OPEN ACCESS
Saudi Journal of Civil Engineering
Abbreviated Key Title: Saudi J Civ Eng
ISSN 2523-2657 (Print) |ISSN 2523-2231 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com/journal/sjce/home

Review Article

Sheltering Execution Printable Plan in Jordan

Mohanad Akeila[1*], Kelvin Kuok King Kuok[1], Christopher Preece[2]

[1]Faculty of Engineering, Computing and Science, Swinburne University of Technology, John St, Hawthorn VIC 3122, Australia
[2]Professor of Management, College of Engineering, Abu Dhabi University, UAE

DOI: 10.36348/sjce.2021.v05i07.003 | **Received:** 16.07.2021 | **Accepted:** 19.08.2021 | **Published:** 30.08.2021

***Corresponding author:** Mohanad Akeila

Abstract

The sheltering execution plan of a 3D printed shelter is planned to demonstrate the design of an existing camp, but it is built using printable sheltering units rather than tents and prefabricated cabins. The Zaatari Refugee camp in Jordan is selected as a case study for multiple reasons. The Zaatari Camp is located in Jordan, and was established on a large scale within short notice. The camp is built in a country ranked as one of the most expensive in the Middle East. The economy of the country and the needs of refugees make it an attractive case study to implement printable sheltering units, allowing for the investigation of the performance of a printable camp against existing sheltering camps covering aspects of time, cost, occupancy, and implementation perspectives. Achieving positive performances of a printable camp in Jordan will ensure that camps will be suitable and affordable in other countries with stronger economies, along with cheaper construction rates. The 3DP shelter is found to be a cost-effective solution in Jordan, which means that the printed shelters can achieve higher cost efficiency measures in less expensive countries in the Middle East, such as Turkey.
Keywords: 3D Printed Shelters, Printable camps, time, cost, occupancy, implementation.

1. INTRODUCTION

The Zaatari camp has witnessed and housed a large number of Syrian refugees since 2012. The camp managers changed the sheltering units from tents to caravans over the years (Ledwith, 2014). Therefore, changing from current cabins to 3DP shelters is a feasible transitional sheltering solution. The data collected for this case study includes the camp design, access routes, refugee distribution, and allocation of zones. The camp was designed to fit 10,000 3DP sheltering units. The printable shelter has to be printed in groups in order to fulfil the printer's structural dimensions. The selected printer can print up to a 7m x 40 m structure. However, the overall printing capacity has three shelters, each sized at 4.6 m x 1 m, with 2 m spacing kept between each shelter to fulfil the UN access routes requirement. Figure 1 shows the Zaatari Camp layout plan that was divided into 12 districts to host refugees. This paper will investigate the design principles of printable camps, the time and cost efficiencies of printing the camps and advances in technology for quicker printable camps in the future.

Figure 1: Zaatari Camp Districts Distribution (UNHCR 2018c)

2. LITERATURE REVIEW

In the initial phases of a catastrophe, a shelter is a crucial determinant for survival. In order to ensure safety, personal safety and climate protection, and to encourage resistance to diseases and ill health, a shelter mine is indispensable beyond survival. It is essential for people's dignity, the support of the family and the community and recovery from a disaster. The Sphere Book of Shelter Preparedness suggests five main standards. Firstly, strategic planning, which focuses on existing shelters and settlement solutions are prioritized through the return or hosting of disaster-affected households, and the security, health, safety and well-being of the affected population are ensured. Secondly, people must have sufficient covered space to provide dignified accommodation. Essential household activities can be satisfactorily undertaken, and livelihood support activities can be pursued as required. Thirdly, the design of the shelter should be acceptable to the affected population, and provide sufficient thermal comfort, fresh air and protection from the climate in order to ensure their dignity, health, safety and well-being. Fourthly, the construction approach should be in accordance with safe local building practices, and it should maximize local livelihood opportunities. Finally, the adverse impact on the environment can be minimized by the settling of the disaster-affected households, along with the material sourcing and construction techniques used.

3. SHELTERING CAMPS IN THE MIDDLE EAST

The purpose of this section is to discuss the existing sheltering camp in the area, and to highlight the major defects that the printed shelters will overcome. The shelters in the region suffer from refugees over the absorption capacity in which a shelter is designed to fit up to 5 refugees. However, in some shelters, the refugees exceed the count of 10 (Tiltnes, Zhang and Pedersen, 2019). Therefore, the design of the shelter shall consider the principal dimensions in the Sphere Book that allow enough space for each refugee. The Sphere Book recommend 3.5m2 per person in order to practice the minimum activities of humans throughout the day (IFRC, 2011). The natural event over the existing shelters in the region is destroying not only the shelter structure, but also refugee safety, in which many refugees flee in event of fire, sand storms and floods. In Lebanon, hundreds of Syrian refugees flee after a blaze of fire brought the tents to ash (Houssari, 2020). The thermal insulation of the provided shelters to refugees plays a huge role in the suffering of those refugees during the winter, where the temperature reaches zero and they just have to survive with a jacket and a blanket.

3DP shelters have imposed a magnificently outstanding result over the structural stability and energy consumptions. The structural analysis presented in our previous paper titled, “Evaluating the Structural Stability of 3-D Printed Shelters in Jordan”, has shown that 3DP shelters stand against the natural events as well as the printed shelters outstand the performance of steel and timber shelters of the same dimensions. Thus, the printed shelter is a rigid structural sheltering solution for refugees in the Middle East. The energy consumption, carbon emission, ventilation, and mechanical cooling were studied in a previous paper titled "Evaluating the Environmental Performance of 3-D Printed Shelters in Jordan". The paper's analysis resulted in finding the printed shelter to be a more effective environmental solution than the existing steel shelters. The assessment was developed through a cloud-based simulation platform that measured the shelter performance against pre-defined climate conditions. The analysis of the printed shelter was taken further by considering the performance of the shelter in a time and cost manner, and to define the feasibility of the technology in the Middle East region. The paper titled "Evaluating the Visibility of Building Syrian Refugee Shelters by 3-D Printing Technology in Jordan" has shown that printed shelters are a cost effective and time efficient sheltering solution in semi-permeant residencies rather than in temporary settlements. The purpose of this paper is to investigate the time and cost efficiency of printed shelters when placed in large-sized camps, taking Zaatari in Jordan as a case study. The first stage of studying the performance of printed camps is by designing it. The design will consider the number of refugees to be sheltered in each unit, taking into consideration the actual exiting refugees in the Zaatari camp. Furthermore, the design will study the exiting deviation of zones, districts, and suburbs in order to identify the number of printers required to build the camp. Upon design completion, the cost of the camp will be calculated by taking the cost of a single unit estimated by contractors in Jordan. The cost efficiency of the printed shelter will be calculated based on the amount that will be saved over a 15-year span. The comparison period of 15 years, which falls between 5 and 17 years, identified by Oxford University (Marion et al., 2017) is the average lifespan of the refugee camp. The 15 years was selected as a comparison period between multiple types of shelters as the structural analysis presented in previous papers shows that printed shelters can last for at least 15 years. Furthermore, the durability of the timber shelter does not exceed 5 years, which made 3 shelters to be required for the same refugee in the 15-year span. Similarly, the transitional steel shelters that are currently in Jordan camps are built to be durable for 3 years, which require 5 steel shelters in the span of 15 years. According to the durability of the shelters and the construction period for each one, the comparison between the printable camp and the steel and timber camps will be made in order to define which camp will be the most efficient over the 15-year span.

4. DESIGN OF PRINTABLE CAMP

The Zaatari camp was established in 2012 to host Syrian refugees escaping from the internal war (Ledwith, 2014). The displacement of Syrian refugees resulted in more than 100,000 refugees in the first couple of years. The design of the printable camp developed on the current refugees in the camp is counted to be 70,000 to 80,000 refugees accommodated in 10,000 shelters. The design of the printable camp respected the distribution of existing districts and zones. The camp begins from district D1 at the upper left corner of Figure 1.

The districts of the camp were labelled with different names such as phases, sectors, and modules during the transition of the shelters from tents to prefabricated cabins. The new distribution of the camp's sectors matches the original district distribution place, except in three locations listed as D3, D4, and D5. District D5 occupies 40% of the D3 and D4 population, and it is renamed as phase 5. The 40% reduction occupancy in district D3 and D4 results in a downgrade of the district description to sectors 3 and 4. The purpose of referencing the current shelter occupancy distributions in the design of the printable camp is to use it in the calculation of the number of printable shelters for each district. Figure 2 presents the current prefabricated cabin distribution in the Al Zaatari camp.

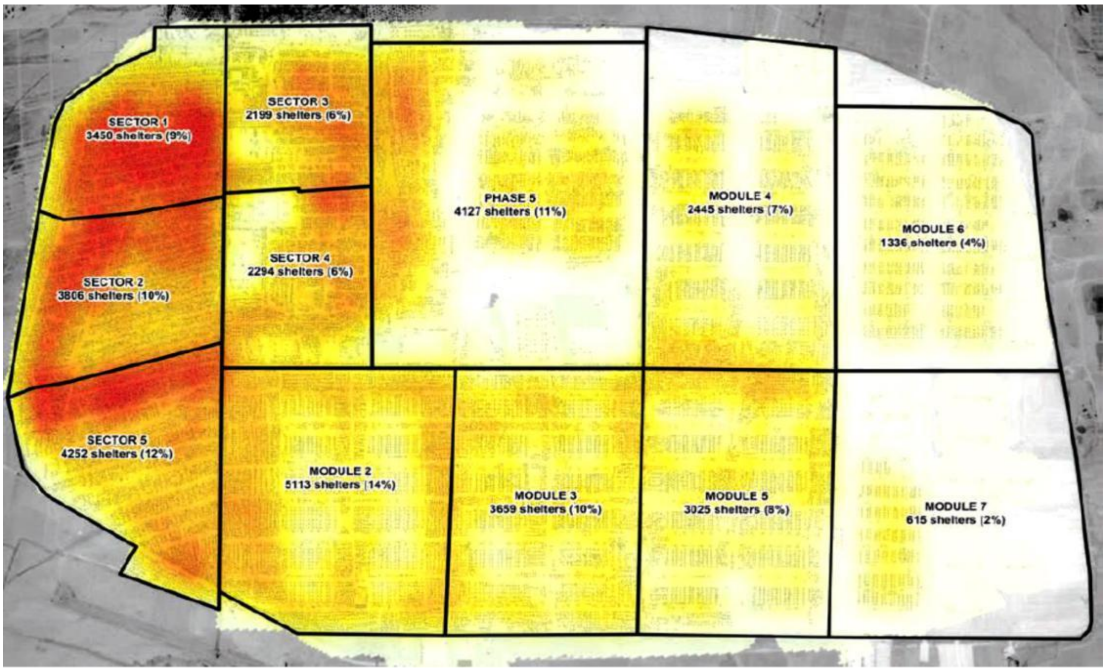

Figure 2: Distribution of Shelters in Zaatari Camp (Ledwith, 2014)

The total number of shelters donated to the Zaatari camp shown in Figure 1.2 was 36,321 shelters in 2014 (Ledwith, 2014). The numbers were reduced to 26,000 prefabricated cabins in 2020 to host 76,143 refugees. The printed shelter model living area is 26.5 m2, which can fit eight refugees, as each refugee requires 3.5 m2 of living area (IFRC, 2011). Therefore, the 26,000 prefabricated cabins can be replaced by 10,000 printed shelters. The districts of the printed camp were developed individually to define how many printed shelters remained out of a series of groups of three. The printing of each individual 3DP shelter will cost the contractor more money and time for assembly and dismantling of the three prints. The layout presented in Figure 3 is developed in reference to the occupancy percentage of the original shelters.

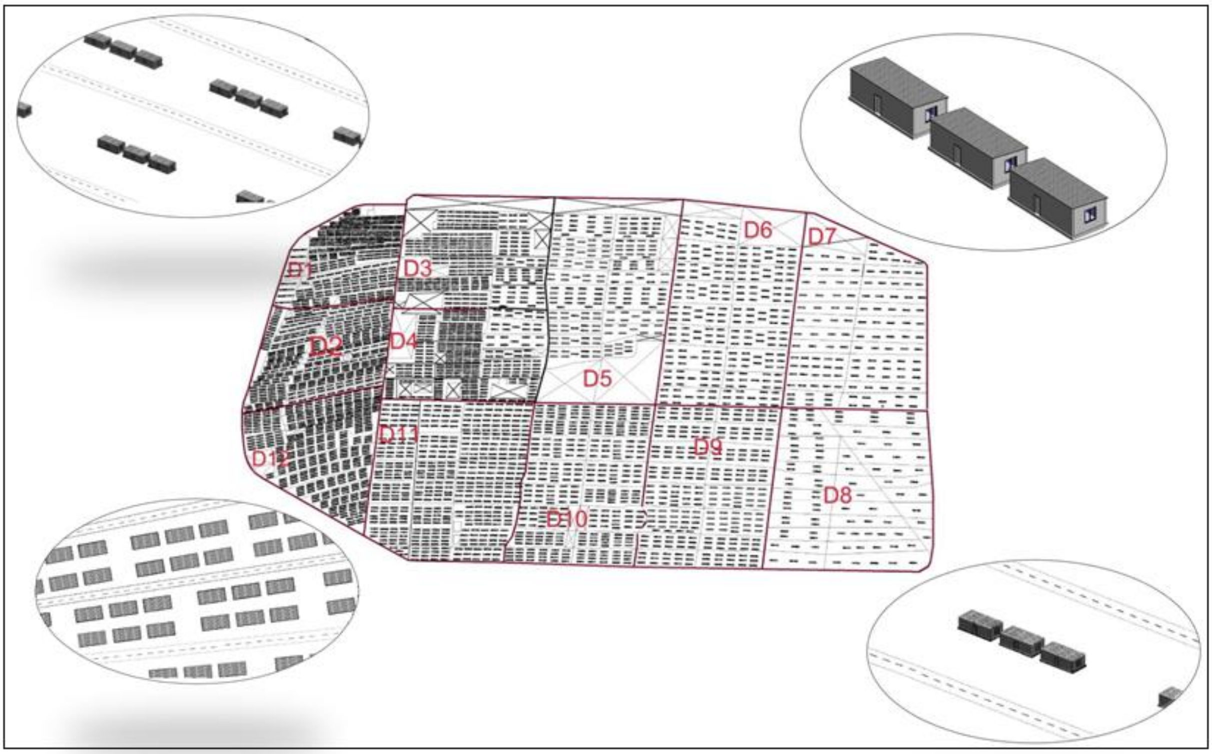

Figure 3: The Distribution of 3DP shelters in Zaatari Camp

The areas containing crosses are kept for hospitals, schools, community centers, offices, warehouses and distribution centers. The shelters placed in group of three result in a well-organized sheltering camp, with access routes between districts as well as between blocks. The blocks in the Zaatari camp are the sub-districts separated by access roads. Table 1 developed in relation to the distribution layout in order to analyze the number of single prints required to complete 10,000 units.

Table 1: Printed Shelters in Each District of the Zaatari Camp

District	*Occupancy Percentage*	*In the model*	*Number of Groups*	*Shelters Should be*	*Differences*	*Balance*
D1 (Sector 1)	9%	900	300	900	0	0
D2 (Sector 2)	10%	999	333	1000	-1	0
D11 (Module 2)	14%	1401	467	1400	1	
D3 (Sector 3)	6%	600	200	600	0	0
D4 (Sector 4)	6%	600	200	600	0	0
D5 (Phase 5)	11%	1101	367	1100	1	0
D10 (Module)	10%	999	333	1000	-1	
D6 (Module 4)	7%	699	233	700	-1	0
D9 (Module 5)	8%	801	267	800	1	
D7 (Module 6)	4%	399	133	400	-1	-1
D8 (Module 7)	3%	300	100	300	0	0
D12 (Sector 5)	12%	1200	400	1200	0	0
Total	100%	9,999	3,333	10,000	-1	-1

The sum of the distribution percentage of the shelters from the original distribution is 1%, which are 100 shelters out of the 10,000 units. Therefore, the 1% will be distributed in a district with a low population that can accommodate an additional 100 shelters without compromising accessibility. The printed shelters in district D1 (Sector 1) hosts 9% of the camp's capacity. Due to the approach of three shelters in one group, the district can have its required occupancy with a single print cycle. In D2, however, the capacity of the district is 1,000 shelters; a number which will result in fractions when divided by three. Therefore, one shelter will be cancelled from the district and added to another district requiring an additional shelter to close the group pattern. D8, at the Module 7 suburb, is found to be in a wide area that allows the additional 1% missed from the original sheltering distribution, completed by the camp developers. Therefore, the shelters in D8 are increased by 100 shelters in order to achieve the overall capacity of the required 10,000 units.

The distribution schedule presented in Table 1 has been rearranged in order to eliminate the additional and missing shelters from individual districts. The shelters shifted among the districts will show the number of single prints required to cover the camp at the end. After the eliminations between one district and another, a single shelter remained alone without a group in D7. A single shelter will need 27.5 hours to be printed, 24 hours to set up the printer and 24 hours to dismantle the printer. A single unit will require 60% of the time preserved to print three units at the same time since the calculated printing time for three units is 130.5 hours (5.4 days). Therefore, the printable execution plan developed on a camp similar to Zaatari will not require a reduction in the time and cost efficiencies resulting from single prints.

5. COST OF PRINTABLE SHELTERING CAMP

In this section, the research will study the cost efficiency obtained by printed shelters over steel and timber shelters, as well as tents and pre-fabricated cabins. The design study that was developed by using the Zaatari camp shows time and cost losses in only a single unit for more than 10,000 printable shelters. Therefore, the cost and time impact of the single unit over the project execution programme and project designated budget remains neglected. The 3DP shelter cost of US $14,395 in Jordan includes the overhead of 25 printers to build the camp. The 25 printers required to build the camp within two years will cost US $24.55 million since each of the printers will build three shelters in 5.4 days. A single printer can produce up to 16.7 shelters per month since each of three shelters require one day of printer assembly, another day of printer dismantling, and 27.5 hours of printing for each shelter. The competitive market cost per shelter is US $11,938 without the overhead of the printer cost. The US $24.55 million cost of the printers will be distributed over the 10,000 sheltering units in order to reach the price of US $14,395 for each 3DP shelter for the Zaatari camp. The changes in shelter numbers can affect cost efficiency and production performance since the cost efficiency of a camp is dependent on the design principles established prior to camp execution. The spacing between groups can further impose cost efficiencies by reducing the need of continuous surveys on site. A symmetrical camp can be constructed from a single control point that connects one shelter to another with a constant spacing distance.

The sheltering camp study was developed on an existing layout of unequal districts by a continuous survey to identify shelter coordinates in reference to a master control point. The survey activities will not add additional costs for the printed shelters since the cost for the survey is included in the costs of the shelter printing and construction. All of the shelter types placed in the same orientation and randomly distributed throughout the districts, as presented in Table 1.1, will not release any cost efficiencies for the construction cost of the camp since all shelter types will require continuous surveying in order to build each shelter in the camp.

The camp of Al Zaatari was first built to house refugees using tent dwellings. The cost of a single tent for the Zaatari camp was US $500 (UNCHR, 2016). The durability of the UN Refugee tents is normally for one year under normal climate conditions. However, under extreme climate conditions, such as heavy rain in winter and high temperature in summer, the tents will only last for six months. The annual cost of the tents for one family with five members is US $1,000. The occupancy capacity of the tent is limited to five people, leading to a requirement of 16,000 tents every year in order to host 80,000 refugees (UNHCR, 2014). The Zaatari camp would cost the United Nations and supporting aid organizations US $240 million over a 15-year lifespan. The lifespan of a timber shelter is only five years, while a steel shelter lasts for just three years. The steel and timber shelter durability is estimated in reference to the Shelter Design Catalogue issued by the UNHCR in 2016, and the Post-disaster Shelter Design Manual issued by IFRC in 2013. A steel shelter in a refugee camp located in Jordan will be replaced five times over the course of the camp's lifespan (15 years), while a timber shelter will be replaced three times, as the durability of it is 5 years. The estimated cost of reconstructing a timber and steel shelter is US $82,287.90, and US $26,158.50, respectively, over the full 15-year lifespan.

Prefabricated cabins were supplied during the transitional stage of the Zaatari camp to provide Syrian refugees with a safer and more secure type of shelter. The caravans each cost US $3,125, and have a durability of three years. Thus, the cost of the cabin over 15 years will be US $15,625. The caravan's maximum holding capacity is six refugees per cabin, and 13,500 units of caravans are needed to house 80,000 refugees (Barakat, 2016). Table 2 summarizes the cost of building the Zaatari camp with different shelter options.

Table 2: Summary of Zaatari Camp Construction Cost with Different Shelter Options

TYPE OF SHELTER	CAMP COST OVER 15 YEARS (US$)
3DP SHELTER	144 M
TIMBER SHELTER	823 M
STEEL SHELTER	262 M
TENTS	240 M
CARAVAN	211 M

The aim of studying the construction cost of an entire printable camp is to identify how feasible and cost efficient 3DP technology can be for constructing shelters in the Middle East. The case study of the Zaatari camp shows a very efficient competitive cost saving construction methodology over normal construction methods for different types of shelters. Figure 4 summarizes the cost efficiencies of a 3DP camp in Jordan compared to a steel sheltering camp, a timber sheltering camp, a tent camp, and a prefabricated camp.

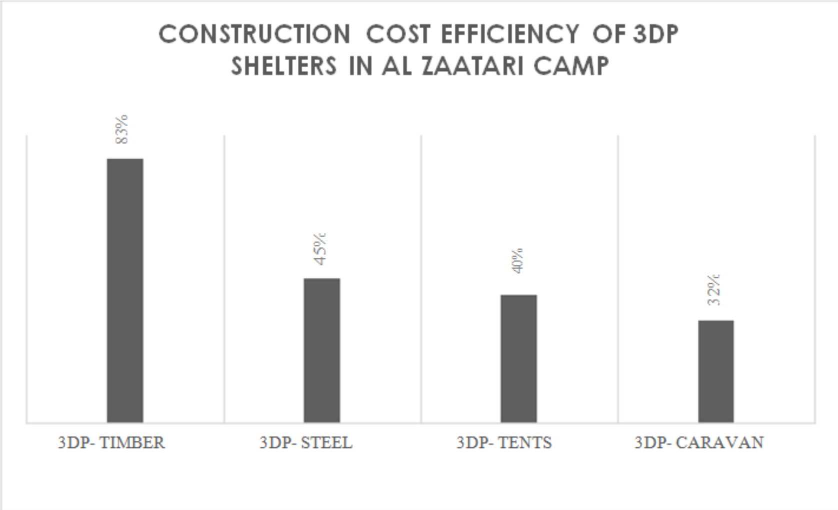

Figure 4: Cost Efficiency of 3DP Shelters in Zaatari Camp

Using the 3DP shelters for the Zaatari camp will impose a cost efficiency of 83% over the timber shelters built to host the same number of refugees. The saving of US $118 million over 15 years between the 3DP shelter and the steel shelter results in a cost efficiency of 45%. The printed camp has a cost efficiency of 40% over a camp constructed of tents. The Zaatari camp's construction was completed in April 2013 (Ledwith, 2014). Assuming that the camp continued to shelter the refugees in tents, which need to be replaced annually, the camp would cost US $112 million between 2013 and 2020, neglecting the cost of demolition each year. The 3DP technology is found to be extremely competitive not only in relation to steel and timber, but also to simpler types of shelters that need changing on a continuous basis. The printed shelters in the Zaatari camp could achieve a cost efficiency over caravans of 32%, which equates to US$67 million. The following section of the printable execution plan will define the time required to construct each of the camp districts, and examine a possible methodology to achieve high time efficiency.

6. TIME PLAN OF PRINTABLE CAMP

The execution period of construction in this section will study the printing duration of each district and identify an approach to increase time efficiency.

The infrastructure development of the camp will not be considered in this execution plan, as the road and drainage system will remain the same during the transitional period of the camp. Table 3 summarizes the printing period using 25 printers in each of the camp districts.

Table 3: Printing Period of Shelters in Each of Zaatari Districts

District	*Occupancy Percentage*	*Number of Shelters*	*Printing Groups*	*Printing Period by 25 Printers (Days)*
D1 (Sector 1)	9%	901	300	64.8
D2 (Sector 2)	10%	999	333	71.928
D3 (sector 3)	6%	600	200	43.2
D4 (sector 4)	6%	600	200	43.2
D5 (phase 5)	11%	1101	367	79.272
D6 (Module 4)	7%	699	233	50.328
D7 (Module 6)	4%	399	133	28.728
D8 (Module 7)	3%	300	100	21.6
D9 (Module 5)	8%	801	267	57.672
D10 (Module)	10%	999	333	71.928
D11 (Module 2)	14%	1401	467	100.872
D12 (Sector 5)	12%	1200	400	86.4
Total	100%	10000	3333	720

The steel and timber shelters were found to be quicker in construction than printable shelters. The steel shelter construction time was estimated to be 24.5 hours, while the timber construction time was estimated to be 27.4 hours. The aid organizations gave a period of two years to construct the printable camp; therefore, a figure of two years has been used to calculate the number of printers required to establish the camp within the given period. Keeping this two years as the construction period for the other two shelters (steel and timber) will identify how much reduction can be applied on the cost efficiency presented in Figure 3 in order to construct the camp faster than expected.

The time efficiency of the printed camp over steel, timber, caravan, and tent camps was calculated on two different perspectives in order to define whether the time efficiency is possible in building the camp in comparison to a single construction cycle, and whether it is possible to achieve it over the summation of individual construction periods as the camp requires to be constructed at every re-construction cycle. The summation of individual construction periods achieved a high level of time efficiency by the 3DP camp over the other camps, as the printed camp will stay in place for at least 15 years. However, each of the other camps will require demolition and reconstruction. Table 4 presents how long each camp will require construction time over the 15-year period.

Table 4: Time Efficiency of 3DP Sheltering Camp in a 15-Year Span

Shelter Type	*Single Construction Cycle*	*No's of Shelters*	*Construction Cycles in 15 Years*	*Total Camp Construction Time over 15 Years*	*3DP Camp Time Efficiency over 15 years*
Steel	2 years	10,000	5	10 years	80%
Timber	2 years	10,000	3	6 years	67%
Tent	6 month	16,000	15	7.5 years	73%
Caravans	7.5 month	13,500	5	3.1 years	36%

The cost efficiency in the first-time analysis approach will not require compromises to achieve time efficiency, since the 3DP camp will be built once and remain for 15 years. However, in case of the steel and timber shelters, each camp will require a total of 10 and six years respectively to be constructed over the 15-year lifespan of the camp. The 3DP camp achieves a time efficiency of 80% over a steel camp and 67% over a timber camp. The tent camp requires 16,000 tents to shelter 80,000 refugees, since the maximum capacity of the tent is only five refugees. Therefore, a tent camp will require 7.5 years to be constructed every 15 years, since each cycle of constructing the camp will require six months, and the printed camp achieves a time efficiency of 73% over y tent shelters.

The second time efficiency perspective is used to identify the decrease in cost efficiency in order to achieve time efficiency with each construction cycle of the camp. The second perspective will present a more realistic time efficiency to aid organizations, as the demolishment of the camps will be needed to be done in gradual phases, rather than a total demolishment and reconstruction. Therefore, the first construction cycle of building the camp with 3DP versus building the camp by steel, timber, or porta-cabins or tents, has been investigated to define the time efficiency that a printable camp can achieve with a shorter construction period.

The original cost of the 3DP camp of US $144 million has to increase in order to achieve the time efficiency against each individual camp's building cycle. The perspective of reducing the cost efficiency in order to achieve time efficiency on a single cycle of construction is realistic, as the transition of the refugees following the first construction cycle will be gradual rather than absolute. This means that the camp developers will be supplying and shifting families from one shelter to another without disturbing the ongoing everyday life of the camp. Therefore, studying the time from a single construction cycle perspective will determine the amount of investment the developer is required to invest in order to construct the printed camp in a competitive timeframe. The second perspective of defining the printable camp's time efficiency through comparing single construction cycles between one camp to another found that a printed camp can achieve time efficiency only if more printers are devoted to print the camp in less than two years. The additional printers are calculated by multiplying the time duration required to print three shelters in one group by the number of shelters, and then dividing that by the trailed number of printers. If the configured new construction duration is found to achieve time efficiency but not cost efficiency, then the number of printers will be reduced in order to achieve a balance between cost and time efficiency.

The construction periods of the steel and timber camps are kept constant at two years in order to analyse the variables of the cost over a similar construction period. Table 5 presents the cost efficiency results of a printed camp when compared to other types of camps, taking into consideration the number of printers required to construct the printable camp quicker. The printed camp's cost efficiency related to that of the timber camp's drops from 83% to 81% due to an increase in the number of printers on site to print the camp in 1.4 years instead of two. The time efficiency of reducing two years to 1.4 is calculated to be 30%. When compared to the steel sheltering camp, the printed camp achieves a cost efficiency of 36% in comparison to the 45% cost efficiency achieved by having 25 printers on site. The time and cost efficiency achieved by the printed camp over the steel camp doubles the number of printers that is needed to be on site; adding US $24.5 million to the camp's construction cost.

Table 5: Zaatari Printed Camp Time Efficiency Over Single Construction Cycle

Camp Shelters	*Shelters Per Camp*	*Single Cycle Construction Duration*	*New No. Of Printers*	*3DP Camp New Cost*	*Printed Camp Cont. Period (years)*	*Printed Camp Time Efficiency*	*Revised Cost Efficiency (15 year span)*	*Original Cost Efficiency*
Timber Shelter	10,000	2 years	35	154	1.4	30%	81%	*83%*
Steel Shelter	10,000	2 years	50	168.5	1	51%	36%	*45%*
Tents	16,000	6 month	110	222.5	0.47	6%	26%	*40%*
Caravan	13,500	7.5 month	85	203	0.58	7%	4%	*32%*

The drop in the efficiency of printed camps over tents and caravans is a result of the low price of the sheltering units. Thus, a single printed unit costs 15 times the cost of a simple tent. The printed camp achieves a time efficiency of a week less than the construction period of the tent camp. Finally, the caravan camp's cost efficiency reduces to 4% from 32%, as 85 printers need to be devoted to build a camp in less than 7.5 months. The number of printers is calculated by multiplying the camp capacity (10,000) by 5.4 days (duration to print three shelters), and dividing that by the number of printers. The outcome of this formula will stipulate how long the printers need to print the camp. The number of printers is estimated by a trial-and-error concept, in order to find the number of printers that will achieve both cost and time efficiency.

7. CONCLUSION

In summary, three-dimensional printing is found to be an efficient construction methodology to build refugee camps in the Middle East, once its efficiency can be achieved over the long term. The printed shelters placed in specific camp orientation can achieve the religious, cultural, safety, and stability requirements of refugees. The execution plan shows a three-step process towards the easy mobility of the printing technology in any camp located in the region. The first is to survey the dedicated ground of the camp and divide the camp into zones, in which each zone will consider a minimum of 2.5 m of patrolling and access routes between printed shelters. The case study camp demonstrates the best printing methodology, with a dedicated printer for three shelters printed in one cycle. Camp developers adopting the technology will need to study the floor printing capacity of the printer to estimate the cost of the printers, which plays a major role in controlling the cost efficiency of a printed camp.

8. DATA AVAILABILITY

Access to Data is Restricted: The research presented in the paper is part of a PhD research that is funded by Swinburne university of technology. The models of the research as well as the analytical theme remain under the custody of the university database till the project is completed. Any use of data should be communicated with the author of the paper to ensure no violation of the university copyright of the research.

REFERENCES

1. Barakat, G. (2016). *Site planning and shelter Camp Restructure Project Report Zaatari Refugee Camp April 2016*. Mafraq. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/ZaatariCampRestructur eReport-April2016.pdf.
2. Houssari, N. (2020). *Hundreds of Syrians flee as refugee camp torched in Lebanon, Arab news*. Available at: https://www.arabnews.com/node/1783491/middle-east (Accessed: 28 March 2021).
3. IFRC. (2011). *The Sphere Project: Humanitarain Charter and Minimum Standards in Humanitarian Response*. 3rd edn. Hampshire: The Sphere Project. doi:10.3362/9781908176202.
4. Ledwith, A. (2014). 'Zaatari : The Instant City', *An Affordable Housing Institute Publication*, 1, pp. 1–95.
5. Marion, C. (2017) 'Shelter in displacement', (55).
6. Tiltnes, Å. A., Zhang, H. and Pedersen, J. (2019) *The living conditions of Syrian refugees in Jordan Results from the 2017-2018 survey of Syrian*

refugees inside and outside camps. Available at: https://www.fafo.no/images/pub/2019/20701.pdf (accessed 08.02.19).

7. UNCHR. (2016). *SHELTER DESIGN CATALOGUE, UNHCR Shelter and Settlement Section*. Available at: https://cms.emergency.unhcr.org/documents/11982/57181/Shelter+Design+Catalogue+January+2016/a891fdb2-4ef9-42d9-bf0f-c12002b3652e (Accessed: 20 May 2019).
8. UNHCR. (2014). ‘Unhcr Family Tent for Hot Climate’, pp. 51–73. Available at: http://www.unhcr.org/53fc7df49.pdf.
9. UNHCR. (2018). ‘Zaatari Refugee Camp - Infrastructure and Facilities’. Mafraq: United Nations High Commissioner for Refugees, p. 1.