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BIM for Fast-track Construction under COVID-19 Circumstances: A Comparative Case Study in the African Context

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Under COVID-19 circumstances, the majority of Architecture, Engineering, and Construction (AEC) contractors around the world found themselves handcuffed, facing the sudden restrictive measures to be mandatorily applied in worksites imposing a necessary shift in the typical practices for building. Building Information Modeling (BIM) technologies associated with fast-track construction were found to be an efficient solution for several countries to quickly build health care facilities to meet the rising number of COVID-19 cases. Based on a comparative study, this paper explores the applicability of BIM-based building operation for fast-track construction in the African context and discusses the associated challenges as well as needed elements for its implementation. The study reveals that to reach the full performances of BIM, the African AEC industry has to mainly handle the aspects related to skills, bidding, payment, infrastructure, and availability of local construction materials and technologies.
Key Words: Building Information Modeling, modular, prefabrication, Africa, Leishenshan hospital

Introduction and Context

The restrictive measures imposed against COVID-19 namely distancing, gathering avoidance, and wearing masks with constant hands sanitization carried several industries and economic sectors to firstly slow down or stop their activities, then readapt or shift their practices, strategies, or business models. Consequently, almost all economic sectors were heavily impacted, mainly those based on labor such as Architecture, Engineering, and Construction (AEC) industry. For instance, the African AEC industry experienced a 51% loss of sales value compared to 2019 (Arezki et al., 2021) and the construction backlog indicator decreased by 20.2% in the USA (Jeon et al., 2022). However, the pandemic circumstances have emphasized the automation and remote abilities provided by Building Information Modeling (BIM) at all stages of construction chain value (Meisels, 2020). Digital practices are becoming the essential key to future success in the AEC industry. Deloitte report (Meisels, 2020) revealed that 76% of AEC executives are likely to invest in at least one digital technology in 2021 and emphasized that BIM tops the list of digital initiatives allowing AEC companies to be differentiated. Indeed, BIM helped to keep the AEC field in activity (F. Lin & Howell-Jones, 2020) and enabled several contractors to effectively manage fast-track construction for the required health facilities to handle the sudden increasing number of people affected by the COVID-19 pandemic (Yang et al., 2020; Zhou et al., 2021).

This study aims to enlighten researchers and decision-makers on the strength of BIM-based building operation for fast-track construction in challenging conditions due to human aspects (distancing, contamination…etc.), explore its applicability in the African context, and identify the challenges as well as needed elements for its implementation. Thus, this paper could be a start point to develop further studies helping to create innovative approaches, strategies, or technological tools related to BIM-based fast-track construction. For this purpose, a comparative study between an already realized project in a BIM-expert environment and its analogy in the African context will be conducted. Case study 1 consists of Leishenshan hospital, in China, as a reference, and case study 2 is an analogic project to be built in the African context for which the focus group set a similar building environment in terms of climatic conditions and location features.

Literature Review

BIM Benefits to Overcome COVID-19 Impacts:

The COVID-19 crisis forced the AEC industry to migrate toward smart technologies headed by BIM, leading then to safer construction, smarter planning and design, faster and more predictable timelines, and more sustainable buildings (F. Lin & Howell-Jones, 2020). BIM market rose by 9.8% in 2020 compared to 2019 to reach US$5.71 billion and it is expected to grow to US$11.96 billion by 2027 at a compound annual growth rate of 11.1% (Fortune Business Insights, 2021). Actually, in 2020, remote practices and BIM gained wider spread among designers (architects and engineers) and contractors upheld by the additional and larger support provided by suppliers of digital AEC technologies to help AEC operators to accelerate digital transformation (Meisels, 2020).

BIM is an innovative technology allows the different stakeholders of a project to work simultaneously on a same 3D digital model. It enables real-time design modification, progress tracking, and visualization (Schimanski et al., 2021). Wang et al. (2021) showed that implementing a BIM-led coordination strategy can break through the economic dilemma of the AEC industry caused by the pandemic as it enables participants to coordinate and communicate on a unified information platform helping to effectively address problems and guarantee adequate supervision. Through its digital and automation features, BIM allowed working remotely, inclusively and collaboratively (C.-L. Lin et al., 2021) and demonstrated a big ability to share information among building participants, improve quality and optimize time and costs (Yang et al., 2020). Specifically, it helped to anticipate the contamination risks and build the facilities accordingly, manage the overlapped tasks planning and logistics, previously assess and prepare the needed resources for the project, and closely supervise and check the construction progress on a real-time basis (Yang et al., 2020; Zhou et al., 2021). Besides, it helped to automate area disinfection. Where, based on the already-stored information in the BIM model, a multidisciplinary team of researchers was able to develop specialized service robots capable of disinfecting potentially contaminated surfaces and automating the transport of essential items (Şahan, 2021, p. 19).

Fast-Track Construction

Fast-Track construction aims generally to accomplish a project in a shorter time than normal by applying diverse and innovative methods enabling in-parallel/overlapping on project completion (Lalu et al., 2019). The main principle of the Fast-Track method is well-founded and detailed early planning; Otherwise, it could result in significant delays and re-working (Lalu et al., 2019). Prefabrication and modular design are the most used technologies for fast-track construction. A recent report of Dodge Data & Analytics (Jones et al., 2020) affirmed that using BIM increases the schedule performance from 22% to 61% for prefabrication companies and from 21% to 46% for modular construction companies and showed that 82% of healthcare facilities are expected to use prefabrication and modular construction by 2023 among the surveyed companies.

Indeed, facing the significant spread of the COVID-19 pandemic in 2020, many countries associated prefabrication and modular technology with digital practices to accomplish the needed health facilities in a record time. For instance, in China, Huoshensham hospital was built in Wuhan on an area of 34000 m² in no more than 10 days (Zhou et al., 2021) and Leishenshan hospital was constructed in Jiangxia District, Wuhan in almost 12 days on a field of 21.87 ha with a building area of 79,900 m² (Chen et al., 2021). Similarly, in England, NHS Nightingale Hospital Birmingham was spanning the equivalent of 11 soccer fields and realized in only 4 weeks (Alderton, 2021). Likewise, in Mexico, the six CEMEX Hospitals were installed in 15 days (Alderton, 2021).

Research Design and Methodology

This study uses a 5-step process: First, based on the literature review, Leishenshan hospital was benchmarked as a reference (base) case study for BIM-based fast-track construction built during the restrictive measures related to COVID-19 as it has more available descriptive data. Then, the authors composed a focus group including experts that are knowledgeable of BIM technology and the African construction market. The focus group was composed of an Architect, two contractors, a civil engineer, and a BIM manager. Next, referring to the collected data related to shortlisted project, similar location features were defined for Case Study 2, and then its BIM model was built collaboratively with African engineering firms. Based on feedbacks of the focus group, the construction planning related to each case study was developed, the comparison was discussed, and inferences were drawn.

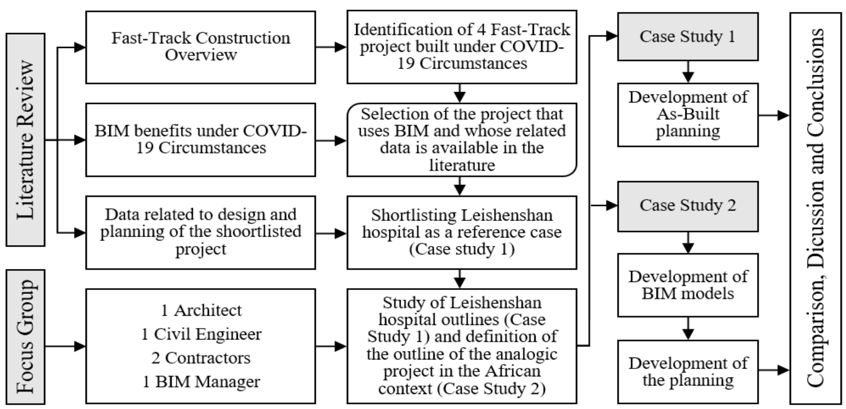

Figure 1. Methodology workflow

The literature review was conducted using Web-of-Science, Google, and Google Scholar based on three groups of keywords: (Fast-Track construction And BIM), (Fast-Track construction And COVID), and (COVID And BIM). As shown in Figure 1, four fast-track projects built under COVID-19 circumstances were identified in the literature. Among those using BIM, the Leishenshan hospital has the most available data related to planning and design. Hence, it was chosen as a reference case study (Case study 1). For comparative study, the focus group discussed building operation time, workforce qualification, needed materials and equipment, and administrative processes.

CASE STUDY 1: Leishenshan hospital, Wuhan-China

Project Outline

Wuhan Leishenshan hospital covers three main areas: 52,000m² for therapeutic isolation (1,600 beds), 9,000m² for accommodation, and 18,000m² for staff living and general logistics. Yet, for the case study, the authors will focus on the two buildings of medical area that, beside the incoming call bloc and mechanical technique Intensive Care Unit (ICU) bloc, contains almost 60,000m² for medical treatment rooms with 1,600 beds (Chen et al., 2021; Luo et al., 2020). The project was assigned to Central-south Architectural Design Institute (CSADI) as responsible for design and follow-up, and China Construction Third Engineering Bureau (CCTEB) Co., Ltd. as turnkey contractor (Luo et al., 2020). It was built based on repetitive modular prefabricated in manufactories and then assembled onsite. In order to respect the required timeline, BIM was used to design, plan and oversee the project (Chen et al., 2021).

The medical treatment area was arranged in repetitive lines of rooms. Each of them was structured in three zones, clean, semi-contaminated and contaminated zone, and two passages, one for medical staff and the other for patients. This area consists of 3,000 container-type prefabricated units.

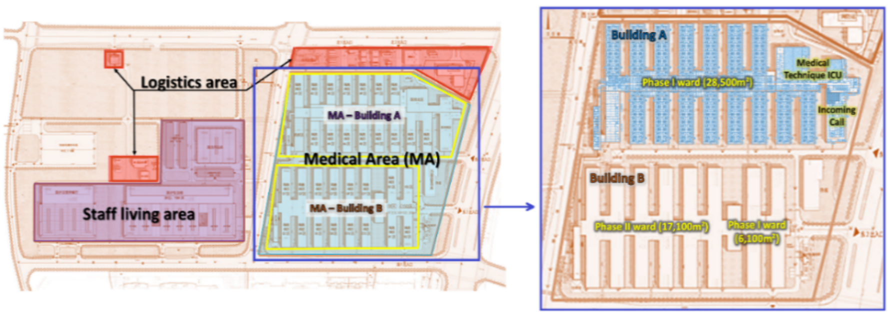

Figure 2. Master plan of Wuhan Leishenshan hospital and medical area (Chen et al., 2021; Luo et al., 2020)

Development of As-Built Planning of The Leishenshan Hospital

The project was built in lockdown period between 26 Jan. and 5 Feb. of 2020 (Chen et al., 2021) by about 1,025 building supervisors and 7,906 construction workers in nonstop 3-shift turn, and used almost 1,491 pieces of excavators, cranes, and other machinery and equipment (Luo et al., 2020). Based on the data collected from the literature (CGTN, 2020a, 2020b; Chen et al., 2021; CSCEC Pakistan, 2020; Luo et al., 2020). The as-built planning of the Leishenshan hospital construction was built during the focus group workshops as shown in figure 3.

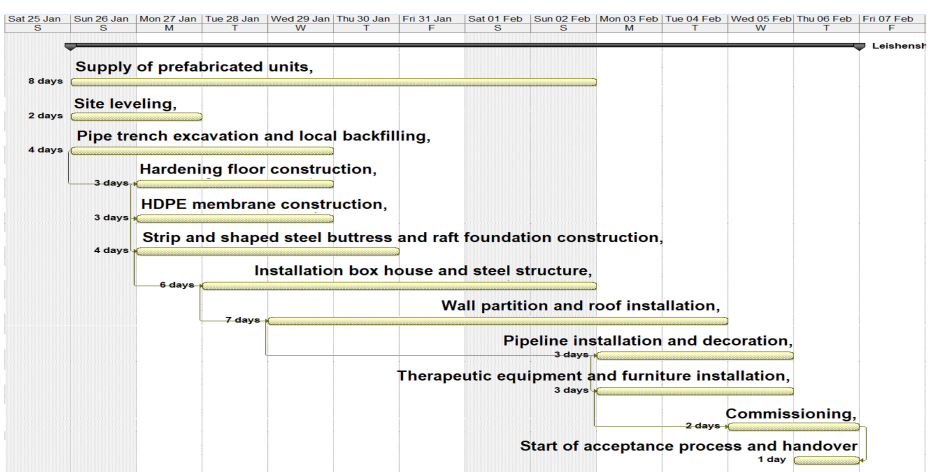

Figure 3. As-built schedule of Leishenshan hospital construction

CASE STUDY 2: Analogic Project in the African Context

Project Outline and Local Context

To well-define the features of the analogic project, firstly the experts participating in the focus group listed and analyzed the collected data about the benchmarked project "Leishenshan hospital" taken as a reference. Secondly, they defined a similar environment where it could be constructed. Therefore, a similar field in Casablanca – Morocco has been designated. In the same vein, since the construction of Leishenshan hospital started 3 days after the beginning of the lockdown, the start date of the analogic project construction was considered on 23 March 2020 (3 days after the beginning of the lockdown in Morocco). Likewise, to define the most optimistic scenario for BIM-based fast-track construction in the African context, the authors held workshops with the focus group. They revealed that the project planning should take into consideration the following constraints related to the local context:

- Since the project owner would be the public authority responsible for health, the project has to respect the conventional procedures imposed by public administrations leading then to long validation process, bureaucracy, important payment delays and so on,
- The construction workforce is mostly not accustomed to using technologies. Generally, only the supervisors could be graduated people, while the production laborers are mostly either handymen that learned by doing or temporary workers which makes investing in their training difficult. Moreover, the Moroccan construction workforce is commonly used to take 3 annual leaves of 2 or 3 weeks each (Aid el Fitr, Aid El Adha, and Aid El Mawlid),
- The majority of required equipment for the project is not produced locally and needs to be imported from industrial countries. Therefore, the planning should take into account the needed time for importation and the related administrative procedures,
- The local market is not used to that kind of fast-track project and needs to practice and validate the first sample as a reference before getting faster. This step should be considered in the planning including the validation process,
- Considering the long payment delays and the necessity of making an upstream payment of the imported equipment including panels, the expenses must be relatively balanced to the revenues with a tolerable margin, which will dependently affect the construction progress.

Development of BIM Models

Based on the plans of building A and the master plan of the medical area (Figure 2), the authors, in collaboration with the local firms, have simulated the remaining building B of the medical area of the hospital and then developed the BIM model as follows:

- Drawing the 2D plans of both building A and B using Autocad (Figure 4),
- Developing the BIM models of buildings A and B using Revit by nesting the modular units and based on the imported 2D-plan imported to the Revit file (Figure 5),

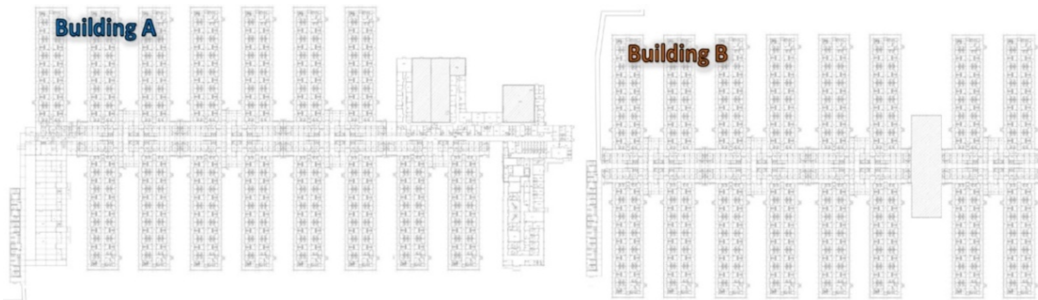

Figure 4. 2D plans of both Building A and Building B of medical area

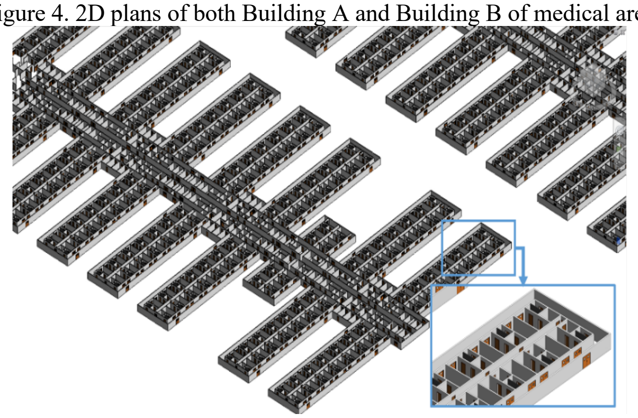

Figure 5. BIM model of Medical area

Development of Construction Planning of the Analogic Project

The focus group workshops defined the construction stages and their durations, and then built the related planning as shown in Figure 6. The produced planning for the analogic project took into account the following hypothesis that are realistic if the project has a complete buy-in of the policy makers:

- The owner is willing to afford the needed investment for that kind of fast-track project using digital aspects, and deliver the necessary payment warranties,
- The project will be funded through banks' funding (based on owners' warrantees) in order to overcome the payment delays and the initial expenses,
- The owner has a restricted team dedicated to fastening validations' process, and ensure the monitoring,
- To reduce the error gap, it is necessary to first validate the materials and equipment to be used and then build a model of the prefabricated unit and have it validated by the owner, architect, engineering firm, and control office,
- The importation process will be launched directly after validating materials and equipment samples. A period of 3 months and 3 weeks is the evaluated time to validate and get the first arrival of materials and equipment taking into consideration the supply chain issues imposed by travel restrictions and worldwide lockdown measures. This period will be used to:
    - Enhance BIM construction efficiency by providing the supervisors with the necessary BIM materials and 2-months training in BIM and COVID-19 measures to be implemented during the construction on-site starting on 26 Mar. 2020,
    - Have enough time to find and recruit the relevant workforce, especially that, according to

survey, in that period the worksites experienced a massive abandonment of the labors because of the fear to be affected because of workers density,

- Proceed with the preparative work (leveling, pipes, backfilling … and foundation) to build the superstructure with minimum of workforce and materials leading then to both handle the workforce aforementioned point, optimize costs and well prepare the logistics.

- Limitation of the three formal leaves of labor to 2 weeks per each (Figure. 6: time intervals in green),
- The project will be divided into six zones (Figure. 7), each one has its own teams and independent working materials with 3-shift work for tasks part of the critical path (Figure. 6: tasks in blue).

The total duration of the BIM construction process of the analogic project in the African context is 206 days in the best scenario.

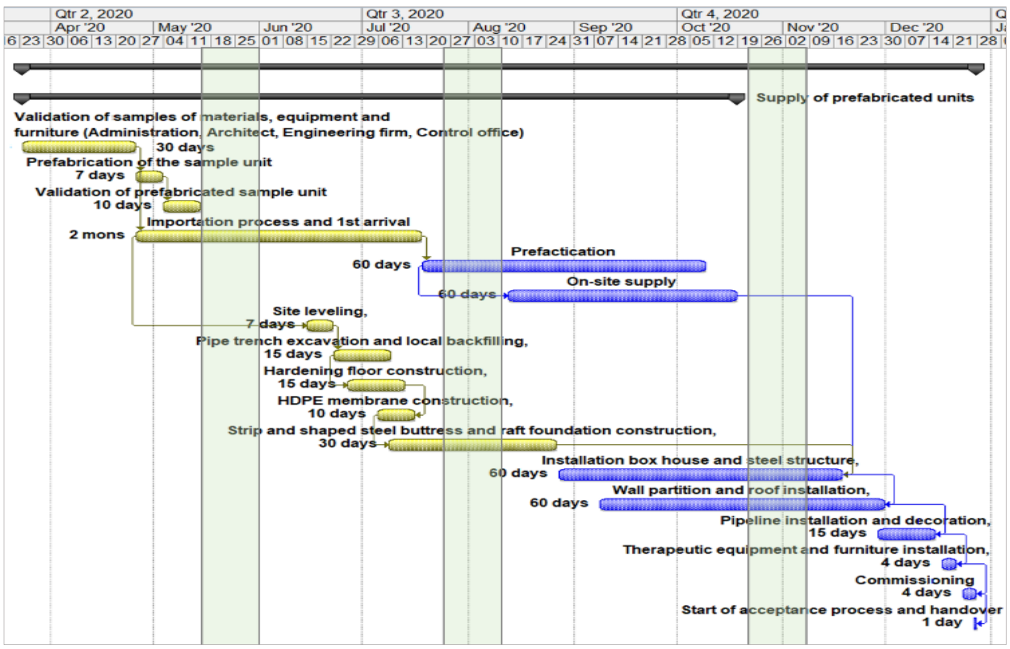

Figure 6. Immediate impacts of COVID-19 (March 2020) on construction site

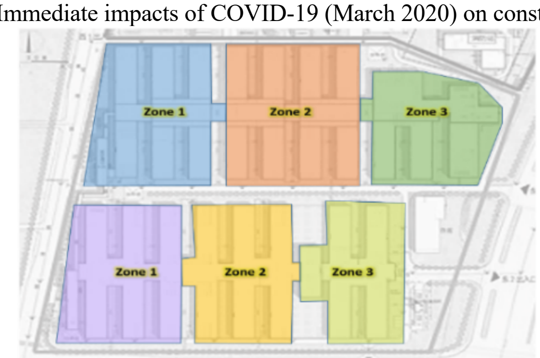

Figure 7. Worksite arrangement

Discussion

Despite the valuable benefits of BIM to both enable construction in crisis circumstances and considerably optimize time, costs and efforts in the AEC industry, Africa is still facing significant challenges hindering the efficient implementation of BIM and more importantly for fast-track construction. The comparative case study revealed that for the same project and under the same circumstances (lockdown, climatic conditions, and location features), in China, BIM-based fast-track construction process enabled the project to be completed in 12 days, whereas in the African context it would take at least 206 days in the best scenario. Indeed, the African firms and experts involved in this study pointed out several needed elements to be satisfied and challenges to be overcome in order to reach the full performances provided by BIM technology in the African context. Namely:

- Lack of skilled workforce in BIM technology for both development and realization stages:
  In the development stage, most architectural and engineering firms are still using non-collaborative tools and have not yet migrated towards BIM tools. While in the construction phase, other than large structures, the contractors are mainly using unskilled or even illiterate workforce, a fact that has been confirmed by several studies (Elliott, 2020; Ghanem, 2020).
- Lack of adequate bidding and payment conditions:
  The contractors are mainly hired based on the less expensive offer, the payment deadlines are significantly high (for instance, 90 to 120 days in Morocco) and for public projects, the invoices' validation process takes a long time. Therefore, the contractors are not willing to fasten work that would increase their expenses and wait for delayed payment.
- Lack of adequate infrastructure:
  To efficiently use BIM technology, the worksite should be well-connected to the cloud, which is not possible out of big cities in Africa because of lack or absence of power and/or internet.
- Lack of locally manufactured construction materials and technologies:
  African construction strongly depends on imported building materials and technologies due to poor local industrialization.

However, this study showed that the private African AEC operators are able to upgrade successfully their current practices toward BIM-based practices and fast-tack approaches if the policy makers pave the path for it. Namely, enhance infrastructure quality, dictate adequate regulations especially in terms of bidding and payment conditions, and promote local industrialization and innovative processes.

Conclusions

Through the analysis of two case studies, this study investigated the applicability of BIM-based building operation for fast-track construction in the African context and inferred the challenges as well as the needed elements to reach the full performances of BIM, with a specific focus on the planning during the construction stage. Based on a thoughtful comparison between the case studies, the research reveals that the needed time for the building operation of fast-track construction in the African context is 17 times more than in a BIM-expert environment. To decrease this substantial incompetency, the African AEC actors, either policy makers or companies, need to overcome the challenges and developed formal strategies to train the workforce in BIM technology, change the bidding and payments conditions, construct an adequate infrastructure mainly power supply and internet, and promote local industrialization of both technologies and martials related to construction field. This paper could be the basis for future research related to frameworks, technological tools, and/or strategies for implementing BIM-based fast-track construction in African countries. However, this study was limited to large-scale companies operating in several African countries, which does not represent all categories of companies composing the African AEC industry landscape and discussed only planning of the construction phase.

Therefore, further studies could be conducted to investigate these specific aspects.

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References

Alderton, M. (2021, October 20). Modular Hospitals: 3 Examples of Prefab COVID-19 Hospitals. *Redshift by Autodesk EN*. https://redshift.autodesk.com/modular-hospitals/

Arezki, R., Djankov, S., & Panizza, U. (2021). *Shaping Africa's Post-Covid Recovery*. Centre for Economic Policy Research (CEPR) and Financial Market Group (FMG).

CGTN. (2020a, February 6). *Time-lapse video shows how Leishenshan Hospital completed in 12 days*. https://www.youtube.com/watch?v=bEVkVdlNaxk

CGTN. (2020b, February 7). *Live: Updates on Wuhan's Leishenshan Hospital amid coronavirus outbreak*. https://news.cgtn.com/news/2020-02-06/Live-The-construction-of-Wuhan-s-Leishenshan-Hospital-NRHuyCspHO/index.html

Chen, L.-K., Yuan, R.-P., Ji, X.-J., Lu, X.-Y., Xiao, J., Tao, J.-B., Kang, X., Li, X., He, Z.-H., Quan, S., & Jiang, L.-Z. (2021). Modular composite building in urgent emergency engineering projects: A case study of accelerated design and construction of Wuhan Thunder God Mountain/Leishenshan hospital to COVID-19 pandemic. *Automation in Construction*, *124*, 103555. https://doi.org/10.1016/j.autcon.2021.103555

CSCEC Pakistan. (2020, February 12). *#Coronavirus Construction of #Leishenshan Hospital*. https://www.youtube.com/watch?app=desktop&v=WVJx0hlESXg+%2F

Elliott, R. (2020). *Study on the Economic Impact of COVID-19 in sub-Saharan Africa Demonstrates High Loss of Income and Usage of Digital Loans* (GeoPoll). Business Fights Poverty. https://businessfightspoverty.org/study-on-the-economic-impact-of-covid-19-in-sub-saharan-africa-demonstrates-high-loss-of-income-and-usage-of-digital-loans/

Fortune Business Insights. (2021). *Building Information Modeling (BIM) Market Size | Global Report, 2027* (Global Business No. FBI102986; p. 150). https://www.fortunebusinessinsights.com/building-information-modelling-software-market-102986

Ghanem, H. (2020). *Africa's Pulse: Assessing the economic impact of covid-19 and policy responses in Sub-Saharan Africa* (2021/052/AFR; Africa's Pulse, Volume 21, p. 136). The Office of the Chief Economist for the Africa Region (OCEAR), World Bank Group. https://reliefweb.int/report/angola/africas-pulse-april-2020-volume-21-assessing-economic-impact-covid-19-and-policy

Jeon, J., Padhye, S., Bhattacharyya, A., Cai, H., & Hastak, M. (2022). Impact of COVID-19 on the US Construction Industry as Revealed in the Purdue Index for Construction. *Journal of Management in Engineering*, *38*(1), 04021082. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000995

Jones, S. A., Laquisara-Carr, D., & Barnett, S. (2020). *Prefabrication and Modular Construction 2020* (SmartMarket Report, p. 68). DODGE Data & Analysis. https://www.construction.com/toolkit/reports/prefabrication-modular-construction-2020

Lalu, M., Tiong, I., & Shidqul, A. M. (2019). Application of Fast Track Method to Accelerate Project Implementation Time in the Hospital Construction. *International Journal of Scientific Engineering and Science*, *3*(11), 49–53.

Lin, C.-L., Chen, J. K. C., & Ho, H.-H. (2021). BIM for Smart Hospital Management during COVID-19 Using MCDM. *Sustainability*, *13*(11), 6181. https://doi.org/10.3390/su13116181

Lin, F., & Howell-Jones, M. (2020, August 7). Here's how smart construction could transform home-building after COVID-19. *World Economic Forum*. https://www.weforum.org/agenda/2020/08/here-s-how-smart-construction-could-transform-home-building-after-covid-19/

Luo, H., Liu, J., Li, C., Chen, K., & Zhang, M. (2020). Ultra-rapid delivery of specialty field hospitals to combat COVID-19: Lessons learned from the Leishenshan Hospital project in Wuhan. *Automation in Construction*, *119*, 103345. https://doi.org/10.1016/j.autcon.2020.103345

Meisels, M. (2020). *Explore digital transformation and business model trends, 2021 engineering and construction industry outlook* (p. 10). Deloitte Group.

Şahan, N. H. (2021, April 9). BIM and AI Integration In Combating Covid-19. *Surveying Group*. https://surveyinggroup.com/bim-and-ai-integration-in-combating-covid-19/

Schimanski, C. P., Pradhan, N. L., Chaltsev, D., Pasetti Monizza, G., & Matt, D. T. (2021). Integrating BIM with Lean Construction approach: Functional requirements and production management software. *Automation in Construction*, *132*, 103969. https://doi.org/10.1016/j.autcon.2021.103969

Wang, W., Gao, S., Mi, L., Xing, J., Shang, K., Qiao, Y., Fu, Y., Ni, G., & Xu, N. (2021). Exploring the adoption of BIM amidst the COVID-19 crisis in China. *Building Research & Information*, *49*(930–947), 1–18. https://doi.org/10.1080/09613218.2021.1921565

Yang, S., Fengyu, D., & Liangbo, M. H. (2020). Wuhan | Leishenshan Hospital, Digital Solutions for Pandemic Response. *Centre for Liveable Cities*, *18*, 6.

Zhou, M., Chen, Y., Su, X., & An, L. (2021). Rapid construction and advanced technology for a Covid-19 field hospital in Wuhan, China. *Proceedings of the Institution of Civil Engineers - Civil Engineering*, *174*(1), 29–34. https://doi.org/10.1680/jcien.20.00024