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RESEARCH ARTICLE

Exploration of humanitarian construction logistics: Lessons from COVID-19 hospitals in China

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ABSTRACT

This paper examines the role of Humanitarian Construction Logistics (HCL) in the swift construction of COVID-19 hospitals in Wuhan, China. These hospital-construction projects had been achieved professionally in despite of their complexities from an organizational and logistical perspectives such as limited time span, integration of multiple equipment and services, and need to coordinate multiple organizations and stakeholders participating in these projects.

Drawing from observations and data from this emergency construction projects, we identify key lessons learned and discuss their implications for enhancing future disaster response efforts. Our analysis underscores the significance of effective management, prefabricated unit modules, transportation strategies, materials management, timescale management, and project management in streamlining emergency construction processes. By addressing these aspects, we aim to improve the efficiency and effectiveness of humanitarian construction logistics globally, build strategic approach on how to coordinate the logistics flows to and from construction sites in emergency context, and present humanitarian construction logistics as a daily operations issue in humanitarian operations instead of approach in an ad hoc manner.

Keywords: construction logistics; humanitarian logistics; logistics management

1. Introduction

The outbreak of COVID-19 in Wuhan, China, in 2020 resulted in a significant health crisis, prompting the urgent need for additional medical facilities[1]. In response, two temporary hospitals (Leishenshan and Huoshenshan Hospitals) were constructed in record time, along with sixteen Fangcang shelter hospitals for mild cases. Humanitarian Construction Logistics (HCL) played a crucial role in these emergency construction efforts, providing essential infrastructure to combat the pandemic[1-7]. The significant role of Humanitarian Construction Logistics (HCL) presented in managing efficiently the intensive flows of materials and resources which delivered to and removed from the construction sites in a timely manner, and coordinating the efforts of different subprojects, subcontractors, and suppliers and their respective material and resource flows[8-13].

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Despite of complex logistics and construction challenges linked to hospital constructions such as large interdependencies between the involved actors relating to the flow of materials and resources, impacts of timeliness and budget, and dynamic complexity and uncertainty[10]. The rapid construction of these facilities demonstrated the effectiveness of innovative strategy approaches which had implemented within Humanitarian Construction Logistics (HCL).

This paper aims to answer on the following main research questions.

1. What are key aspects of Humanitarian Construction Logistics (HCL) in these study cases?
2. What are Lessons learned from Chinese COVID-19 Hospitals for development of Humanitarian Construction Logistics (HCL)?

2. Literature Review

Construction logistics, which involves managing supply chains throughout a project's lifecycle, has been a vital aspect of the construction industry since the 1980s[8,9,11-13]. Humanitarian Construction Logistics (HCL) focuses on optimizing logistics services for humanitarian purposes, emphasizing health, safety, and environmental considerations. While existing literature on HCL is limited, it highlights the complexities and challenges inherent in humanitarian operations, including higher costs, unpredictable demand, and limited visibility and accountability[10].

Literature review showed that some complexities in HCL should be considered:

a) Relatively higher costs and lower productivity due to temporary and complex nature of the project, as well as complexity of interactions between multiple actors in different sectors[9,10].

b) Poor delivery service during construction process as less than 40% of deliveries are delivered in full (right amount, right time and location, damage-free and right documentation)[14].

c) Turbulence, volatile situations, and time pressure are high in humanitarian operations because of the high stakes involved[10,15-20].

d) Demand is unpredictable and supply patterns are unclear[10,18,21-23].

e) Predicting lead time is complex, and sometimes, the available lead time is extremely short[10,17,18,2426].

f) Visibility and accountability are low in HCL because of a lack of information in general along the supply chains[17,18,20,25,27,28].

g) Performance measurement is a complex issue in humanitarian construction logistics[10,25].

h) Information technologies are inadequate[18,28-30].

i) It is common for existing transportation and distribution networks to be destroyed or unprepared when a natural disaster occurs[18,20,25,31].

j) High employee turnover, lack of skilled logisticians, and unclear career paths making the management of human resources cumbersome[18,20,30,31].

k) HCL suffers from non-recognition in terms of career path[18,30,31]. Many organizations have considered humanitarian construction logistics for a long time as a peripheral support function as logistics has been seen traditionally as a voluntary activity[10].

Despite all above-mentioned complexities, Chinese hospitals projects have received increased attention of experts, academic researchers, and media worldwide[6,32-37]. They changed all concepts by implementing

effective HCL practices. Zuo (2020) summarized the outcomes of these projects, which were emergency specialty field hospitals built in 10 days through some intense project work and coordination across a robust supply chain which overwhelmed the challenges such as acquiring essential volumes of materials, limited onsite storage space, huge transportations, frequent and peak hour deliveries, schedule management, resources management, employee movements, assets movements, infrastructure usage, production mechanisms, installation patterns, logistics capacities, and others[38].

This paper will highlight these outcomes as the success in building these hospitals has been acknowledged. Many countries have adopted a similar approach, like Italy, New Zealand, Germany and Russia, and the United States of America, who have built emergency temporary hospitals under time pressure and resource limitations. But their achievements were less significant than in China[4,39,40]. Therefore, this valuable experience will help other countries in their battle against pandemics and contribute to future disaster preparedness and mitigation[3].

3. Research Methodology

This paper employs a combination of analysis of available literature, non-participant observations and internet-mediated observations to collect data on HCL practices during the construction of COVID-19 hospitals in Wuhan. Non-participant observations involve analyzing publicly available resources such as visual documentaries and news reports, while internet-mediated observations entail collecting data from online sources relevant to the research questions. Thematic analysis is used to interpret the collected data and identify key themes related to HCL.

3.1. Research Limitations

The findings of the online observations highlighted the importance of efficient and effective construction logistics in responding to disasters. The use of modern production logistics and advanced project management techniques enabled the rapid construction of temporary hospitals in Wuhan, which played a crucial role in treating patients and controlling the spread of the virus.

However, the study also highlighted some limitations of the non-participant observer methodology. The reliance on publicly available data sources may have resulted in the omission of important details regarding the construction logistics used in building the hospitals. Future research could employ more direct research methods, such as interviews with construction personnel and site visits, to obtain more reliable data. In addition, the authors felt overwhelmed by the scale and different materials available online and the time to review them. Furthermore, the authors spent significant efforts to check the reliability, dependability, validity, credibility, transferability of data from Internet-mediated observation by keeping a detailed record of sites which were visited and used, double-check all URLs which putted in this paper, as well as, knowing the authors' names and affiliations, the sponsors of the web sites, and the dates of internet resources. Finally, comparison these data in object way.

3.2. Data Analysis

Braun and Clarke (2006) refer to thematic analysis as a foundational method for qualitative analyses. Thematic analysis offers a systematic flexible and accessible approach to analyze qualitative data[41,42]. The essential purpose of this approach is to search for themes, or patterns, that occur across a data set (such as a series of interviews, observations, documents, diaries, or websites being analyzed)[42].

The authors committed to use the thematic analysis as it provides an orderly, logical, and systematically way to analyze large qualitative data sets, like in this case, and it led the authors to focus on parts of large data set (herein the data related to humanitarian construction logistics) rather than seeking to analyze all data in an undiscriminating way.

This paper conducted thematic analysis of collected data from Internet-mediated observation among four phases as follow.

a) Becoming familiar with involved data

Authors navigated through proper critical evaluation of academic literature and secondary data sources such as media reports, archival press and practitioners' statements that are publicly available. The aim was understanding principles of humanitarian construction logistics and draw them in literature review section to form theoretical base for non-participant observations method used by authors. The authors searched, showed, and read numerous materials available via internet such as articles, essays, visual videos, blogs, news, and interviews which chronologically documented the construction practices of Chinese COVID-19 hospitals, their logistics functions, and implementation techniques at the construction sites. At the end, the authors comprehended the large and disparate amounts of qualitative data.

b) Coding data

Once the authors had completed all their reading, they observed online materials and focused straightforward on practices of humanitarian construction logistics in Chinese COVID-19 hospitals in terms of planning, operation, control of materials, employee movements, information flows, delivery, transportation, cost, quality, site management, storage, project scheduling, tasks in parallel, prefabricated units, production mechanisms, field factories nearby construction sites, wise usage of machineries, safety, environmental aspects, acquiring essential volumes of materials, frequent deliveries, resources management, assets movements, infrastructure usage, installation patterns, logistics capacities, and others. All these themes transferred to next phase to select the heading themes.

c) Searching for themes and recognizing relationships

In this phase, the authors started to integrate related data drawn from different transcripts and notes, they classified the collected observations under sub-heading themes such as planning, scheduling, transportation, sites logistics, experts' transfers, natural of materials, leadership, catering, and other. Finally, they identified key themes from a data for further exploration by selection and coding of keywords and quotations pursuant to logistics concepts (e.g. management, transportation, storage, and inventory management) that leaded to develop conceptual themes like effective management, prefabricated unit modules, transportation strategies, materials management, timescale management, and project management.

d) Refining themes and testing propositions

The authors produced a thematic description of these themes in section "Discussion and Lessons Learned". They structured around salient themes that extracted from coding of large-scale observations of online materials. That provided a nuanced understanding of the complexities involved in HCL during of Chinese COVID-19 hospitals' projects. That ends with final conclusions.

4. Discussion

The construction of COVID-19 hospitals in Wuhan highlighted several key aspects of effective HCL:

4.1. Effective Management

The successful implementation of HCL relied heavily on efficient management practices. By granting priority access to vehicles delivering goods and building materials through the establishment of green channels, managers ensured timely delivery of essential supplies to construction sites taking into consideration that hospital projects' supplies often twice in compared to regular housebuilding[10]. Additionally, the pre-assembly of prefabricated building units on trucks' floors optimized space utilization and streamlined the construction

process[38]. Also, the effective management allowed to mobilize many interdisciplinary experts (including managers, leaders, supervisors, designers, manufacturers, electricians, IT technicians, logisticians, and building workers) to work together inside and outside projects sites[36,37]. In addition, effective management encouraged over 7,500 workers to work continuously on the construction site (over 18 hours of work per day) in order to create an effective value chain[36-38,43].

4.2. Prefabricated Unit Modules

This paper confirmed the importance of uniform standards in logistics networks. After COVID-19, experts discussed the creation of prefabricated modular mobile hospitals that could be transported where needed as a modern logistics solution to shorten the lead time of disaster responses[10,44,45]. For example, Huoshenshan Hospital was swiftly built with a site area of 34,000 square meters because of its modular structure, which provided a housing-like form for each unit[5].

The use of prefabricated modular units emerged as a crucial strategy for accelerating construction timelines while maintaining quality standards. These uniform units, produced off-site and transported to the construction sites, offered advantages such as rapid assembly, enhanced quality control, and reduced construction waste. The implementation included different approaches:

a) "Flying factories" approach involved the deployment of mobile production facilities that could be swiftly set up on-site. These facilities produced prefabricated modules, which were then transported to the construction site and assembled. This approach facilitated the rapid construction of the hospitals, as well as improved quality control and waste reduction[46,47].

b) Off-site production of prefabricated modules enabled the rapid construction of the hospitals. These modules were manufactured in factories located away from the construction site and then transported to the site for assembly. This approach allowed for the simultaneous production of multiple modules, ultimately reducing the overall construction time[46,48].

4.3. Transportation Strategies

The rapid transportation of personnel, equipment, and materials to construction sites was essential for meeting tight project deadlines. For example, logistics managers coordinated the transportation services effectively in one day (24th January 2020) for 95 excavators' drivers, 33 bulldozers' drivers, five heavy rollers' drivers, 160 dump trucks' drivers, 160 managers and 7,000 workers[38,49]. In addition, transporting the team (including 60 designers, project engineers, design personnel and hundreds of specialists) within 1 hour to work together to complete the designs and construction drawings within 24 hours[38].

Furthermore, innovative transportation strategies, such as utilizing trucks as temporary storage facilities near construction sites which enabled efficient materials management and minimized logistical bottlenecks. The orderly arrangement of trucks outside construction sites demonstrated a coordinated approach to transportation for ensuring smooth operations despite logistical challenges[38].

4.4. Materials Management

Effective materials handling and storage played a crucial role in maintaining construction site safety and productivity. Despite numerous constraints, humanitarian construction logistics contributed to finish the Chinese hospitals' constructions on time by properly managing materials, tools, and equipment, which were considered complex tasks[50]. Proper materials management contributed to overall project efficiency and resource optimization[10] by adhering to best practices in materials management, including minimizing unnecessary handling and damage, construction sites remained clean, organized, and conducive to efficient operations[49,51]. HCL illustrated effective materials management during both planning and execution phases

by handling the high volume of resources considering the tight spaces on the construction sites. Furthermore, projects' leaders had formed a few emergency teams responsible for building seepage prevention and installing sewage and wastewater treatment equipment. They aimed to reach to high level of materials management[38].

4.5. Timescale Management

The importance of scheduling within humanitarian construction logistics is beyond question as the stakes in the humanitarian sector are high, and a well-planned schedule is crucial to achieve humanitarian goals[20].

Scheduling and coordinating construction activities were paramount to achieve project objectives within limited timeframes[10]. The parallel scheduling of activities, such as ground levelling and foundation installation, allowed to overlap tasks and accelerated project timelines. Detailed scheduling from the onset of the projects facilitated efficient resource allocation and mitigated potential delays, underscoring the importance of proactive timescale management in HCL[18,20,31].

4.6. Project Management

Advanced project management techniques were instrumental in optimizing construction processes and reducing overall project durations. By overlapping design and construction phases and mobilizing resources from multiple locations, project managers maximized efficiency and productivity. The integration of expertise teams to expedite design processes and coordinate material transfers exemplified the proactive approach to project management adopted in these emergency construction projects[38,49].

This advanced project management can be understood as managing the interrelation of physical resources, human resources, processes, and knowledge to create a combination of resources that will support competence of humanitarian construction logistics[48]. This advanced management overcame complicated set of challenges related to HCL, such as unpredictable demand (in terms of timing, location, type, and size) for different supplies with short lead times in context of lack of resources[10,25,52].

This advanced project management can transform humanitarian construction logistics to adapt with new, strengthened, and time-critical logistics systems instead of traditional construction logistics focusing on delivering raw materials to sites[10,48]. Furthermore, the project management focused on quality associated with speed, robustness, and integration in context of HCL by established special support groups for procuring services, supply chain, and research, as well as, assigning safety managers to each site to make them safer[49].

5. Lessons Learned

These study cases have provided insights and lessons learned. They appeared that the effective management of HCL decreased uncertainty of getting hold of necessary resources and increased the level of organizational and coordination. HCL can be enabled by employing a modular product architecture that utilizes prefabricated components, which leads to reduce the need for on-site inventory space.

Furthermore, the effective planning for transportation and materials management could be solutions for dynamic complexity and uncertainty associated with complex humanitarian-purposes constructions in emergency context.

Finally, the effective project management minimize negative impacts of HCL by taking a more strategic approach on how to coordinate the logistics flows to and from construction sites in efficient way, leveraging HCL from ad hoc cases to view as a daily activity in humanitarian and emergency operations, and enabling HCL by well-organize timescale management; by experience practitioners; which support different organizations to participate affectively at different times throughout the project's durations.

6. Conclusion

The experiences of HCL in COVID-19 hospital construction projects in Wuhan offer valuable insights for enhancing future disaster response efforts. The provided insights and lessons learned from these cases could be transferable and aspects identified here are a good step in the right direction of understanding what to consider when organizing HCL for complex humanitarian-purposes projects.

This paper shows that HCL has been converted from voluntary activity to organized activity in humanitarian-purposes projects which allows to different stakeholders to participate efficiently in terms limited time span, integration of multiple equipment and services, and need to intensive flow of materials and resources.

By emphasizing effective management practices, leveraging prefabricated solutions, optimizing transportation strategies, and prioritizing timescale and project management, stakeholders (e.g. humanitarian organizations, and construction and logistics practitioners) can improve the efficiency and effectiveness of humanitarian construction logistics in emergency situations.

Future research could build on these findings to further explore the potential of innovative HCL in disaster response efforts, and leveraging HCL as coordination tool of shared resources which should be dealt with as a strategic issue to reach potential benefits.

This paper recommends to future research to study HCL limitations such as large interdependencies between the actors involved, intensive deliveries compared to regular housebuilding, and dependency on materials and resources being delivered to and removed from the construction sites in a timely manner.

Conflict of interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report.

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