.

Table 5. Confidence Intervals

Category	Dispersed CI (95 percent)	Compact CI (95 percent)
Technical	0.71–0.77	0.78–0.84
Sustainability	0.57–0.65	0.80–0.86
Social	0.49–0.57	0.68–0.74

All CI ranges show non-overlap, indicating the superiority of the compact settlement is statistically significant across all categories.

The absence of overlap also confirms the statistical robustness of the compact model superiority under expert-based evaluation. This type of separation is not equivalent to post-occupancy measures, but suggests a pronounced consensus among specialists about differences in morphological analysis.

4.6. Sensitivity Analysis

The sensitivity test was performed to determine if the two settlement models did consistently differ in weight assumptions when the global weights of three components of the criteria were varied. In 100 simulated iterations, the compact settlement would remain top-ranking configurations for all scenarios, indicating the robustness of the comparative outcome. They found a strong correlation between the composite score differences of the two models from 0.11 to 0.18, which indicated strong stability in performance even when the weighting inputs were modified. Because sustainability weights were most beneficial in composite scores, but these changes did not affect the final ranking, which in turn strengthened the confidence in the compact settlement as the preferred architectural solution (see Table 6).

The choice of models is robust and therefore reinforces the claim that the compact settlement is a useful architectural solution.

The quantitative data indicate that the clustered compact settlement is acceptable across all technical, sustainability criteria, and social tests. It is a significant statistical advantage, reliable for expert assessments, and relatively stable in performance even in changes in parameters.

These data support them as the best design model for self-sufficient desert settlements in Jordan.

Combining these data with field observations of desert TSUs and recorded refugee camp densities, the results suggest spatial compactness helps thermal regulation, optimizes infrastructure, and facilitates communal interaction under extreme climatic stress. There were no detailed computational simulations, but expert weighting, statistical validation, and empirical contextualization further contrast the findings.

Table 6. Sensitivity Analysis Results

Scenario	Dispersed Score	Compact Score	Ranking
Baseline Weights	0.63	0.78	Compact > Dispersed
Sustainability +10 percent	0.65	0.84	Compact > Dispersed
Technical –10 percent	0.58	0.72	Compact > Dispersed
Social +10 percent	0.62	0.77	Compact > Dispersed

5. Discussion

The comparison demonstrates that in technical and sustainability practice, as well as socio-spatial terms, the Clustered Compact Settlement outperforms the Dispersed Modular Settlement. The results demonstrate that spatial configuration at the settlement scale plays an important role in hot-arid region moderation, infrastructure, and community functionality. The weighted scores, z-score normalization, and sensitivity analysis are also indicative of strong statistical evidence for this study. The most significant differences were found in the sustainability practice, where space facilitated more efficient use of renewable energy, reduced infrastructure redundancy, and thermal insulation in the desert environment.

These findings are in alignment with the principles of desert architecture, as proposed by Fathy [6], Givoni [7], Brown and DeKay [9]. This includes climatic considerations such as compact clustering, shading networks, and circulation. Sarmento et al. [17] discuss how optimization techniques reduce indoor temperatures, but this study takes this concept to the next level and demonstrates how a compact configuration at the settlement scale also improves functionality through the aggregate benefits of mutual shading and reduced surface area. Friedman [24] also points out that modular dispersion can increase transportation demand and material exposure, causing greater energy demands in hazardous conditions. The present results confirm this interpretation by showing that dispersed layouts result in higher infrastructure redundancy and increased exposure to solar gain.

Technical and sustainability criteria are strongly linked ($r = 0.82$), showing that infrastructure management is highly dependent on environmental efficiency. Kamali and Hewage [25] argue that clustered prefabricated systems reduce construction time and material waste, while Kamali et al. [26] show that localized infrastructure networks help system coordination and reduce operating overhead. Similar to Dong et al., [27], they also note that structural logic is fundamental to resource optimization in prefabricated systems. The present findings confirm that in deserts, central infrastructure and compact spatial logic are beneficial for energy integration and service efficiency.

Compact morphology is also supported by social performance outcomes. Al-Homoud and Samarah [28] show that spatial proximity improves communication efficiency and access within refugee settlements. Kamani Fard and Paydar [29] also show that community-based spatial arrangements foster psychological well-being and place attachment in transitional housing. The present study validates the effectiveness of clustered configurations in increasing opportunities for social interaction and safety. In spite of the flexibility and freedom offered by the dispersed configuration, the present study reveals that the benefits of thermal buffers and infrastructural efficiency far outweigh the benefits of spatial dispersion, especially when subjected to extreme climatic conditions.

Zohourian et al. [30] highlight the benefits of flexibility associated with modular systems. In a moderate environment, the benefits of flexibility are desirable. However, the present study reveals that the benefits of excessive dispersion, as seen in hot arid zones, lead to increased surface area, thereby increasing the surface area-to-volume ratio. Liu et al. [31] highlight the benefits of the dispersed classroom model, which provides better ventilation. However, the benefits of uncontrolled exposure, as seen in the desert environment, lead to increased heat gain. Thus, the morphology of the settlements has to be tailored according to the climatic conditions.

The effectiveness of the compact model has been validated through sensitivity testing. Even under ±10 percent weighting variation, the ranking remained stable. This analytical stability is consistent with Karaoglan Cemre and Alaçam [32], who show that resilient spatial patterns maintain structural advantages despite configurational variation. Aman and Keles [33] have also demonstrated the robustness of multi-criteria decision frameworks as an effective comparative aid in complex spatial systems. The present study confirms the statistically consistent results of expert-weighted morphological comparison.

Overall, the results suggest that compact settlement morphology is a socio-technical adaptation mechanism in desert environments, which integrates climatic moderation, infrastructural efficiency, and social cohesion within a single spatial logic. Compactness is therefore not a prerequisite, but an environmentally responsive solution to extreme conditions. These results provide empirical and analytical support for clustered spatial planning as a structurally resilient approach to self-sufficient temporary settlements in hot-arid regions.

6. Conclusion and Policy Recommendations

The study presented an intensive, multi-criteria approach to the evaluation of self-sufficient temporary shelter settlements in the desert based on extreme environmental and infrastructure constraints facing Jordan in the desert. Based on analyses of factors, AHP weighting, z-score normalization, and confidence interval tests of settlement performance, the finding is that settlement performance, even though it is not based on a single unit, is associated with spatial, social, and technical relationships that determine settlement's overall performance.

This means that the Clustered Compact Settlement can perform much more independently than the Dispersed Modular configuration. While sustainability, engineering, and social problems have inherent challenges to compactness, the most effective definition of compactness is thermal stability, energy integration, infrastructure redundancy, and sanitation efficiency. This indicates that shared resources and spatial consolidation can better accommodate settlement comfort, cost efficiency, and adaptive applications in extremely harsh desert environments.

The focus of this study is on the development of a settlement-level evaluation model rather than one unit evaluation model. This is a scale shift that enhances our understanding of spatial form as a means of environmental performance, utility management, and social organization. It also provides an extremely strong set of weighted indicators for desert climates, which provides a conceptual framework in which to evaluate shelter planning in terms of practice and policy.

Impacts for practice are important. Desert settlements need compact morphologies, central utilities, short service corridors, and shared infrastructure systems to ensure resource losses and resilience. Planning agencies and humanitarian organizations can use criteria developed by planners and those groups to guide site selection, unit aggregation, material choice, and infrastructure strategy. The framework also supports future adaptation, in that designers can test other layouts and new technologies, and refine settlement strategies based on qualitative data.

Finally, the results of this study show how integrating design thinking with spatial configuration, technical systems, and environmental performance is best used to maintain sustainable shelter in desert environments. This material and insights can be used in aiding the future desert settlements as it is likely to enable them to function more efficiently, respond to the needs of multiple purposes, and support multi-functioning systems as a result of an environmental challenge.

The approach utilized in this study is based on expert-weighted multi-criteria assessment supported by field observations rather than longitudinal post-occupancy evaluation or computational environmental simulations. Thus, environmental performance is interpreted as contextually suitable rather than thermally modeled.

The analysis compares two analytical archetypes, Clustered Compact and Dispersed Modular configurations, without modelling hybrid or phased settlement forms. Moreover, the framework is structurally transferable, but the weighting hierarchy reflects the climatic and infrastructural conditions of Jordan's hot-arid desert context and would need to be reconfigured for use elsewhere.

Future research could add simulation-based thermal analysis and post-occupancy studies to further validate and refine settlement-scale performance assessment.

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