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## APPROACH TO HEALTHCARE DESIGN USING BIM IN NEW NORMAL CONDITION

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**Abstract:** SARS-CoV-2 pandemic is continuing to stress our healthcare system and it is hitting our hospitals very hard from 2019 to till now. Many countries and regions of the world faces similar hospital capacity problems due to this unfortunate ongoing international COVID-19 outbreak. This paper could be an initiation for developing further studies which helps to create advance approaches, strategies related to Building Information Modelling (BIM) based fast-track constructions.

**Index Terms -** Field hospital, Wuhan Leishenshan Hospital, Building information modeling (BIM), COVID-19, Healthcare, Modular construction, prefabrication, CEMEX Mobile Hospitals, CURA pods, Therapeutic isolation.

### I. INTRODUCTION

The COVID-19 disaster which made the world upside down has forced many Hospital construction industries around the world to adopt smart technologies like BIM. BIM is a latest technology that lets the various stakeholders of a particular project to work concurrently on a similar 3D digital model. It has enabled appropriate planning and designing with quick and accurate time limits, more secure constructions and sustainable buildings. Based on a comparative study done previously which tells the effectiveness of BIM based HealthCare building operation and the associated challenges as well as needed elements for its proper working. This study aims to enlighten the researchers on the strength of BIM-based Healthcare building operation in difficult situations like social distancing, contamination, fast spreading respiratory infection etc

### II. METHODOLOGY

#### BIM AND PRODUCT, ORGANIZATION, AND PROCESS (POP) MODELING APPROACH :

Building Information Modelling (BIM) technologies associated with quick construction were found to be a perfect solution for several countries to build healthcare amenities swiftly to meet the rising number of COVID-19 cases.

A POP model consists of three models,

Product model - Product model that includes both the geometric and non-geometric attributes of physical objects and allows for quantity take off, ventilation simulations, and other necessary analyses.

Product process model - Product-process model that combines the product model with the construction progress for smooth construction coordination and schedule management.

Organization process model - Organization-process model that integrates the specific project delivery tasks with organizational responsibilities at different project stages.

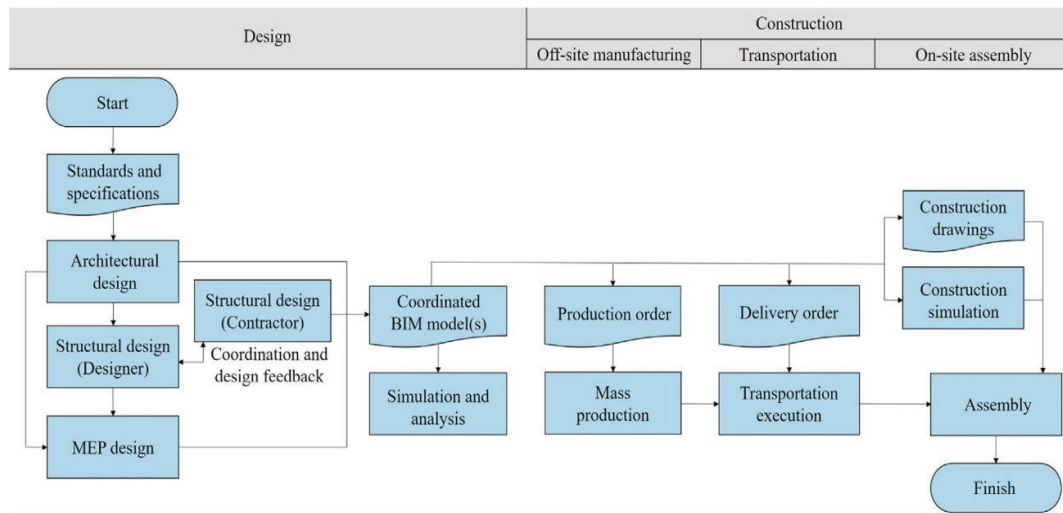


Figure 1: Project delivery methodology, Ex ; Leishenshan Hospital in China  
 (Source: [www.sciencedirect.com/science/article/pii/S0926580520309250](http://www.sciencedirect.com/science/article/pii/S0926580520309250))

As shown in the above Fig 1, first step is the 2D drawing and the second step is the development of BIM modelling. separated BIM models were developed, as all information cannot be stored in a single model due to multidisciplinary characteristics of healthcare buildings. The designer and contractors organizes their own BIM teams especially for its BIM development and execution.

**BIM IMPLEMENTATION AT THE DESIGN STAGE**

BIM model developed during design stage contains functional areas and construction site in addition to individual architectural, structural, and mechanical, electrical and plumbing (MEP) components.

**BIM IMPLEMENTATION AT THE CONSTRUCTION STAGE**

- Production of prefabricated components
- Coordination of various trades during construction

**III. CASE STUDIES**

Table 3.1 (Source: Created by Authors) [1]

Case study - 1		Design / Construction Methodology
Project Name	Leishenshan Hospital	Planning – The plan was Fishbone Layout with medical treatment area (Therapeutic isolation ward) which was built as liner lines of rooms. Each linear lines of rooms contains three zones and two passages. The three zones are clean, semi-contaminated and contaminated zone, and two passages, one for medical staff and the other for patients.  Construction - Two types of Container modules with Modular units formed a skeleton system composed of composite board walls as main elements. The Container modules contains of wall, ceiling, and floor panels included glass fiber insulation with steel plate interiors finishes make an antibacterial atmosphere. Container modules were manufactured in factories and then transported to construction site and installed at the selected areas with the help of mobile crane. The isolation ward has a double-sided cabinet which acts as a conduit between isolation ward and the passages. The cabinet helped the medical team to issue daily medicines and requirements to the patient without entering the ward and hence prevents cross infection.
Location	Isolated parking area of Wuhan Military Games Athletes'Village in Jiangxia District, Wuhan, China	
Architect / Engineering	Zhongnan Architectural Design Institute and later constructed by China Construction Third Engineering Bureau	
Type of Hospital	Temporary Filed Hospital	
Total no. of Beds	1600 Nos.	
Area	52,000m <sup>2</sup> for Therapeutic Isolation (Total - 80,000 m <sup>2</sup> )	
Duration of construction	9 to 12 days (Jan 26 <sup>th</sup> to Feb 6 <sup>th</sup> 2020) and Opened on Feb 8 <sup>th</sup> 2020	

Construction methodology	Container type Prefabricated hospital design / Modular construction	The concept of POP modelling method combined with BIM helps the design and construction of hospital through several aspects.
Design and construction application	Building Information Modelling (BIM) with Product, organization and Process (POP) modeling	
No. of container-type prefabricated units used and sizes	3000 nos. / Dimensions of 6 m × 3 m × 2.6 m or 6 m × 2 m × 2.6 m	

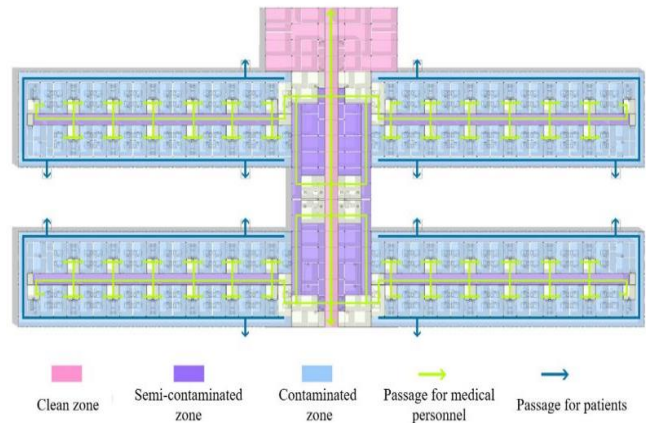


Figure 2: Layout of the Leishenshan Hospital.

Figure 3: Part plan of Therapeutic isolation- “three zones and two passages”

Figure 2 & 3 (Source: [Ultra-rapid delivery of specialty field hospitals to combat COVID-19: Lessons learned from the Leishenshan Hospital project in Wuhan](https://www.sciencedirect.com/science/article/pii/S0926580520309250) www.sciencedirect.com/science/article/pii/S0926580520309250

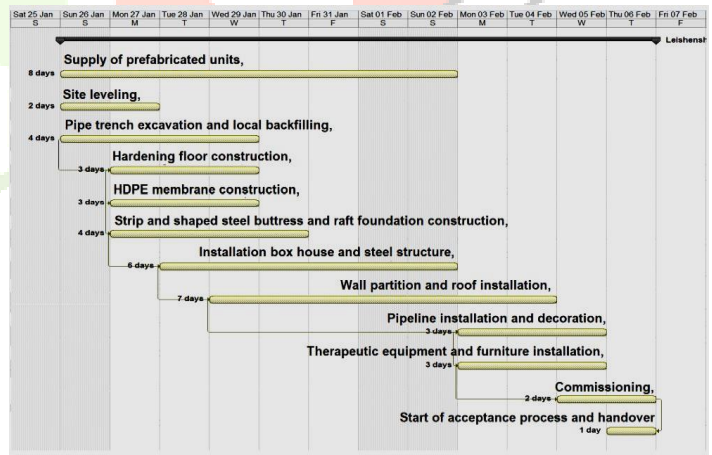
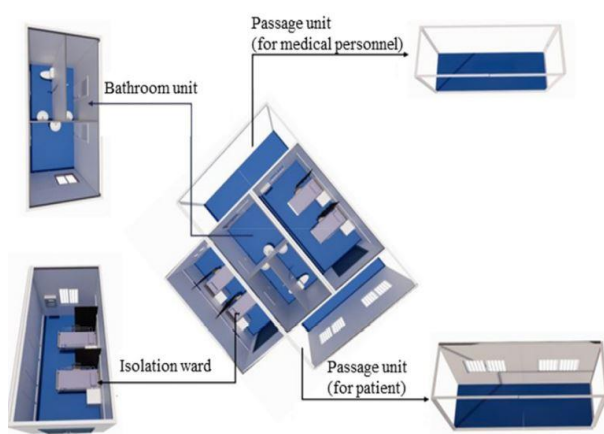


Figure 4: Modular design for Leishenshan Hospital

Figure 5: As-built schedule of Leishenshan hospital construction

Figure 4: (Source: [Ultra-rapid delivery of specialty field hospitals to combat COVID-19: Lessons learned from the Leishenshan Hospital project in Wuhan](https://www.sciencedirect.com/science/article/pii/S0926580520309250) www.sciencedirect.com/science/article/pii/S0926580520309250

Figure 5: (Source: [www.researchgate.net/publication/360617766](https://www.researchgate.net/publication/360617766) BIM for Fast-track Construction under COVID-19 Circumstances A Comparative Case Study in the African Context)

Table 3.2 (Source: Created by Authors)<sup>[1]</sup>

Case study - 2		Design / Construction Methodology
Project Name	CEMEX Hospitals	<p>It was built with prefabricated modules of antibacterial concrete of high durability, have hospital grade vinyl floor and access ramps for patients and stretchers, also, the entrances and exits have intelligent access controls in critical areas. Its finishes and paint also have antibacterial properties.</p> <p>The medical units will have special filters in the air conditioning system, ultraviolet light that will help eliminate viruses and bacteria, air-conditioned septic for biological-infectious hazardous waste and firefighting equipment with smoke detectors.</p> <p>The ability gained from BIM helped sooner construction of this hospital, which was built using prefabricated antibacterial concrete.</p> <p>Concept - Prefabricated, durable, intelligent, and affordable mobile hospital.</p> <p>CEMEX used prefab-housing-design techniques to develop mobile hospital models.</p>
Location	Ciudad Juarez, Chihuahua; Tlalnepantla, State of Mexico; Monterrey, Nuevo Leon; Puebla, Puebla; Culiacán, Sinaloa and Fresnillo, Zacatecas	
Architect / Engineering	Fernando A González	
Type of Hospital	Mobile hospital	
Total no. of Beds / Patients	250 patients	
Area	Totally 4300 m2	
Duration of construction	15 days and opened on 22 <sup>nd</sup> Sep 2020	
Construction methodology	Prefabricated modules	
Sizes	6 mobile hospitals	
Design and construction application	Building Information Modelling (BIM)	



Figure 6 & 7: Exterior and Interior of CEMEX Hospital

Figure 8: Interior of CEMEX Hospital

Figure 6 & 7: (Source: <https://redshift.autodesk.com/modular-hospitals/>)

Figure 8: (Source: <https://responsabilidadsocial.net/cemex-construye-seis-hospitales-moviles-en-tiempo-record-para-atender-pacientes-con-covid-19/>)



Table 3.3 (Source: Created by Authors)<sup>[1]</sup>

Case study - 3		Design / Construction Methodology
Project Name	NHS Nightingale Hospital Birmingham	<p>Two exhibition halls were converted in to 80 wards, each wards were fitted with 42 beds, already 500 fully-functioning equipped beds, with oxygen and ventilators were in-situ and extra space for another 3500beds were created and totally 4000 beds was created.</p> <p>The Skeleton for individual bed bays were made from lightweight material which used to make exhibition stands which can constructed quickly.</p> <p>The whole activity were carefully monitored using PlanGrid, an BIM Autodesk cloud solution, to document progress and communicate issues.</p>
Location	ExCeL exhibition centre, East London, UK	
Architect / Engineering	James Hepburn and Paul Johnson from BDP Architects and Engineers	
Type of Hospital	Field hospital	
Total no. of Beds	4000 nos. – ICU	
Area	1,15,000 sqm	
Duration of construction	9 days and opened on 3rd April 2020	
Construction methodology	Framework construction	<p>Concept - Exhibition center has been modified into a temporary hospital</p>
Design and construction application	Autodesk Construction cloud – Auto desk BIM Collaborate	



Figure 9: Exterior of NHS Hospital



Figure 10: Interior of NHS Hospital

Figure 9: ([Source: www.buildingbetterhealthcare.com/news/article\\_page/NHS Nightingale Hospitals an experiment in risk-conscious modular construction/165772](http://www.buildingbetterhealthcare.com/news/article_page/NHS_Nightingale_Hospitals_an_experiment_in_risk-conscious_modular_construction/165772))

Figure 10: ([Source: www.theguardian.com/artanddesign/2020/apr/07/how-to-build-a-hospital-in-nine-days-emergency-architecture-in-a-pandemic-coronavirus-outbreak](http://www.theguardian.com/artanddesign/2020/apr/07/how-to-build-a-hospital-in-nine-days-emergency-architecture-in-a-pandemic-coronavirus-outbreak))

Table 3.4 (Source: Created by Authors)<sup>[1]</sup>

Case study - 4		Design / Construction Methodology
Project Name	CURA pods (Connected Units for Respiratory Ailments)	<p>CURA is a neatly packed intensive-care pods for patients with respiratory infections, constructed in a 20-foot length intermodal container with bio-contamination using negative pressure. Each pod contains, two ICU beds equipped with ventilators and monitors as well as IV fluid stands and syringe pumps.</p> <p>The two glass windows were installed on the opposite sides of the containers, for doctors and nurses to check the status of patients, both inside and outside of the pods. It's also, allow visitors to get closer to relatives in a safer setting. Each unit works independently and can be shipped anywhere.</p> <p>Individual pods are connected to each other by inflated structure to create a multiple modular layout (4 beds to 40). This can be established with few hours and the units could be as fast to mount as a hospital tent but as safe as isolation ward.</p>
Location	Officine Grandi Riparazioni complex in central Turin, Italy	
Architect / Engineering	Carlo Ratti and Italo Rota of Carlo Ratti Associate	
Type of Hospital	Temporary hospital – Covid 19	
Total no. of Beds	92 nos.	
Area	8900 m <sup>2</sup>	
Duration of construction	4 weeks and opened on 19 <sup>th</sup> April 2020	
Construction methodology	Ship Container	<p>Concept - It is exactly a miniature of hospital room, with all medical equipment necessary for respiratory care ICU</p>
Sizes	6.1 m long with 9sqm interior space	

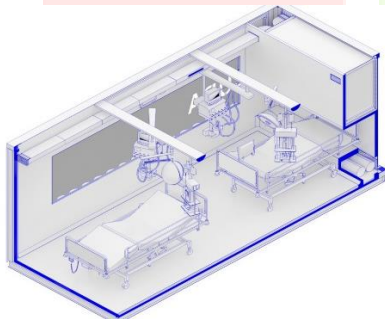


Figure 11: Isometric view of CURA pods







Figure 12 &amp; 13: CURA pods

Figure 11: ([Source: www.archdaily.com/936247/carlo-ratti-converts-shipping-containers-into-intensive-care-pods-for-the-covid-19-pandemic](http://www.archdaily.com/936247/carlo-ratti-converts-shipping-containers-into-intensive-care-pods-for-the-covid-19-pandemic))

Figure 12&13: ([Source: www.archdaily.com/938074/carlo-rattis-first-intensive-care-pod-installed-at-a-temporary-hospital-in-turin-italy?ad\\_medium=widget&ad\\_name=related-article&ad\\_content=936247](http://www.archdaily.com/938074/carlo-rattis-first-intensive-care-pod-installed-at-a-temporary-hospital-in-turin-italy?ad_medium=widget&ad_name=related-article&ad_content=936247))

## IV. COMPARATIVE STUDY

Table 4.1 (Source: Created by Authors) <sup>[1] [2] [3]</sup>

Description	 Leishenshan Hospital	 CEMEX Hospitals	 NHS Nightingale Hospital	 CURA pods Hospital (Connected Units for Respiratory Ailments)
Location	Wuhan, China	Tlalnepantla, State of Mexico;	East London, UK	Turin, Italy
Architect / Engineers	Zhongnan Architectural Design Institute and later constructed by China Construction Third Engineering Bureau	FernandoA González	James Hepburn and Paul Johnson – BDP Architects and Engineers	Carlo Ratti and Italo Rota of Carlo Ratti Associate
Area	Total area - 80,000m <sup>2</sup> 52,000m <sup>2</sup> - Isolation beds	4300 m <sup>2</sup> - 6 Mobile hospitals	1,15,000 m <sup>2</sup>	8900 m <sup>2</sup>
Type of Hospital	Temporary Field hospital	Mobile hospitals	Temporary Field hospital	Temporary hospital
Total no. of Beds	Therapeutic beds - 1600 Nos. Isolation beds - 1600 Nos.	250 Patients	ICU Beds - 3500 Nos.	ICU Beds - 92 Nos.
Duration of construction	9 to 12 days and opened on Feb 8th 2020	15 days and opened on 22nd Sep 2020	9 days and opened on 3rd April 2020	4 weeks and opened on 19th April 2020
Sizes	Container - 3000 nos. / 6 m × 3 m × 2.6 m / 6 m × 2 m × 2.6 m	-	-	Each Pod - 6.1 m long with 9 Sqm interior space
Construction Methodology	Parking lot of the Wuhan Military Games Athletes Village has been changed to Temporary Field hospital	Prefabricated modules were used for construction	ExCeL Exhibition centre has been changed to Covid 19 hospital.	Ship Container has been modified to small hospital room.
	Two types of modules with Modular units form a skeleton system composed of composite board walls with glass fibre insulation and steel plate finishes.	Prefab-housing-design techniques with Antibacterial concrete were used to develop mobile hospital modules.	Totally Five exhibition halls were converted in to 4000 bedded wards. Skeleton for individual bed bays were made from lightweight material which used to make exhibition stands which can constructed quickly.	It is exactly a miniature of hospital room with 2 ICU's bed.  Individual pods are connected to each other by inflated structure to create a

				multiple modular layout (4 beds to 40).
Application used for Design and construction	Building Information Modelling (BIM) with Product, Organization, and Process (POP) modeling	Building Information Modelling (BIM)	Autodesk Construction cloud – Auto desk BIM Collaborate	–

## V. CONCLUSIONS

This above Research studies records the varies experience of the development of Prefabricated Field and Mobile hospital projects all around the world during COVID 19 Pandemic. It has been found that combined approach of POP modeling and BIM has helped the design and construction of healthcare projects during Covid 19 Pandemic a lot.

Healthcare is a complex and critical in Architectural, Engineering and Construction market segment with many challenges. BIM tools can increase the effectiveness with which owners, designer, and builders effectively develop and execute Healthcare projects. Future studies were expected to look in to the utility of BIM and other latest technologies to strengthen public health systems during pandemic and other calamities.

## VI. REFERENCES

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