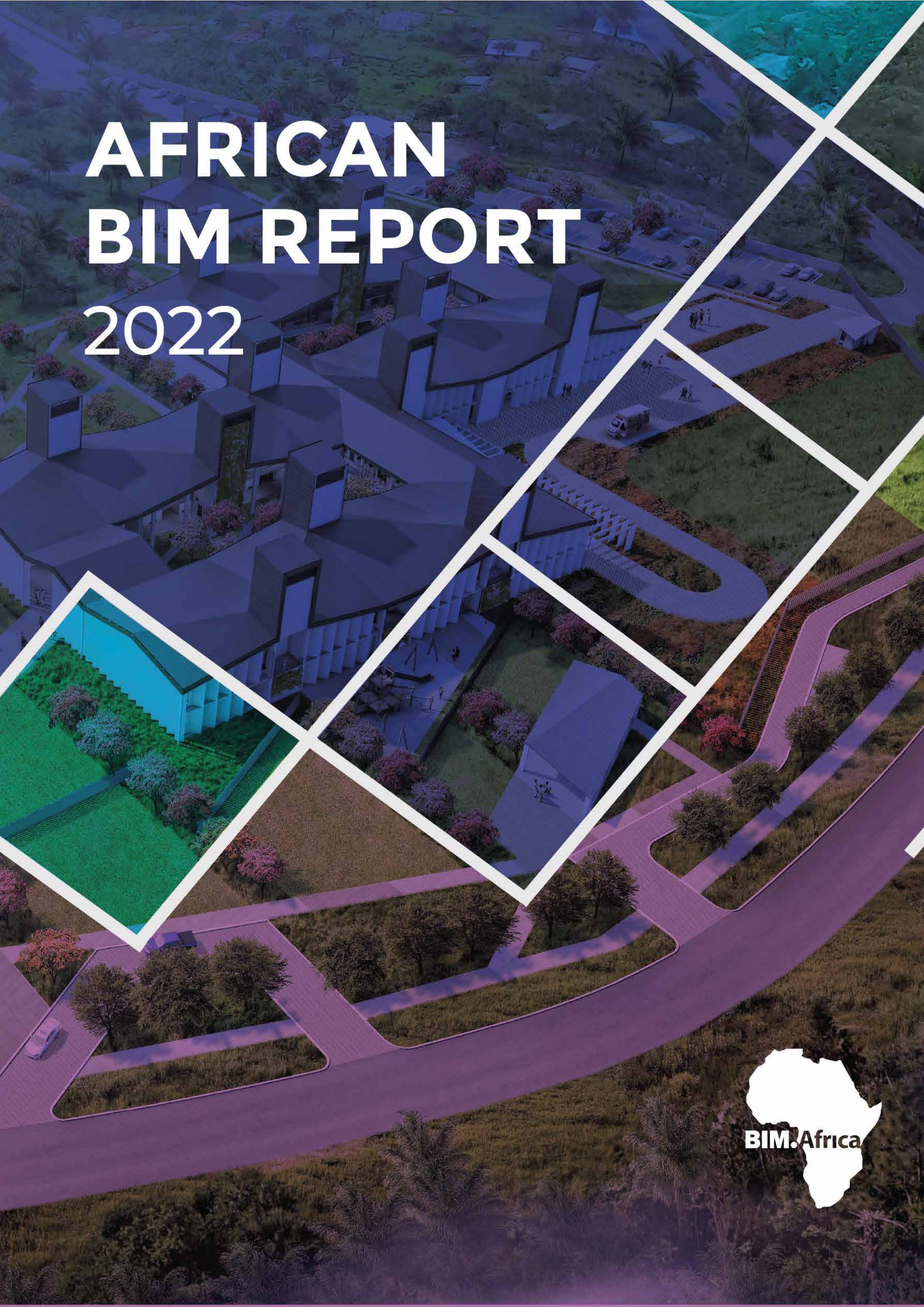


AFRICAN BIM REPORT 2022

BIM.Africa

The African BIM Report (ABR) is authored by the Research and Development Committee of BIM Africa and provides a biennial status review of the adoption and implementation of Building Information Modelling (BIM) across the African built industry.

The electronic copy of this report can be downloaded at: www.bimafrica.org/reports.

Disclaimers

Cover image: Rendering of New Redemption Hospital Caldwell- MASS Design Group.

Suggested citation

BIM Africa (2022). African BIM Report 2022. Authored by the Research and Development Committee. Available at https://bimafrica.org/reports/

Kamal Ben Addou Idrissi
Chairman, Board of Directors

Moses Itanola
Executive Director

When the inaugural report was published in 2020, it was daunting to conduct a continent-wide survey. Our resolve at that time was that the report represented a great starting point for broader engagements in subsequent editions. In 2022, recording above 1,100 survey entries from over 39 countries, and with even regional distribution, validates our hopes back then. Alongside our other activities, truly, the report pushed frontiers of knowledge forward and contributed to efforts to digitise the African built environment.

Leveraging our volunteer network, strategies, and programs, we are now championing the digital transformation of the African construction industry. Since the inaugural report, we have hosted and presented in up to 20 virtual and physical events, contributed to five publications, formalised six partnerships, and joined the Global Alliance for Buildings and Construction (GlobalABC) hosted by the United Nations Environment Programme (UNEP). The two editions of our co-hosted virtual conference (BIMHarambee.Africa) recorded 3,900+ registrations.

With a unique 3D printed plaque, the Innovation Awards 2021 recognised nine exceptional individuals and firms from Egypt, South Africa, Nigeria, Algeria, Mauritius, and Tunisia.

How has the industry faired since 2020? The African BIM Report 2022 is critical to answering that question for us all. The survey results highlight major and minor shifts in industry awareness, adoption, and implementation. Intriguing articles from some projects shared their approach to BIM implementation, challenges faced, and the strategies adopted to mitigate and achieve success. Experts also provided their opinion on innovative technologies and the way forward for the industry.

As noted in the inaugural report, the voyage before us all is both exciting and astounding. We are providing a strategic platform to connect with industry stakeholders and share strategies for developing Africa. BIM Africa Summit (BAS) 2023 will be hosted in Marrakech, Morocco, on the 18th and 19th of May 2023, focusing on the digital advancement of the built environment for a sustainable Africa.

Read on, and let's catch up in Marrakech!

Dr. Abdullahi Saka
Director, Research and Development

Introduction

The Research and Development Committee of BIM Africa initiated the Africa BIM Report (ABR) to discuss the progress and opportunities of digital technologies in the African Architecture, Engineering, Construction, & Operations (AECO) industry. In 2020, the first report (ABR 2020) was published and made available in English and French. The ABR 2020 showcased projects that employed digital technologies, featured articles from experts, and presented the findings of the first continent-wide BIM survey in Africa. The report received positive feedback from stakeholders, featured in academic and industry research, and contributed to the discourse on BIM.

Two years later, we are glad to release the ABR 2022, which presents the BIM status on the continent and explores digital technologies opportunities. The report has been made available in English, French & Arabic to reach a wider audience, and we engaged regional partners across the five African regions. ABR 2022 presents different projects that have employed BIM or because of their distinct features, from Mauritius and Burundi in East Africa to Egypt and Morocco in North Africa. The expert articles are drawn from various areas – Digitization, Digital twins, 3D printing – that are important for leveraging the benefits of digital construction in Africa. Also, the report summarizes the findings of the African BIM Survey (ABS) 2022 and compares the change in the status quo since the last survey.

Interestingly, the ABS 2022 survey depicts a growing level of awareness in the industry. Although the growing awareness has not translated to a high level of adoption yet, it is a necessary step towards digital transformation. We are witnessing more firms producing 3D models, working collaboratively on design compared to the previous years, and coming out of the COVID-19 pandemic.

More firms are reporting the adoption of BIM on some of their projects with varying levels of implementation. The level of implementation is expected to progress in the coming years as more firms project to adopt BIM, thereby creating a supportive environment for digital transformation in the industry. Albeit the outlook is positive, the industry is still bedevilled with many challenges impeding widespread adoption. Knowledge-related barriers, lack of government support, client demand and cost are still major bottlenecks in Africa. Thus, stakeholders must do more collectively to engage the AECO industry's regulatory bodies, clients, and professionals. Currently, the top-down BIM drive is difficult because of the lack of buy-in from governments, and there have been calls for government mandates in Africa. However, would BIM mandates lead to widespread adoption or a BIM divide in the already fragmented industry? BIM policies need to be context conscious as the sector comprises about 90% of Small and Medium Sized Enterprises (SMEs), which are often risk-averse compared to their large counterparts. Effective policies should consider a mix of nudge and mandate to encourage digital transformation in the African AECO industry.

Lastly, the African continent is progressing slowly towards BIM whilst most developed economies are ahead. However, the future is promising and full of opportunities in industry 4.0. Perhaps, the African AECO industry would leapfrog to BIM and digital transformation as the continent skipped landlines for mobile phones. Digital transformation of the industry would contribute immensely to bridging the infrastructure gaps, and BIM is a key step. As we buckle up and continue to engage stakeholders, we look forward to the digitalization of the African built environment.

Acknowledgements

The Research and Development Committee would like to acknowledge the guidance and leadership of the BIM Africa Board of Directors, Strategic Advisors, Country Representatives, and the Operations & Programs team in publishing this report. We appreciate the various communities and professional institutes that shared the African BIM Survey 2022 with their user base and all the survey respondents.

We immensely appreciate the following partners and volunteers for their important support, input, comments, contributions, and reviews throughout the development of the African BIM Report 2022:

Secretariat:

Dr. Abdullahi Saka
Leeds Beckett University, UK

Secretariat:

Adeniyi Adeoye
BIM Africa Nigeria

Coordinator:

Dr. Abdul-Majeed Mahamadu
University College London, UK

Regional Partners:

Northern Africa

Prof. Mohamed Marzouk
Cairo University, Egypt

Dr. Mostafa El Hawary
Cairo University, Egypt

Southern Africa

Prof. Innocent Musonda
University of Johannesburg, South Africa

Adetayo Onososen
University of Johannesburg, South Africa

Western Africa

Prof. Martin Morgan Tuuli
Ghana Institute of Management and Public Administration (GIMPA), Ghana

Central Africa

Dr. Henry Abanda,
Oxford Brookes University, UK

Eastern Africa

Dr. Rehema Monko,
Ardhi University, Tanzania

Survey Team:

Dr. Lovelin Obi
Northumbria University, UK

Oludolapo Ibrahim Olanrewaju
Victoria University of Wellington, New Zealand

Khalid Bouguerra
Universiti Teknologi Malaysia

Project & Expert Articles:

Moses Itanola
BIM Africa, Nigeria

Hafiz Oyediran
BIM Africa, Nigeria

Cheima Ayachi
Tunisia

Flint Svinurai
National University of Science and Technology, Zimbabwe

Arabic Translators:

Mohamed Mostafa AboAuf
Khatib & Alami, Egypt

Amr Mohammad Basiony
Khatib & Alami, Egypt

Souhayl Othman
BIMandbeam, Tunisia

French Translators:

Christian Bahara Kika
LAES-GC Engineering, DR Congo

Manon Bonnafous
INTEGRALE Ingénierie, La Réunion

Aziz Gbedourorou
Polytechnic School of Abomey Calavi, Benin

Aboubacar Guiré
Bridges and Building, Burkina Faso

Raymond Tuyizere
Real Contractors, Rwanda

Design: Arabic

Mohamed Alaa,
Khatib & Alami, Egypt

Design: French

Messan Blewussi Sallah
Consultations Projects Afrique, Morocco

Table of content

List of Figures

DIGITAL TWIN: NEW ERA FOR HEALTHCARE PROJECT DELIVERY

Orascom Construction and its Digital Transformation vision in Ahl Masr Hospital

While facility management is crucial for mega and complicated healthcare projects, delivering high-quality as-built BIM models is essential. Laser scanning is vital in this process to match Orascom's digital transformation vision.

Orascom Construction PLC Board is committed to developing and implementing a complete digital transformation that has already become an integral cornerstone of the way we deliver projects. Where applicable, required, or commercially necessary, we will strive to configure our resources to start out right by building the BIM model to suit our ultimate goals. These goals include better technical coordination and work-shop drawing enhancement, time schedule interface, progress measurement interface, and accurate as-built capability.

In addition, our goals include delivering client-friendly Facility Management capability and other functions deemed necessary to enhance both the construction efficiency and enhanced use for the client after handover. Our BIM strategy aligns with the overall business key drivers and defines our BIM Project Maturity Menu. This clearly sets out how we define and leverage our BIM deliverables across the project lifecycle and, significantly, across all project activities.

Ahl Masr Hospital project is the first and largest hospital and research centre for free treatment of trauma and burns victims in Egypt, the Middle East, and Africa. The hospital is located in the 1st settlement in the New Cairo district, covering a land area of over 20,012m^2, which the Ministry of Housing allocated. The hospital has a built-up area of 45,245m^2 and a 175-bed capacity.

Figure 1: Design rendering of the Ahl Masr Hospital project

"Ahl Masr Hospital is the first and largest hospital and research centre for free treatment of trauma and burns victims in Egypt, the Middle East, and Africa."

Proper coordination between all stakeholders is a crucial driver for delivering high-quality projects in complicated projects involving multiple stakeholders such as subcontractors, sub-consultants, and suppliers from different disciplines.

Enormous challenges were predicted during the planning phase of the Ahl Masr Hospital project, especially since the project Structure Skelton was already erected on-site by the previous contractor.

The construction BIM model was a leading-edge for predicting, analysing, and solving coordination issues and congested areas, considering more aspects like clear height, equipment manoeuvrability, medical equipment, and medical gases special requirements.

Coordination was achieved by implementing different tools, software, and technological solutions like BIM modelling, automation, simulation tools, and using Scan to BIM methodology to capture updated site conditions, track deviations, and keep the construction model updated.

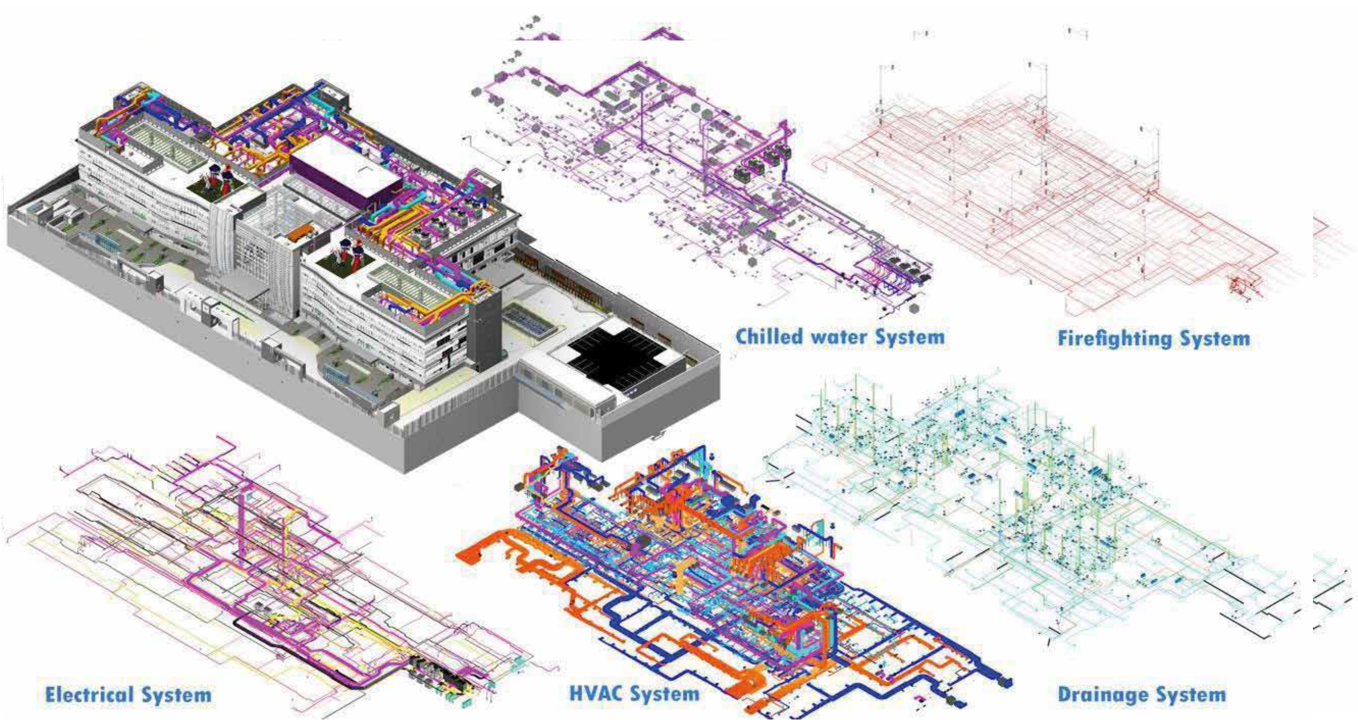


Figure 2: BIM Model of various components of Ahl Masr

Scan to BIM

Scan to BIM is a technique for constructing a digital twin, whereas Scan to BIM is a tool used in developing as-built models by using 3D laser scanning.

A laser scanner is used to record a detailed 3D scan, which is then imported into 3D BIM software (such as Autodesk's Revit, SketchUp, and others) to build high-end accurate as-built models. Laser scanning was first employed for recording current conditions and designing purposes in the AEC industry in the 1990s.

For Renovation, Refurbishment, Retrofit, or Reconstruction Projects, it is quickly becoming a common procedure for Laser Scanning Organizations, Surveyors, Property Owners, Architects, MEP Engineers, and General Contractors or Construction Management companies.

Scan to BIM is used to depict all on-site construction activities during construction. It detects inconsistencies between site conditions and construction BIM models, which are compared to the tolerance values provided in the applicable codes and regulations. There are various elements to consider throughout the construction phase, producing markup drawings and helping for a better QA/QC process.

Scan to BIM best practice

Before Implementing the scan to BIM Methodology, our BIM team developed a Framework containing three stages as follows:
1. Process planning.
2. Data acquisition.
3. Data processing, registration and visualisation.

Framework Implementation

1. Process planning

A. Collecting information based on a site survey as shown below.

FLOOR	NO. OF ZONES	TOTAL BUILT UP AREA	TOTAL NO. OF SCANS	DURATION OF SCANNING (working days)	NO. OF CREWS	NO. OF SCANNERS USED
FIRST FLOOR	4	4800 m^2	800	14 DAYS	1	1
GROUND FLOOR	3	4700 m^2	800	14 DAYS	1	1
BASEMENT 1	4	11700 m^2	600	18 DAYS	1	1
BASEMENT 2	4	11700 m^2	500	18 DAYS	1	1
ROOF	2	5680 m^2	300	7 DAYS	1	1

Figure 3: Process planning for scan to BIM

B. Selecting the scanner type: selection was according to specific criteria that achieve the fastest scanning duration with the highest quality. The scanner's size was critical as it needs a small physical dimension to allow easy manoeuvring through congested MEP and medical systems.

2 The data acquisition.
During the data acquisition phase, a zoning system was established to allow parallel modelling and laser scanning processes.

3. Data processing, registration, and visualisation.
This phase contains data processing and registration of each zone, linking the point cloud with the BIM model and quality assurance.

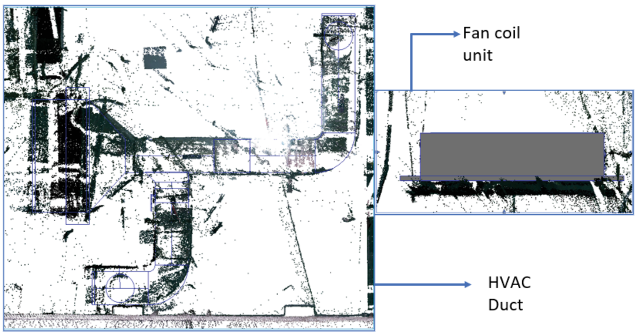


Figure 4: Linking Point cloud with BIM Model of Ahl Masr

The results of the developed As-built model were awe-inspiring, as shown below:

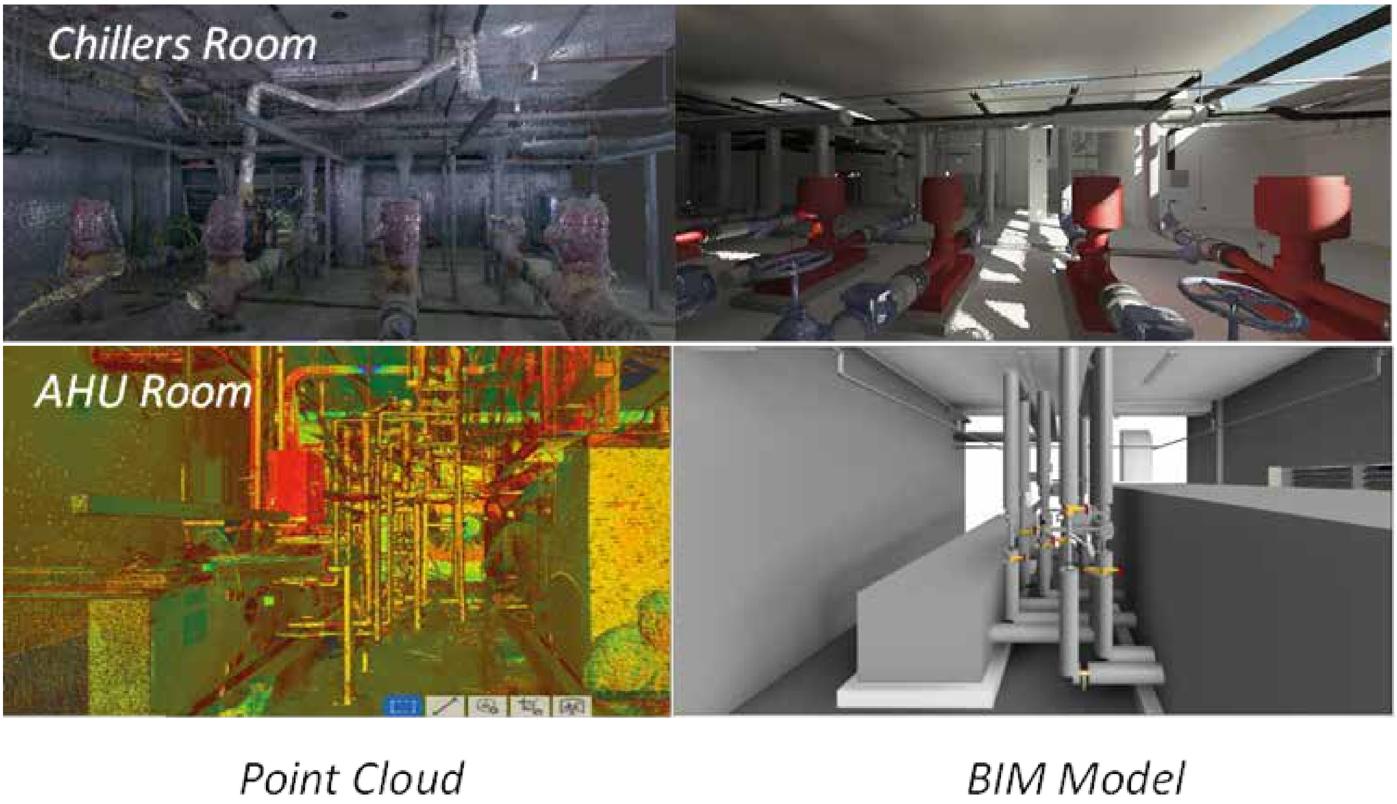


Figure 5: : As-built Point Cloud versus BIM Model of Ahl Masr Hospital

Laser scanning vs traditional surveying

1. Less surveying duration with more accurate results
2. Less modelling duration with more accurate results.

The laser scanning method and highly coordinated process between the scanning and modelling teams proved successful. Through this process, the team could deliver a high-end accurate as-built model in a highly competitive time frame and challenging congested systems.

Conclusion

It has been well proven that building information modelling, collaboration tools, and laser scanning dramatically improve the delivery of asset information models in such complicated healthcare projects as Ahl Masr Hospital. This will enhance facility management, maintenance, future extension, and renovation to allow better operation.

Building information management is the core of Orascom's construction towards a complete digital construction process and investment in technological solutions as a part of our integral continuous improvement policy.

IMPLEMENTATION OF BIM ON LARGE-SCALE MIXED-USE DEVELOPMENT

PRODESIGN

Figure 6: BIM Model of Telfair North Phrase 1

Telfair North Phase 1

Client: Oficea Company Ltd
Architects: SK Osmond Lange Limited, IYER cc, G+F Associated Ltd,
Structural Engineer: ARUP (Mauritius) Ltd
MEP consultants: Prodesign Engineering Consultants Ltd, Arup (Mauritius) Ltd
BIM manager: Prodesign Engineering Consultants Ltd
Main Contractor: General Construction Co Ltd

Introduction

Prodesign is an innovative firm of consulting engineers specializing in Mechanical, Electrical and Public Health (MEP) and Green Building Design, founded in 1997 in Mauritius. Prodesign has designed over 2,000,000ft² of office buildings, shopping malls, hotels, residences, and the largest hospitals in Mauritius. Prodesign strives to propose innovative services such as BIM, Augmented & Virtual Reality, IoT and AI for Construction. These innovative tools are essential enablers for the digital transformation of the industry while the concept of Construction 4.0 is gradually beginning to impose itself in the African region.

About the project

The Telfair North Phase 1 project consists of four Nos multi-storey office blocks with an interconnected super basement parking within the Telfair precinct as part of Mauritius's Moka Smart City development. The project sits on a 12,000 m^2 basement car park, with a total built area of 37,708 m^2.

The new office blocks aim to provide a controlled and harmonious office environment to cater for the demand of companies willing to rent or relocate their offices to the smart city.

Drivers

The client wanted office blocks that fulfilled the functional needs; include a variety of suitably sized office spaces, be retail-friendly, and consider accessibility and through flow. The aim was to create a practical and maintainable building constructed with low-maintenance materials. Another key requirement for the project was sustainability through achieving LEED Silver rating certification, which would increase its attractiveness to potential clients while adhering to the smart city's guidelines. The brief to the BIM manager was to ensure the design was fully coordinated before construction and to update the BIM model until final delivery to their Operations and Maintenance team.

"Prodesign strives to propose innovation services such as BIM, Augumented Reality, Virtual Reality, Internet of Things and Artificial Intellegence for construction."

BIM USES

Prodesign Engineering Consultants, as BIM managers, recognised the importance of collaboratively working on this project and advised the client to adopt the Building Information Modeling (BIM) process. A BIM Execution Plan (BEP) was developed at project onset in line with BS 19650. The client objectives were translated into the BIM uses described below:

i. Cost-effective and timely delivery of design information.
ii. Integrated coordinated services information.
iii. Optimisation of the design process and avoidance of duplicated effort.
iv. Identification and resolution of clashes prior to construction.
v. Provision of an As-Built BIM model, linked to an asset register for Operations and Maintenance.

How we overcame BIM challenges?

1. BIM interoperability

The design teams used ArchiCAD and Revit as the model authoring software to produce their relevant BIM models. The multiple software implies that native files could not be shared due to each software vendor having a file format incompatible with the other software package.

An open BIM approach was adopted to facilitate effective data sharing between the project stakeholders, and all BIM models were converted into the neutral format IFC 2x3 schema. The adoption of IFC ensured information sharing, collaboration, integration, and effective communication between all parties since the project's onset.

2. Model size

The second challenge of this project was the management of the information containers from the various stakeholders to create the federated BIM model. The federation strategy adopted had to cater for the following:

a. Allow the different design teams to work on other parts of the models simultaneously.
b. Ease the transmission of information to other design teams/ contractors by reducing the sizes of the individual information containers.
c. Be practical for uploading and downloading information containers between the BIM authoring software and the Common Data Environment.

Due to the size of the project, the federated model was broken into 30 easily managed models and adhered to the above requirements.

BIM IMPLEMENTATION/PLANNING

The following were adopted to meet the BIM uses outlined for the project.

1. Cost-effective and timely delivery of design information

Due to the frequency of exchanges and the amount of data shared and to comply with BS 19650, a Common Data Environment (CDE) was established. BIMsync was chosen since it is an Open BIM platform supporting all IFC types while being in coherence with the practices of the project stakeholders. The platform allowed a single source of truth for all information containers while providing controlled access to documents and models. Automatic versioning of documents and models ensures that the latest information is available to anyone at any time.

Additionally, approval of drawings and materials was being done directly on the platform, which provides better transparency.

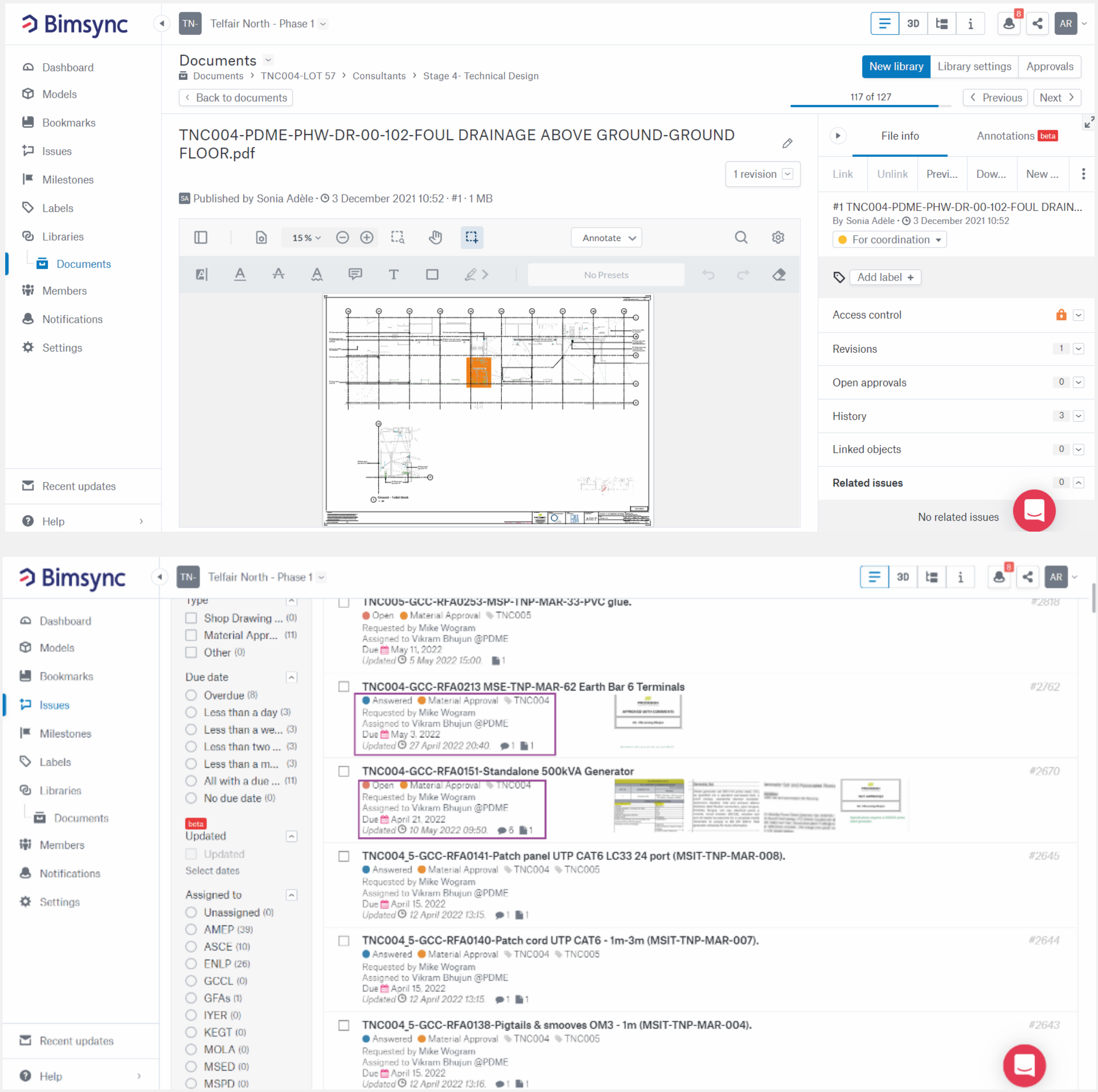


Figure 7: Common Data Environment adopted for Telfair North

2. Integrated coordinated services information/Design Optimization

A federated model of the project was adopted throughout the design phase. The model allowed for seamless coordination between the various MEP systems while considering the architectural or structural constraints.

The federated model also promoted a better understanding of the design intent across disciplines and heightened transparency among the stakeholders across the project lifecycle.

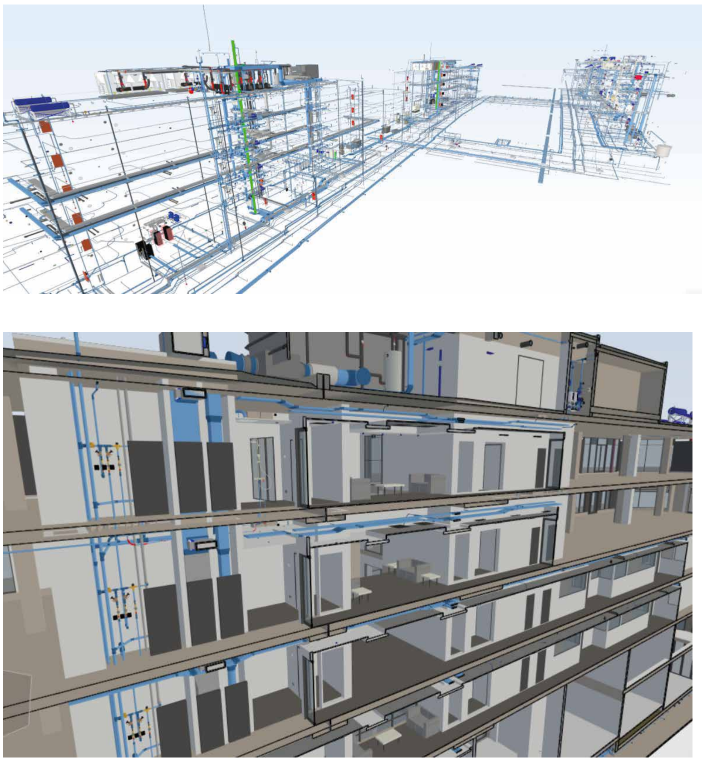


Figure 8: Federated BIM Model with MEP systems

3. Identification and resolution of clashes before construction.

The visibility provided by integrating multiple models into a single platform allowed for visual clashes to be easily identified. Solibri was used as the clash detection software to automatically create issues based on a set of rules defined in the BIM execution plan.

All issues raised by the BIM manager were synchronised on BIMsync (as BCF format), assigned to relevant project members with a due date and tracked. These issues were discussed during coordination meetings for effective resolution.

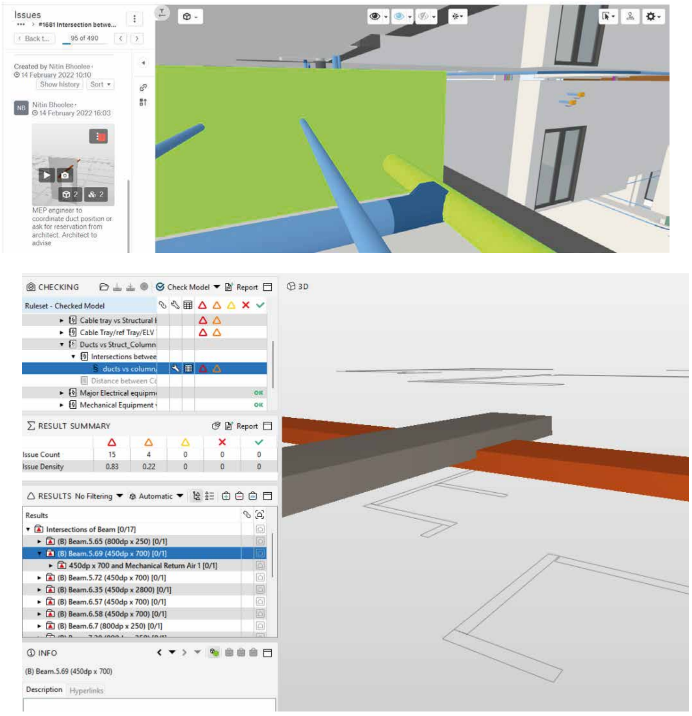


Figure 9: Clash detection to aid effective resolution

4. Provision of an As-Built BIM model, linked to an asset register for Operations and Maintenance

The project is currently in the construction stage. The consultants' models are available to the contractors on BIMsync. The federated model serves as the basis for all project documentation and gives the contractors a better understanding of the design intent.

Per the BEP plan, the main contractor is currently preparing MEP shop models up to LOD 500, from which shop drawings shall be extracted for approval by the relevant consultant. The modelled elements shall also possess custom performance and asset parameters which shall be filled in together with the specifications per the Material approval request (MAR) sheets. These parameters have been selected carefully to help in the O&M phase of the project.

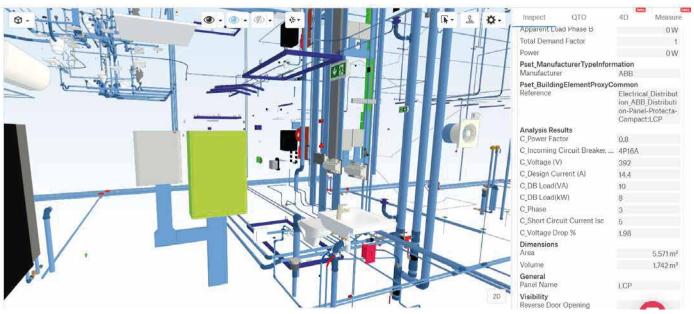


Figure 10: Federated BIM for Operations and Maintenance

Construction is currently in full swing, and we all look forward to seeing the project come to fruition.

Deena El-Mahdy

Assistant Professor at the British University in Egypt, Egypt.

3D PRINTING IN CONSTRUCTION IS MORE THAN JUST WALLS

Are we ready to compete for our construction techniques with 3DP?

With the crisis resulting from global warming, the dramatic increase in population growth calls for new housing and construction. More than 60% of the high energy and carbon emissions from construction sectors are affecting the climate condition. With the integration of BIM and HBIM in construction, the need for automation and digitalization started to increase rapidly to overcome the limitation of the traditional techniques. Thus, we need to ask ourselves, are we ready to compete for our construction techniques with 3D printing?

Vernacular architecture has been found throughout history all over the world. Communities use earthen materials that are locally available on the site using several building and construction techniques. Clay has been spread widely where people generate their homes by themselves, which is basically considered architecture without an architect. In Africa, many cases can be seen using the available material there. For instance, one of the oldest mosques, the Great Mosque of Djenne in Mali, New Gourna in Luxor, Egypt, Shali fortress in Siwa Oasis in the western desert of Egypt, Ghadames in Libya, and Ksar Aït Benhaddou in Morocco, etc.

The potential of earthen materials and construction techniques such as; rammed earth that relays on ramming earth between formwork [1], Karshief that is based on deposing salt and clay in a form of small balls and putting them layer by layer [2], [3], Adobe that depends on using sun-dried bricks to dry the bricks[1], and wattle and daub, etc. With all these examples, some limitations can be found such as durability regardless of the use of clay and mud, where buildings need maintenance after every rainy season. Accordingly, such sustainable materials are replaced with concrete and fired bricks that are more durable and can reach high spans despite the high energy and carbon emissions they release.

The 3D printed construction industry is changing so fast. The rapid increase in industry 4.0 encourages the use of automation and digitalization in construction. Many additive manufacturing (AM) such as 3D printing (3DP) started to be integrated to overcome the limitations of the traditional techniques. Some advantages can be seen using those fabrication tools through reducing the number of materials used, doing dangerous tasks, and requiring a lot of time and effort. Another feature of 3DP can be seen regarding the form complexity it can reach compared to the traditional techniques without any formwork, which reduces the waste materials and increases the time of the construction.

For structure optimization, based on the calculations resulting from the simulation, 3DP can only print the parts that need reinforcement without the need to print the whole thickness which is not needed. Plastering and finishes are one of the costly items in building construction, yet, in 3DP, no finishes are needed which reduces the cost.

In addition, 3DP can reach zero waste material by reducing the transportation during printing on-site. 3DP can be implemented on-site or off-site through prefabrication modular units and then assembled on-site.

The sustainability of the 3DP can be seen either in material consideration or in the printing process. For instance, several projects are using concrete for its durability to face harsh climatic conditions and its water resistance. Although the high energy and carbon emissions the concrete generates, 3DP offers a good example for material and structural optimization where it extrudes materials on the needed parts only. 3DP can seem all sustainable from the energy and carbon emissions it reduces, yet, there are some aspects regarding using a heavy machine like the printer, a pump, and a generator to make all these tools work.
3DP can be either done on-site or off-site depending on the flexibility of the printer and the scale of the projects. For instance, small modular units can be printed off-site, or even modular walls, then transported to the site. While some cases depend on printing directly on-site. If the material from the site is not suitable for printing, additives can be added to the mixture to enhance its printability.

However, many 3DP projects are depending on the earthen materials from the site, such as the TECLA house in Italy, where they used mud directly on the site. WASP crane was used in this project with earth from the site. Another project we constructed as a team of researchers under the supervision of (the Institute for Advanced Architecture of Catalonia) IAAC in Barcelona in February 2022 as shown in (Fig.1). The project was part of the 3DPA program output, which is considered the first in Spain and fourth in the world that 3DP earthen material on-site. The project collaborators are Colette, 3D Wasp, UN-Habitat, Humanitarian scenarios, and Smartcitizen. Unlike other projects, it was built based on environmental, structural, and thermal performance studies.

Future considerations and predictions for 3D printing in construction should consider the social aspect

Many challenges were faced during printing on-site regardless of the climatic condition where temperature and humidity kept changing dramatically during the day and noon. This differentiation results from some cracks during the drying and shrinkage process.

Yet, the challenges that could face printing on-site from the available materials there, that material tests should be done to reach good extrusion and flowability with taking into consideration the mechanical behavior of the printed layers. Another challenge of printing on-site is that it needs to consider the changes in the climatic conditions which would have a great impact on the flowability of the materials if the changes happened in temperature and humidity. Printing off-site allows a stable extrusion system providing the same climati conditions for all the printed modular units that fit the behavior of the material and are then transported back and assembled to the site as the work by Luai Kurdi, founder and CEO of tPRINT 4D as shown in (Fig.2).

Figure 11: The 3DP earthen unit in Spain, at IAAC, 3DPA Program 21/22, Photo by Deena El-Mahdy, 2022

Figure 12: The 3D concrete printing modular walls, by, Luai Kurdi, 2019.

For the technical aspect of 3DP, there are 3 main systems used in construction: 1) gantry system, 2) robot arm, 3) Delta Wasp. In some cases, it is hard to move the robot out of specific climatic conditions, however, some projects as Gramazio and Kohler group worked on the fabrication of a robot that can be transported in a unit on-site to be able to use it directly [4] [5]. Both gantry systems and Delta Wasps can reach wide spans and can easily print on-site.

The materials through the extrusion should be able to extrude out of the nozzle, flowable with a suitable ratio of water content, and printable where the layers can hold each other while keeping their shape. The water content is critical when it exceeds the amount in the mixture, as during the drying process, some shrinkage would happen and cause cracking in the wall if it is not treated with other admixtures to reduce the shrinkage.

Future considerations and predictions for 3D printing in construction should consider the social aspect, as it is not about replacing physical labor with machines, but developing their skills and experiences on how to use such techniques.
A study of the life cycle assessment is needed to assess this technique ‘by taking into consideration:

The material testing phase

Examine the material behavior due to location and environmental-climate conditions, as temperature and humidity play an important role in the consistency of the flow from the extrusion.
Testing the soil on the site is needed to check the ingredient's quality and if any additives, fibers, or aggregates are needed.

The design and evaluation phase

Geometry optimization for reducing the materials needed, and the tool path for the form.
Structural analysis test for form assessment
Calculate the maximum angle in case of any cantilever during printing which will affect the opening direction.

The construction phase

Manage the maximum number of layers per day to test if they are able to hold each other while keeping their shapes.
Observe the climatic condition during printing on-site to control the speed, extrusion, and pressure in relation to the material flowability.
Monitor the 3DP construction to observe any cracking during the drying and shrinkage process.

References

1. Dabaieh, M., Heinonen, J., El-Mahdy, D., & Hassan, D. M. (2020) A comparative study of life cycle carbon emissions and embodied energy between sun-dried bricks and fired clay bricks, Journal of Cleaner Production, 275.

2. Rovero, L., Tonietti, U., Fratini, F., & Rescic, S. (2009) The salt architecture in Siwa oasis - Egypt (XII-XX centuries), Construction and Building Materials, 23 (7), pp. 2492–2503.

3. El-Mahdy, D., Gabr, H. S., & Abdelmohsen, S. (2021) SaltBlock as a 3D printed sustainable construction material in hot arid climates, Journal of Building Engineering, 43.

4.Gramazio, F. (2007) R-O-B- Mobile Fabrication Unit, Gramazio Kohler Research, ETH Zurich. https://gramaziokohler.arch.ethz.ch/web/e/projekte/135.html (accessed June. 04, 2022).

5. Helm, V., Ercan, S., Gramazio, F., & Kohler, M. (2012) In-Situ Robotic Construction: Extending the Digital Fabrication Chain in Architecture, in ACADIA: Synthetic Digital Ecologies, pp. 169–176.

PARCELLE O CASANEARSHORE CASABLANCA
First 100% BIM project in Morocco

Continuum
YOUR BIM PARTNER

Figure 13 : BIM Model of Parcel O Casanearshore - Credits : Continuum BIM

Team Leader BIM Management Team: M. Ayoub Loutry

Team Leader Marketing & BD Team: Mrs. Lobna Bouanani El Idrissi

Parcelle O is the most recent development of the Casanearshore Park, the largest offshore park in North Africa located in the city of Casablanca. The office complex, composed of 4 buildings covering an area of approximately 49,900m², is the first project in Morocco developed entirely with BIM from design to its current execution phase. Birthed from the desire of the project owner EWANE Assets, a subsidiary of the MEDZ Group, these office buildings are also the first project in Morocco to be triple certified HQE, BBCA and Ready to Osmoz. The Continuum BIM team is the BIM Manager of this project.

Building Information Modeling (BIM) policy defines the processes necessary for the collaboration of the project contributors.

1. BIM at the Design Stage

After establishing the Building Information Modeling (BIM) policy that defines the processes necessary for the collaboration of the project contributors, a process for monitoring the different disciplines was put in place for the project. Through this process, the various project contributors each modeled the materials and elements of the design to create BIM models. Cabinet NMK is the architectural firm responsible for the architectural BIM models according to the architectural design approved by EWANE Assets. NOVEC Engineering office designed and modeled the Structural, Mechanical, Electrical, Plumbing, and Firefighting components of the building to create the Structural and Mechanical, Electrical, and Plumbing (MEP) BIM models of the building. Throughout the project, the management and coordination team from SAVE Project oversaw the managing and communication between the various contributors and professionals on the job. In this phase of the project, The BIM management team was able to document and track all changes to the various models through constant filings within Autodesk Docs. This platform allowed for tracking of all changes on the models and daily verification between the different project contributors.

During the design process, the BIM Management team established verification reports of the models by checking the coding requirements (verification of metric codes, project parameters, project's structure, verification of families) and the modeling requirements (composition of walls and layers within each wall, building block breakdown). Thanks to this BIM model, ADDENDA office was able to carry out thermal simulations of the buildings to obtain the environmental certifications.

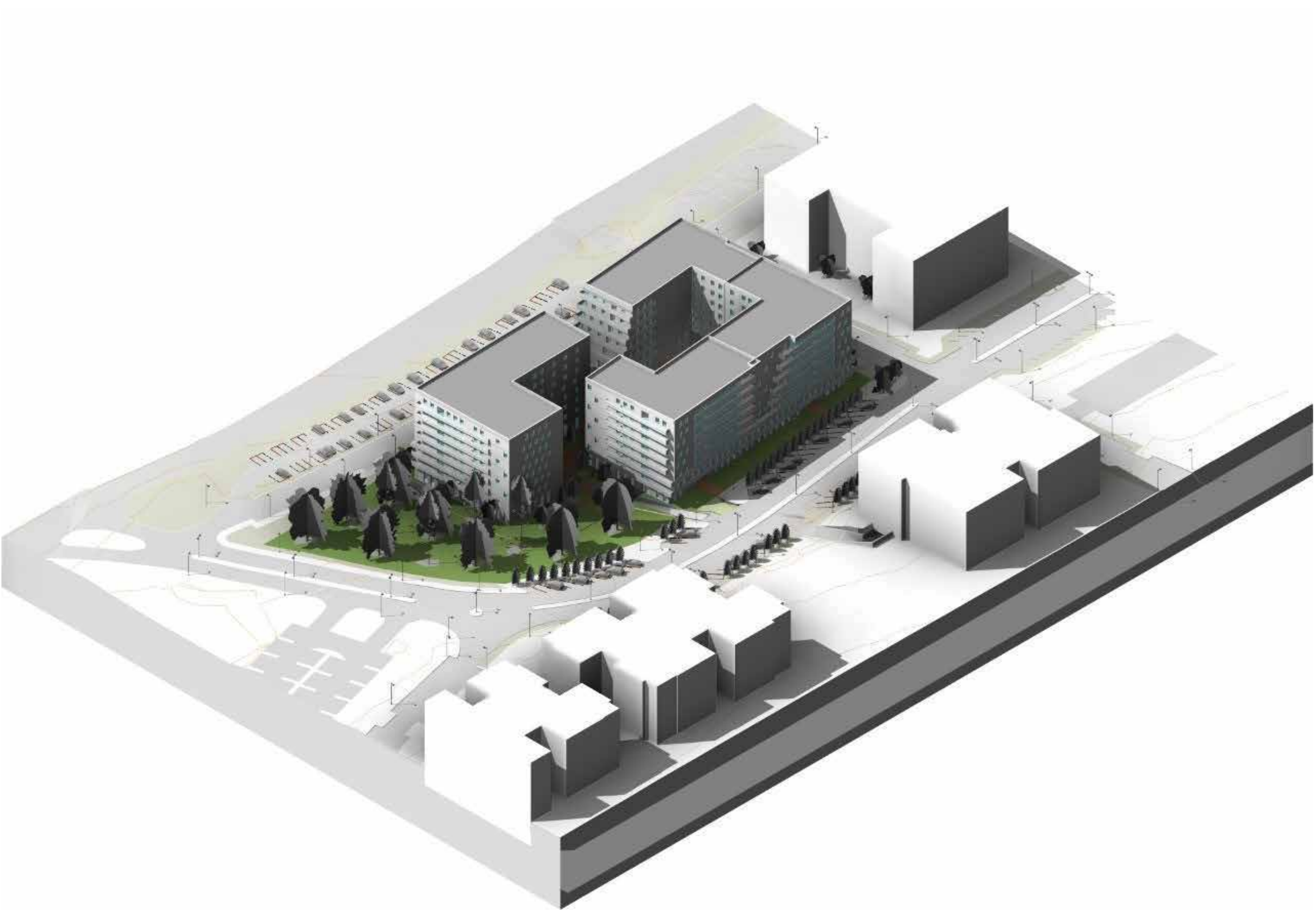


Figure 14: BIM Model on layout

2. BIM Coordination - BIM Synthesis

After the validation and verification of the different models received from the Architectural Firm and the Engineering Office, several conflicts were identified either within the models or between one model and another.
Through a process created internally by Continuum BIM based on Autodesk Navisworks and Autodesk Dynamo software, the various clashes defined in the BIM convention led to more than 537 groups of conflicts detected. This in-house process identifies clashes between models and communicates them to the contributors responsible for the creation of each model.

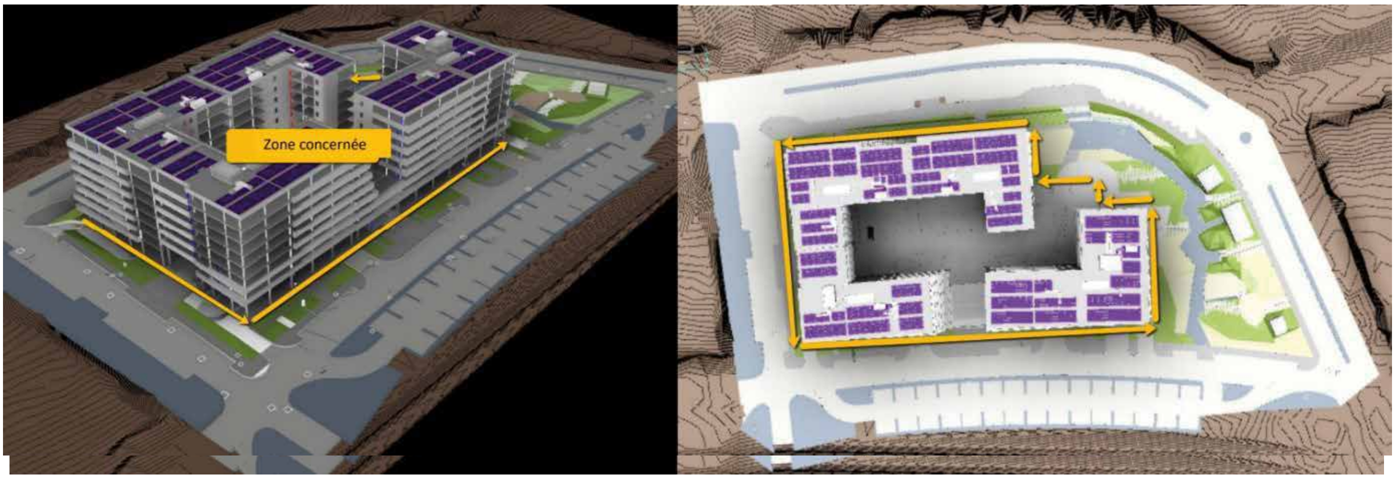


Figure 15 : Clash Detection Zone Limitation - Credits : Continuum BIM

Several meetings were organised between the different contributors under the supervision of the BIM Manager to resolve the clashes in question without creating new ones. The intervention of the BIM Manager in this step was essential to ensure that new clashes are avoided, and the model was adequately within the defined BIM conventions.

Throughout the process, all changes to the models were uploaded to the Autodesk Collaborate Pro platform. A notification is automatically sent to the relevant teams to view the changes and the impact such changes have on their models.

The Clash Detection process took about 2 months of continuous work by the different teams and in four clash detection rounds. After each round, coordination meetings were held. The teams model the solutions approved in the meeting, which leads to the next rounds. At the end of the 4th round, the clashes were 99.2% solved. The remaining 0.8% were clashes related to the form of execution on site.
This clash detection process allowed to solve more than 500 clash groups that had to be solved with the classical method on the construction site, which would have induced more time and more costs compared to the 2 months spent resolving these clashes.

At the end of the 4th round, the clashes were 99.2% solved. The remaining 0.8% were clashes related to the form of execution on site.

3. Preparing the BIM Tender Consultation file of execution firms (Dossier de Consultation des Entreprises)

After the clash detection stage was completed, the architectural and engineering offices extracted the quantities from the various Coordinated BIM models. These quantities allowed the company to accurately quantify the investment needs of the project. This Quantity Take-Off (QTO) process was critical in this project due to the specificity and usage of different types of materials on the same objects. Pumice bricks, Raw Earth and Concrete Blocks were all used to make up certain objects. For example, the walls supporting the sanitary facilities (the lower part of the walls is made of concrete blocks and the upper part is made of raw earth). The QTO process avoided any confusion and gave the exact quantities of the project.

After this process, a BIM consultation file was created for the project. This file contained the BIM specifications, the BIM mock-ups of the project in a Navisworks Document (NWD) format and the contents of the classic consultation files, i.e.,plans, schedules, and special specifications (CPS). At the launch of the tender, all contractors who submitted bids were invited to a general presentation of the project being the first project in Morocco where the BIM is to be used throughout the project. The presentation outlined the several project peculiarities such as the use of District Cooling technique and specific materials. The project management team under the aegis of the Ewane Assets team and the coordination team, Save Project also presented and clarified all ambiguities.

The particularity of the BIM DCE (Dossier de Consultation des Entreprises) also appears in the conditions of site management. The team introduced Autodesk BUILD solution as the basic solution to manage the construction site and required all the companies on the project to use it. The Parcel O CNS is the first BIM project in Morocco managed entirely in the Cloud.

4. BIM during Project execution and site management

Following the launch of the project, the Continuum team conducted a training on the use of the Autodesk Build solution for all project contributors. The Save Project team reinforced the use of the BIM platform by no longer accepting email exchanges between teams. The BIM platform was the hub for all types of documents, PVs, problem discussions and more.

In parallel, the execution studies were launched. Updates were made on the BIM DCE model according to the optimizations made. The BIM Referent of the execution company realizes BIM pre-synthesis of the updated models. After finalizing the pre-syntheses, the BIM Manager of the project launches the rounds of BIM syntheses between the models according to several rounds. To monitor and follow the project execution process, the Coordination team, Save Project, created a 4D schedule to visualize and follow the progress of the site.

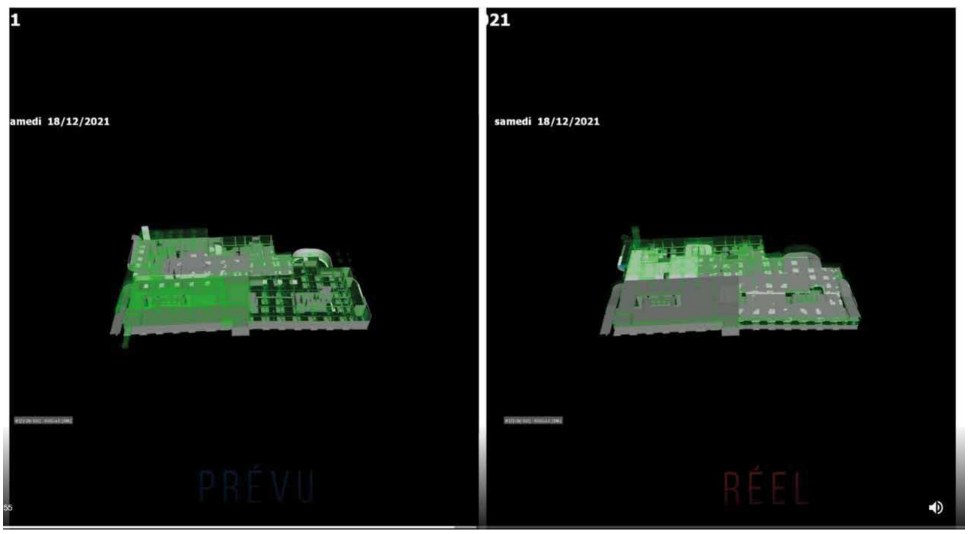


Figure 16 : 4D simulation - Actual progress vs Planned progress - Credits: Continuum BIM

To manage the construction site in an optimal way, electronic tablets/pad were made available to the various project stakeholders to use the PlanGrid or Dalux platforms and detect discrepancies directly.

However, since the project is a pilot project in Morocco, some changes on the pathways may occur due to the lack of adaptation of workers and subcontractors to the BIM process. For this reason, a decision to reframe communication was taken.

From now on, any change requires the validation of the BIM Referent and the modification of the models.

To remedy any type of subsequent constraints and changes, SCAN To BIM of the Parcel is performed during construction by the Continuum BIM team before closing the ducts and ceilings, not only to resolve any changes and have an as-built model but also to evaluate the performance of the companies in the reattachment phase vis-à-vis the construction of a work such as the BIM Model.

Figure 17 : BIM Model vs Execution - Credits : Continuum BIM

5. Future Objectives

The future objective of the current BIM process is the delivery of an As-Built BIM Model which will integrate the geometric aspect as executed, the partitioning, MEP path, equipment data sheets, BMS data, materials, and families.

The main objective for deploying BIM in this project was to create a Digital Twin of Parcel O. The Digital Twin will allow the operational management of the building based on a Facility Management solution connected to all the building installations including: the deployed BMS, surveillance cameras, installed IoT sensors and others. The FM solution will integrate the coding of the equipment and materials and the ticketing of the panels. The integration of the FM solution will be more fluid since the project has adopted BIM from the design stage.

Being an office development, the BIM models of the different spaces to be rented in Parcel O will be made available to the tenants. Any changes in the facilities of the leased spaces will have to be validated by the Facility Management team and integrated into the BIM models. Tenants will have as-built BIM models of their office space to manage their space.

The Digital Twin will allow for the daily monitoring of the status of each of the building's equipment and installations, providing for preventive and planned maintenance operations. It will also allow monitoring of energy consumption levels and intelligent space management.

"The main objective for deploying BIM in this project was to create a Digital Twin of Parcel O."

AFRICA BIM SURVEY (ABS) 2022: FINDINGS

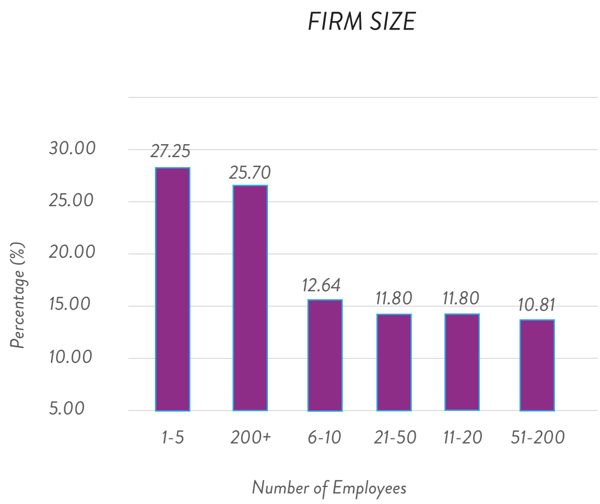
Sequel to the first continental-wide survey in 2020, the BIM Africa Research and Development Committee embarked on the African BIM Survey (ABS) in 2022 to assess the BIM status after two years. The ABS recorded over 1,100 entries from professionals in all five African regions during the data collection period (March – June 2022), representing a significant turnout compared to the ABS 2020 during the COVID-19 pandemic outbreak.

The survey was made available in English, French and Arabic to cater for Africa's most prevalent official languages. In a bid to improve the data collection process, a regional data collection approach was employed against the central data collection adopted in 2020. Evidently, this approach improved the response rate and distribution of the responses across the regions.

We thank the regional partners, organisations, communities, and professional bodies that shared the African BIM Survey 2022 with their user base and all the survey respondents. We hope that the findings of this research will contribute to the discussion on BIM and digital construction in the African Built Environment.

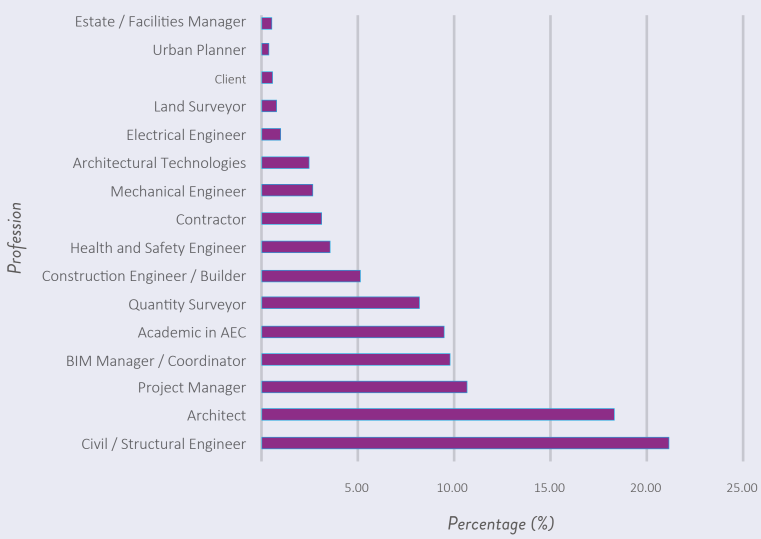
1. About your Organisation - Including yourself, approximately how many people are employed in your organisation?

To understand the demographic distribution of the respondents, the survey assessed the number of employees in the respondents' firms. More than 25% of the respondents are from firms with less than five employees, and about a similar percentage are from firms with over 200 employees. Taken together, about 75% of the respondents are employed with Small and Medium Sized Enterprises (SMEs) having less than 200 employees. This resonates with the distribution of firms in the Construction Industry, where SMEs often account for more than 90% of the industry.



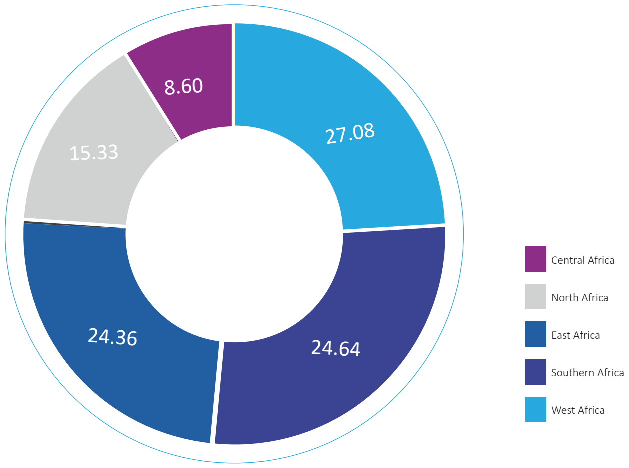
2. What is your main profession?

Most respondents are Civil/Structural Engineers, Architects, Project Managers and BIM Managers/Coordinators. Also, there are responses from a variety of other professionals in the built environment. These respondents are professionals involved in the planning, design, construction, operation, and maintenance phase of the projects. This shows that the survey respondents are from diverse backgrounds and reflect inclusive participation of most professions.



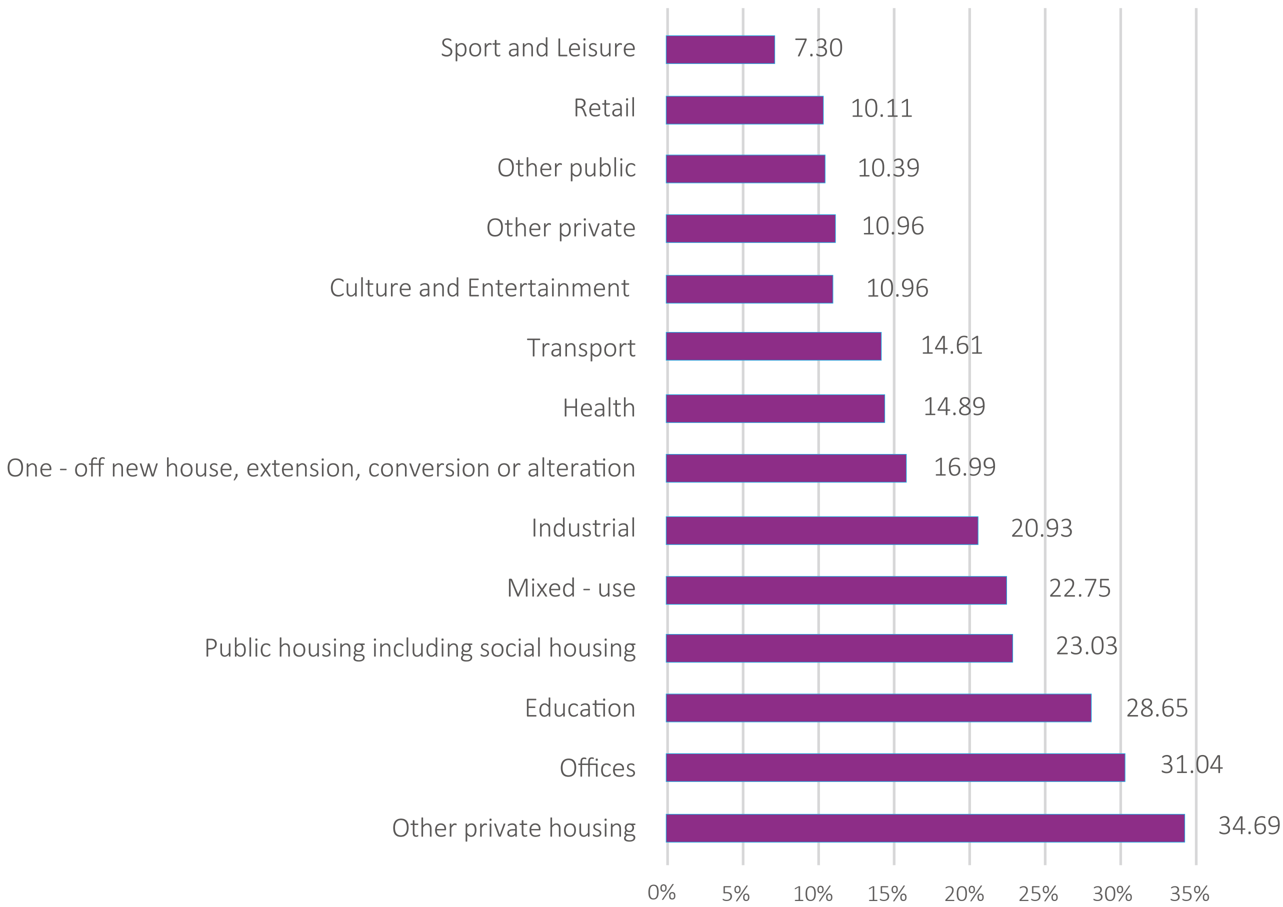
3. Location

The respondents were from 39 countries across all five regions in Africa. Southern, Western, and Eastern African regions each represent between 24 – 27% and account for 76% of the total responses. This indicates that the sub-Saharan Africa region, coupled with Central Africa, accounts for about 85% and the remaining 15% from Northern Africa. The respondents are from six countries in Southern Africa (top 3 are South Africa, Zimbabwe, and Botswana), 11 countries in West Africa (top 3 are Nigeria, Ghana and the Benin Republic), and 11 countries in East Africa (Ethiopia, Kenya, and Tanzania). Seven countries from North Africa (top 3 are Egypt, Algeria and Morocco), and four countries from Central Africa (Cameroon, Democratic Republic of the Congo, Angola, and Central African Republic). Compared with ABS 2020, this current survey reflects more evenly distributed responses across all regions.



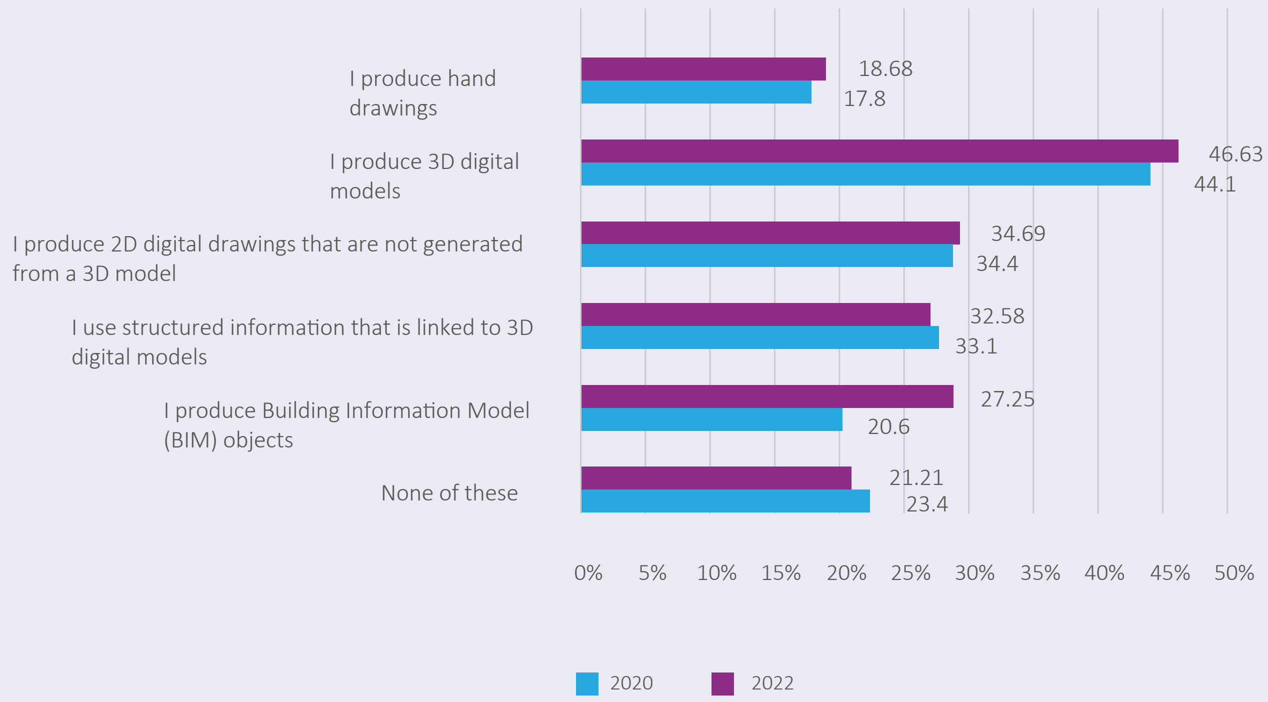
4. In the last twelve months, which of the following construction project types have you been involved in?

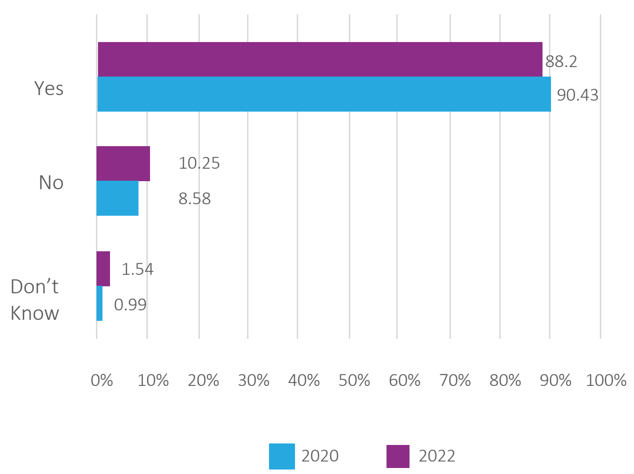
The survey inquired about the projects the respondents have been involved in over the last twelve months to evaluate the nature of their practice. About 35% were involved in other private housing, 31% in offices, and about 29% in Education related projects. Although, this distribution of the nature of practice is in tandem with the ABR 2020 except for One-off new house, extension, conversion, or alteration projects that dropped from the most reported project in 2020 to 7th in 2022. Thus, the ABR 2022 witnessed more participation from firms involved in private housing than in 2020.



5. Which of the following statements apply to you?

We enquired about the working practice of the respondents to gain insights into the modus of Operandi of the firms in the African Construction Industry. In the ABS 2022, about 47% of the respondents produced 3D digital models, and 27% produced BIM objects. However, about 19% are still involved in producing hand drawings, and 35% produce 2D models that are not generated from 3D models.
Notably, these practices are not mutually exclusive, as firms producing BIM objects could still be involved in the manual production of drawings. Compared to ABS 2020, more respondents produce BIM objects and 3D models. However, about the same proportion of the respondents (33%) use structured information linked to 3D models. This could reflect improvement in the working practice of African firms towards using intelligent and information-rich models.



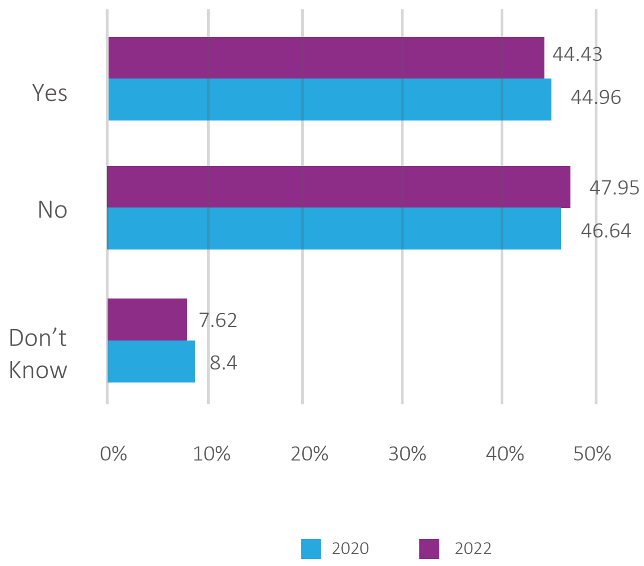


6. Before taking this survey, had you ever heard of BIM (Building Information Modelling)?

The level of awareness of BIM across Africa has been high over the last couple of years as a result of the concerted effort of stakeholders, and BIM becoming a buzzword in the industry. About 88% of the respondents had heard about BIM prior to taking the survey, compared to 90% in 2020. This depict a high level of awareness of the respondent. However, does awareness translate to BIM adoption and implementation?

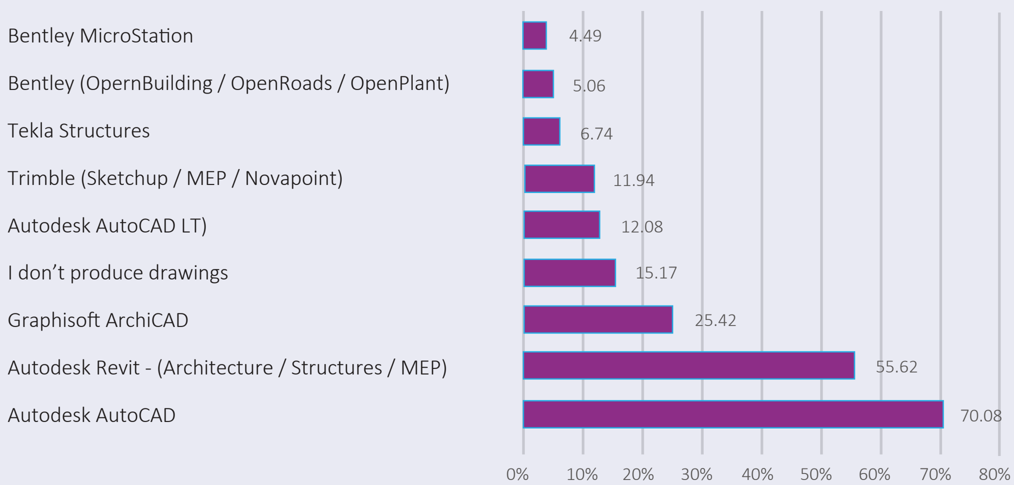
7. Within your organisation, have you adopted BIM for projects you have been involved with?

To answer the previous question on the relationship of awareness to BIM adoption, we asked if the respondents have adopted BIM on projects in which they have been involved. About 44% have adopted BIM, whilst about 47% have not adopted BIM in 2022. Compared with the ABS 2020, this represents the same implementation level on projects after two years. It is also noteworthy that the 44% that have adopted BIM for projects did so at varying level of implementation. However, the BIM level or degree of implementation was not assessed. Also, the same proportion that had adopted BIM in 2020 are most likely doing so in 2022 at an advanced level based on their experience over the years. In addition, there has been an improved understanding of BIM in Africa over the last two years, implying that the firms that reported BIM adoption in 2022 are 'doing' BIM and not mere 'modelling' rampant in previous years.



8. Which of these tools have you used for your designs or projects?

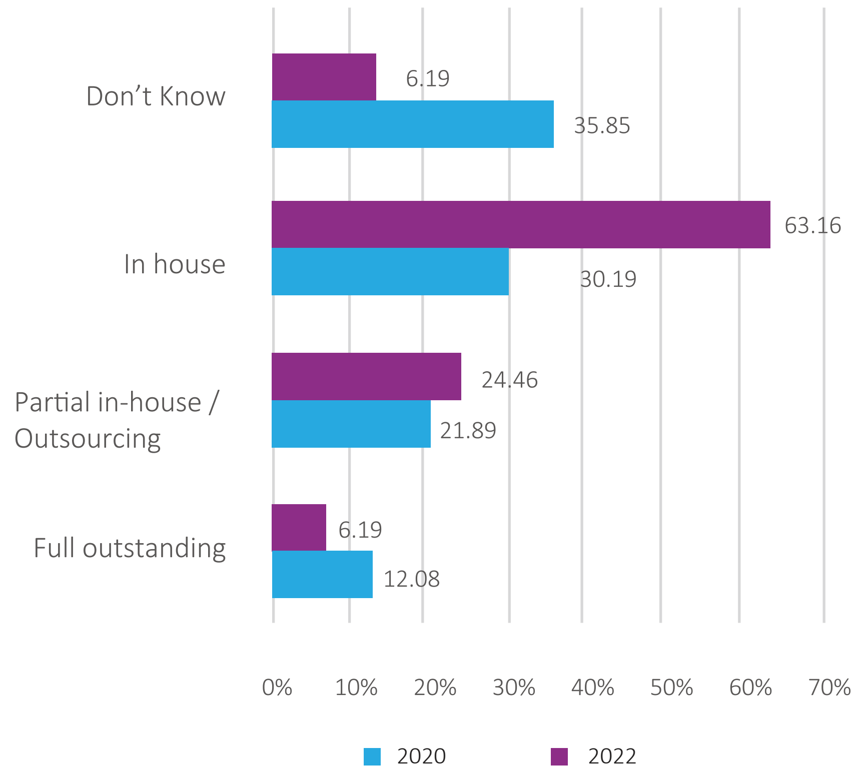
The tools employed for design in practice were assessed, and 70% reported Autodesk AutoCAD, followed by Autodesk Revit (about 56%) and Graphisoft ArchiCAD (25%).



The ranking of these tools is fairly similar to the ABS 2020 findings. However, there is an increase in the proportion of respondents that reported using these tools for design in 2022.

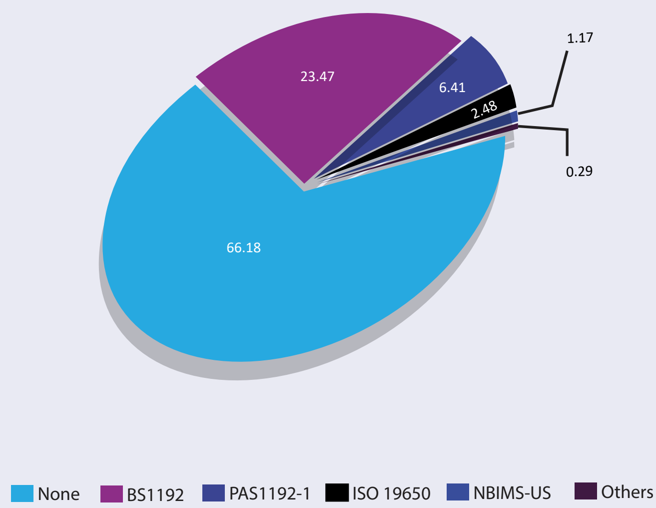
9. How does your firm implement BIM?

About 63% of the respondents are implementing BIM in-house compared to 30% in 2020, corroborating the assertion of improved knowledge about BIM. Most importantly, 94% of the respondents are aware of the mode of BIM implementation in their firm, compared to 64% in 2020. This validates our position that those who adopted BIM in 2020 are now implementing it at an advanced level.



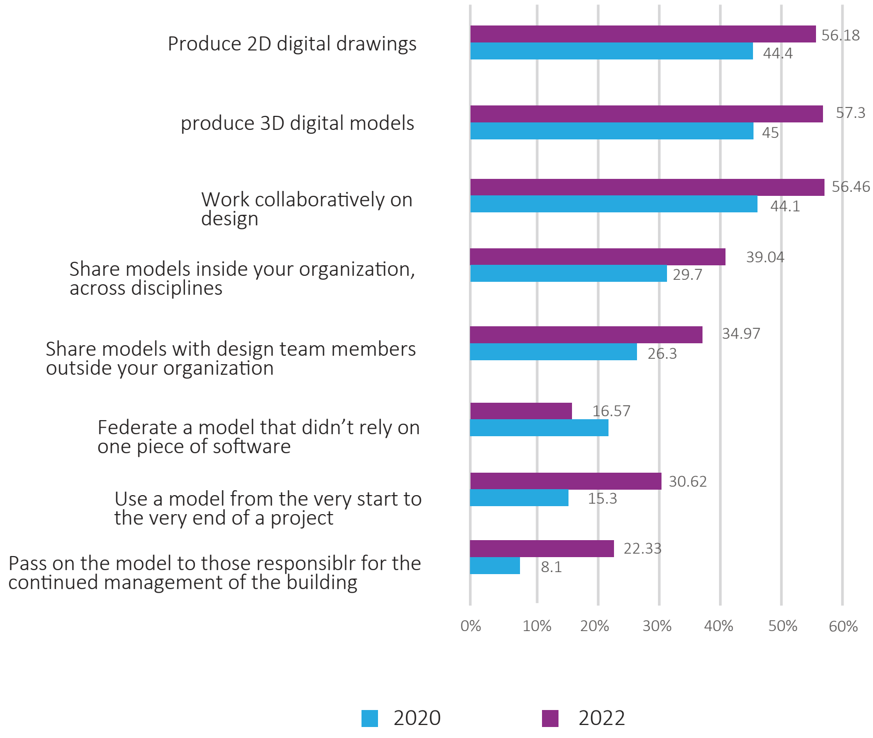
10. What BIM standards have you adopted or utilised?

As the level of adoption is still low, 66% of the respondents do not use any BIM standard, which could be related to a lack of BIM usage in their firm. 23% of the firms utilised BS 1192, and 6% reported using PAS 1192. 2.48% utilised ISO 19650, and 1% of the respondents adopted NBIMs-US. Although BS 1192 and PAS 1192 have given way to ISO 19650 since 2019, many respondents are still using BS 1192 and PAS 1192, which could be because of the perceived complexities in ISO 19650 in a bid to make it a generic standard. Also, the distribution of the responses could be related to the stronger link between the African Construction industry, and Europe compared to the US/North America.



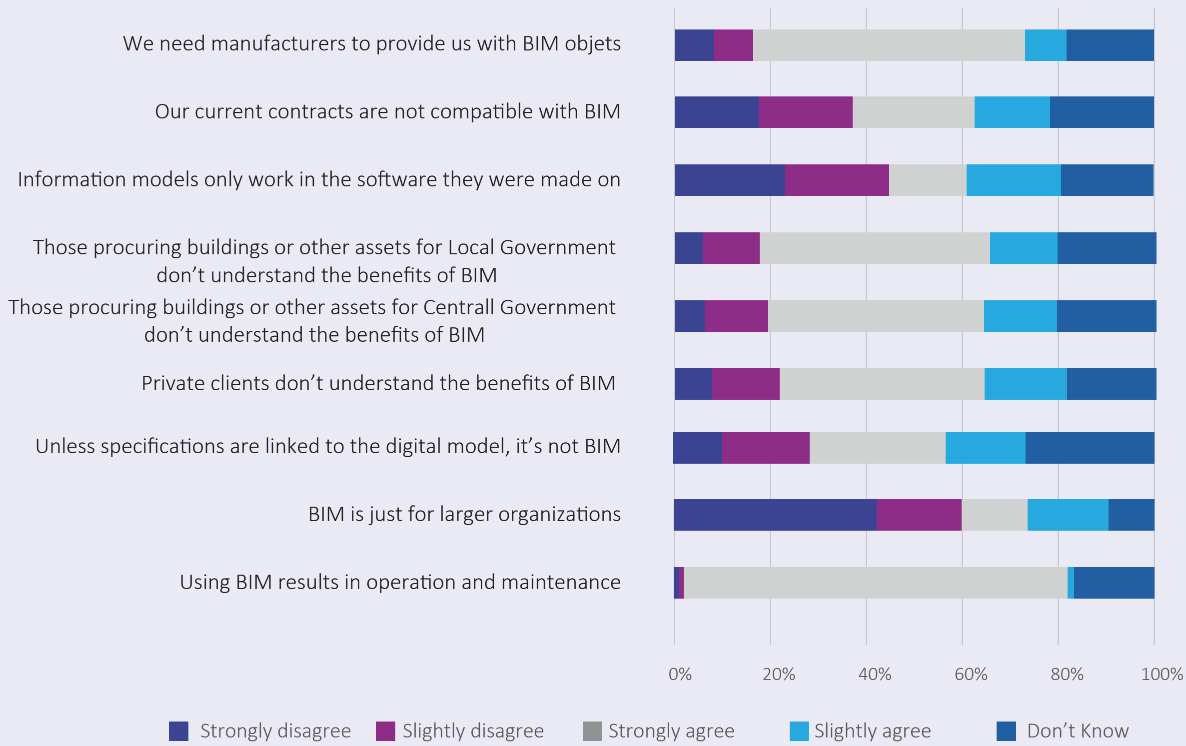
11. From your experience of the projects you were involved in over the last 12 months, did you ever…?

More than half of the respondents produce 2D digital drawings, 3D digital models and work collaboratively on design. Although, a similar proportion that produces 2D digital drawings also produces 3D digital models because of the non-mutual exclusiveness of the option. More respondents now share models across disciplines with the design team outside their organisation and use a model from start to end of the project compared to 2020. This reflects a growing trend towards collaborative design in Africa, albeit slowly. Interestingly, about 22% pass the model to those responsible for the management of the building to leverage the benefits of BIM in the operation and maintenance of the project.



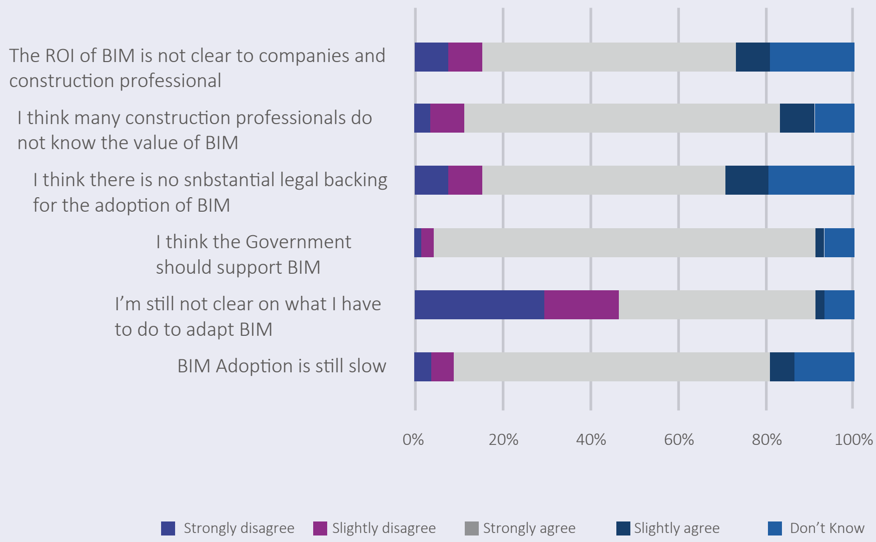
12. How strongly do you agree or disagree with the following statements about BIM?

With the high level of awareness and growing adoption in the African Architecture, Engineering and Construction (AEC) Industry, it is important to examine the industry's perception of BIM. About 79% of the respondent strongly agreed that BIM is beneficial in the operation and maintenance phase of the project, even though most of the models employed during the design and construction phase are often not used during this phase. Thus, stymying the impact of BIM in this phase. Interestingly, the perception of BIM's suitability for only large firms is waning as about 60% disagreed that BIM is just for larger organisations compared to 50% in 2020. However, there is still a lack of support from stakeholders such as governments, clients, and manufacturers in the industry, as most respondents believe these stakeholders do not understand BIM and its benefits.

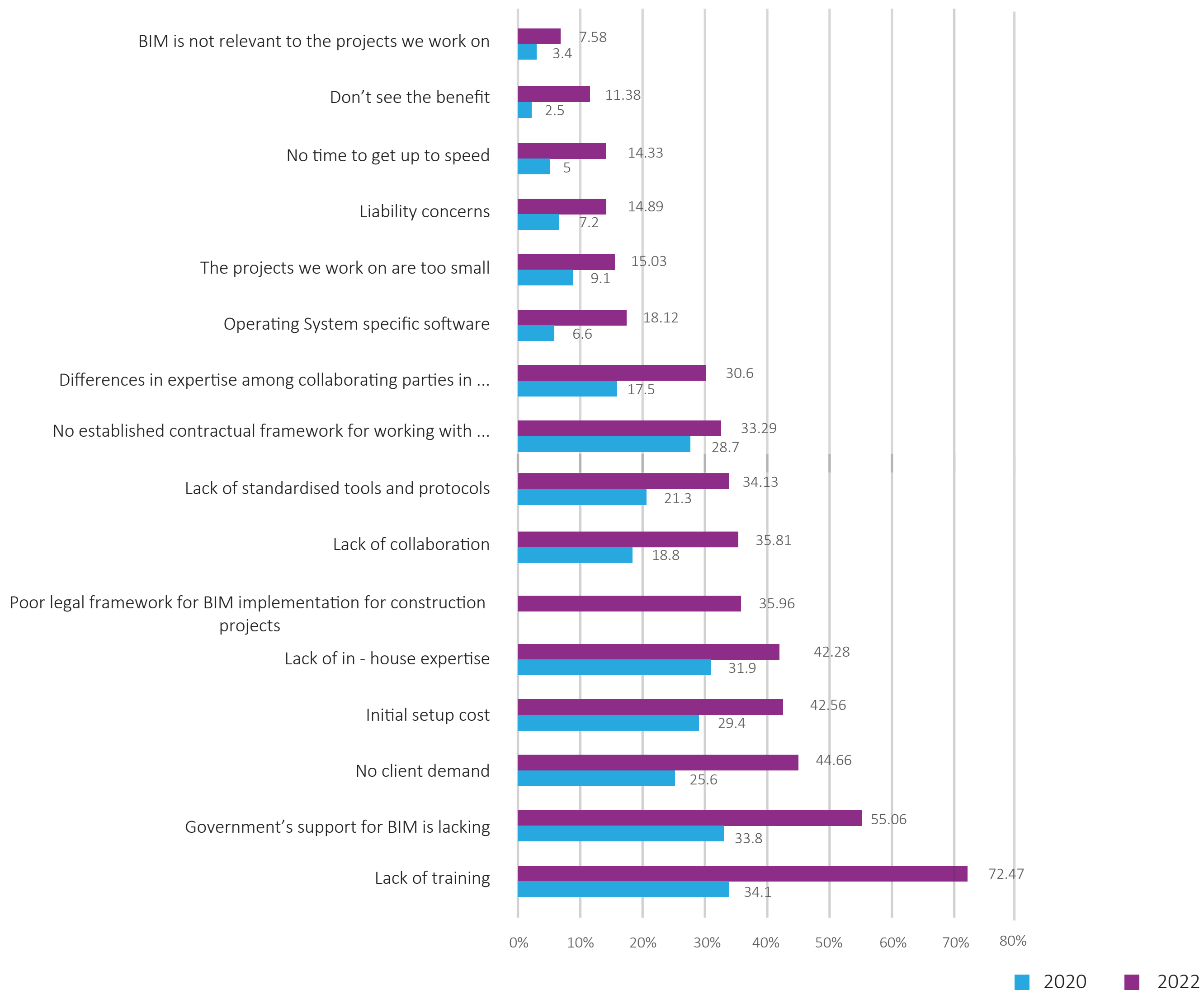


13. How strongly do you agree or disagree with the following statements about BIM?

Furthermore, about 77% of the respondents corroborated that the adoption of BIM is still slow. However, this represents an improvement from 90% in 2020. Also, there is still a perception of a lack of knowledge in the industry by professionals and construction firms.



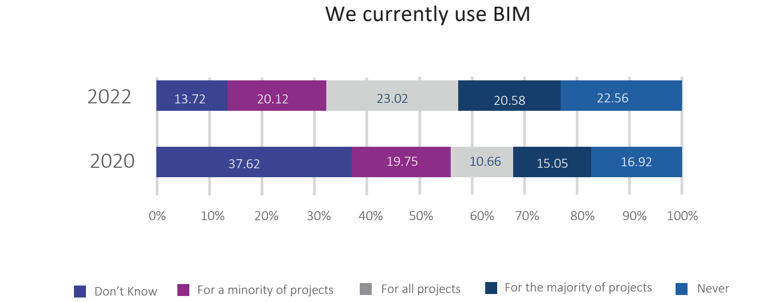
14. What do you think are the main barriers to using BIM?



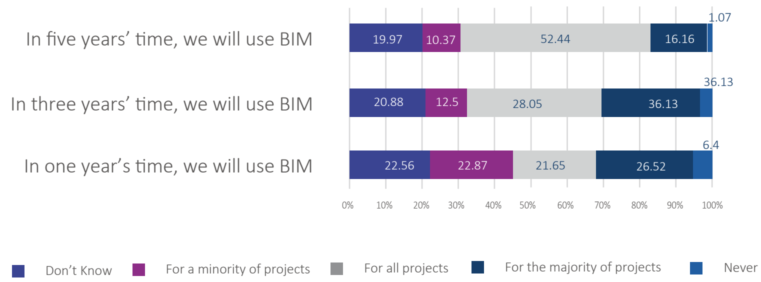
With the perceived high awareness of BIM in the industry, we enquired about the challenges impeding widespread BIM adoption. The top barriers are lack of training, lack of government support, no client demand, initial cost, and lack of in-house expertise. These barriers have been consistently reported in the industry, and there have been efforts by the stakeholders to tackle them. For instance, BIM Africa launched the Student Advocacy program to equip students from selected institutions across Africa with BIM knowledge and skills. Introducing new curricula and programs such as the Integrated Engineering Design Management (IEDM), and Africa Sustainable Infrastructure Mobility (ASIM) among others in Africa, are also long-term solutions to the lack of training and expertise. However, overcoming the challenges of government support and client demand requires further efforts by the stakeholders in the African built environment to engage the regulatory bodies. Thus, the current challenges facing the African built environment impede widespread adoption of BIM and the top-down approach.

15. How would you describe your organisation's future use of BIM?

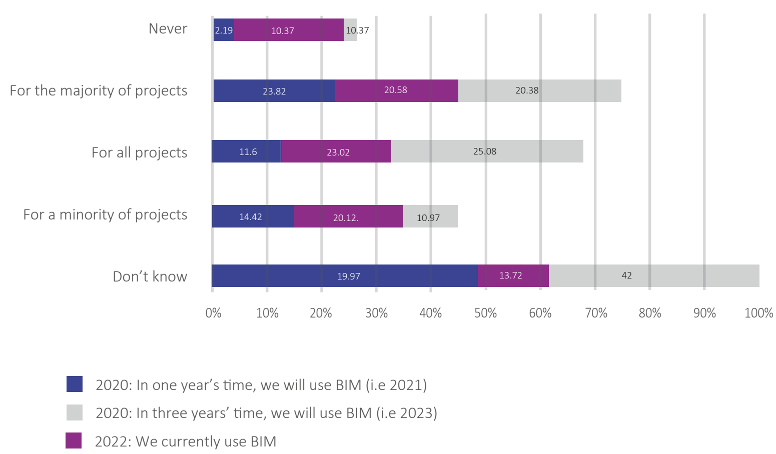
Although BIM has been implemented in some firms, only 23% employed BIM for all projects, compared to about 11% in 2020. Also, about 64% of the respondents have implemented BIM either for all projects, the majority, or the minority of their project, compared to 45% in 2020. Similarly, this reflects the increased awareness level as only 36% does not know or have never implemented BIM compared to 55% in 2020.



Projecting into the future, the respondents were asked about the prospect of using BIM in the next one year, three years and five years. Interestingly, more firms hope to implement BIM in the coming years, and the projection reaches about 79% in 2027. However, would all these firms projecting BIM use end up using BIM? Thus, we compare the projection in 2020 with the status quo in 2022.

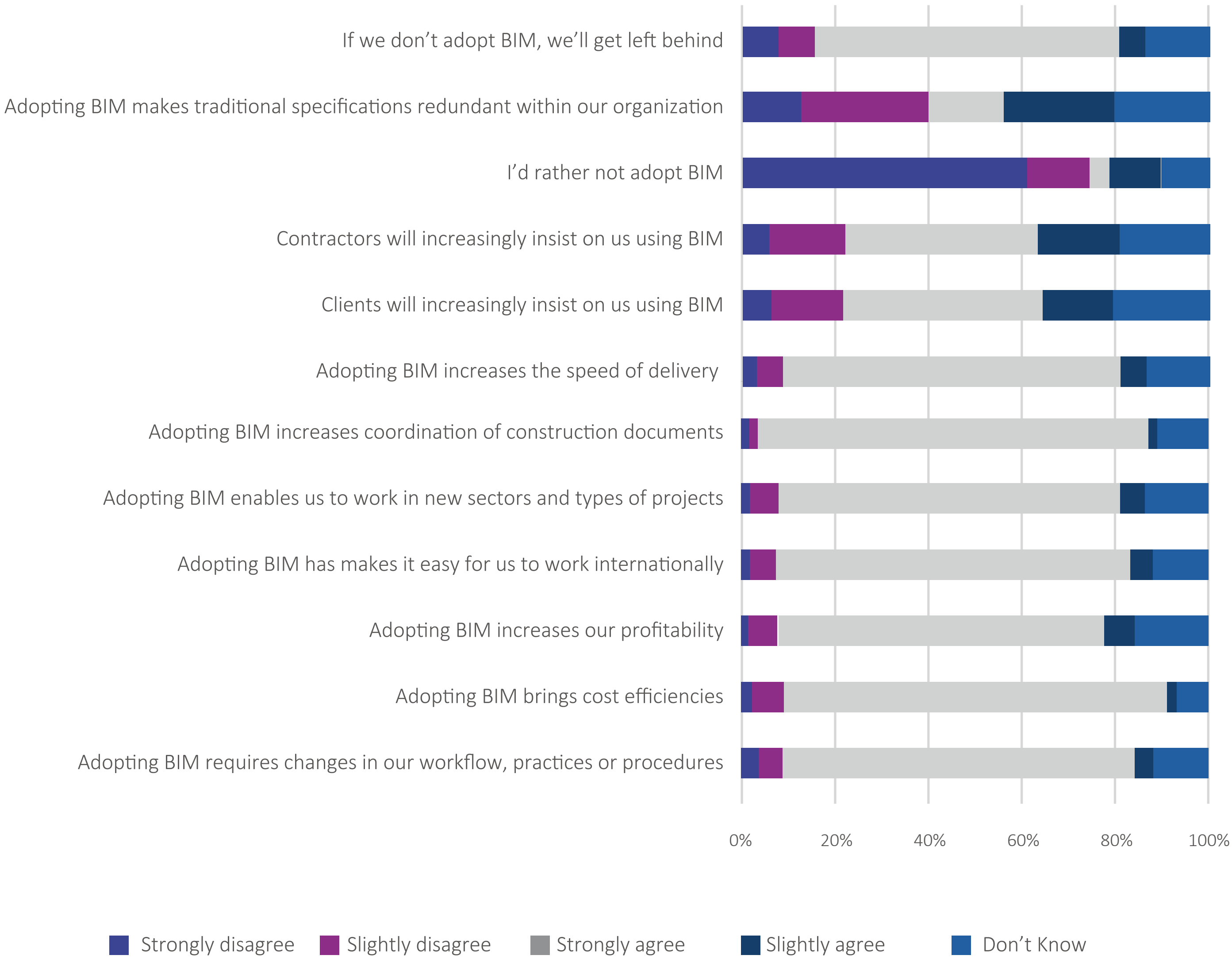


In 2020. about 12% and 25% of the respondents projected to use BIM for all projects by 2021 and 2023, respectively. This aligns with the 23% currently using BIM for all projects in 2022. Similarly, in 2020 about 24% and 20% of respondents projected to be using BIM for most projects by 2021 and 2023, respectively, whilst in 2022 about 21% reported to be currently using BIM for most projects. Thus, the projections made in 2020 have proven relatively accurate regarding the future BIM outlook. It is hoped that the forecast for the next five years will come to fruition. However, efforts are required to overcome the industry challenges.



16. From your experience or understanding of using BIM, how strongly do you agree or disagree with the following statements?

With the growing adoption of BIM in the African built environment, we examined the perception of the respondents as regards BIM in their work practice. Most respondents concur with the need to be BIM compliant. They agree that adopting BIM would lead to improved project delivery in the industry. Similarly, about 81% agree that BIM requires changes to workflow, which could serve as a bottleneck in an industry with a culture of resistance to change. Interestingly, the respondents hold the opinion that there would be an increased demand for BIM from clients and contractors.



What is the future of BIM and digital construction in Africa?

Lastly, the respodents expressed their opinion about the future of BIM and digital construction in Africa. The opinions of the respondents reflect a positive outlook for the African AEC, however, efforts are required to record significant progress on the continent.

BIM adoption is slow and there is need for a bottom top push:

"Because Africa is seemingly slow to get on the train regarding construction processes, I still see BIM taking another year or two for a substantial adoption. At a time when other economies are talking about digital twins, we are still in the BIM adoption discussion. A legal angle may speed up adoption."

"There's no doubt that the future is digital. The pace and extent to which it will be adopted will depend on demonstrable value to clients, consultants and the industry (pull factors) rather than legislative push. It's hard enough enforcing basic building regulations."

"The African AEC industry needs to adopt contracts that encourage the adoption of BIM during the project lifecycle. Project managers should advise clients on the benefits of such new technologies."

"It will be massive if more public and private stakeholders adopt and implement it in their projects. It is going to revolutionise how projects will be delivered for built environments. There is huge room for growth."

BIM is beneficial but there is need to address the bottlenecks:

"One hindrance to BIM can be software versions and interoperability issues. Many people use old versions that hinder collaborations and coordination."

"The future of BIM improves collaboration; it's about creating better workflows within the office. BIM can help construction companies improve planning, be able to offset clashes between disciplines, and increase the delivery time for each project."

"2D CAD is dead. People must also realise that BIM is not a 3D model or a piece of software. It is a process. One also needs to work with the end in mind and understand you are working with databases in visual form."

"The future of BIM and digital construction will be determined by the availability of BIM software on the African market. Right now, BIM software's are expensive and hard to purchase for most firms."

"Adopting BIM is the future. Governments will understand step by step that it's very beneficial for clients to use BIM in their projects. They will start implementing the legal framework and procedures to use in all projects."

"Africa will leapfrog to BIM the same way they leapfrog from "no phones" to mobile phones."

Mohamed Marzouk

Professor of Construction Engineering and Management, Structural Engineering Department, Faculty of Engineering, Cairo University, Giza, Egypt.

Kareem Adel

Lecturer Assistant, Construction and Building Engineering Department, College of Engineering and Technology, Arab Academy for Science Technology & Maritime Transport (AASTMT), Cairo, Egypt

DIGITAL TWIN AND DATA SCIENCE FOR OPERATION AND MAINTENANCE OF BUILT ASSETS

Nowadays, 4D and 5D BIM are intensively used at the pre-construction and construction stages, where all stakeholders engage and collaborate. However, these BIM models are considered decoupled or outdated and serve limited purposes after the projects' completion while neglecting future uses during the maintenance and operation stages (Boje et al., 2020). Digital Twin (DT) can afford a workable solution for this issue by providing useable up-to-current BIM models.

Digital Twin is a realistic digital representation of assets, processes, or systems mirroring their up-to-current properties, condition, and/or performance (Gürdür Broo et al., 2022; Lee et al., 2021). DT includes five main components; 1) physical asset, 2) virtual model (n-dimensional BIM models), 3) connections, 4) data, and 5) services. The physical asset is the base of the virtual model. The virtual model mirrors the physical asset in a controlled digital environment. Connections allow data collection, transfer, and feeding into virtual models. Services refer to DT functional applications such as simulation, decision making, and monitoring and control of physical assets using Data Science (DS) tools and techniques to enhance the asset's reliability, performance, or condition (Jiang et al., 2021).

DT can contribute to the built asset management in many useful use-cases in the maintenance and operation stages. These cases include but are not limited to detection, structural analysis/diagnosis, automatic control, and retrofitting. Regarding detection, DT can be employed for asset inspection and defect detection for heritage buildings, bridges, roads, and railways. This can be done by capturing geometric information using laser scanners, thermal imaging cameras, and IoT sensors, feeding this information into a digital model, and processing it to a usable form. Regarding the structural analysis/diagnosis, DT can produce 3D finite element models for simulation and mechanical performance evaluation of existing structures. For automatic control, DT can utilize data from virtual models to control and manage the physical asset in a timely manner using bidirectional systems similar to cyber-physical systems (CPS). This use case is mainly directed to energy consumption and ventilation management.

For retrofitting, DT can integrate geometric and non-geometric information to generate pre-retrofit models for existing buildings using 3D laser scanning and ground-penetrating radar (GPR).

These models afford a thorough understanding of buildings under renovation or reconstruction and assist in developing different related management plans (Jiang et al., 2021; Opoku et al., 2021).

DT can contribute to the built asset management in many useful use-cases in the maintenance and operation stages.

As referred earlier, Data Science (DS) tools and techniques are used and integrated into DT functional applications or services. Therefore, the effective integration between DT and DS necessitates defining DS and its stages. Data science (DS) is defined as "the scientific study or analysis of actual happenings with historical data using a set of scientific methodologies, and AI algorithms, processes, or systems" (Sarker, 2022). As shown in Figure 1, using DS in DT-based systems involves six major stages (Abdelrahman et al., 2021; Parimbelli et al., 2021), including:

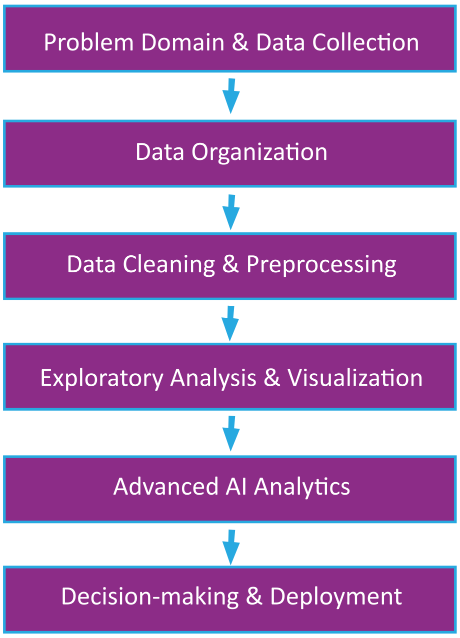


Figure 18: Sequential Stages of DS

Understanding problem domain and data collection:
This stage involves identifying DT services' potential variables, constraints, and outcomes. Based on this identification, the related data can be collected in raw form using data connections or from generated DT models.

Data Organization:
This stage involves organizing and structuring the data based on several factors such as data type, quantity, sufficiency, feature importance, and reporting metrics to support data-driven modelling.

Data cleaning and pre-processing:
This stage involves transforming the dataset into a comprehensible format by removing or fixing incorrect, corrupted, wrongly formatted, noisy, duplicate, mislabeled, or incomplete data that typically occur when combining data from multiple sources.

Exploratory data analysis and visualization:
It involves initially analyzing data using statistical and visualization methods in an unstructured manner to reveal initial trends, attributes, and points of interest and produce data summaries. This stage is essential to judge the data essence and provide a primary evaluation of its quality, quantity, and characteristics.

Advanced analytics using AI modelling:
This stage involves developing different sets of data-driven AI models to achieve the best fitting outcomes of the intended DT service. Furthermore, the performance of these models is evaluated using several validations and assessment metrics, including but not limited to accuracy, precision, error rate, recall, and applicability analysis.

Decision-making and deployment:
This is the final stage comprising the data product. A data product is a tool or system that utilizes DT data to assist individuals in making intelligent decisions regarding the service under consideration. This tool supports visualized predictive analytics, descriptive data modelling, data mining, and extraction while employing a friendly user interface for ease of use and deployment.

Over the past five years, DT technology back-ended with DS has gained considerable attention from the research community, which has led to an amounting growth in scientific literature. For instance, Zheng et al. (2022) introduced a digital twin-based method to simulate the buildings' performance during operation and maintenance. The method aims to indicate the defects and damage in critical regions of buildings that can cause building collapse. Liu et al. (2020) introduced a safety assessment framework to track the structural behaviour, status, and activity of prestressed steel structures throughout their life cycle using DT.

Based on this framework, a machine learning model was developed to predict and quantify the structures' safety risk level. Borjigin et al. (2022) employed the DT technology to assess the life cycle performance of precast advanced track light rail systems. The assessment was based on environmental and economic impacts while addressing energy consumption, CO2 emissions, and life-cycle-cost analysis. Seo and Yun (2022) introduced a DT-based framework for evaluating lighting energy savings in educational buildings while considering existing buildings' hardware, operational schedule, and a probabilistic model of occupant behaviour. The framework aims to help decision-makers determine the best-fit strategies for lighting energy-saving. Yu et al. (2021) introduced a DT-based decision analysis framework for tunnels' operation and maintenance

The framework relies on extended COBie standards for defining tunnel twin data, semantic web technologies for achieving data fusion, and a rule-based reasoning model for decision processing. Yu et al. (2020) introduced a performance prediction approach for highway tunnel pavement integrating DT technology and multiple time series stacking. DT was employed to afford dynamic up-to-current data about the pavement condition. At the same time, multiple time series stacking was utilized to provide real-time dynamic predictions about pavement performance. Liu et al. (2021) developed a novel framework for the structural health prediction of prestressed steel structures. The framework relies on a DT model that provides real-time information regarding the structures' operation and maintenance conditions. This information is further processed to predict structural health and provide a basis for early safety warnings.

Zhao et al. (2022) introduced a DT-based framework for evaluating ventilation systems in public toilets. This framework involved simulating the pollutants' diffusion using computational fluid dynamics and addressing the related energy consumption and indoor comfort. Hosamo et al. (2022) utilized DT, BIM, and Internet of things (IoT) and semantic technologies to propose a predictive maintenance framework for air handling units (AHU). The framework relied on three major modules for implementation:

1) operating AHU fault detection using APAR method,
2) predicting AHU condition using a machine learning model
3) maintenance planning.

Zhao et al. (2021) employed 3D laser scanning technology to develop an up-to-current existing building energy model. This model was utilized to evaluate the retrofitting schemes of existing buildings, improve their energy efficiency, and satisfy their energy demand. Lu et al. (2020) provided a DT-enabled anomaly detection system for monitoring built assets during operation and maintenance phases. The system allows effective data integration/search and facilitates decision-making and anomaly detection. A case study for pumps in the HVAC system was utilized to assess and highlight the effectiveness of the proposed system.

Despite the contributions of these studies, they experience some limitations. First, data collection and communication are confined to a centralized framework which is subjected to a high possibility of data losses or single-point failures. Second, data coordination and transfer for future uses are not guaranteed. Third, data traceability is not guaranteed due to constant overwriting. Fourth, the proposed operation mode is either cloud-based or client-server. Fifth, the operation involves intermediaries while providing partial or no control over sensitive data. Inspired by Industry 4.0, technologies such as Blockchain (BC) and Inter-Planetary File System (IPFS) can collectively afford a potential solution to better leverage the DT's benefits and overstep these limitations. Accordingly, developing a DT-based framework, system or approach is foreseen to comprise five layers, as shown in Figure 2.

Blockchain and IPFS technologies can be used to better leverage DT’s benefits and oversteps its limitations.

First, the data sensing layer includes IoT sensors attached to the physical asset components for real-time data collection. Second, the modelling layer includes a digital platform for developing up-to-current virtual models using collected data. Third, the data storage layer includes a permission BC network for storing textual/numeric data captured by IoT sensors and a private IPFS network for storing digital models developed by the processing layer. Fourth, the analytics layer includes AI algorithms for simultaneously processing the collected data and the developed up-to-current virtual models to serve a specific outcome. Fifth, the communication layer includes a friendly user interface utilized by relevant stakeholders to explore the maintained data or models in BC and IPFS networks and communicate their related analytics.

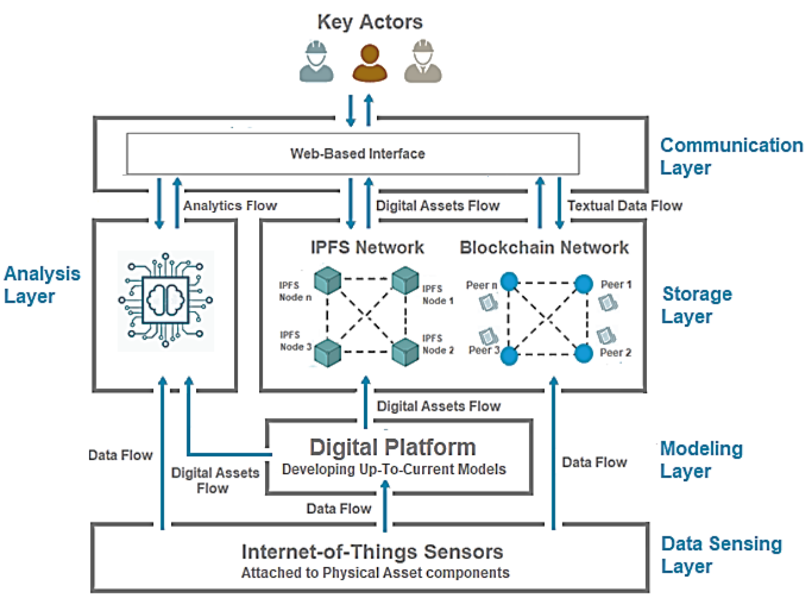


Figure 19: Layers of DT-based Framework

References

Abdelrahman, M. M., Zhan, S., Miller, C., & Chong, A. (2021). Data science for building energy efficiency: A comprehensive text-mining driven review of scientific literature. Energy and Buildings, 242, 110885. https://doi.org/10.1016/j.enbuild.2021.110885

Boje, C., Guerriero, A., Kubicki, S., & Rezgui, Y. (2020). Towards a semantic Construction Digital Twin: Directions for future research. Automation in Construction, 114, 103179. https://doi.org/10.1016/j.autcon.2020.103179

Borjigin, A. O., Sresakoolchai, J., Kaewunruen, S., & Hammond, J. (2022). Digital Twin Aided Sustainability Assessment of Modern Light Rail Infrastructures [Original Research]. Frontiers in Built Environment, 8. https://www.frontiersin.org/articles/10.3389/fbuil.2022.796388

Gürdür Broo, D., Bravo-Haro, M., & Schooling, J. (2022). Design and implementation of a smart infrastructure digital twin. Automation in Construction, 136, 104171. https://doi.org/10.1016/j.autcon.2022.104171

Hosamo, H. H., Svennevig, P. R., Svidt, K., Han, D., & Nielsen, H. K. (2022). A Digital Twin predictive maintenance framework of air handling units based on automatic fault detection and diagnostics. Energy and Buildings, 261, 111988. https://doi.org/10.1016/j.enbuild.2022.111988

Jiang, F., Ma, L., Broyd, T., & Chen, K. (2021). Digital twin and its implementations in the civil engineering sector. Automation in Construction, 130, 103838. https://doi.org/10.1016/j.autcon.2021.103838

Lee, D., Lee, S. H., Masoud, N., Krishnan, M. S., & Li, V. C. (2021). Integrated digital twin and blockchain framework to support accountable information sharing in construction projects. Automation in Construction, 127, 103688. https://doi.org/10.1016/j.autcon.2021.103688

Liu, Z., Bai, W., Du, X., Zhang, A., Xing, Z., & Jiang, A. (2020). Digital Twin-based Safety Evaluation of Prestressed Steel Structure. Advances in Civil Engineering, 2020, 8888876. https://doi.org/10.1155/2020/8888876

Liu, Z., Jiang, A., Zhang, A., Xing, Z., & Du, X. (2021). Intelligent Prediction Method for Operation and Maintenance Safety of Prestressed Steel Structure Based on Digital Twin Technology. Advances in Civil Engineering, 2021, 6640198. https://doi.org/10.1155/2021/6640198

Lu, Q., Xie, X., Parlikad, A. K., & Schooling, J. M. (2020). Digital twin-enabled anomaly detection for built asset monitoring in operation and maintenance. Automation in Construction, 118, 103277. https://doi.org/10.1016/j.autcon.2020.103277

Opoku, D.-G. J., Perera, S., Osei-Kyei, R., & Rashidi, M. (2021). Digital twin application in the construction industry: A literature review. Journal of Building Engineering, 40, 102726. https://doi.org/10.1016/j.jobe.2021.102726

Parimbelli, E., Wilk, S., Cornet, R., Sniatala, P., Sniatala, K., Glaser, S. L. C., Fraterman, I., Boekhout, A. H., Ottaviano, M., & Peleg, M. (2021). A review of AI and Data Science support for cancer management [Review]. Artificial Intelligence in Medicine, 117, Article 102111. https://doi.org/10.1016/j.artmed.2021.102111

Sarker, I. H. (2022). Smart City Data Science: Towards data-driven smart cities with open research issues. Internet of Things, 19, 100528. https://doi.org/10.1016/j.iot.2022.100528

Seo, H., & Yun, W.-S. (2022). Digital Twin-Based Assessment Framework for Energy Savings in University Classroom Lighting. Buildings, 12(5). https://doi.org/10.3390/buildings12050544

Yu, G., Wang, Y., Mao, Z., Hu, M., Sugumaran, V., & Wang, Y. K. (2021). A digital twin-based decision analysis framework for operation and maintenance of tunnels. Tunnelling and Underground Space Technology, 116, 104125. https://doi.org/10.1016/j.tust.2021.104125

Yu, G., Zhang, S., Hu, M., & Wang, Y. K. (2020). Prediction of Highway Tunnel Pavement Performance Based on Digital Twin and Multiple Time Series Stacking. Advances in Civil Engineering, 2020, 8824135. https://doi.org/10.1155/2020/8824135

Zhao, L., Zhang, H., Wang, Q., Sun, B., Liu, W., Qu, K., & Shen, X. (2022). Digital Twin Evaluation of Environment and Health of Public Toilet Ventilation Design Based on Building Information Modeling. Buildings, 12(4). https://doi.org/10.3390/buildings12040470

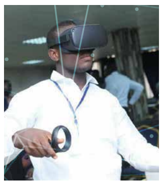
Zhao, L., Zhang, H., Wang, Q., & Wang, H. (2021). Digital-Twin-Based Evaluation of Nearly Zero-Energy Building for Existing Buildings Based on Scan-to-BIM. Advances in Civil Engineering, 2021, 6638897. https://doi.org/10.1155/2021/6638897

Zheng, Z., Liao, W., Lin, J., Zhou, Y., Zhang, C., & Lu, X. (2022). Digital Twin-Based Investigation of a Building Collapse Accident. Advances in Civil Engineering, 2022, 9568967. https://doi.org/10.1155/2022/9568967

"A unique platform to influence the digital transformation of the African built industry."

SUMMIT FORMAT

- Mind-boggling keynote presentations
- Insightful panel discussions
- Product and technology exhibitions
- BIM Africa Impact Report launching
- Project case study presentations
- Innovation Awards 2023 Dinner
- In-Person Networking and Engagement
- Project visit – Innovations in Morocco



DEPLOYING BIM FOR DEVELOPING BURUNDI REPUBLIC BANK HEADQUARTERS AMA GROUP

Figure 20 :Rendering of Burudi Republic Bank Headquarters

The Headquarters of the Burundi Republic Bank is a real estate construction project for banking use with an area of 24,000m² in Bujumbura, Republic of Burundi. Construction work is currently in progress. The project contains two basement levels and nine Ground floors, with a footprint of 8540m² and a capacity of 1,800 people. The Building Façades are composed of on glazed façade and a perforated external panel (in Aluzinc) enveloping the building, distanced by 2m from the glazed facade.

Figure 21: Approach view of the building

The scope of the project for AMA Group is design, procurement and construction of the building, finishing works, and all the MEP building services. The project contractor was also required to ensure the maintenance of the building for two years after the completion of construction works.

One of the project challenges was that the engineering, procurement and BIM teams are located at the AMA Group Head office in Tunis, Tunisia. Also, some equipment and construction materials needed to be procured and transported to the project site in Bujumbura from Tunis or European countries. To avoid critical project impact, the time for any expedition must be less than two months.

Considering that the project is located in a country without a sea border, and almost all materials will be imported, it is critical to monitor prompt material procurement according to the project schedule. The procurement team need to optimise the number of containers, fill every container to its maximum capacity, and select an appropriate grouping of compatible goods to be shipped in the same container.

BIM Implementation.

Very few organisations in Tunisia and Burundi specialize in BIM implementation to support stakeholders in implementing project processes. AMA Group led in this aspect and deployed BIM in the project execution of the Headquarters of the Burundi Republic Bank.

Training challenges

Training on software is largely available worldwide, but we had to face challenges in transforming BIM modellers' habits to have them respect BIM templates, codifications, EIR, and BEP constraints within a short time.

BIM Management platform

We choose the Plannerly platform to manage BIM model production. The platform permits collaborative BEP writing and approval, with library content that can be used. We also created object scope with interactive tools and prepared the planning for all the teams by discipline. The platform is linked with a 3D model shared on Autodesk BIM360. We can verify object properties and check modelisation progress.

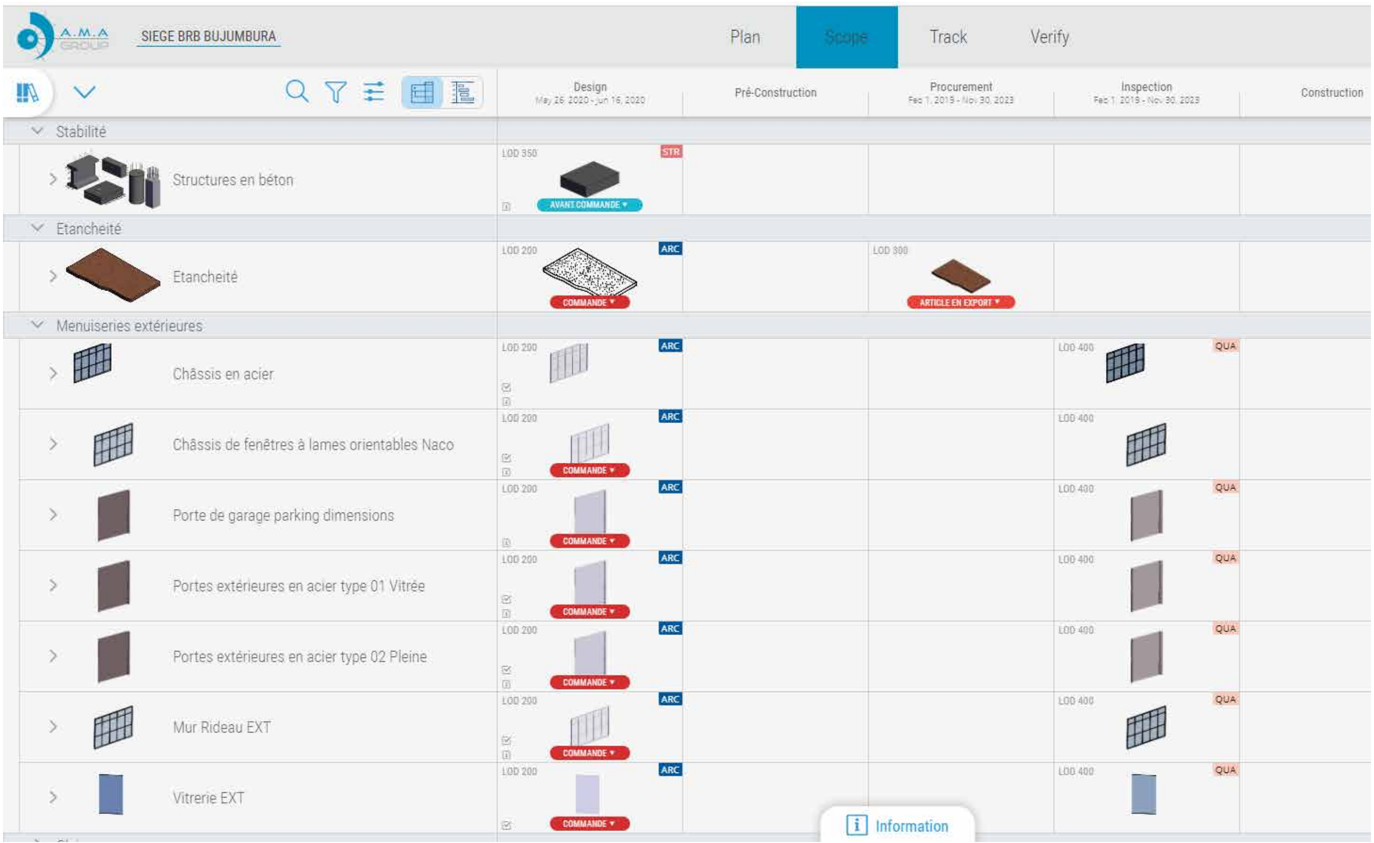


Figure 22: Creating scope objects on plannerly.

Common Data Environment

The Common Data Environment (CDE) is used to collect, manage and share models, non-graphical data and all documentation. We adopted BIM 360 Autodesk Construction Cloud solution as the CDE for the project to share the project model amongst all project team members, facilitate collaboration and avoid duplication and errors.

The CDE folders were structured respecting the ISO 19 650 prescriptions. The main exchange folders are: Work In progress, Shared, Published, and Archived.

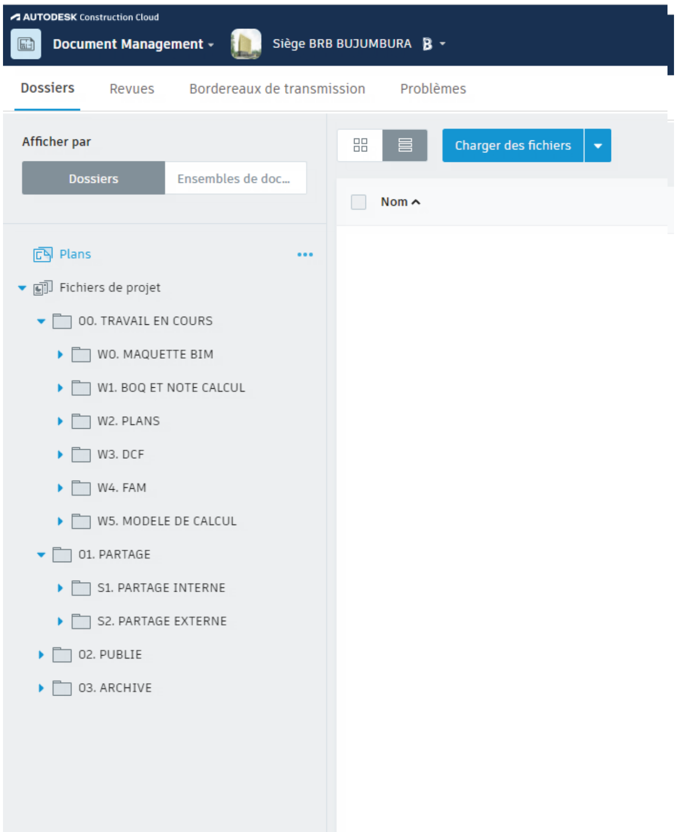


Figure 23: "BIM 360 CDE" folders organization

With the ACC (Autodesk Construction Cloud), the design collaboration permits sharing of the central model between engineering and construction teams. The ACC Model Coordination enabled the BIM coordinator to do the clash test detection and transmit all issues, on BIM 360, to concerned persons to make corrections on their models.
To track the closure of issues created on BIM 360, we shared a tracking table of its problems daily.

> "Very few organisations in Tunisia and Burundi specialize in BIM implementation to support stakeholders in implementing project pricesses."

BIM MATURITY AND USES:

The BIM Maturity for this project is Level 2. To achieve the contractor objectives, the BIM management team decided to deploy these BIM Use processes for the project:

DESIGN AUTHORING:

The process in which 3D software is used to develop a Building Information Model based on criteria that are important to the building design development.

CLASH DETECTION:

A process in which clash detection software is used during the coordination process to determine field conflicts by comparing 3D models of building systems. The goal of clash detection is to eliminate significant system conflicts before installation.

QUANTITY TAKE-OFF AND COST ESTIMATION:

A process in which the BIM can be used to generate an accurate quantity take-off and cost estimate early in the design process and provide cost effects of additions and modifications with the potential to save time and money and avoid budget overruns.

PHASE PLANNING:

A process in which BIM is utilized to effectively plan the construction sequence and space requirements on a building site. 4D modelling is a powerful visualization and communication tool that can give a project team, including the owner, a better understanding of project milestones and construction plans.

ASSET MANAGEMENT:

Mainly to do 3D coordination of all the trades, extract accurate quantities and manage the maintenance of the MEP equipment via a COBIE- Coswin workflow.

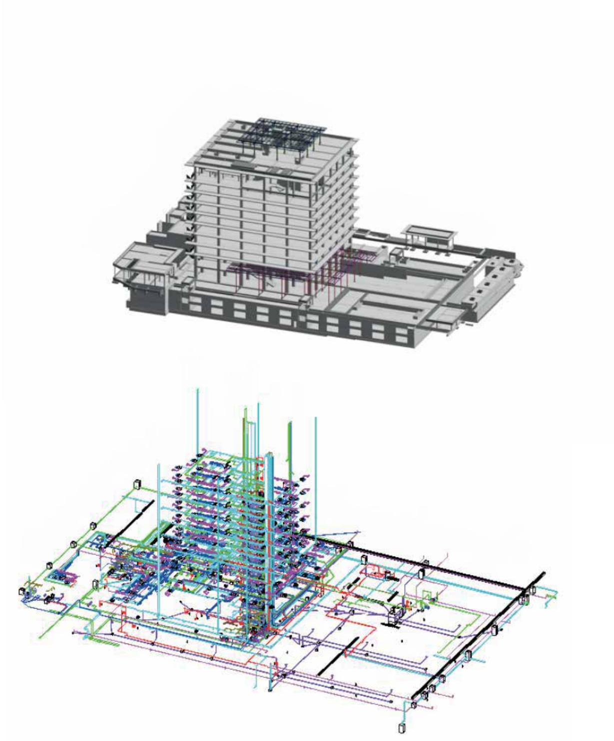


Figure 24: BIM Model and MEP systems

CREATION OF OUR DIGITAL INTEGRATION BRANCH

We created a solution called RPS (Revit, primavera, SAP), allowing contractors to take full advantage of 3 powerful tools generating pertinent boards daily. Our solution synchronises data about cost and schedules entirely on the cloud between BIM models and ERP / Scheduling tools. We developed plugins ready to use on Revit / SAP / primavera, allowing a friendly interface for end uses.

The fact that Autodesk AEC solutions are open to all kinds of API allowed our developers to reach very friendly plugins to demystify BIM -ERP for contractors RPS takes information from BIM models through Autodesk applications and synchronises both ways, all allowing project life cycle data between SAP S4 HANA ERP and Primavera P6

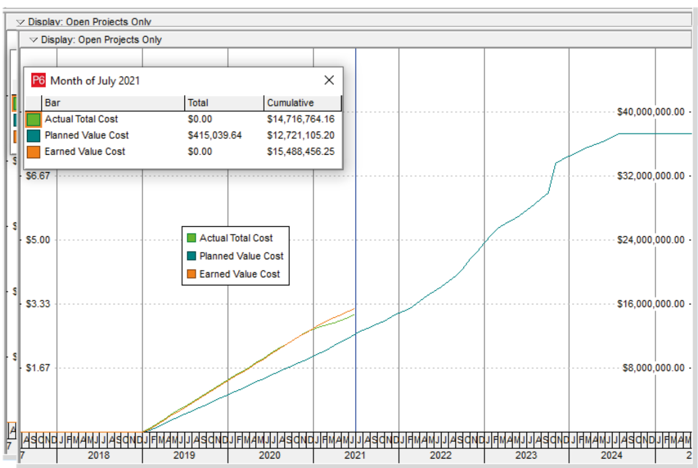


Figure 25: Earned Value Management of Primavera P6

> Our solution synchronises data about cost and schedules entirely on the cloud between BIM models and ERP / Scheduling tools.

BIM DIMENSIONS

To more understand our construction project and the process of linking additional dimensions of data to our building model.

4D BIM DIMENSION

In this dimension of BIM, we include the schedule of all the construction stages. It brings about a good working relationship and cooperation among the stakeholders with clear deadlines.

5D BIM DIMENSION

This dimension represented 4D BIM + estimate or cost. We integrated cost, schedule, and design in our 3D output. So this dimension improves the project cycle and allows modifying costs at any given time.

Earned Value Management using Primavera P6 and SAP
Expenditure monitoring (actual cost) on SAP distributed by WBS allows you to update project expenditure on primavera P6 and use the earned value management method.

As an output of primavera P6, we have:
ActualTotal Cost: SAP data (module MM/PS/CO)
Earned Value: Primavera P6 data
Planned Value Cost: Primavera P6 data

Advantage :

Simplify the insertion of the required information in the BIM template on REVIT.

Quantification of the reinforced concrete elements of the structure will allow controlling the monitoring and forecast of purchases on Primavera

Modelling this one according to the construction schedule will make a better 4D simulation & 5D on Naviswork.

Real-time project information management on SAP S/4 HANA: Purchasing, Subcontracting, Main work, equipment, stock, etc

Interfacing real expenditure (actual cost) from the SAP project to primavera P6.

6D BIM DIMENSION

6D BIM involves adding other relevant information that supports the facility's management and operation in the hopes that it will bring about a better business outcome. We developed a solution to optimize energy using a perforated panel to cover all buildings after solar analysis and panel study. In this project, we started the process by increasing the level of details and information of the BIM model. After that, we created a study of energy consumption without a perforated panel. The next step was dimensioning with several iterations until having the optimal dimensions. The optimization was done after creating a solar analysis and mechanical study. At the end of this step, we created another energy consumption by using the perforated panel. As a result of the study of consumption, we had to optimize the energy consumption using this perforated panel with 33%.

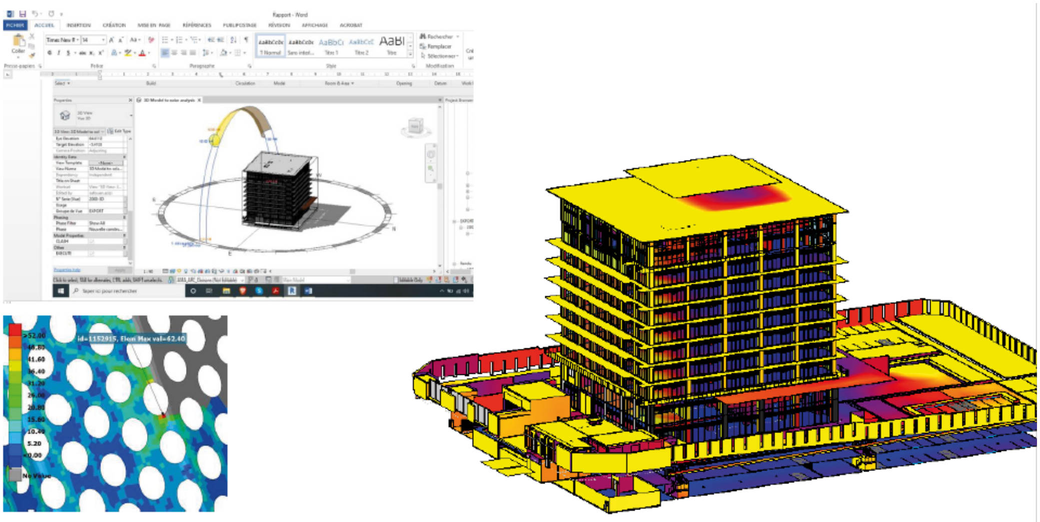


Figure 26: Contribution of BIM 6D to the energy economy

7D BIM DIMENSION

7D BIM basically comprises 3D + time schedule + cost intelligence + sustainability. We used 7D building information modelling to maintain and operate a project throughout its entire life cycle. Using a 7D CAD in BIM would help optimize the project management from its design stages until its demolition.

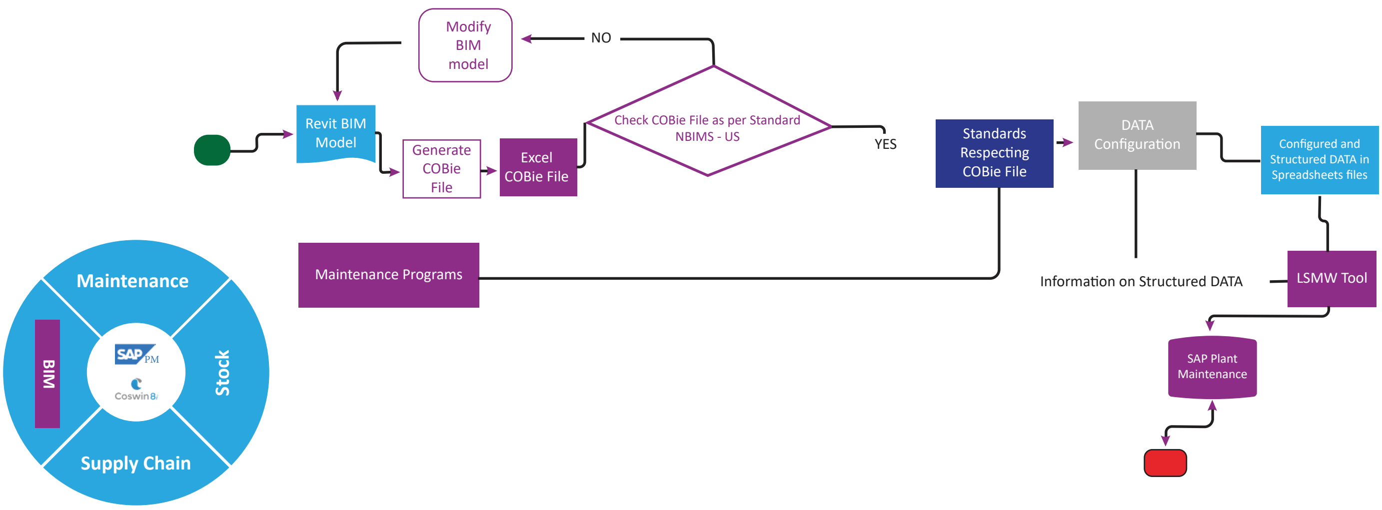


Figure 27: BIM 7D Workflow using SAP

Innocent
Musonda

Professor of Construction Project Management, Director, Centre for Applied Research, and Innovation in the Built Environment (CARINBE)
University of Johannesburg

Adetayo
Onososen

Researcher at Centre for Applied Research, and Innovation in the Built Environment (CARINBE).
University of Johannesburg

DIGITAL TRANSITION IN DEVELOPING COUNTRIES' BUILT ENVIRONMENT – A DYNAMIC CAPACITY DEVELOPMENT APPROACH

Background

It is unarguable that sustaining growth and productivity in the construction industry in Africa requires a shift from how we execute projects and employ more technology in the processes. However, it is also notable that the construction industry, as is the case in many parts of the world, is reluctant or slow to adopt technology. The delay in technology adoption is partly ascribed to the requirements of having the right imperatives in place, which must be balanced with the much-needed governance or institutional support. The difficulty with creating robust institutions and convincing imperatives in developing countries is that most have weak governance systems. Therefore these can further delay technology adoption and reduce digital benefits to all. Digitalisation is crucial in the built environment, especially in developing countries. A digitalised built environment can trigger the much-needed industry transformation and foster national economic growth, given its level of contribution to Gross domestic products in many countries. Moreover, having come out of the shock and impact of covid-19, the need to accelerate recovery, sustain growth and improve productivity has become direr. Therefore, this piece aims to explore how we can encourage the digital transition toward digitalisation in developing countries through a dynamic capacity development approach with a cautionary note on not confusing the concept with the market-aligned advocacy-driven approach solely based on the need for profit. This article looks at the need for digital transformation, the challenges, and how we can transition to digitalisation using the dynamic capacity development approach.

Digitalisation in the Built Environment

Digitalisation, also referred to as digital transformation, characterised by increased use of digital technologies, can enormously contribute to national economic growth, especially for economies in the global south. However, the construction industry is characterised by poor information management, lack of collaboration and rampant corruption. These ills inevitably result in projects that go beyond budgeted costs and time, inferior quality and safety performance. Unsurprisingly, the built environment is perceived as a dirty, difficult, dangerous and dishonest industry.

It is an industry that is not transparent. The lack of transparency is partly attributed to the quality and level of collaboration in the built environment which some have aptly described as poor. Actors in collaborative endeavours are disjointed and lack clear pathways on how to drive collaboration. The current conversation in the African-built environment reveals a prominent gap in knowledge and awareness of digitalisation to address the transparency and collaboration issue. However, there are many questions about digital transitioning towards digitalisation. Transitioning questions include: At what stage can we begin to move forward? How can the status quo be changed? How can we enhance information management to achieve transparency? Should digital approaches be mandatory or non-mandatory? - These are dilemmas whose answers will determine the success or failure of digital transitioning efforts across the continent.

Technological advancements are reinventing our way of life, nature of work and economical operations. The built environment is not left behind in exploring how adopting these technologies can improve efficiencies and deliver a sustainable infrastructural ecosystem. The Centre for Digital Built Britain contends that access to the correct information (data) at the right time in a format that all parties can trust is increasingly recognised as a vital enabler of the construction industry's digital transformation. Incorrect information or single-sided information leaves us vulnerable, and vulnerabilities are costly. How this information is acquired, processed, communicated, when it is transmitted, and how much information is gotten are the underlying motivation driving the need for enhanced information management.

Information management matters. Consequently, a lack of effective information management can deprive (money, time or quality) or lead to project failure. Information management is therefore well suited as a tool to improve the capacity of the built environment to provide sustainable and efficient infrastructure delivery. Enhancing the industry's information management systems and workflows would lead to significant economic growth, especially in developing countries.

The danger of poor information management is that it has a negative impact on the social value of infrastructure. In the construction industry, poor information management leads to disputes, enables corruption, is a basis for unfounded claims and creates contentious project environments. This impact on the image of the built environment as a fertile ground for incendiary corrupt practices has further encouraged the need for digitally enabled systems that Building Information modelling offers.

Therefore, much more is at stake in this journey towards digital transitioning and must be curated with utmost concern. We must ponder what fails when a project fails or is abandoned. Loss of stakeholders, investment, or the unfilled gap between social value and social justice? Therefore, the call for digitalisation or digital transformation is urgent.
While some quarters have expressed legitimate concerns on why a cautionary approach to digitalising the built environment is preferred, we argue that we must dynamically transform the industry by focusing on people, processes, change management, and organisational culture transformation.

How we drive adoption is particularly important. Much has been demonstrated that mandates to enforce compliance breeds resentment. From the mask mandate of COVID-19 to BIM mandates in some countries, the experiences are similar. The experience from BIM mandates globally offers insight into digital transitioning in Africa: mandates are problematic and require all stakeholders' buy-in. While certain elements need compliance to accelerate growth, enforcement should be applied to specific paradigms pivotal to sustaining growth and increasing productivity.
Integrating a cultural overhaul with employee trust leads to new ways of thinking about digital transformation. Large investments in technology for digital transformation must be avoided if the cultural component of the transformation is not well addressed. Doing this will help prevent the current dilemma expressed by executive officers in digital adoption from not living up to cost-benefit justifications. As a result, management must set the right example of properly leading change or conveying the true end goals. One perspective in this regard is not to exaggerate people's willingness to change.

Benefits of digitalising the built environment

Nations worldwide are beginning to make strategic policies on harnessing digital transformation benefits and information management skills capacitation to achieve sustainable development. Interest in digital transformation at national levels is influenced by its immense benefits, such as the potential for creating novel procedures, services, and markets. In the construction sector, the benefits include changing how we build, communicate information, and make decisions. More importantly, given the challenges of corruption influencing project delivery in the African nations, digital transformation benefits parties involved in the value chain through increased transparency and the capacity for a more effective and sustainable construction sector. By harnessing digital transformation, efficient information sharing and dissemination enables project professionals to rehearse project execution, analyse massive amounts of construction data, and resolve difficult project issues quickly.
Digital transformation also contributes to an effective asset information system by providing real-time project data to manage assets more efficiently. The asset information model enables a predictive maintenance regime to assess the state of a building's operational equipment and determine when repair should be performed.

Digitalisation Challenges in the built environment

The pace of change across other sectors with regards to digital transformation is exponentially accelerating and radically altering our world. However, it is not the case in the built environment. Despite the benefits of digital transformation, several challenges are affecting digitalisation. The challenges include investment cost, how to commence digital transitioning and skills capacitation. The increased use of digital technologies allows organisations to enhance their infrastructure and asset performance. However, the ability of organisations to adopt and convert digital transformation investment into meaningful gains is a critical challenge affecting the uptake in the construction industry.

Therefore, overcoming the difficulties is necessary to unlock digital transformation's speed and potential for infrastructure delivery. One way to digital transformation is through training. However, issues such as training people are not simple problems with textbook solutions. For instance, capacity development often requires a shift in cultural mindset, overcoming Resistance to Change, achieving Buy-In from management, and ensuring the focus of reskilling not only on using tools but also on providing a clear vision of why digital transition is needed and inevitable.

Failures of digital transformation projects have continued to haunt enterprises, with many executives expressing disappointment. Therefore, we must rethink digital transformation and how we transition to digitalisation by focusing on a people-oriented digital approach. According to Boston Consulting Group research, an incredible 70% of digital transformation programs fail to meet their goals. Transiting digitally towards profitable transformation is, therefore, not to build change around technological infrastructure but to weave dynamic capacity development in organisational DNA (deoxyribonucleic acid) and cultural contexts of the people.

The digital transition is not always easy. However, by identifying and addressing critical organisational, workforce, users and policy requirements, the potential is incomparable to the conventional approach to infrastructure delivery and management. To effectively transition the built environment to digitalisation or digital workflows, organisations must adapt to conditions and develop a capacity in which all parties, i.e. private, public, academia and scientific institutions, are involved to quickly adopt, learn and adapt to rapidly changing conditions in the digital eco-system.

The COVID-19 pandemic revealed how quickly an industry could transform under pressure toward adopting technology. However, change under such pressure also has negative impacts. The huge job losses are examples resulting partly from digitalisation during the Covid-19 pandemic. Moreover, the increasing need to improve productivity and eliminate inefficiency-related issues has placed the built environment in a place where digital-driven systems and processes are inevitable. While there are current arguments about what values digital innovations in robotics, wearables, sensors, drones, computer vision, reality capture, Blockchain, Computer Vision, Digital twin, internet of things, and artificial intelligence offer the built environment, the change is inevitable. The nascent stage of these innovations must not suggest rejecting the favourable and the perceived unfavourable, or as the adage goes, "throwing the baby out with the bathwater".

Consequently, our focus at the Centre for Applied Research and Innovation in the Built Environment (CARINBE) has been to deliver real-value-adding digital adoption paradigms that champion people-centred digital transformation. Similar to this is understanding human-technology interactions as a holistic focus area to ensure the integration of digital technologies to reduce inefficiencies, eliminate hazards, and ensure safety is balanced with socio-cultural paradigms around workers. Digitalising the African-built environment is not just about technology adoption, but it is a powerful tool, a voice to truly represent and highlight the success stories, prowess, and grit of the African-built environment

A dynamic capacity development approach

The built environment plays a pivotal role in delivering socio-economic amenities in infrastructure such as residential homes, economic infrastructure, transport facilities, health infrastructure etc. The intersection of varied literacy levels operating towards achieving a common goal renders the built environment peculiar in capacity development. These peculiarities and the need to sustain growth in developing countries through proactive digital adoption rather than catching up is a plan that cannot be solely assigned to the government agencies.

Ohno and Ohno (2012), in "Dynamic Capacity Development: What Africa Can Learn from Industrial Policy Formulation in East Asia", propounds that the vital developmental lesson Africa can take from East Asia isn't adopting similar policies but "the methodology by which individually unique but equally effective policies were designed and implemented". This methodology, in a broad sense, includes technicalities of policy-making procedure and organisation and how non-economic factors such as passion, nationalism and the sense of pride and humiliation are strategically mobilised under strong leadership to serve as driving forces of catch-up industrialisation."

"Failures of Digital Transformation projects have continued to haunt enterprises, with many executives expressing disappointment."

These alternative approaches, rather than a blanket pathway, considers a social perspective through which distinctive historical processes of change and transformation in different countries are built around proposed digital transitioning roadmaps (Khan, 2011). Integrating historical, political, social and economic knowledge into digital adoption efforts offers a better story that considers all stakeholders without creating adversarial relations in the built environment. The priority then becomes identifying areas of the built environment that significantly impact productivity and are most likely to make a difference when integrated with digital technologies.

Equally, skills development via public-private development partnership in the form of a bottom-up development approach provides the critical and needed drive from civil society to unlock constraints on growth. This model ensures that delayed government policy decisions characterising African countries do not constrain the adoption efforts.

We, therefore, propose that conversations around digital transitioning in Africa should revolve around the following:

1.Focus on the Intent
Identifying objectives helps clarify pathways and outcomes. A clear understanding of priorities, goals and strategies helps formulate and unite with a vision to garner support from all stakeholders. More importantly, focusing on intent eliminates adoption for the sake of it and simply just driving the profitability of technological tools supply chain. To ensure relevance, business challenges must be addressed alongside the industry's need and intent for digital transformation. Definition of intent gives identity. Blind and absolute mimicking of developed economies' approaches does not offer the much-needed cultural context to peculiar scenarios. Before thinking about adopting digital tools, a clear understanding of the problems to be solved must be properly articulated. Companies that conduct transformation efforts for the sake of change without a clear aim will move in several different ways with no alignment, eventually leading to failure. This frustrates efforts when the focus is solely on the technology and fails to identify that the technology is only a means to an end.

2. People-centred digital adoption
prioritise people-empowering digital systems. Technology adoption should support the development of workers. An employee-driven approach fosters trust and removes the perception that technologies are coming to replace human workers. A people-centred digital transformation is a socially sustainable model that delivers a win-win system for all and avoids sabotage. Resistors emerge when people are not at the centre of digital adoption. With the current Mindset of leadership, the right culture, and clear goals, digital initiatives have many chances of success.

3. Focus on Gauging change mindset and culture readiness:
Historically, people and systems rarely adjust positively to absolute change at once. While systems have better coping mechanisms, this is not plausible to people. Change management, therefore, requires gauging cultural readiness before the change and then using that information to appropriately design and organise transformation to satisfy people's change demands. This approach fosters organic interests and a positive disposition towards digital transformation. Without an appropriate change mindset, digital transitioning is bound to fail. Transition is often characterised by sabotage, distrust and an unenthusiastic disposition to adoption. How leadership communicates digital roadmaps and their intent is pivotal in achieving the mindset shift needed for effective transformations. The industry is widely notable for the passive adoption of innovations. This culture must be changed to ensure the digital transition.

4. Focus technology to prioritise creating and expanding work:
Digital transformation communication must not be understood to be just technology adoption that results in unintended consequences or the perception that the "techies" are here to take the jobs. It must be conceptualised and driven in an approach that communicates it as a tool to improve current workflows and systems.

5. Balance infrastructure solution needs with people
empowering and capacity development - It is critical that infrastructure development is balanced with social equity. A built environment that will transit dynamically with capacity development must be channelled towards providing equal opportunities to different sectorial stakeholders. The high incidence of disparities and inequality infrastructure emboldens must also be addressed alongside calls for infrastructure to respond quickly to future shock events.

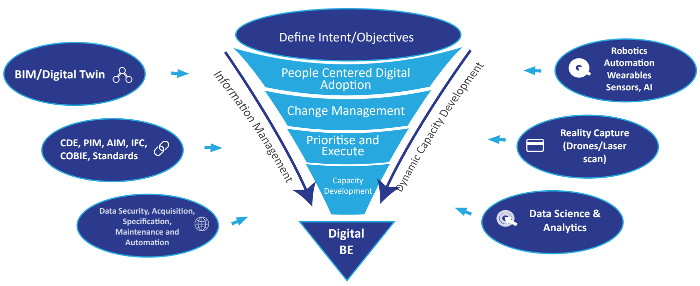


Figure 28: Focus pathways for digital transitioning through dynamic capacity development

Concluding Remarks

Africa's pathway to digital transformation requires going beyond recommending optimal adoption roadmaps lifted from prescribed routes of developed economies. While lessons of success of digital adoption elsewhere are important, point-blank acceptance of such pathways does not fit the current terrain of Africa's socio-economic realities. The low-adoption logjam of the digital approach to delivering infrastructure requires a broader reflection on the interaction between economic, political, and social constraints and dynamics. Poor governance capabilities in African economies and short-sighted developmental strategies hamper digital innovation. The divide between suggested approaches from developed economies and realistic local adoption methods is motivated by underlying differences in socio-economic and cultural constructs. An approach that fits the African terrain's economic and political circumstances, if adopted continuously and customised to the peculiarities of individual states, is likely to be more successful than the mandates approaches that have characterised the western world. This is because mindless adoption without recourse to the nature of transferability or social scenarios might fail. The priority for Africa's digital transformation must, therefore, not be perceived as competing with the global North. Instead, it should be to incorporate vital learning experiences integrated with home-grown approaches to deliver a more realistic digital transition in the continent. Digital transition nonetheless necessitates suitable policies, structures and success-enhancing governance criteria supported by public, private, and higher learning institutions or research institutions.

To effectively and sustainably transition digitally, we posit that the conversation should increasingly be about people and not solely focused on technological tools and processes such as Building Information Modelling (BIM). Capacitating people; data literacy amongst construction workers and stakeholders will guarantee a more endearing disposition and faster digital transformation. It should not be about the popular cliché that the construction industry must adopt technology to remain relevant. Although it is inevitable for the construction industry to adopt digital transformation, we must ensure that the choices are channelled towards improving how digitalisation delivers infrastructure in a resilient and sustainable way. Digital silos must ensure a holistic digital transition where leadership and system workers identify the need and work progressively towards integrating needed understanding, platforms, cultural engagement and workforce enablement. In so doing, it is possible to ensure that "digital transformation becomes human transformation".

Users must be at the forefront of digital transformation, and it must permeate the entire enterprise. Hitch-free digital transition advances organisation and industry-wide buy-in and team collaboration to achieve objectives in a transparent and efficient approach. The time to digitally transition is now as it is critical to staying competitive. In conclusion, digital transformation is inevitable for the African continent. However, it is up to Africans to decide which pathway is appropriate for the African context to carry everyone along and sustain growth reforms in the industry.

References

Gill, N., Musonda, I. and Stafford, A. (2019) Duality by Design: the global race to build Africa's infrastructure. Cambridge University Press, Cambridge.

Khan, M.H. (2011) 'Governance and Growth: History, Ideology, and Methods of Proof', in Good Growth and Governance in Africa: Rethinking Development Strategies. Oxford Scholarship. DOI:10.1093/acprof:oso/9780199698561.003.0002.

Musonda, I. and Okoro, C. (2021) 'Assessment of current and future critical skills in the South African construction industry', Higher Education, Skills and Work-Based Learning, ahead-of-p (ahead-of-print). doi: 10.1108/HESWBL-08-2020-0177.

Ohno, I. and Ohno, K. (2012) Dynamic Capacity Development: What Africa Can Learn from Industrial Policy Formulation in East Asia, Good Growth and Governance in Africa: Rethinking Development Strategies. doi:10.1093/acprof:oso/9780199698561.003.0007.

REDEMPTION HOSPITAL CALDWELL: RENEWING TRUST IN LIBERIA'S HEALTHCARE INFRASTRUCTURE.

MASS.

Clients: Liberia Ministry of Health, The World Bank.

Partners: AEP Consultants, Inc., Fall Creek Engineering/ Sherwood Engineering Mazzetti, Nous Engineering, Transsolar, Conspectus, Inc., GAD Studio.

Contractor: WEST Kevcon, Inc.

In the aftermath of the Ebola outbreak, as part of the National Investment Plan for Building a Resilient Health System (2015-2021), the Liberian Ministry of Health (MOH) identified the rebuilding and expansion of Redemption Hospital as a critical priority. Collaborating with the MOH on a series of projects and initiatives since 2010, MASS Design Group developed the Master Plan and Design Documents for the new Redemption Hospital in Caldwell. The project is a centrepiece of Liberia's renewed drive to build an optimized system to avert future epidemics and deliver comprehensive services to a growing population. In only a few short years, Liberia has taken bold steps to transition from an emergency relief model of health service delivery to a functioning, decentralized health system.

Figure 29: Rendering of New Redemption Hospital Caldwell - MASS Design Group

“The project is a centrepiece of Liberia's renewed drive to build an optimized system to avert future epidemics and deliver comprehensive services to a growing population”

Phase one of the hospital, funded by the World Bank Ebola Emergency Response Project grant, is a two-story, 155-bed facility encompassing comprehensive pediatric and maternity services. The project used innovative ventilation strategies in the form of solar chimneys to minimize energy use, ensure adequate infection control, and reduce operational costs. The 9,200 m² hospital development won the Future Healthcare Design category of the European Healthcare Design Award.

Figure 30: Approach of New Redemption Hospital -MASS Design Group.

The primary infection control strategy uses natural ventilation and solar chimneys for cycling the air inside the hospital with clean air twelve times per hour. The architecture achieves this through cross ventilation from the windows and breeze blocks and is supported by twelve solar chimneys that heat up and pull contaminated air out of the ward spaces, even when the windows are closed.

The solar chimneys also ensure patient comfort by cooling the wards with fresh air from the microclimate created by our planted courtyards and the adjacent wetland. The atmosphere within the wards is also cleaned by Ultraviolet Germicidal Irradiation (UVGI) fixtures. Ceiling fans pull air upwards, where the UVGI fixtures decontaminate it.

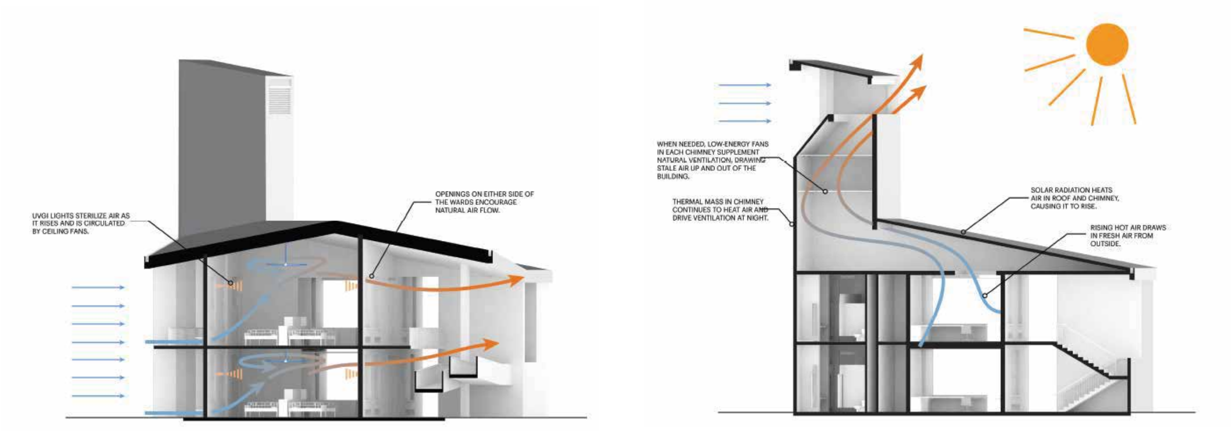


Figure 31: Ventilation, solar and UGVI fixture - Mass Design Group

All the waiting spaces in the hospital are on the exterior to reduce the transmission of airborne infection in waiting areas. Wind patterns informed the placement of the hospital's naturally ventilated and mechanically ventilated spaces. Two courtyards within the hospital capture the prevailing winds from the southwest, naturally ventilating clinical spaces and waiting spaces. The surgical department is mechanically ventilated and is positioned as a bridge between the two southwestern facing facades to maximize its exposure to the prevailing winds.
The interior finishes and casework utilize sustainably sourced, local rubberwood. Firestone, the tire manufacturer, sustainably plants and taps rubberwood trees in Liberia to produce their tires. Once the trees are fully tapped, they are milled to make dimensional lumber and butcher block sheets. MASS uses the wood for casework, wall panelling, countertops, ceilings, and furniture throughout the hospital in place of expensive imported materials. The use of locally sourced building materials for construction invests back into the local community, offering future growth and self-sustainability opportunities.

Figure 32: View of courtyards within the hospital - Mass Design Group

The Redemption landscape further supports the project's mission to renew trust in Liberia's health care system. The landscape, including a restored wetland, will provide infrastructure for a healthy and resilient hospital campus. It is strategically divided into four zones: Campus, Site Edge, Wetland, and Infrastructure. Each component is critical to creating a healthy campus that supports the safety and well-being of patients, staff, and visitors. The design learns from the most innovative hospital designs worldwide and considers the challenges of health care delivery in Liberia.

Figure 33: Construction works at the project site

BIM.Africa

Authored by
Research and Development Committee
BIM Africa Initiative

research@bimafrica.org

@BIM Africa

BIM Africa Initiative is a civil society organization formed to enable and regulate the adoption and implementation of Building Information Modelling (BIM) in the Architecture, Engineering, Construction, and Operations (AECO) Industry across Africa

With a focus on SDGs 9, 11, and 17, BIM Africa aligns with the United Nations 2030 Agenda for Sustainable Development by fostering innovation in the Construction Industry through local and global partnerships towards the delivery of Smart, Resilient and Sustainable Infrastructure and Urban Development.

The African-wide advocacy for BIM adoption and implementation is reinforced by extensive academic and market research programs, certification programs, round-table meetings, seminars and webinars, formulation of locally-adapted standards, chapters, volunteering, and professional development opportunities.