

An Approach to Simulating Construction Process in Post-Disaster Sheltering

Mahdi Afkhamiaghda, Kereshmeh Afsari, Ph.D., Emad Elwakil, Ph.D., Randy Rapp, Ph.D.

Purdue University
West Lafayette, Indiana

Post disaster housing and sheltering is considered a cyclic process which contains a broad range of activities in different characteristics such as social aspects, labor management, and environmental concerns. Most of these issues, if not all, are linked together and can affect each other's activities and progress. As the population size increases and cities expand and become denser, this link and relation between different tasks become more and more complex. Not knowing the links between each of these elements and how processes are sequenced can result in long delays in the process, cost overruns, and even a poor quality job in the affected region. This research investigates how construction simulation and mapping process can facilitate post-disaster temporary sheltering process by breaking down the process into smaller activities. This approach will lead to considering all affecting elements in work activities, which can result into more accurate decision making and planning.

Keywords: construction, construction simulation, mapping, post disaster, temporary shelters

Introduction

When a disaster strikes in a region, many people lose their homes entirely or their houses become uninhabitable (Escamilla, & Habert, 2015; Plyer, 2015). Therefore, there is an urgent need to provide shelters for these affected people (Hong, 2017) as time plays a crucial role in post disaster construction. Due to the severity and impact of the process, the construction team working in a post disaster site are formed by a hodgepodge of professionals hired by contractors and volunteers who usually do not have the required expertise and strategy in the field (Berkowitz, 2012; Quarantelli, 1999). Therefore, it is of vital importance to have a clear and understandable plan before approaching the process (Hidayat & Egbu, 2010). Computer simulations are considered as one of the tools that are used to show the model's behavior (Abourizk, 2010) as they create models that represent the overall logic of various activities, resources, and environment. Every model, aside from its functionality, is consisted of one or more systems, where each system is a group of server units which perform the main work and auxiliary units that help completing the works. The balance between server and the auxiliary unit is crucial, as any inconsistency between these two can either lead to a queue of units waiting to be served or an idle server. Each of these scenarios can have a negative effect on cost, time, resource, and in total the effectiveness of the project.

Just like construction, post disaster planning and management are considered as work tasks, which are linked and related to each other through different sequences and orders. On the other hand, in order to simulate a process, one needs to first break down the whole work order into smaller sequences and make sure all the elements are present in the simulation (Abourizk, 2010; Halpin & Riggs, 1992). However, unlike a normal construction process, post disaster management and planning covers a broad range of topics. Social, logistical, and environmental issues are just a few of the elements which play a key role in the effectiveness of the project (Rapp, 2011). Therefore, in order to create an effective plan, it is necessary to understand the sequence and relationship of each of these issues with each other and how they are linked together.

Many researchers have studied post disaster planning from different aspects and perspectives, Nath et al (2017) have discussed factors and elements which effect the shape, quality, and type of natural disaster shelters. Bosher & Dainty (2011) have argued the factors for risk reductions. Nejat (2018) discusses how the social impact and people living in the region can affect the process, in addition, many studies have been performed on assessing and analyzing the impact of disasters. Unmanned aerial vehicles such as drones have been used for estimating and assessing the scale and severity of the damages (Bendea et.al. 2008) and locating the most impacted area, to find out the most affected regions and amount of debris in volume.

However, just like any activity, post disaster sheltering is a system which is shaped by numerous factors and nodes which are link together. While many researches have been done on assessing different factors which can help the reconstruction and recovery process in post disaster separately, there has not been too many work on reviewing the relationship of these nodes and how all these factors and elements are link together. Therefore, a comprehensive disaster plan and management idea which covers different kinds of topics is needed in advance (Hidayat & Egbu, 2010).

This paper focuses on how the mapping and civil processes in the construction industry can assist the post disaster sheltering process. This would facilitate creating models that represent the overall logic of various activities, resources, and the environment. The result of this study can assist in representing a real world situation considering all surrounding conditions, consequently resulting in better understanding of the work tasks and how each task is related to other.

Method

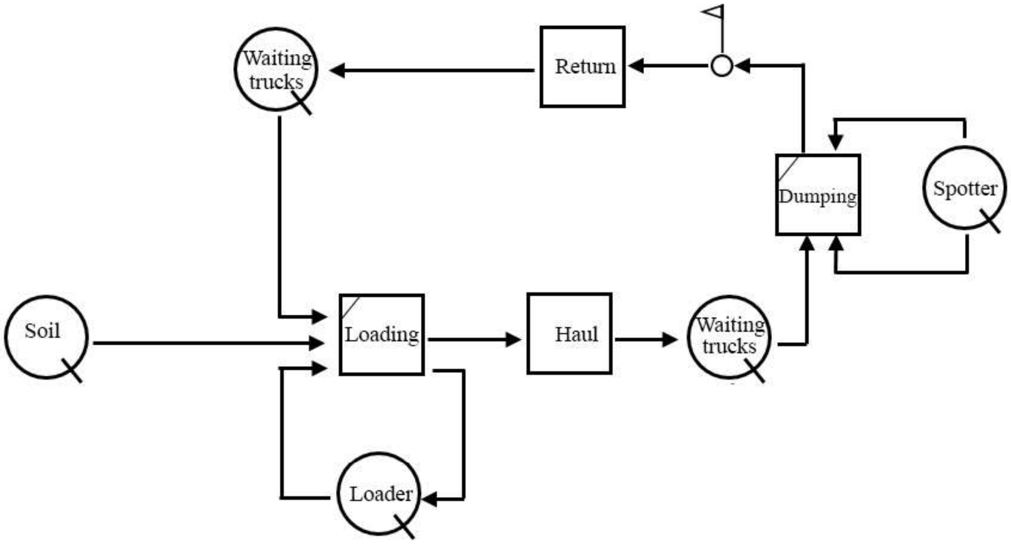
Temporary post disaster sheltering processes can benefit from mapping and construction simulation. First, the researchers review the issues and the elements necessary to simulate the process using a CYCLONE model. Key tasks and factors which form the process were selected from literature review. A simple process has been modeled using this approach to demonstrate how it is used in the construction industry. In the next step, the researchers describe an overall of the elements and factors which effect the post disaster situation and makes it different from a normal construction work. By producing a CYCLONE model of creating temporary shelters in a post disaster situation, the researchers tend to show the link and sequences of work tasks. This would make it easier for the contractor to better understand the effect of each process within the whole activity.

Mapping

The first step to create any simulation is to breakdown the whole process into smaller tasks. In order to have the best result and most clear understanding, one should get as detailed as the collection of data on that matter is still possible. Below is a diagram of the breakdown system for the total project:

Fig1: work breakdown structure of a construction process

Consider a simple earth moving operation in construction (Fig 2), in this process, trucks hired by the contractor enter the site and go to the loading zone where the loader fills the trucks with the excavated soil. In the next step, trucks leave the site for dumping the soil in the predefined area, where the process is controlled by a spotter. Finally, the trucks return to the construction site again to be loaded. This cyclic process continues until all soil (resource) is excavated.



a)

```
NAME EARTHMOVING PROCESS LENGTH 1000 CYCLES 30
NETWORK INPUT
1 QUE 'LOADER WT'
2 QUE 'SOIL STOCKPILE'
3 QUE 'TRUCK WT'
4 COM 'LOADING' SET 4 PRE 1 2 3 FOL 3 5
5 NOR 'HAUL' SET 5 FOL 6
6 QUE 'WAIT TRUCKS'
7 QUE 'SPOTTER'
8 COM 'DUMPING' SET 9 PRE 6 7 FOL 7 9
9 FUN COU FOL 10 QUA 1
10 NOR 'RETURN' SET 10 FOL 3
DURATION INPUT
SET 4 TRI 1 1.5 2
SET 5 TRI 5 6 7
SET 9 DET 1.5
SET 10 TRI 4 5 6
RESOURCE INPUT
2 'LOADER' AT 1 FIX 60
1000 'SOIL' AT 2 FIX 60
10 'TRUCKS' AT 3 FIX 25
1 'SPOTTER' AT 7 FIX 30
```

b)

Legend: QUE = Queue COM = Combi NOR = Normal FUN = Function COU = Counter QUA = Quantity

Fig. 2: Earthmoving Operation

a) Construction Process Map Diagram b) WEBCYCLONE Code Model

Work tasks are considered as the smallest unit in this process which can either be NORMAL or COMBI. NORMAL work tasks are the ones which are not bounded to a server and are considered as active processing units, which in the aforementioned example are the trucks driving to the dump site and returning. COMBI operations are another type of work task which are similar to the normal work task modeling element. However, they are constrained by the server idle, and are also considered as part of the process where a service is being done (Akhavian & Behzadan, 2014). The duration of these tasks effect the overall process functionality –in this model, the trucks loading and dumping operations. These operations must be followed with at least two queues (Huang & Hsieh, n.d). In addition to the work tasks, resource and clients are the other two elements which form the CYCLONE model (Akhavian & Behzadan, 2014). In this model, the soil stockpile is the resource while the trucks are the clients in the model.

Depending on different factors such as arrival rate of the unit, the service rate, number of servers and the queue length, the mapping system outline can change (Halpin & Riggs, 1992). Therefore, knowing the duration of each work task is of vital importance for creating a model (Stallings, 2000). The raw data for the time input is usually gathered from previous similar projects or expert opinions. In the next step, the users can utilize mathematical models for validating the data such as deterministic, probabilistic, or triangular methods.

Post Disaster Sheltering

When a disaster strikes, the ultimate goal is to get the affected region to a normal condition, where the performance rate and the functionality of the city goes back to an acceptable rate (Platt, 2017). Therefore it covers a broad range of activities, which would reduce risk and lean towards a holistic perspective and a resilient community (Bosher & Dainty, 2011). In terms of construction, recovery is not only removing debris and waste from the site or restoring and fixing damaged facilities and buildings to a usable condition. It also covers the reconstruction process for the damaged structures (Rapp, 2011). Therefore, as speed is crucial, the final quality of the outcome in this process is also an important criterion for measuring the success. Each of these steps need to be planned and managed accordingly. Removing debris from the site, ordering and shipment of materials to rebuild the region, sheltering the affected people while supplying the basic needs like food and sanitary issues are just a glimpse of a wide range of tasks that needs to be dealt with. The sheltering process for the affected people contains from being homeless to having again permanent housing contains three main steps.

1-Emergency shelters: these shelters are provided for the affected people and should not last more than a week

2-Temporary shelters: these shelters are designed so that they can be relocated after usage, people stay up to 24 months in some cases before their housing is completed.

3-Permanent housing: the state where people move from temporary shelters to their new permanent housing.

Temporary shelters and how they are built are of vital importance as these spaces need to be held to a certain level of standard in terms of hygiene, sanitation, ventilation, aesthetics, and structural quality as people tend to live in these spaces for a long period of time (up to 24 months). One cannot simply define one general rule and process for temporary housing for all natural disasters (Abolnour, 2013). Nath et al. (2017) have categorized the key indicators which effect the sheltering process effectiveness. These factors cover a broad range of topic from hygiene, facilities, infrastructure, comfort and health of the occupants all the way to the availability of materials and labors. This study focuses on creating a comprehensive plan and model for the post disaster situation, which covers the processes that take place from the point that disaster strikes to the point that people are settled in temporary shelters. Using this approach, the user would be able to view the link and connection between each of the tasks. This approach tries to model and identify indicators and factors which affect the temporary shelter process using a mapping model. This process have two main players; first is the affected people which go through registration process by local government personnel for emergency sheltering (Quarantelli, 1995) and then moved to temporary shelters after a short period of time (McIntosh, 2013). Next part of this process is from the standpoint of firms which make a contract with local government for reconstructing the region, this process would involve site assessment, planning shelters, ordering materials (Rapp, 2011), hiring labors from the locals (Berkowitz, 2012; Quarantelli, 1999), and training them (Bilau et.al, 2015) in order to create temporary shelters.

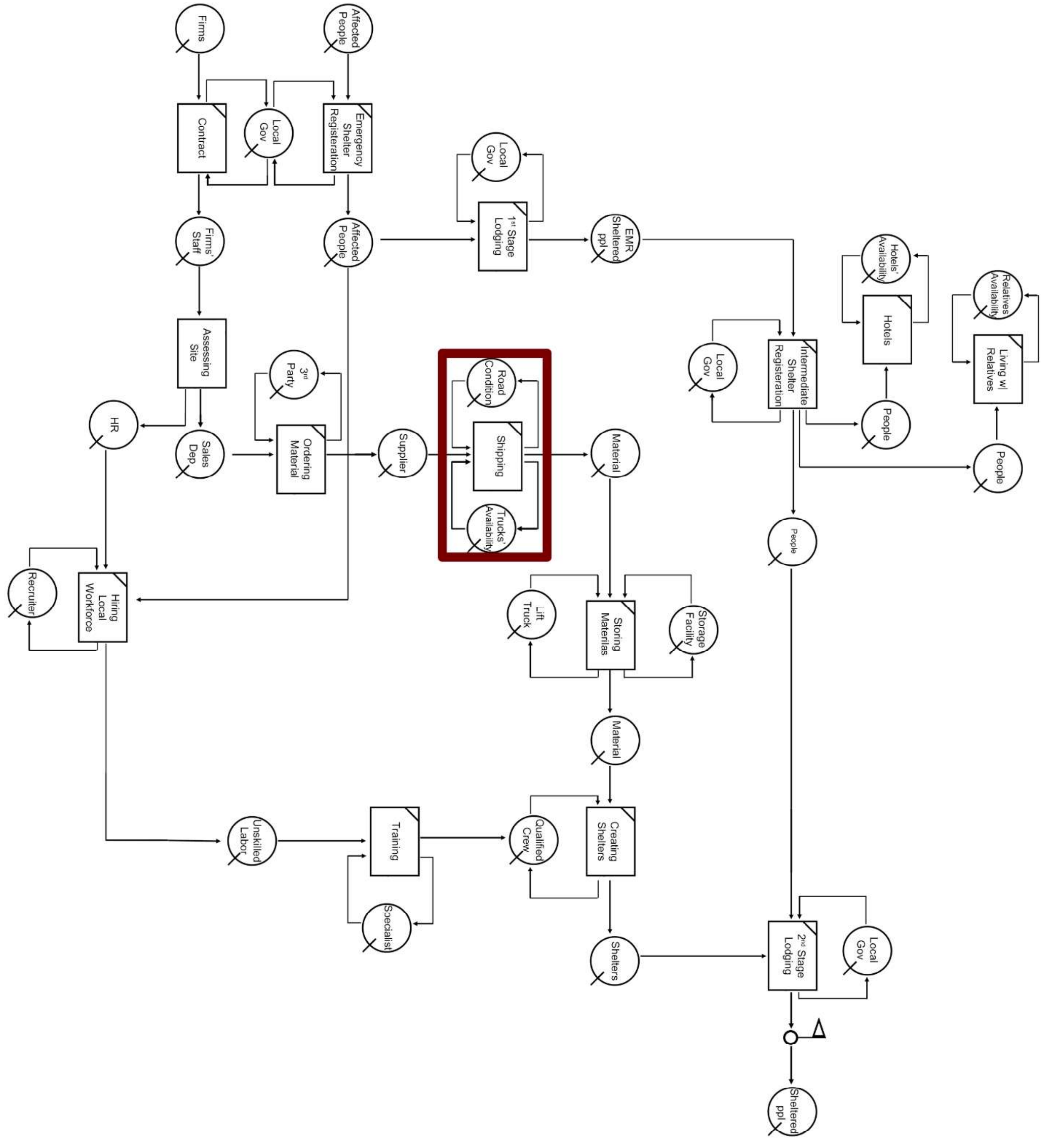
Results & Discussion

Post disaster sheltering contains a broad range of elements which need to be addressed and satisfied. Mapping the process using the CYCLONE modeling technique can result in better understanding the work sequence, and how it can help in decision making. In order to show how a process is simulated by breaking the whole process into smaller tasks, the researchers have created a CYCLONE diagram of the sheltering process (fig 3). This model shows the procedure which the effected people and contractors go through in the process, and it is based on the needs of on-site traditional sheltering where the raw materials are shipped to the site. Using this approach, the stage and level of work which the contractors need to offer their service to the affected people can be visualized. This would help the contractor to better plan the work sequence in advance .Using this model, the user is able to see some of the controlling elements which might not be so obvious without modeling and mapping the process. This would result in smarter decisions which can save time, reduce costs, and deliver high quality finished products.

In fig 3, different tasks and work processes which were mentioned earlier in the work are linked together to form the whole process. In addition to the resource that they are using, each task is bounded by one or more servers, which perform the task. Take the "Shipping "activity (highlighted in fig 3) for example, while the mapping shows all the pre tasks that led to it, it also shows how it is vulnerable to road conditions of the region and the trucks' availability and whether or not they are functioning. In this model, road condition and trucks' availability would act as controlling elements, which can decide the practicality of the shipping process. Knowing this facts and therefore assessing the road condition of the adjacent regions, the manager can decide in the type of sheltering material and construction. It is important to understand that the type and magnitude of controlling elements are not fixed and are changable based on the community characteristics such as density, climate, population, and culture of the region. This approach can help the project manager to find and evaluate the factors which have a decided effect on the project early in the process, and which can result in saving cost and time, while increasing safety and process quality.

Conclusion

The study demonstrates how mapping the post disaster process can lead to creating smarter decisions by the user as it would help them to see all the links and causations between work tasks. In addition, this approach will enable the user to thoroughly investigate any controlling element that can cause restriction to their work procedure. This research focused primarily on indicators which effect the total process of creating temporary shelters in general, this would result in mentioning the tasks and controlling elements in the scale of the total process. However, it is worth noting that each of the work tasks shown in Fig 3 have the capability to be expanded and modeled solely. Future research would address this process where the effect of issues such as location, culture, and climate will be more visible and palpable.



Firms
Affected People
Contract
Local Gov
Emergency Shelter Registeration
Firms' Staff
Affected People
1st Stage Lodging
Local Gov
EMR Sheltered ppl
Assessing Site
HR
Sales Dep
3rd Party
Ordering Material
Supplier
Road Condition
Shipping
Trucks' Availability
Material
Hiring Local Workforce
Recruiter
Lift Truck
Storing Materias
Storage Facility
Material
Unskilled Labor
Training
Specialist
Qualified Crew
Creating Shelters
Shelters
Intermediate Shelter Registeration
Local Gov
Hotels' Availability
Hotels
Relatives Availability
Living w/ Relatives
People
People
People
2nd Stage Lodging
Local Gov
Sheltered ppl

a)

```
NAME POST_DISASTER SHELTERING PROCESS LENGTH 1000 CYCLES 30
NETWORK INPUT
1 QUE 'AFFECTED PEOPLE'
2 QUE 'LOCAL GOV'
3 COMBI 'REGIISTER FOR EMERGENCY SHELTERING' SET 1 PRE 1 2 FOL 2 4
4 QUE 'REGISTERED PEOPLE'
5 COMBI 'EMERGENCY SHELTERING' SET 2 PRE 4 6 FOL 6 7
6 QUE ' FEMA PERSONNEL'
7 QUE ' EMERGENCY SHELTERED PEOPLE'
8 COMBI 'REGISTER FOR SHELTERING' SET 3 PRE 7 9 FOL 9 10 11 16
9 QUE 'LOCAL PERSONNEL'
10 QUE 'PPL STAYING AT HOTELS'
11 QUE 'PPL STAYING WITH RELATIVES'
12 COMBI 'STAYING AT HOTELS' SET 4 PRE 10 13 FOL 13
13 QUE 'HOTELS' STAFF'
14 COMBI 'LIVING WITH HOST FAMILIES' SET 5 PRE 11 15 FOL 15
15 QUE ' HOSTS'
16 QUE 'PPL FOR TEMPORARY SHELTERS'
17 COMBI 'SHELTERING' SET 6 PRE 16 18 41 FOL 18
18 QUE 'PERSONNEL'
19 QUE 'FIRMS'
20 COMBI 'BINDING CONTRACT' SET 7 PRE 2 19 FOL 2 21
21 QUE 'FIRM'S PERSONNEL'
22 NOR 'ASSESSING SITE' SET 8 FOL 23 24
23 QUE 'HR PERSONNEL'
24 QUE 'SALES DEPARTMENT'
25 COMBI 'HIRING LOCAL WORKFORCE' SET 9 PRE 4 23 26 FOL 26 27
26 QUE 'RECRUITER'
27 QUE ' UNSKILLED LABOR'
28 COMBI 'ORDERING MATERIAL' SET 10 PRE 24 29 FOL 29 30
29 QUE '3RD PARTY'
30 QUE 'LOCAL CONTRACTOR'
31 COMBI 'SHIPPING MATERIALS' SET 11 PRE 30 32 33 FOL 32 33 34
32 QUE ' ROAD CONDITION'
33 QUE ' TRUCK AVAILABILITY'
34 QUE 'MATERIALS'
35 COMBI 'STORING MATERIALS'SET 12 PRE 34 36 37 FOL 36 37 38
36 QUE 'STORAGE CAPACITY'
37 QUE '# OF LIFT TRUCKS'
38 QUE 'STORED MATERIALS'
39 COMBI 'CREATING SHELTERS' SET 13 PRE 38 40 FOL 40 41
40 QUE 'QUALIFIED CREW'
41 QUE 'BUILT SHELTERS'
42 COMBI 'TRAINING WORKFORCE' SET 14 PRE 27 43 FOL 40 43
43 QUE 'SPECIALIST'
44 FUN COU FOL 45 QUA 1
45 QUE 'SHELTERED PEOPLE'
```

b)

Fig3: Sheltering Process in Post Disaster Situation CYCLONE model

a) Construction Process Map Diagram b) WEBCYCLONE Code Model

References

1. AbouRizk, S. (2010). Role of simulation in construction engineering and management. Journal of construction engineering and management, 136(10), 1140-1153.
2. Abulnour, A. H. (2014). The post-disaster temporary dwelling: Fundamentals of provision, design and construction. HBRC Journal, 10(1), 10-24.
3. Akhavian, R., & Behzadan, A. H. (2014). Evaluation of queuing systems for knowledge-based simulation of construction processes. Automation in Construction, 47, 37-49.
4. Bendea, H., Boccardo, P., Dequal, S., Giulio Tonolo, F., Marenchino, D., & Piras, M. (2008). Low cost UAV for post-disaster assessment. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 37(B8), 1373-1379.
5. Berkowitz, M. R. (2012). Work Hour Limitations in Disaster Workers. American journal of disaster medicine, 7(3), 189-198.
6. Bilau, A. A., Witt, E., & Lill, I. (2015). A framework for managing post-disaster housing reconstruction. Procedia economics and finance, 21, 313-320
7. Bosher, L., & Dainty, A. (2011). Disaster risk reduction and 'built-in'resilience: towards overarching principles for construction practice. Disasters, 35(1), 1-18.
8. Escamilla, E. Z., & Habert, G. (2015). Global or local construction materials for post-disaster reconstruction? Sustainability assessment of twenty post-disaster shelter designs. Building and Environment, 92, 692-702.
9. Halpin, D. W., & Riggs, L. S. (1992). Planning and analysis of construction operations. John Wiley & Sons.
10. Hidayat, B., & Egbu, C. O. (2010, September). A literature review of the role of project management in post-disaster reconstruction. In Procs 26th Annual ARCOM Conference (pp. 1269-1278). Association of Researchers in Construction Management.
11. Hong, Y. (2017). A study on the condition of temporary housing following disasters: Focus on container housing. Frontiers of Architectural Research, 6(3), 374-383.
12. Huang, R. Y., & Hsieh, B. C. SYSTEM MODELING OF OBJECT-ORIENTED CONSTRUTION PROCESS SIMULATIONS.
13. McIntosh, J. (2013). The implications of post disaster recovery for affordable housing. In Approaches to Disaster Management-Examining the Implications of Hazards, Emergencies and Disasters. InTech.
14. Nath, R., Shannon, H., Kabali, C., & Oremus, M. (2017). Investigating the key indicators for evaluating post-disaster shelter. Disasters, 41(3), 606-627.
15. Platt, S. (2017, June). Factors Affecting the Speed and Quality of Post-Disaster Recovery and Resilience. In International Conference on Earthquake Engineering and Structural Dynamics (pp. 369-403). Springer, Cham.
16. Plyer, A. (2015). Facts for features: Katrina impact. The Data Center
17. Quarantelli, E. L. (1995). Patterns of sheltering and housing in US disasters. Disaster prevention and management: an international journal, 4(3), 43-53
18. Quarantelli, E. L. (1999). The disaster recovery process: What we know and do not know from research.
19. Rapp, R. R. (2011). Disaster recovery project management: Bringing order from chaos. Purdue University Press.
20. Stallings, W. (2000). Queuing analysis. WilliamStallings. com/StudentSupport. html.