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TECHNICAL PAPER

Shortage of Healthcare Facilities during COVID-19 Pandemic Outbreak

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ABSTRACT

PURPOSE: This paper aims to examine the influence of pandemics on the construction industry and explores different structural systems that could be adopted to facilitate fast construction during pandemic.

DESIGN/METHODOLOGY/APPROACH: The design of the paper follows an introductory section including a literature review of the difficulties related to shortage of healthcare facilities during pandemics and the different possible structural systems that can be adopted. The methodology was listed considering the various possible structural systems. Parameters affecting choices are laid considering economic factors and time limitations.

FINDINGS: The COVID-19 pandemic revealed many vulnerabilities in healthcare systems, including a lack of suitable facilities to accommodate the increased surge in patients. Having a system to decide an accommodation plan for such eventualities is needed; it should understand the pros and cons of each structural system that could be adopted for new healthcare facilities.

ORIGINALITY/VALUE OF THE PAPER: The paper's originality stems from considering an humanitarian issue from a practical point of view, considering implications on the construction industry. The research discusses the suitable structural systems while considering accommodating medical requirements in healthcare facilities.

PRACTICAL IMPLICATIONS: The paper paves the way for a comprehensive decision support system that can help in choosing the optimum structural system for a new healthcare facility based on a limited budget and time constrictions.

KEYWORDS: *Fast construction; Pandemic; Healthcare; emergency preparedness*

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INTRODUCTION

The first coronavirus wave caused many healthcare facilities to be overwhelmed with patients. Due to the high number of cases, many patients were unable to get immediate medical attention. Hospitals in Italy were flooded with cases in a short period due to the rapid spread of the pandemic (Fraser and Wynn, 2020). In South Korea, for instance, the shortage of hospital beds led to the deaths of patients (Kuhn, 2020). Many countries responded by conveying additional funds to support healthcare facilities during the pandemic. Alternative care facilities were widely adopted in other countries (Kaye *et al*., 2021). Since Roman times, many countries have constructed new hospitals using prefabrication and off-site construction techniques to accommodate increasing demand (Adebayo *et al*., 2006). Recently, these techniques, used together with additional resources, were adopted to build a temporary hospital of 2,000 bed-capacity in 10 days, Leishenshan Hospital, China (Cheng *et al*., 2020). Many factors affect the design of healthcare facilities to ensure their suitability for hosting pandemic patients. In certain circumstances, therefore, it is necessary to find potential alternative structural systems to cope with increased need for fast construction.

The construction and design of new healthcare facilities necessitates the co-operation of several engineering and medical disciplines. The process includes analysis of design possibilities in time-consuming and costly steps. Different structural systems could be adopted considering construction materials, detailing, fabrication, and construction procedures. The selection of the optimum structural system is not a direct matter, and, in addition to several sustainability and environmental constraints, many factors have to be considered, including availability of resources, functionality of the building and number of floors (Balali *et al*., 2010; Dreher, 2014). The total cost of the project is heavily affected by the selected structural system and the construction time resulting from that decision (Balali *et al*., 2014a; Arora, 2004).

Reaching the optimum system with the least possible cost is the main aim of any design team; however, requirements related to environmental impact, aesthetics, operational needs, and construction speed pose a governing factor in many cases. Structural engineering design of complex systems requires data collection and processing in large number of calculations to reach a level of reliability in the safety of the design. The revolution in computer technology and numerical computation methods allows complex calculations towards optimised solutions. Many researchers have investigated different structural alternatives to propose procedures for reaching the optimum solution. For instance, Gasser and Schuëller (1997) applied a reliability-based optimisation technique to choose structural systems based on total costs. Günaydın and Doğan (2004) investigated use of neural networks to estimate costs of buildings at early phases of design. Juhua *et al*. (2011) considered both cultural conditions and building construction techniques to propose a decision-making model based on an analytic hierarchy process method. Balali *et al*. (2014b) recommended a multi-criteria decision-making technique to select the best structural system for low-rise multi-housing projects. Turskis *et al*. (2019) employed a multi-criteria assessment method to select suitable structural solutions for a one-storey building.

Despite existing research efforts, there is a lack of effort addressing optimum structural systems that would allow fast construction of healthcare facilities in response to pandemic outbreaks (Saad and Hassan, 2022). The aim of this research, therefore, is to investigate the different factors affecting the structural design of healthcare facilities while considering building shape, available construction materials, associated cost, and construction method. This aims to provide guidelines for fast construction of healthcare facilities as a counter-measure for the increase in the number of patients in case of pandemics. The suitability of the structural system is determined based on least cost while considering time constraints in such situations.

Methodology

The paper first explores an optimum structural system that satisfies the requirements of fast construction in a timely and cost-effective manner, and sustainable performance over time. An investigation of the potential structural systems and advanced construction methods is carried out, considering construction materials, fabrication and construction procedures, and sustainability. A discussion of structural impact and life cycle cost analysis is conducted for the selected candidate structural system to develop recommendations for the most effective system.

Table 1 lists common structural systems and materials together with associated advantages and disadvantages. Conventional reinforced concrete (RC) skeletons and steel frames are the most common structural systems in many regions, especially in the Middle East. Generally, RC systems have many advantages, for example the low associated costs during construction and operation phases in addition to excellent performance in acoustic and thermal insulation. However, RC buildings require longer construction time in addition to possessing low strength-to-weight ratio. Steel structures are usually faster to construct but impose higher construction and operation costs. Composite steel-concrete construction provides an alternative that combines the advantages of both steel and concrete; however, it is complex to design and construct, leading to longer construction periods.

Prefabricated modular units offer many merits that would help to accelerate construction of hospital beds and have become increasingly popular in the past decade due to their perceived cost and time-saving benefits (Gbadamosi *et al*., 2020; Witcher, 2020). Prefabricated modular units are typically constructed off-site, delivered directly to the construction site, and then assembled quickly. This approach facilitates rapid construction and shorter project timelines, making it a very desirable option for construction professionals. Prefabrication also promotes efficiency in the construction process due to its design-build capabilities, allowing projects to be designed and built simultaneously. However, there are some drawbacks that make them less suitable for certain projects. These drawbacks include their limited flexibility, lack of customisation options, and increased cost. Additionally, it can be difficult to find contractors who specialise in this type of construction, making it harder to find reputable professionals who can guarantee quality work. The labour costs required for assembly are often greater than traditional construction methods, so project budgets can also be affected. Kelly (2020) reported use of modular construction by the Darwin Group in Cardiff in the UK to deliver a new £33m COVID-19 hospital building to ensure capacity for patients in the event of a second spike in serious coronavirus cases.

Table 1: Advantages and Disadvantages of Structural Systems for New Build Healthcare Facilities

Competing Structural Systems	Construction Method	Advantages	Disadvantages
Conventional RC Skeleton	Cast in situ	Common, low cost, fire resistance, acoustic and thermal insulation, high capacity, low maintenance	Heavy, long construction time
Steel Moment Resisting or Braced Frame	Assembly on site	Common, short construction time, sustainable material, robustness, and ductility	Costly, low fire resistance
Modular Light Steel Building	Segmental Construction	Lightweight, short construction time, sustainable material, robustness, and ductility	Costly, low fire resistance, shape constraints. Only for low-rise buildings
Steel Container Modules	Segmental Construction	Recycled shipping containers, easy transport	Additional reinforcing needed to strengthen container when openings are cut in walls
Precast Concrete	Precast Segmental Construction	Fire resistance, acoustic and thermal insulation, high capacity	Costly, heavy, potential cracking at corners
Composite steel-concrete skeleton	Assembly on Site + Cast in situ	Fire resistance, acoustic and thermal insulation, high capacity	Heavy, long construction time, complex design and construction

Source: Saad and Hassan 2022

Figure 1 illustrates the sequential steps that help select the optimum structural facility, allowing fast construction of healthcare facilities in response to pandemics. First, several possible construction sites for a selected zone are investigated. A potential site is selected based on a set of criteria including ease of construction, distance from city centre, available nearby facilities, geotechnical conditions in the area. For the selected site, a preliminary architectural design will be assumed following local standards, medical requirements and common practice for public healthcare facilities (e.g., an average of 100 beds in hospitals). A comparative analysis is conducted to compare between the potential structural systems presented in Table 1. Structural design is performed for each candidate, to size the different members within the building skeleton. Afterwards, the cost and duration of construction are estimated. Costs associated with the initial investigation of site, design, permits and approvals, site preparation, and foundations are common among all possible potential structural alternatives. Therefore, analysis usually only considers the costs that vary with the structural alternative being considered (e.g., material procurement, equipment and labour utilisation, and construction method).

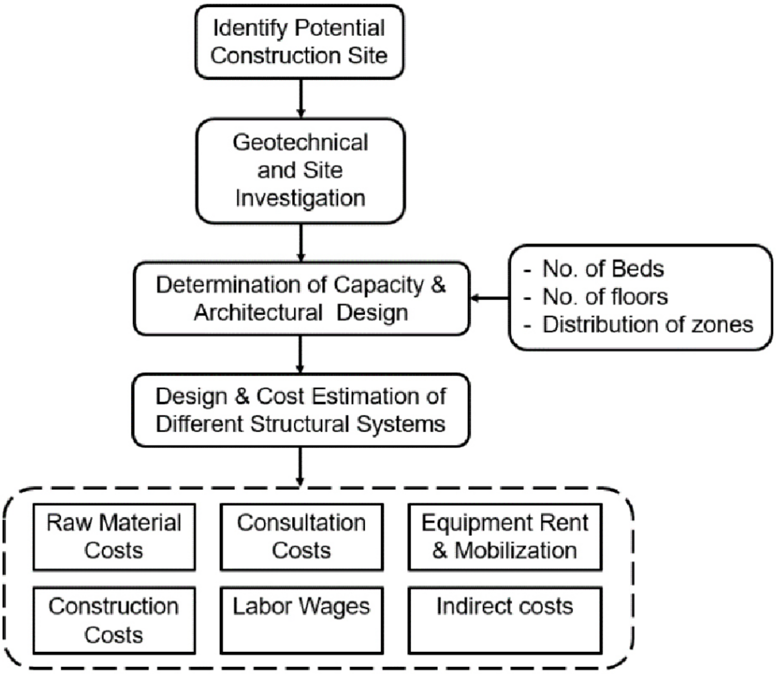

Figure 1: Procedure for Selection of Optimum Structural System
Source: Saad and Hassan 2022

Estimation of Construction Time and Cost

Models for accurately predicting time and cost of construction projects have been investigated by several researchers (Skitmore and Ng, 2003; Love *et al*., 2005; Hoffman *et al*., 2007; Czarnigowska and Sobotka, 2013). Construction cost and time can be estimated based on available budget and related time constraints, or using a detailed analysis of work packages while considering available resources. This usually depends on the experience and judgement of the estimator (Alfeld, 1988). Bromilow's time-cost (BTC) model offers reasonable estimates of time needed for construction projects (Bromilow, 1969). Many studies were carried out to enhance the accuracy of the BTC model (Skitmore and Ng, 2003; Ireland, 1985). Construction time and cost is usually related to building characteristics, contractor selection method, level of trained labour, and contractual arrangements. However, there is no clear relationship between decisions taken regarding structural systems at the preliminary design stages and the incurred costs. The cost and time associated with conceptualisation, approval, and contracting is not considered in the current study. It is assumed that these new facilities are governmental, therefore, permits and approvals will take the least time. Foundation works are also excluded. For low-rise buildings, the difference in foundation works is minor, leading to similar associated costs and construction time. Construction and material costs are estimated based on building price index (BPI) in the price book (Langdon, 2020) in addition to locally collected data for average rates.

CONCLUSIONS

The COVID-19 pandemic affected many economic and humanitarian aspects in both positive and negative ways, especially in labour-intensive industries such as the construction industry. The spread of the pandemic disrupted contractors' plans and deliveries of goods and materials. Manufacturing and production facilities were impacted by internal workforce and facility management challenges caused by the pandemic. The current research aims to bridge the research gap related to required fast construction during pandemic outbreaks. The major goal is to provide clear guidelines for choosing the best structural system that can be used to build a permanent healthcare facility in the shortest amount of time possible while staying within a strict budget.

REFERENCES

Adebayo, A.K., Price, A. and Gibb, A. (2006): *Impact of modern methods of construction on healthcare infrastructure*. Loughborough University, Conference contribution. Available at: https://hdl.handle.net/2134/19921.

Alfeld, L.E. (1988): *Construction productivity: On-site measurement and management*. McGraw-Hill, US.

Arora, J. (2004): *Introduction to optimum design*. Elsevier, California, USA: London, UK.

Balali, V., Mottaghi, A., Shoghli, O. and Golabchi, M. (2014a): Selection of appropriate material, construction technique, and structural system of bridges by use of multicriteria decision-making method. *Transportation Research Record*, Vol. 2431, No. 1, pp.79-87.

Balali, V., Zahraie, B. and Roozbahani, A. (2014b): A comparison of AHP and PROMETHEE family decision making methods for selection of building structural system. *American Journal of Civil Engineering and Architecture*, Vol. 2, No. 5, pp.149-159.

Balali, V., Zahraie, B., Hosseini, A. and Roozbahani, A. (2010): Selecting appropriate structural system: Application of PROMETHEE decision making method. In *2010 Second International Conference on Engineering System Management and Applications* (pp.1-6), IEEE, 30 March 2010.

Bromilow, F.J. (1969): Contract time performance expectations and the reality. *Building Forum*, Vol. 1, No. 3, pp.70-80.

Cheng, W., Zhang, F., Hua, Y., Yang, Z. and Liu, J. (2020): Development of a psychological first-aid model in inpatients with COVID-19 in Wuhan, China. *General Psychiatry*, Vol. 33, No. 3, p.e100292. DOI: https://doi.org/10.1136/gpsych-2020-100292.

Czarnigowska, A. and Sobotka, A. (2013): Time-cost relationship for predicting construction duration. *Archives of Civil and Mechanical Engineering*, Vol. 13, pp.518-526.

Dreher, P.E. (2014): Structural Systems and Design Considerations for Low-Rise Generational Specific Housing Buildings. Proceedings of *2nd Residential Building Design & Construction Conference*, 19-20 February, Penn State, University Park.

Fraser, J. and Wynn, M. (2020): US hospitals will run out of beds if coronavirus cases spike, USA TODAY, 13 March 2020. Available at: https://www.usatoday.com/in-depth/news/investigations/2020/03/13/us-hospitals-overwhlemed-coronavirus-cases-result-in-too-few-beds/5002942002/.

Gasser, M. and Schuëller, G.I. (1997): Reliability-based optimization of structural systems. *Mathematical Methods of Operations Research*, Vol. 46, No. 3, pp.287-307.

Gbadamosi, A.Q., Oyedele, L., Olawale, O. and Abioye, S. (2020): Offsite Construction for Emergencies: A focus on Isolation Space Creation (ISC) measures for the COVID-19 pandemic. *Progress in Disaster Science*, Vol. 8, p.100130. Available at: DOI: https://doi.org/10.1016/j.pdisas.2020.100130.

Günaydın, H.M. and Doğan, S.Z. (2004): A neural network approach for early cost estimation of structural systems of buildings. *International Journal of Project Management*, Vol. 22, No. 7, pp.595-602.

Hoffman, G.J., Thal Jr, A.E., Webb, T.S. and Weir, J.D. (2007): Estimating performance time for construction projects. *Journal of Management in Engineering*, Vol. 23, No. 4, pp.193-199.

Ireland, V. (1985): The role of managerial actions in the cost, time and quality performance of high-rise commercial building projects. *Construction Management and Economics*, Vol. 3, No. 1, pp.59-87.

Juhua, L., Lishou, T. and Lei, Y. (2011): Application of AHP Method in Building Construction and Cultural Combined-By Human Living Environment Construction of PengAn as the Background. Proceedings of *International Conference on Management and Service Science*. Available at: DOI: https://doi.org/10.1109/ICMSS.2011.5998157.

Kaye, A.D., Okeagu, C.N., Pham, A.D., Silva, R.A., Hurley, J.J., Arron, B.L., Sarfraz, N., Lee, H.N., Ghali, G.E., Gamble, J.W. and Liu, H. (2021): Economic impact of COVID-19 pandemic on healthcare facilities and systems: International perspectives. *Best Practice & Research Clinical Anaesthesiology*, Vol. 35, No. 3, pp.293-306.

Kelly, M. (2020): Modular firm to deliver £33m COVID-19 facility. *Construction News* (CN), Available at: https://www.constructionnews.co.uk/buildings/modular-firm-to-deliver-33m-covid-19-facility-05-10-2020/.

Kuhn, A. (2020): How a South Korean city is changing tactics to tamp down its COVID-19 surge. NPR. Available at: https://www.npr.org/sections/goatsandsoda/2020/03/10/812865169/how-a-south-korean-city-is-changing-tactics-to-tamp-down-its-covid-19-surge.

Langdon, D. (2020): *Middle East Construction Costs Handbook*. CRC Press, Florida, US.

Love, P.E., Tse, R.Y. and Edwards, D.J. (2005): Time–cost relationships in Australian building construction projects. *Journal of Construction Engineering and Management*, Vol. 131, No. 2, pp.187-194.

Saad, D.A. and Hassan, M.M. (2022): Decision Support System for Fast Provision of Healthcare Facilities in Response to COVID-19 Pandemic Outbreak. In Proceedings of the *Canadian Society of Civil Engineering Annual Conference 2021* (pp.459-471), 30 May 2021. Singapore: Springer Nature Singapore.

Skitmore, R.M. and Ng, S.T. (2003): Forecast models for actual construction time and cost. *Building and Environment*, Vol. 38, No. 8, pp.1075-1083.

Turskis, Z., Urbonas, K. and Daniūnas, A. (2019): A hybrid fuzzy group multi-criteria assessment of structural solutions of the symmetric frame alternatives. *Symmetry*, Vol. 11, No. 2, p.261.

Witcher, T.R. (2020): Hotels and Hospitals: Designers Create More Health-Care Spaces. ASCE News, Available at: https://news.asce.org/hotels-and-hospitals-designers-create-more-health-care-spaces/.

BIOGRAPHY

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