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Impact Assessment of Morphology and Layout of Zones on Refugees' Affordable Core Shelter Performance

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Abstract: The number of migrants increases globally due to natural disasters, global warming, and war conflicts. Inefficient and unsustainable construction approaches for migrant shelters have resulted from improper planning and design systems regarding lifespan, materials and techniques, and socio-cultural aspects. Therefore, the study aim has an incentive to assess the impact of the morphological, siting, and layout of zones and shelters for the long-term displacement prototypes considering sustainability concepts from social context, affordability, adaptability, low-impact construction materials, and techniques. Furthermore, applying the dynamic simulation IDA ICE 4.8 tool was cardinal to justify the comprehensive reported outcomes based on the bottom-up construction method after assessing energy and thermal comfort performance in seven cases. The energy performance assessment regarding heating reveals the superiority of the compact layout plan system, while the open-layout plan system is superior for electric cooling assessment. Concerning thermal comfort performance for the number of accepted hours category, the open-layout plan system is superior. Fanger indicators for thermal comfort assessment demonstrated the superiority of the horizontal-compact layout plan scheme. The carbon dioxide (CO_2) concentration level assessment shows that the open-yard layout cases have better results than other systems. To conclude, sustainable prototypes for displaced people should involve several aspects such as lifespan, socio-cultural and affordability, thermal performance and energy-efficient, and environmental impact. The beneficiaries from the methods and the results of this study would be firstly the Syrian refugees in the Middle East context, then various places and involved people affected by the displacement issue globally.

Keywords: post-disaster shelters; bottom-up constructions; planning and designing systems; siting and layout systems; energy performance; thermal comfort

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1. Introduction

Unsolved conflicts, global warming, and natural disasters are vital issues that inevitably lead to the increasing number of migrants worldwide [1,2]. Forcibly displaced people were 79.5 million by the beginning of 2020, according to the United Nations High Commissioner for Refugees (UNHCR) [3], while after only one and a half years, the UNHCR declared that the number has risen to more than 84 million globally [4]. There are complex reasons behind the increasing migration in the most unstable regions in the Middle East and North Africa (MENA), including Iraq, such as natural disasters, political situations, external intervention, internal armed conflicts, and ethnic persecution [5,6]. The global increasing tendency is recently even magnified due to the Russia–Ukraine conflict.

Many studies show that the displacement period has taken decades globally for millions of migrants, especially, for instance, Rohingya minorities, Palestinians, and Somalians [7–9]. However, adequate planning and designing of migrant settlements and shelters are essential and should not be disregarded. In contrast, coordination requirements and dependency circumstances are usually the main factors for considering camp planning as the last option [10]. The predominant methods are planning a temporary camp rather than a permanent one and designing isolated spaces and units without an integrated option [11]. Thus, these camps usually burden international organizations, host countries, and the environment due to the short lifespan of the shelters [12,13]. Neglecting the socio-cultural aspects is another fact of improper planning and designing systems. For instance, shared sanitation, isolated spaces for one householder, narrow alleys, and disregarding socio-cultural background by international organizations are vital factors that lead to missing privacy, gender-based violence, and conflicts [14,15]. Consequently, the pre-planning approach should consider comprehensive methods and strategies that involve more efficient permanent shelters and a deep investigation of the socio-cultural aspects.

Due to the budgetary shortage for refugees and inefficient performance of shelters, unsustainable fossil fuel is the predominant source of operation energy [16]. On the other hand, unrenewable energy sources have many negative consequences, such as health-risk effects, cost issues, and environmental impact. For instance, according to the World Health Organization (WHO), it is the source of indoor air pollution and causes 20,000 deaths of displaced people yearly [17]. In addition, supplying diesel fuel as a primary energy source for providing electricity in displaced camps costs approximately USD 30 million annually [16]. Therefore, passively achieving comfortable thermal conditions can significantly reduce fossil fuel energy dependence [18]. Furthermore, one of the fundamental requirements of a comfortable environment is to keep thermal conditions and indoor air quality (IAQ) suitable for the residents since they directly impact their productivity, health, and morale [19,20].

There are several categories to assess building indoor thermal comfort performance, such as Fanger comfort model indicators and carbon dioxide concentration level (CO_2). Fanger [21] created a well-known comfort model based on two indices, predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD), for the assessment of occupied spaces [22]. PMV and PPD are measurements used to estimate thermal comfort in an inhabited zone based on metabolic rate, clothing, air velocity, humidity, air temperature, and mean radiant temperature [21]. PMV value is based on the ASHRAE thermal sensation scale [21,23], demonstrated through seven classes: 3, 2, 1 indicates hot, warm, and somewhat warm, 0 denotes neutral, while -1, -2, -3 denotes slightly cool, cool, and cold, respectively. According to ISO 7730 (2005) [24], there are three categories for evaluating the range of PMV: [-0.2, +0.2], [-0.5, +0.5], and [-0.7, +0.7] represent categories A, B, and C, respectively [25]. Additionally, IAQ is affected by contaminant gases, for instance, carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), radon (Rn), and sulfur dioxide (SO_2) [26]. The concentration level of CO_2 is determined mainly by the ventilation rate and the number of people [27]. European Standard EN 13779 for IAQ classification utilizes 1500 parts per million (ppm) as a maximum level of the CO_2 concentration, while it recommends keeping the level below 1000 ppm [28,29].

Environmental issues are the direct consequences of previous issues, such as continuing and increasing displaced issues, short lifespan and inefficient shelters, and improper planning and designing systems. The mentioned issues lead to high amounts of resources, for instance, materials, energy, land, and money, which directly impact the environment through waste and pollution [30]. On the other hand, low-impact construction (LIC) materials and techniques are considered sustainable approaches with minimum environmental impact [31]. However, LIC materials and techniques involve both the bottom-up (building on-site from local materials by displaced people or local laborers and could be managed by non-governmental organizations or local authorities) and top-down methods (prefabricated approaches) [32], while the bottom-up method has the highest level of satisfactory and culturally more acceptable approach due to the self-construction involvement of displaced people, locally sourced materials, durability, minimum impact on the environment, and efficient cost [14,33].

There is a tendency for many entities involving researchers to investigate and enhance the quality of displaced people camps and shelters by improving the thermal performance and eliminating its impact on the environment. For instance, Bredenoord invoked that a planning system considering the incremental approach is a sustainable solution for long-term projects [34]. Furthermore, Hendriks et al. [35] evaluated cost, time reduction, and maintenance of traditions concentrating on expected long-term effects by analyzing self-built housing cases as a strategy for the post-disaster recovery of low-income groups. In addition, staggered urban planning design based on outdoor Iwan core function and upgrading direction for displaced refugee camps in Syria was proposed by Al Asali et al. [10]. Likewise, by manipulating LIC materials and techniques, a study produced an assessed model with low carbon emissions that was comfortable and energy-efficient by adopting passive strategies [36]. Moreover, another study investigated the three pillars of sustainability (social, economic, and environment), focusing on existing solutions and novel designs in displaced people shelters [37]. Finally, another study referred to the several strategies for adaptation and incremental phases through designing shelter zones and layout, paying attention to lifespan, materials, and cost of shelters considering socio-economic aspects [38].

At present, accomplishing sustainable prototypes for displaced people should involve several factors such as lifespan, socio-cultural and affordability (refugees and host countries can afford them), thermal performance and energy-efficient, local planning and designing systems, and environmental impact. However, those factors have not yet been considered together in the previous literature. Therefore, the original contribution of this study is considering all the above factors in addition to the incremental possibility through proposing comprehensive prototypes typologies for the refugee's core shelters (open to the yard and compact, horizontal and vertical on the main road, separated spaced or studio layout one) considering the socio-cultural (based on the Middle East cultural context) and local planning and design systems in the Duhok city north of Iraq. Additionally, the design techniques of these models will allow them to be used by low-income people, newly married couples, or the refugees themselves even after the incremental stage. To guarantee sufficient comfort and permanent prototypes, this study aimed to assess the impact of the morphological, siting (location of the zones in the prototype and the model represented in the different cases), and layout of zones and shelters for the long-term displacement models. This study would be part of the larger doctoral study titles developing prototype performance for refugees' affordable core shelters considering sustainability.

2. Materials and Methods

2.1. Methods Description and Conceptual Framework

This research is the successive process continuing the previous study presented in [39]. This study question is, what is the impact of the morphological aspects and siting zones on the refugee's prototype performance? Varied methodological approaches were adopted to answer the study question and achieve its aim. The qualitative method was used for exploring, describing, and interpreting through literature review, conducting authorities, case studies, site visit, and observation. However, the quantitative method was applied through Excel software calculation and simulation software assessment to prepare, analyze, and assess performance. The four essential scientific steps were considered to create the study's conceptual framework, as shown in Figure 1.

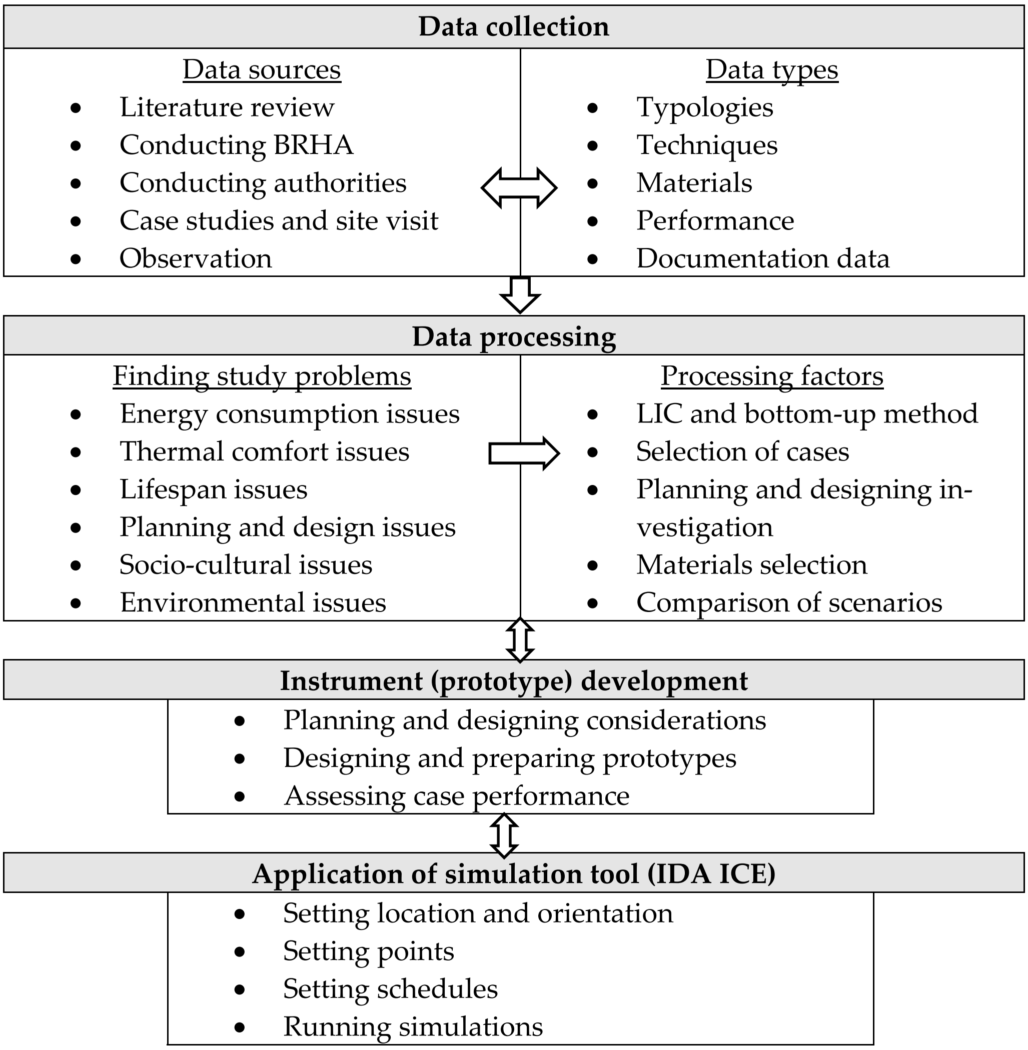

Figure 1. The conceptual framework for study methodology.

2.2. Data Collection

The study began by understanding the context and literature regarding post-disaster shelter typologies, techniques, materials, performance, and documentation. The collected data consisted of both primary data, such as observation and site visiting, and secondary data, such as conducting and consultation with authorities, in addition to literature review. Concerning the study sample cases, the research context selected Syrian refugee shelters in Duhok city in the north of Iraq. A cold climate characterizes Dohuk city in winter (mean daily temperatures 4–11 °C) and hot, dry summer (mean daily temperatures 32–36 °C) as a semi-arid climate region [40].

Several challenges were faced regarding permission and access to the cases, such as security considerations and a strict long routine to obtain raw data and visit camps. Hence, the data regarding the first case (Case 1) were gathered by conducting the Board of Relief and Humanitarian Affairs (BRHA) in Duhok city to investigate the impact of the bottom-up method application, while later, to explore more and understand the impact of morphological, zones sitting, typologies, and context of the cases, several refugee camps were studied, and one of the camps was accessed. Therefore, Domiz-one (Figures 2 and 3) was visited as Iraq's most prominent refugee camp with core shelter cases.

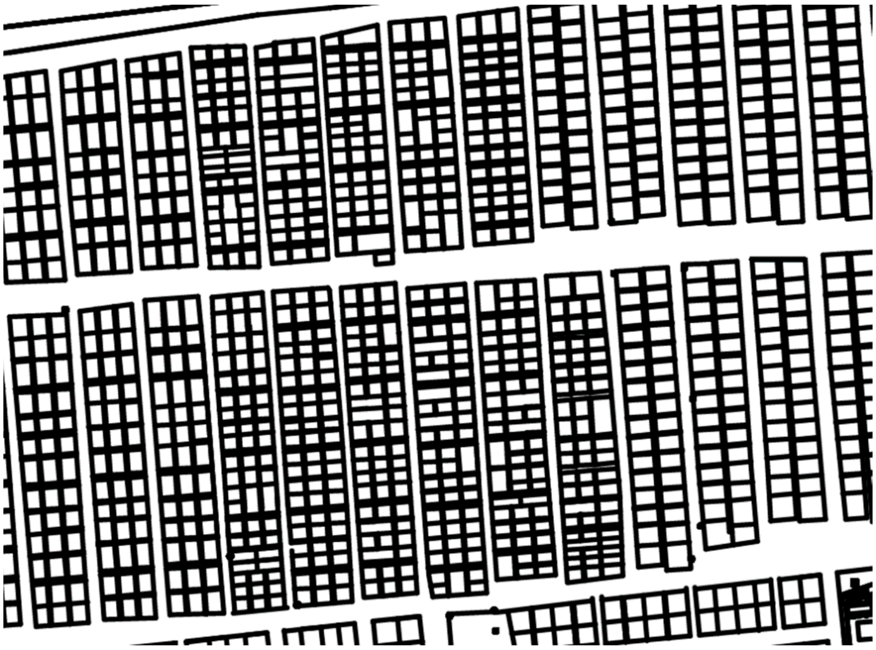

Figure 2. Planning blocks layout in Domiz-one refugee camp.

Figure 3. Domiz-one refugee camp typical core shelters. (Source 1st Author).

Concerning ethical considerations, the identities of shelter owners remain anonymous. Likewise, photos were taken in a way that none of the refugees appeared as a significant consideration by authorities and camp administration, as is evident in Figure 3. Additionally, refugees and authorities were informed about the purpose of the study.

Data associated with seven core shelter typologies were investigated and observed to answer the study question. Moreover, data relating to the urban planning system and block layout were obtained through direct conduction with the General Directorate of Urban Planning and Municipality in Duhok city. Eventually, the typical planning systems were illustrated via AutoCAD and SketchUp drawing programs, as shown in Figure 4.

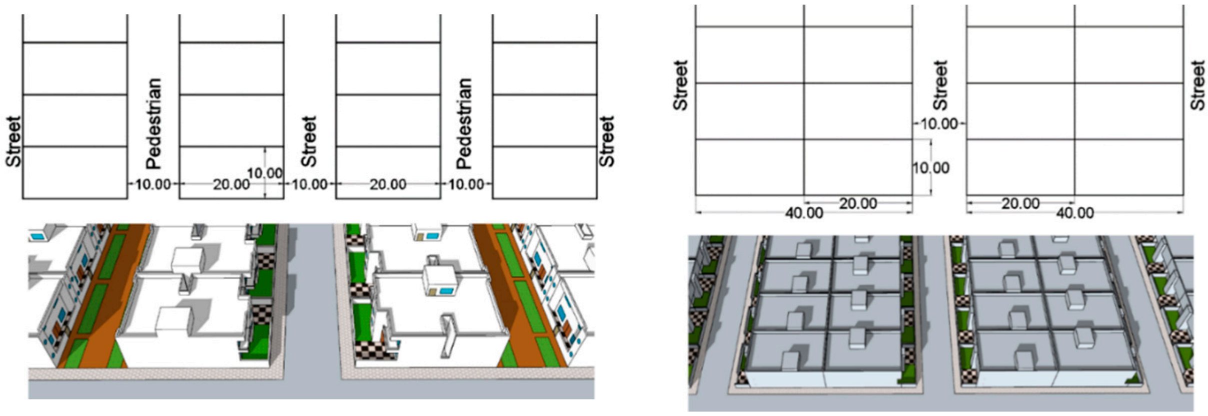

Figure 4. Typical urban planning blocks layout in Duhok city.

2.3. Data Processing

Several problems were detected after the critical investigation, site visit and observation, and data processing for the post-disaster shelter issues. The most prominent issues are the shelters' energy consumption and occupants' thermal comfort. Following these, the short lifespans of shelters compared with the displaced period is another critical issue regarding sustainability. Further issues include planning and designing system considerations, such as designing isolated spaces and units without an integrated option, inequality in plot sizes, irregularity, diversity, and randomization in siting blocks, and designing shelters (Figures 2 and 3). Furthermore, the socio-cultural factor regarding privacy and behavior is an additional crucial issue. Subsequently, the environmental issues are anticipated consequences' problems.

Following identifying problems, the procedures and analyzed process required several considerations. Firstly, LIC through the bottom-up method was suggested as a more flexible, durable, and affordable technique. Then, regarding the case size, it was targeted to host a family of five people as an average household size in the Kurdistan Region of Iraq (KRI) and a more typical size in the camps [41]. Later, cases with an area of 50 m^2 (5 m $\times$10 m) were targeted and prepared to follow the typical planning system in Duhok city even in the future expansion stage with 100 m^2 (10 $\times$ 10 m), as shown in Figures 4 and 5.

Several LIC materials and techniques were manipulated and proposed, such as cob, straw-bales, and earth-bags for the prototype walls. The reason behind using triple materials for one prototype wall is that it is not easy to build thousands of shelters with one material. Moreover, it gives the opportunity to build a shelter with more than one material in different incremental stages. Furthermore, straw and earthen materials are the most abundant low-impact materials in the region, as they are easy and fast to build with the involvement of the displaced people. Finally, the high quality of the techniques regarding the high thermal mass of the earth-bags and the high insulation factor of straw-bales was proposed for the incremental and upgrading stage, while the wood, straw, and soil (WSS) technique was proposed for the roof as an easy, fast, local, and low-impact traditional technique. This purpose is to replace the original materials of the case, which are solid concrete blocks for walls and zinc sheets or sandwich panels for the roof.

Although relying on some references [42,43], the physical properties of materials represented in the specific heat, heat conductivity, and density were reviewed to identify the thermal transmittance (U value); however, due to this study's scope, there is a limitation to refer to the time-lag and thermal storage of the materials in detail. Finally, Excel sheets and IDA ICE software were used to assess and identify the best scenario performance among the nine prepared scenarios to be pursued by the study's next step (Table 1).

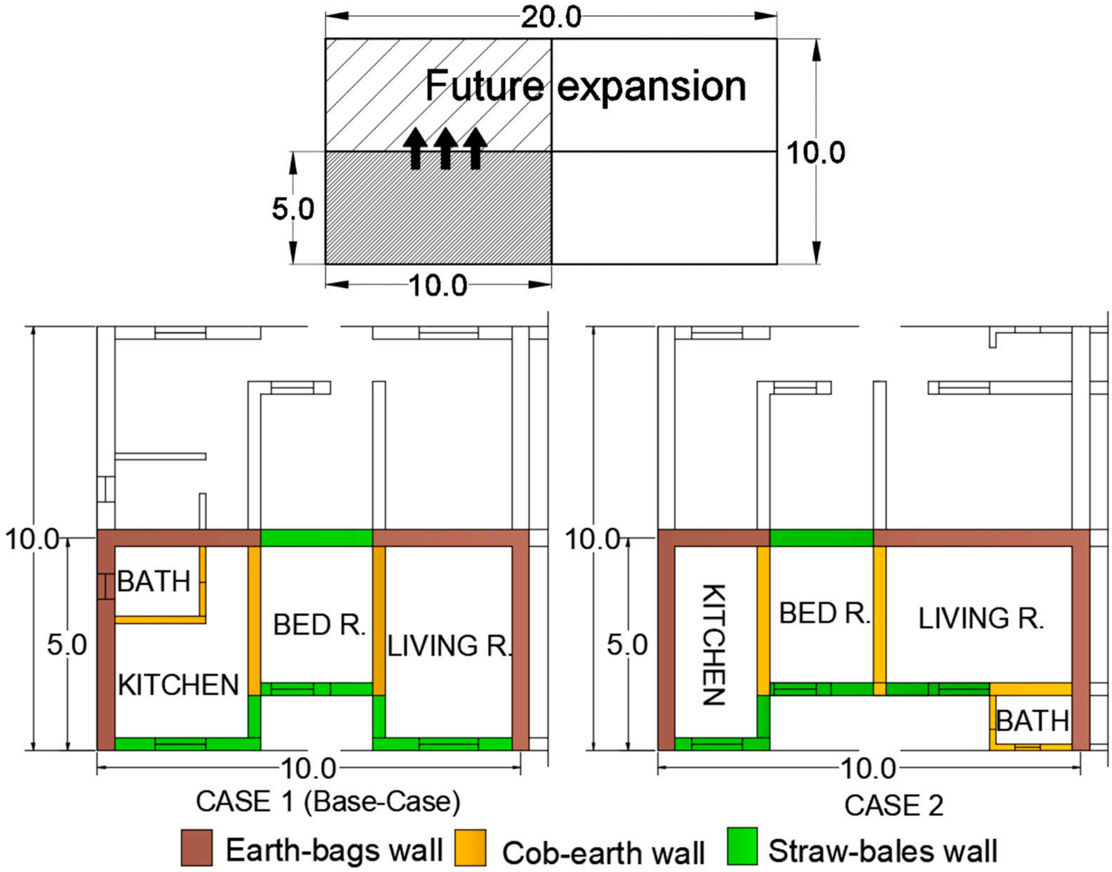

Figure 5. Cases 1 and 2 with the layout-block planning system.

Table 1. Materials thermal transmittance (U value) and scenario components.

Materials	**U value (w/(m^2·k)**	**Materials**	**U value (w/(m^2·k)**	**Materials**	**U value (w/(m^2·k)**
Zinc roof	5.88	Concrete blocks wall	15 cm = 3.24	PVC door = Door 1	2.0
Sandwich panels roof	0.44	Earth-bags wall	40 cm = 0.57	Wood door = Door 2	0.54
Wood + Straw + Soil = (WSS) roof	0.26	Cob earth wall	15 cm = 1.86 30 cm = 1.17	One pane glazing = Window 1	5.8
Lightweight concrete floor = F1	0.85	Straw-bales wall	30 cm = 0.14 40 cm = 0.10	Double pane glazing = Window 2	2.9
Case one (C1) Scenarios	Components				
Base model scenario 1 (C1S1)	Zinc roof + Concrete blocks wall + F1 + Window 1 + Door 1				
Base model scenario 2 (C1S2)	Sandwich panels roof + Concrete blocks wall + F1 + Window 1 + Door 1				
Scenario 3 (C1S3)	Wood + Straw + Soil (WSS) roof + Concrete blocks wall + F1 + Window 1 + Door 1				
Scenario 4 (C1S4)	Cob earth wall + Zinc roof + F1 + Window 1 + Door 1				
Scenario 5 (C1S5)	Earth-bags wall + Zinc roof + F1 + Window 1 + Door 1				
Scenario 6 (C1S6)	Straw-bales wall + Zinc roof + F1 + Window 1 + Door 1				
Scenario 7 (C1S7)	Zinc roof + Concrete blocks wall + F1 + Window 2 + Door 2				
Scenario 8 (C1S8)	Best Roof (WSS) + Best Wall (Straw-bales) + F1 + Window 2 + Door 2				
Scenario 9 (C1S9)	Best Roof (WSS) + Proposed variation wall (Cob earth + Earth-bags + Straw-bales) + F1 + Window 2 + Door 2				

2.4. Instrument (Prototypes) Development

Besides adopting methods and approaches, prototype development is another study outcome. Regarding planning schemes, the seven assessed prototype cases with three planning block systems were derived from the conventional typical planning system in Duhok city in KRI as an attached system [44]. For instance, the most familiar system in the Domiz-one camp for Cases 1 and 2 (Figure 5) was prepared to be fixed in a planning block system with dimensions 10 × 20 m as an end-off attached unit with two façade sides initially, then semi-detached after a future expansion stage. On the other hand, Cases 3, 4, and 5 (Figure 6) were designed to fix in the planning block system with dimensions 10 × 40 m as an attached system for the central units with a single-side façade firstly, followed by two opposite-side façades after upgrading. Furthermore, as a sustainable consideration and not to consume land concerning extreme urban sprawl, both Cases 6 and 7 (Figure 7) were designed to fix the planning block system with dimensions 20 × 40 m as an attached system for the central units with a single façade side even in a future expansion stage.

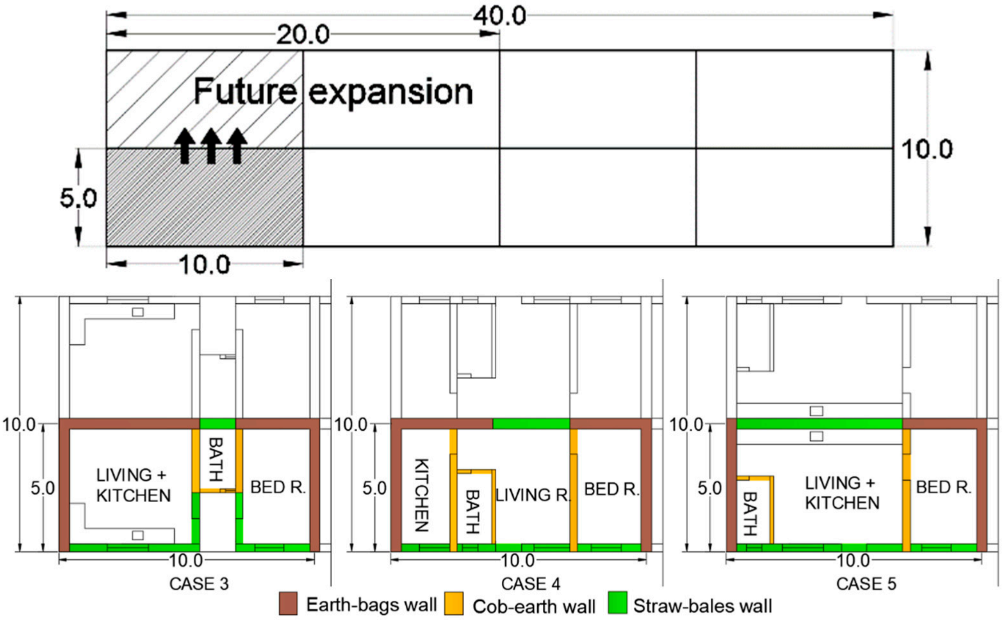

Figure 6. Cases 3, 4, and 5 with the layout-block planning system.

Concerning designing prototypes, several factors were considered after the site visit, conducting authority, and observation process.

- The first design factor is locally called the eastern or open to the yard layout design system (Cases 1, 2, and 3) and the western or compact layout design system (Cases 4, 5, 6, 7).
- The second factor is an open spaces plan or studio (Cases 3, 5, 7) and a close or separate space plan (Cases 1, 2, 4, 6) pattern design.
- The other design factor is a horizontal plot layout design (Cases 1, 2, 3, 4, and 5) and a vertical plot layout design (Cases 6, 7).

Eventually, for adaptability reasons and to prolong the prototype lifespan and upgrade it to 100 m^2 in an incremental future phase, scenario ninth (C1S9) techniques were adopted and applied for all seven cases. In conclusion, due to manipulating three classes of materials in one prototype's walls, the setting of the straw-bales location between the prototypes beside it demonstrates superior performance [39].

In the final stage, the annual performance of the cases was simulated and assessed through energy and thermal comfort. Regarding energy performance, various categories were taken under the total delivered energy assessment: electric cooling, fuel heating, equipment tenant, lighting facility, and domestic hot water (DHW). The adopted thermal comfort performance assessment categories were accepted hours ratio, PMV and PPD, and CO_2 concentration level.

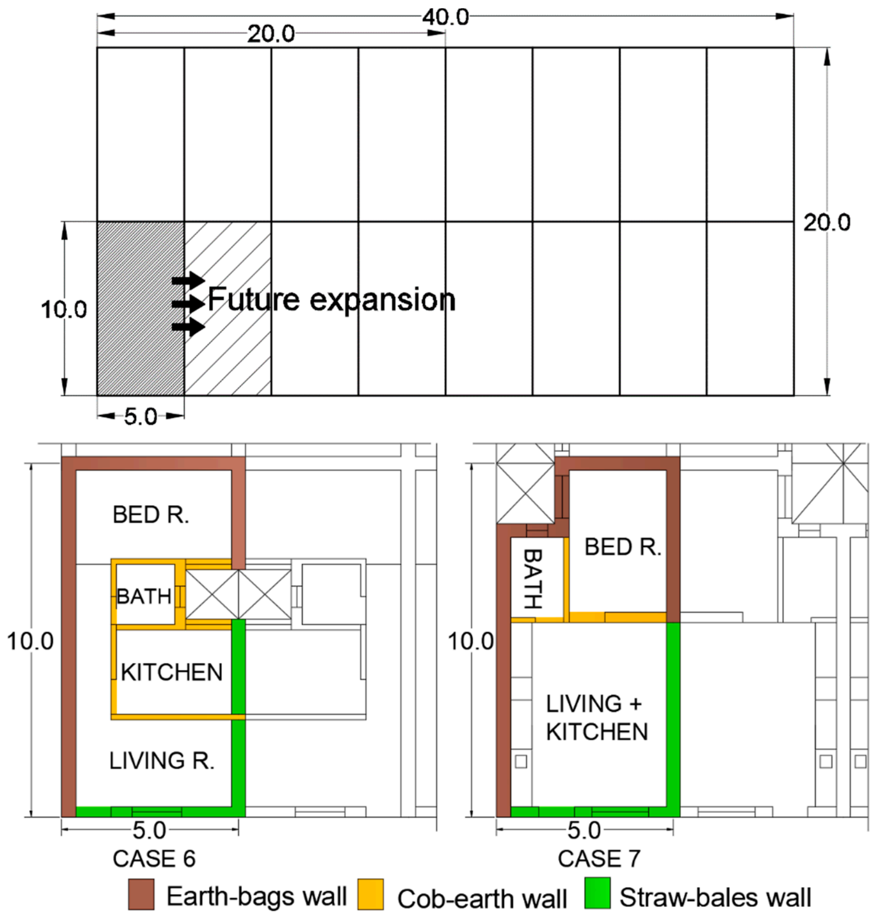

Figure 7. Cases 6 and 7 with the layout-block planning system.

The total categories were assessed once to reveal the entire performance concerning the energy evaluation, while this was not possible regarding thermal performance assessment due to the variety in the numbers of zones, areas, and occupation hours. Consequently, Equation (1) was derived from another scientific study [45] and applied via Excel software calculation to identify the representative summation ratio and average hours level.

$$N_{ah} = \frac{\sum_{z=1}^{z=n} N_z \times A_z \times O_z}{\sum_{z=1}^{z=n} A_z \times O_z} \quad (1)$$

To describe the equation, N_{ah} represents the average annual hours, N_z represents the number of annual hours, A_z represents the total area of each zone, O_z represents the occupied hours of each zone, and finally, n represents the total number of thermal zones of the prototype.

A representative summation ratio depending on Equation (1) was identified beside each zone's performance for assessing the accepted hours category. Furthermore, concerning PMV assessment, a good standard of comfort Category B ±0.5 according to ISO 7730 with average annual hours was targeted. Likewise, Category B was selected to quantify average annual hours with a dissatisfaction ratio of <10 for PPD assessment. Finally, the average number of annual hours with a CO_2 concentration of <1000 ppm was counted as a recommended level by European Standard EN 13777.

2.5. Application and Simulation Tool (IDA ICE)

For assessing the performance of the nine scenarios (Table 1) relating to Case 1 and seven prototypes (Figures 5–7), the study utilized the simulation program Indoor Climate and Energy IDA ICE 4.8. Concerning the planning and layout system, the attached layout with two façade side locations and south orientations were specified for all the models. Later, the set points for the cooling and heating temperature controller levels were specified as 26 °C and 18 °C as a standard for the comfort level [30]. In contrast, the central air handling unit (AHU) for mechanical ventilation was absent (depending on the passive system). The set point for domestic hot water (DHW) specified 30 letters per person daily. Regarding heat gains, the level of activity for occupants is set at 1.0 MET and constant clothing 0.85 ± 0.25 CLO to be automatically adapted between limits to obtain comfort. Concerning occupancy time, several schedules were identified, as shown in Table 2. Finally, the simulations were run under annual processes (1 January–31 December) application for all seven prototypes.

Table 2. Prototypes spaces and occupancy time schedules.

Spaces and Occupants	Occupancy Time
Bedroom for one person	No one present (7:00–13:00, 15:00–21:00), one present (13:00–15:00), otherwise fully present
Living room for three people	One present (8:00–12:00, 14:00–17:00), otherwise fully present
Living room for two people	No one present (21:00–7:00) one present (7:00–7:30, 8:00–12:00, 12:30–13:00, 15:00–18:00), fully present (7:30–8:00, 12:00–12:30, 18:00–21:00)
Kitchen for one person	No one present (18:00–7:00, 7:30–11:30, 12:00–12:30, 13:00–17:30), otherwise fully present
Bath for one person	One present (6:30–7:00, 12:30–13:00, 17:30–18:00), otherwise no one

3. Results and Discussion

3.1. Energy Assessment

The assessment of total delivered energy considered comprehensive results for five categories (Figure 8). Significantly, the most consumed category for all cases is DHW because it is set up on 30 letters per person daily based on the observation of socio-cultural context and the crucial impact of ablution five times daily. Meanwhile, this ratio could be decreased to half based on the essential water supply ratio as guidance for displaced people [15]. Additionally, another factor that could be taken into consideration is that, usually, zinc tanks on the roof of the building have used for water in the region [46], which means that during the hot summer season, the water does not need to be warmed (it is already warm) for showers, ablution, or dishwashing. Consequently, the ratio of DHW in the study can be decreased dramatically in the summer season because, apart from washing clothes, it is not required in any other amount. The results reveal that the best-performing prototypes compared to the first base case (Case 1) are Cases 4 and 5, with saved ratios of 9.5% and 12.3%, respectively, equivalent to 567 and 736 kWh annually. Significantly, the most effective categories for giving superiority are fuel heating and electric cooling, while the performance of the other three categories is almost the same.

Concerning fuel heating, there is a considerable saving of annual energy compared to Case 1 from both Cases 4 and 5 by 80% and 84.8%, respectively. Moreover, the fuel heating demand ratio for Cases 4 and 5 compared to the total energy demand for the same cases is dramatically low, which is simply 2.2% and 1.8% of the total cases' energy. Undoubtedly, this is due to the compact layout shape and smaller thermal bridge area than other prototypes, which results in low heat loss levels and effective heat gain in the winter season. On the other hand, Case 2 is considered the worst regarding fuel heating by consuming 52.6% more than Case 1. Consequently, this is due to the largest thermal bridges of Case 2 and its more oversized open-layout yard, high heat loss ratio, and less heat gain by the living room due to setback location.

Furthermore, concerning the electric cooling energy demand, the preference for the open-plan (studio) layout cases (Cases 3, 5, and 7) is apparent due to the sufficient air circulation in hot seasons. For instance, the ratios of the cooling energy saving for Cases 3, 5, and 7 compared to the first base case (Case 1) are 25.9%, 25.1%, and 20.7%. Although Case 2 has the worst performance regarding fuel heating, concerning cooling energy, compared to Case 1, it saves 17.5%. Consequently, this superiority is due to the layout and size of the open yard and the bath location role of Case 2 in preventing the living room from overheating. Interestingly, there is a certain level of energy consumption for electric cooling in the winter season (November, December, January, and February) due to the excellent insulation and high heat gain ratio, especially for horizontal cases. For instance, Cases 1, 4, and 5 consume 77.9, 68.8, and 49.8 kWh, respectively, and both Cases 3 and 2 consume 35.1 and 31.2 kWh, respectively. In comparison, the two vertical cases (Cases 7 and 6) consume 31.1 and 25 kWh, respectively, for cooling in the winter.

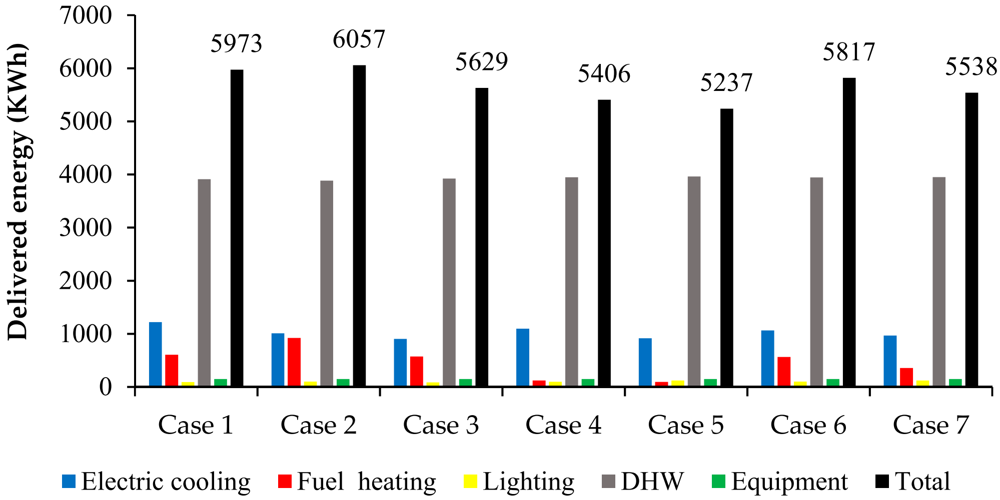

Figure 8. Energy performance assessment.

3.2. Thermal Comfort Assessment

3.2.1. Accepted Hours Ratio

Thermal comfort without a cooling option was specified to quantify the representative ratio of accepted hours (Figure 9) based on Equation (1). The accepted hours ratio includes good and the best hours, depending on the range temperature set points specified by the simulation software. The contribution of the occupancy hours ratio annually for the living room is the most influential and crucial class among the representative results, occupying 8760 h, followed by 4380 and 730 h for the bedroom and the kitchen and then the bathroom with simply 546 h. Consequently, the simulated process revealed that the best-performing cases are Cases 7, 3, and 5 with a 1% ratio of unaccepted hours analogous to the representative number of 49, 67, and 99 h, respectively. Alternatively, both Cases 1 and 4 have the lowest performance ratio with 13% and 7%, equivalent to 944 and 518 h, respectively.

Moreover, the results quantified the good hours ratio in Figure 10 due to the vast similarity in the accepted performance for some zones. The results revealed that Case 5 still performs best with approximately the highest ratio in all zones. However, the performance of the bedroom (Case 1 with 2) and bathroom (Cases 1, 4, and 6 with 2, 3, and 7) for some lowest performing cases compared to the highest performing are better, while the superiority of the combined living plus kitchen zone is distinct due to its highest occupancy ratio. Hence, the preference for the open-plan layout compared to the separated zones layout is clear regarding thermal comfort–accepted hours. Furthermore, the role of the bath location in keeping main zones from heat loss and gain is another prominent factor, for instance, in Cases 2 and 5. Additionally, the well-insulated and high heat gain amount during the winter overheated some zones and led to a significant ratio of unaccepted hours, for instance, the living room for Cases 1 and 4 and the bedroom for Cases 4 and 5.

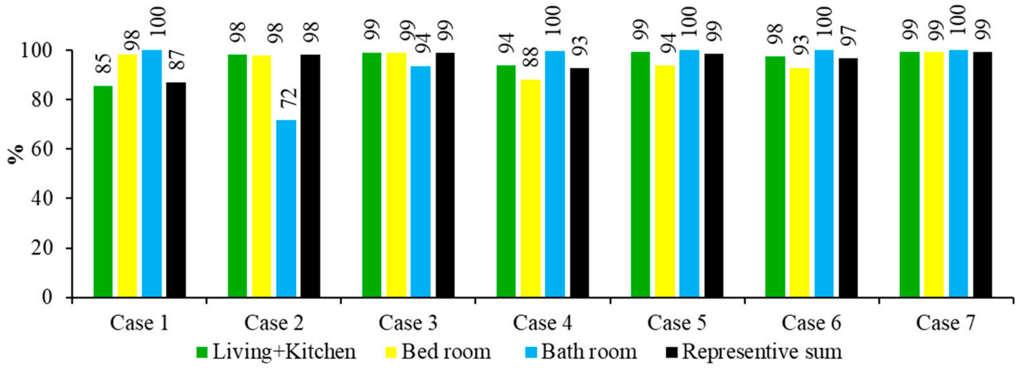

Figure 9. Thermal comfort–accepted hours ratio.

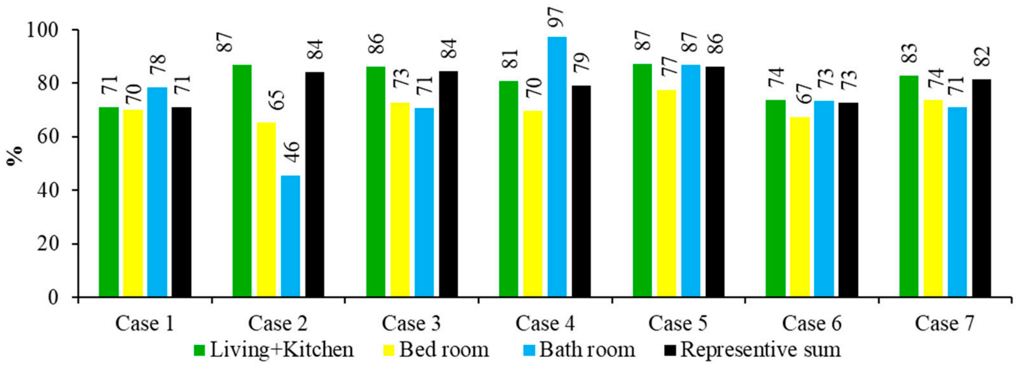

Figure 10. Thermal comfort–good hours ratio.

3.2.2. Fanger Comfort Model Indicators (PMV, PPD)

Concerning predicted mean vote (PMV) assessment and based on Category B as a good comfort standard with class [−0.5, +0.5], the results in Figure 11 were detected. The results revealed that the best-performing cases are Cases 4 and 5, compared to the base case (Case 1), with ratios of 15.06% and 12.58%, respectively, while the worst case is Case 6 with 6.27%. For assessing predicted percentage dissatisfied (PPD) as a thermal comfort dissatisfaction ratio for the occupied zone, and based on ISO 7730 (2005) [23], Category B was used, which refers to 10% of the dissatisfaction ratio [25]. Consequently, regarding PPD assessment, approximately the same comparison results as PMV were detected. For instance, Cases 4 and 5 performance ratios were the best, while Case 6 was still the worst.

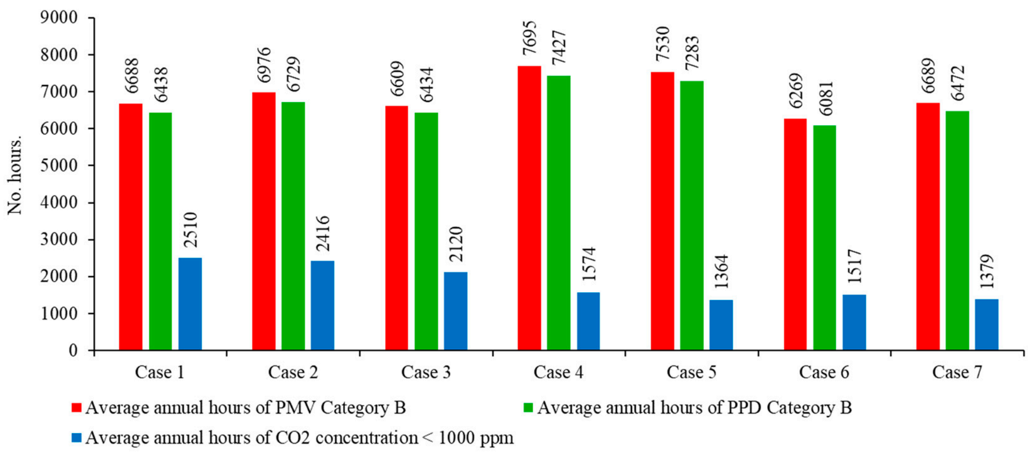

Figure 11. Fanger's indicators (PMV, PPD) and carbon dioxide concentration (CO_2) performance.

In conclusion, both the PMV and PPD assessment results generally show the superiority of the horizontal-compact (Cases 4 and 5) layout plan compared to the vertical-compact (Case 6 and 7) and horizontal-open into the yard (1, 2, and 3) layout plans. Consequently, a low circulation air ratio for the separated spaces and vertical layout plan (Case 6) is evident compared to the open-plan and vertical layout (Case 7) and the other horizontal layout plans. Additionally, the narrowest and small open-yard area beside the orientation of the doors for Case 3 is another reason compared to Cases 1 and 2.

3.2.3. Carbon Dioxide Level (CO_2)

For assessing IAQ performance, this study depended on the average annual hours with a CO_2 concentration of <1000 ppm recommended by European EN 13777 for a safe and healthy environment [28,47]. The assessment revealed that the performance of open-to-yard cases (Cases 1, 2, and 3) is better than the compact layout cases (Cases 4, 5, 6, and 7). The revealed ratios for less than 1000 ppm for Cases 1, 2, and 3 are 28.65%, 27.58%, and 24.20%, respectively, while for Cases 4, 5, 6, and 7, they are 17.96%, 15.57%, 17.31%, and 15.74%, respectively. Consequently, the performance of the cases with an open yard is better than the compact layout cases due to the opening of doors to the yard directly and exchanging air more efficiently. For instance, compared to other cases, the superior performance of the bedroom (Cases 1, 2, and 3) and the kitchen (Cases 1 and 2) is a crucial factor of superiority. Hence, it is recommended to set a special opening schedule for compact layout cases compared to the one open to the yard to enhance IAQ and eliminate the unaccepted overheated hours in the winter season.

4. Conclusions

Due to the permanent reasons (natural disasters and conflicts) globally, the continuing issue and the increasing number of displaced people are prominent. Improper planning and designing systems regarding lifespan, materials, techniques, and socio-cultural aspects lead to unsustainable and inefficient construction shelters. Therefore, the study aims to assess the impact of the morphological, siting, and layout of zones and shelters for the long-term displacement prototypes. Consequently, mixed methodology revealed comprehensive outcomes based on the bottom-up construction method and critical investigation of the planning and designing systems and socio-cultural context. Besides the new process and methods for creating models, the study outcome is new prototypes derived from the local planning and designing systems considering sustainability concepts from socio-cultural context, affordability, LIC materials, and techniques. As a result, the planning system of dwelling blocks would be embedded into the public planning system in Duhok city even in the incremental phase (future expansion).

By utilizing the dynamic simulation tool IDA ICE 4.8, the assessment of the energy and thermal comfort performance of seven cases was quantified. Firstly, the energy results generally revealed the superiority of the compact layout plan regarding fuel heating; for instance, Cases 4 and 5 save 80% and 84.8% compared to the first base (Case 1). Undoubtedly, that is due to the compact layout shape and smaller thermal bridge area than other prototypes, which results in low heat loss levels and effective heat gain in the winter season. However, concerning electric cooling, there is a superiority of the open-plan (studio) layout; for instance, Cases 3, 5, and 7 save 25.9%, 25.1%, and 20.7% compared to Case 1 due to the proper adequate circulation of air ratio in hot seasons and less heat gain compared to others.

Concerning the thermal comfort performance, there is a significant difference between the accepted hours ratio and Fanger indicator (PMV, PPD) categories compared to the carbon dioxide level (CO_2) concentration category. Therefore, regarding the accepted hours category, there is a superiority of the open-plan (studio) layout (Cases 3, 5, and 7) due to the proper adequate air circulation and the bath location's role in preventing main zones from heat loss and gain. Additionally, regarding PMV and PPD, the assessment revealed the superiority of the horizontal-compact (Cases 4 and 5) layout plan due to the good heat loss and gain performance compared to (Cases 1, 2, and 3) and more efficient air circulation compared to (Cases 6 and 7). Conversely to other categories regarding CO_2 concentration performance assessment, the results revealed that the open-yard layout cases (Cases 1, 2, and 3) have better results than the compact layout cases due to opening doors to the yard directly and exchanging air more efficiently. Meanwhile, it is recommended to set schedules for openings to be open more frequently for compact layout cases to enhance indoor air quality (IAQ) and eliminate the unaccepted overheated hours in the winter season.

Based on these conclusions, a more critical investigation of shelter planning and designing systems and affordable and adaptable strategies should be considered. In addition, a future investigation could address various locations and orientations besides the incremental phase approach to better understand the comprehensive prototype's performance. Eventually, the beneficiaries of the methods and the results of this study would be the Syrian refugees in the context of the Middle East and generally various places and involved people affected by the displacement issue globally.

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