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Digital and Sustainable Built Environment Digest [DS-BED]

- Unlocking Africa's Construction Potentials: The Revitalization solutions.
- Sustainable and Innovative Construction Materials.
- Construction Digitalization.

Sustainable Human Settlement and Construction Research Centre (SHSCRC)
DSI-NRF Research Chair in Sustainable Construction Management and Leadership in the Built Environment
Faculty of Engineering and the Built Environment
University of Johannesburg

Our activities in pictures

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Our Future Reimagined

From the Editor-in-Chief

Welcome to the inaugural issue of the Digital and Sustainable Built Environment Digest (DS-BED), a visionary publication housed under the Sustainable Human Settlement and Construction Research Centre (SHSCRC) at the University of Johannesburg. Our mission, through this digest, is to foster a deeper understanding of sustainable practices and construction digitalisation within the built environment and to ignite a robust dialogue among professionals, researchers, and students alike in this critical field.

As the Editor-in-Chief, it is my privilege to introduce a platform that not only highlights innovative research but also bridges theoretical concepts with practical, actionable solutions that can be implemented in your work in the construction and built environment sectors. The DS-BED is committed to advancing knowledge and practices that resonate with the global sustainability goals, particularly in the context of the African continent's unique challenges and opportunities.

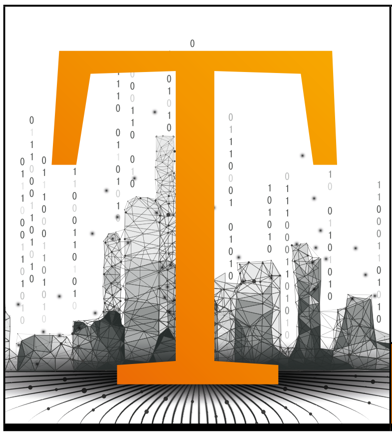
This first issue is a composition of insightful articles and research findings that reflect our thematic focus on sustainability and digital transformation in the construction industry. From exploring blockchain technology's potential to revolutionise the construction industry to discussing the retrofitting designs of existing commercial buildings for net-zero energy use, our contributors—comprising esteemed academics and pioneering researchers—provide comprehensive analyses and forward-thinking perspectives.

Moreover, this issue delves into the significant role of local content development and revitalization strategies in the African construction industry, a timely discourse given the continent's vast untapped potential and the urgent need for infrastructural development that aligns with sustainable practices. Furthermore, we spotlight groundbreaking materials like the 'Blue Roof' and 'Carbon Fibre', which represent the innovative strides made towards more sustainable and resilient construction materials.

As we launch this digest, we invite our readers—academics, industry professionals, policymakers, and students—to engage with the content, contribute to the discussions, and collaborate on research initiatives that drive us towards a more sustainable and digitally integrated future.

Thank you for joining us on this journey. Let's build an informed community and a sustainable future, one insightful article at a time.

Prof. Clinton Aigbavboa
Editor-in-Chief: Digital and Sustainable Built Environment Digest (DS-BED)



The SHSCRC: The Beginning and the Visionary Progression

Mr Peter Adekunle

The Sustainable Human Settlement and Construction Research Centre (SHSCRC) - sustainable housing is the official housing research and information centre for housing development in South Africa. The founder of the research centre, Professor Clinton Ohis Aigbavboa, is a researcher in the field of sustainable human development at the University of Johannesburg. Prof. Clinton is passionate about his work and always eager to learn more at every opportunity. He got the inspiration to establish the research centre when he attended a conference in Europe. At the conference in Europe, he was thrilled as the conference was a whirlwind of presentations, workshops, and networking events. Prof. Clinton was thus exposed to a wealth of new ideas and cutting-edge research. One presentation in particular caught his attention. It was given by a team of researchers from well-funded research centre in Europe, who presented their latest findings and discussed their approach to tackling some of the most pressing issues in sustainable human development.

As Prof. Clinton listened to their talk and chatted with the presenters afterwards, he felt a spark of inspiration. He realised that he too could make a difference in the field, and that by starting his own research centre, he could create a space for like-minded researchers to collaborate and make breakthrough discoveries. Over the next few months, Prof. Clinton began to develop his vision for the research centre, with the support of his academic mentor, Professor Wellington Thwala. He wrote up a proposal and pitched it to his university's administration, who were impressed by his enthusiasm and commitment. They agreed to provide some initial funding and support, and Prof. Clinton began to assemble a team of researchers and staff. There were many challenges along the way, from securing funding and recruiting top talent, to navigating the complex regulations and paperwork required to establish a research centre. But Prof. Clinton was driven by his vision and his passion for the field, and he persevered.

Today, the research centre is thriving, and has become a hub for cutting-edge sustainable human development research, with a team of talented researchers and staff working together to tackle some of the most pressing challenges in the field. The SHSCRC provides services to the National Department of Human Settlement, Provincial Human Settlement Departments, municipalities, metros, agencies, nonprofit organisations, and for-profit businesses. The custodian of the centre is the Faculty of Engineering and Built Environment (FEBE) at the University of Johannesburg, South Africa.

The centre is situated at the research village of the University of Johannesburg, Bunting Road campus. The centre fulfils its Human Settlement (sustainable

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housing) research agenda through the preparation of working papers, research notes, and major reports, and by supporting the National Human Settlement Department agenda, including its allied programmes such as workshops, annual conferences, and symposia, to extend and deepen the understanding of topics as deemed necessary.

Looking forward, the research centre will continually focus on sustainable human development and remain dedicated to exploring and finding solutions to some of the most pressing issues in sustainable development today, such as green buildings, the circular economy, sustainable materials, net-zero buildings, smart buildings, resilient infrastructure, and social sustainability. As such, the research centre's goals are aligned with the pursuit of sustainable development goals (SDGs) set by the United Nations. These research would be aimed at developing practical and effective solutions to challenges arising in the field of sustainable development, while also promoting social and economic development. Another important goal for the research centre is to focus on promoting interdisciplinary collaboration between researchers from different fields, such as economics, engineering, and social sciences. Such collaboration can lead to innovative and more effective solutions that are tailored to specific local contexts. The research centre would seek to engage with local communities and stakeholders to understand their needs and priorities. This would involve working with local partners to co-design and implement research projects that address the specific needs of these communities, while also building capacity and empowering local actors to take a leading role in sustainable development efforts.

CONTENT

Who We Are!

The Sustainable Human Settlement and Construction Research Centre (SHSCRC) is home to the Department of Science and Technology (DST)/National Research Foundation (NRF) South African Research Chair in Sustainable Construction Management and Leadership in the Built Environment. It is also home to the Construction Industry Development Board (cidb) Centre of Excellence. The SHSCRC, along with its Research Chair and Centre of Excellence, is an entity of the University of Johannesburg, within the Department of Construction Management and Quantity Surveying, subject to the governance rules and structure of the Faculty of Engineering and Built Environment of the University.

The research centre is comprised of a team of inter-disciplinary experts, academics, and professionals in the delivery of high-quality research consultancy in the construction industry and Built Environment. In the last eight years of its establishment, the research centre has:

- Produced more than seventy (70) PhD graduates,
- Produced about two hundred (200) master's degree graduates.
- Mentored more than fifteen (15) Post-Doctoral Research fellows (PDRFs)
- Published more than one thousand (1000) journal articles in reputable journals.
- Published over one hundred (100) book chapters, and
- Published over 20 Books.

Vision Statement

To be a globally renowned and leading Built Environment Research Institute with a focus on impact-driven multidisciplinary research to enhance Sustainable Human Development.

Motto

SHSCRC: Shaping Tomorrow's Built Environment Today.

Mission Statement

- Developed expertise and academics to make a tangible and novel contribution to the built environment.
- Utilization of interdisciplinary research methods, models, and frameworks in digitalization and sustainability for the built environment and the construction industry.
- Build a global and formidable team of researchers with an interdisciplinary network.
- Utilization of innovations, technologies, and technologies of Construction 4.0.
- Promote sustainable construction practices in all built environment projects.
- Collaborate and partner with the public and private sectors on projects and issues in the construction industry and the built environment.
- Promote user/public satisfaction practices and mechanisms in construction and built environment projects.
- Provide and promote strategies, models, and frameworks for all topics and emerging trends in the Built environment and construction industry.

Our Mandate

- Become a solution centre and consultants on challenges in the Built environment and the construction industry.
- Promote scholarly activities in the Built environment and construction industry.
- Provide execution frameworks and implementation models for government policies, white papers, and green papers.
- A melting pot for private, public, and international organizations on concepts and emerging trends in the construction industry.
- Bridge the gap between Academia and professional practice in the South African Built Environment.

- Promote Gender equality in the construction industry.
- Optimize the fourth industrial revolution (4ir) technologies and sustainability in the Built Environment and the Construction industry.

Our Identity

- Innovation
- Cutting–edge Research
- Publications of emerging trends
- Industry–Academic Collaborations.
- Professionalism
- Ethics and integrity
- Technological partnership
- Gender equality
- Borderless research

Our Culture

- Excellence in thinking and Research
- Collaborative Efforts in research activity
- Resiliency with the vision, mission, and mandate of the research centre
- Innovative thinkers.
- Problem solvers and smart workers.
- Attention to details.
- Recruiting the best and producing the best.

What we stand for

- Groundbreaking research output
- Interdisciplinary research
- Intelligent and innovative solutions.
- 4IR innovations in the built environment
- Unity, Harmony, and Love
- Research collaborations and Business Partnerships
- Contributing to actualization of the Sustainable Development Goals (SDG) of the United Nations.

Research Goals / Activities

- Source of interdisciplinary research and information on human settlement, construction projects, construction management concepts, construction 4.0 technologies, and sustainable construction management.
- Provide research and consultancy services to Government Agencies, Business Organizations, Non-Profit organizations, National Department of Human Settlements, Provincial Human Settlements departments, Municipalities, and Metros.
- Publish research findings, analysis, commentaries, debates, and theorization in accredited journals, and academic books.
- Publication of a quarterly Digest on Digitalization and Sustainability in the Built Environment.
- Qualitative and Pastoral care supervision of Post-Graduate Research students (Masters & PhD candidates), and Post-Doctoral Research Fellows (PDRF), engaged in various research agendas conceptualized by the centre.
- Promote sustainable and innovative construction materials, technology, and systems.
- Present and publish research findings and novel concepts in top-rated local and international conferences.
- Organize and support seminars, research bootcamp, workshops, scholarly lunch, and conferences.
- Provide briefings and commentaries for the media, when necessary, on concepts, policies, innovations, technologies, and schools of thought in the Built Environment and Construction Industry.
- Undertake relevant projects in Human Settlements, the Built Environment, and the Construction Industry.
- Recruit top, smart and disciplined international and local researchers as Research Associates.
- Contribute to the University of Johannesburg Global Excellence and Stature (GES) goal.
- Ensure high ethical and professional standards in Research Activities, Consultancy Services and Project Management.
- Offer relevant training and short learning programmes (SLP) within the Built Environment and Construction Industry.
- Provision of Relevant frameworks, policies, case studies, and models within the Built Environment and Construction industry.

Research Areas

The research centre's multidisciplinary and interdisciplinary research includes the following research areas in the Built Environment and Construction Industry:

- Housing Development and Human Settlement Research: Housing markets & affordability, low-income housing, housing financing, post-occupancy evaluation studies, housing satisfaction, regulatory impacts on affordable housing, public–private housing partnerships, and diffusion of innovative housing technologies in residential consumption.
- Stakeholder Management
- Construction Digitalization and Construction 4.0
  - Cyber Physical Systems, Digital Twin
  - Building Information Modeling
  - Blockchain in Construction

  - 3D Printing
  - Prefabrication and Alternate Building Technology (ABT)
  - Artificial Intelligence (AI)
  - Internet of Things (IoT) Technology
  - Virtual/ Augmented Reality
  - Cloud Computing.
- Environmental Pollution
  - IEQ and Outdoor
  - Decarbonization/ Net zero Building
- Skills Development in the Built Environment
- Construction Skills of the Future.
- Circular Economy
- Biomimicry + Construction industry
- Human Resource Management (HRM) Research in the Construction industry.
- Supply Chain Management and Logistics
- Water Management in the Built Environment
- Facility/Maintenance Management in Buildings
- Professionalism
- Construction Education and the Future of Work.
- Construction Entrepreneurship
- Mentoring in the South Africa Construction Industry
- Urban Development and Urbanization.
- Leadership Development
- Social Sustainability (Health & Safety)
- Renewable Energy and Energy Efficiency in Housing Development
- Housing Studies/Science
- Resource Management in the Built Environment
- Programme and Project Management
- Construction and Built Environment Policy Analysis, Formulation, and Implementation.
- Construction Leadership
- Construction Business and Economics
- Sustainable Construction Materials
- Public–private partnerships (PPP) and Private Finance Initiatives (PFI) in Construction Projects.
- Management of Project Enterprises, Joint Ventures, Networks and Supply Chains.
- Infrastructure Management and Investment in the Construction Industry.

Value to the Society

- To make the built environment digitally sustainable for humanity
- Address pertinent local and state issues using research instruments and technological innovations.
- Aid economic, social, and environmental sustainability in the built environment.
- Initiate needed and relevant policies for the built environment and construction industry in South Africa.
- Advance and promote relevant built environment and construction management policies, laws, regulations, and parliamentary Acts.
- Increase the number of women in the South African Construction industry and Built Environment

Benefits to the University of Johannesburg

- Improve the world ranking of the university through excellent and citable research output from the centre.
- Attract international funding to the University.
- Produce reputable, dependable, and knowledgeable professionals.
- Advance the University 4IR mandate in the Construction Industry
- Promote the name of the University as a contribution to the success of the SAChI.

Benefits to the Republic of South Africa

- Attract investors to the country through innovative research on sustainable construction materials, relevant frameworks/ models, and technological innovation.
- Offers solutions to the challenges in the South African Construction industry.
- Propagate the adoption and building mechanism of net zero building.
- Increase the number of women in the South African Construction industry.
- Aid the attainment and achievement of relevant policies and plans of the government of the Republic of South Africa:
  - South African National Infrastructures Development Plan 2025
  - CETA – National Skills Development Strategy (NSDS III)
  - Sector Skills Plan (SSP) – 2026
  - National Skills Development Plan
  - National Development Plan 2023
  - Council for the Built Environment Act, 2000

Benefits to Southern Africa

- Utilize technological solutions to drive up GDP contribution from the Construction industry.
- Recommend innovative and sustainable construction materials to tame the region’s high cost of building materials.

- Research and design alternate financing models for low-income houses in the region.
- Increase women professionals in the Construction industry.
- Propagate the adoption of Construction 4.0 technologies in Construction project delivery, construction project maintenance, and construction project methodology.
- Contribute to the attainment of the Southern African Development Community (SADC) Vision 2050.
- Provide relevant implementation frameworks to the 2027 Long-Term Action Plan of the Regional Infrastructure Development Master Plan of SADC.

Benefits to Africa

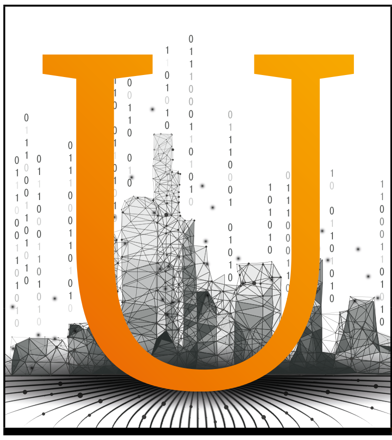
- Provide a vital strategic action plan on digitalization and sustainable practices.
- Build a vast network of researchers in the built environment for the convergence of ideas and cross-pollination of solutions to emerging trends in the continent.
- Contribute to the actualization of the Agenda 2063 of the African Union.
- Provide implementation strategies for lowering the cost of adopting construction 4.0 technologies among construction companies.
- Contribute novel frameworks and sustainable financing models in bridging regional infrastructure gaps, working in tandem with the Programme for Infrastructure Development in Africa (PIDA).
- Influence the formation of needed policies, plans, and initiatives within the Built Environment in accordance with continental needs and success stories in developed countries.

Values to members of the Research Centre

- Career and capacity development
- Increased research efficiency and leadership dexterity
- Provide mediums and networks for strategic interactions with professionals and experts in the built environment.
- Increased technological know-how in the construction industry.
- Provision of Grants, Bursaries, and financial support.
- Increased teaching and lecturing capability.
- Provision of employment opportunities and developing employability capacity.

Contribution / Expectations of Members to the Research Centre

- Engaging in contemporary and knowledge-based research
- Integration of sustainability and digitalization into all research activity
- Collaborations for efficiency and productivity
- Promotion and advancement of the centre’s vision and mission
- Alignment of research activity to the research centres’ benefits to South Africa, Southern Africa, Africa, and the world
- Yearly presentation and publication in reputable conferences in the built environment and construction industry
- Yearly publication in top-rated journals
- Commitment to finishing relevant degrees within the frameworks of the research centre
- Promotion of Harmony, Love, Unity, and support for other members of the research centre.



Unlocking Africa's Construction Potentials: The Revitalisation Solutions

Dr Liphadzi Murendeni, Dr David Love and Dr Akinradewo Opeoluwa

Introduction

The construction industry has been the cradle of human civilisation, connected to everything related to Man. The industry is the economic heartbeat of any nation, dictating the pace of socio-economic development, detailing the inflow of foreign investment to any country, and shaping the human capital development of people. It is the beauty of civilisation. One can postulate that an economy with the untapped potential of her construction industry is heading towards sluggish perils if concrete steps are not taken. The various categories of workforce, types and supply chains of materials, and manufacturing processes in the construction industry make it a contributory solution to economic prosperity. However, the depressing poverty rate and consistent economic trough in Africa show that the construction industry is poorly optimised. The region has the highest number of people living in extreme poverty, with one-third of its youth unemployed. Hence, tapping into and unlocking the African construction industry's potential is one of the Sustainable Human Settlement and Construction Research Centre (SHSCRC) goals at the University of Johannesburg.

If revitalised, the construction industries in Africa offer economic opportunities and prosperity to the more than 1.2 billion people living in the 54 African countries. This is as the urbanisation rate increases year in and year out. According to Statista, the urbanisation rate in Africa is expected to increase to 45.9%. The continent is also home to the youngest population in the world, as 40% of its population is below 16 and about 4% above 65 years old, with a resultant youthful population of 400 million, the highest in the world. Also, the region has about 30% of the world's mineral resources, and is the site of the next world powers, as the saturation level of

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economies in Europe and China increases daily. Given these intrinsic statistics, with a cross-generational and multiplier effect on Africa's economy, revitalising the construction industry in Africa is inevitable. Also, recent technological advances, together with a globalisation-led business-friendly climate across the world, are pointers that the continued stagnation and sluggishness of the African construction industry will further diminish the economic potential of Africa. Therefore, the focus of this article and other articles in this Educational Digest is the revitalisation of the African construction industry, and to tap into its multidimensional and cross-sectoral benefits for Africa's prosperity.

African Construction Industry Market

Various studies have shown that the construction industry is the largest in Africa, with high employment rates and a high investment turnover. According to Mordor Intelligence, the construction market value in Africa is 55.6 billion USD as of 2023 and is projected to be 71.20 billion USD in 2028 at a CAGR of 5.07%. A detailed analysis by Deloitte in 2021 on African construction trends stated that there are 462 projects as of 2021 valued at 521 billion USD, with most projects in West Africa (153 projects at 172.8 billion USD), followed by Southern Africa (106 projects valued at 147.7 billion USD), then East Africa (102 projects valued at 60.6bn USD), then North Africa (86 projects valued at 132.2 billion USD), and Central Africa with the least number of projects (15 projects valued at 7.4 billion USD). Moreover, the report highlighted the top five countries in Africa with the highest project numbers: Nigeria (55 projects valued at 100.9bn USD), Ghana (47 projects valued at 22.5bn USD), Egypt (42 projects valued at 108.8 bn USD), South Africa (37 projects valued at 54.7bn USD), and Ethiopia (30 projects valued at 12.1bn USD). Furthermore, according to the report, 73.8% of these projects are owned by African governments, followed by 10.6% owned by consortia, 8.9% owned by private domestic firms, while the United Kingdom, United States of America, EU countries, China, Canada, International Development Finance Institution (DFI), Australia, Asian countries, and Nigeria own the rest. Also, according to the report, funding for African construction projects comes predominantly from governments (31.4% of the projects), consortia (21.6% of the projects), and China (10.6% of the projects), while the rest of the funding for African projects comes from private domestic sources, African DFIs, International DFIs, Asian countries, EU countries, African countries, the UK, the US, Russia, Australia, and Brazil. In addition, the report revealed those handling the construction of the African projects. The report shows that most of the African projects are built by China (27.1% of the projects), followed by private domestic firms in Africa (25.3% of the projects), consortium builds (18.4% of the projects), the United Kingdom (11.5% of the projects), other Asian countries (8.7% of the projects), with the remaining 9% of the projects being built by various African governments, the US, and EU countries. These projects are predominantly in the following sectors: Transport, Energy & Power, Real Estate, Water, Shipping & Ports, Healthcare, Oil & Gas, Social Development, Education, and Mining.

These statistics show the massive potential of the African construction industry. They also show the rising "Chinalisation" of the sector, which depicts the economic interest of China in Africa. Moreover, a critical analysis of the different builders of the projects shows the high skill shortage and low mechanization in the African construction market. This calls for a revitalisation of the African construction industry that will usher in new pathways to awaken and unleash the continent's latent potential. Also, compared with the population and the evolving urbanisation, African construction projects are minimal, further showing that the industry is a goldmine.

Challenges of Construction Industries in Africa

Construction industries across Africa have been plagued by abandoned, failed, and poor-quality construction projects over the last 25 years. Moreover, the rise in the number of international firms handling major construction projects further cements the lackadaisical processes in the construction industry of the continent. Also, the capital flights from various construction projects are a concern. The first major challenge is the lack of project management capacity in managing the tripod project constraints of time, quality, and cost. Most projects face cost overruns, time overruns, and poor quality of projects that have chased away investors' confidence and become a stumbling block to economic growth from construction projects. Most project managers and construction project managers cannot effectively deliver a project within the project budget. This is because most projects lack adequate financing structures that ensure the project is carefully priced, with room for inflation and socio-cultural tendencies. Also, project delivery beyond the planned schedule has led to the dissatisfaction of project stakeholders and shareholders. Consistent cracks in structures, the high maintenance cost of infrastructure, and recurring building collapses in the region point to low-quality projects in the industry in terms of non-conformance with standardised materials, and construction processes that are not in line with global practices. Hence, addressing this deficiency in managing project constraints will go a long way towards realising project goals and objectives.

Furthermore, non-compliance with due process during pre-construction, construction, and post-construction is another problem in the continent's construction industry. Many have labelled this phenomenon as corruption. Many construction players, both local and foreign, in the African construction industry, fail to realise that due to greed, the economic effects of sabotaging due processes during pre-construction stages in terms of tender bribing, unjustifiable and shameless inflated project cost, and payment failures, are significant. This reduces financial trust between the bribe-giver and the bribe-taker, as these ugly scenarios stifle the economic potential of these projects both directly and indirectly. Tactical and operational managers' corruption in material procurement also hastens the project's lifecycle. This is very common regarding quantity, quality, size, texture, colour, and standardisation. All these factors cripple the construction industry in both the short and long term. Moreover, favouritism during employment in recruiting unqualified construction workers, who go on to use "common sense" when global best practices are required, further sickens the industry. Therefore, non-adherence to due process, standards, and global best practices during all the stages of construction limits the capacity of the construction industry to be a competitive industry in the global market.

Another challenge is the three phases of skills deterioration in the African construction industry. These include the obsoleteness of skills, deskilling, and skill shortages among construction industry personnel and workers. Many construction workers in Africa, due to low levels of education, stagnant skill levels, and lack of exposure, possess construction skills that are not useful by modern standards in the global construction industry. Also, most skills face deskilling as advancements in various technologies are changing the level of skill sophistication needed to deliver a construction component. In addition, this has led to a skill shortage in the African construction industry. Many African construction industry personnel and workers are only versed in building construction projects. Also, most construction project managers are only knowledgeable about building construction projects. This has led to a massive skills shortage in other areas of the African construction industry, such as railway projects, sophisticated highway projects, energy projects, and shipping and port projects. For instance, in all railway projects across the continent, there is always an influx of Chinese engineers and workers to work on the project. Africa has a youthful population, yet we rely on countries 5500 miles away to bring in their workers, leading to capital flight, a redundant workforce, and inescapable reliance on maintenance. There is a need for skill recalibration in the African construction industry.

Furthermore, poor supply chain management and sophisticated bureaucratic bottlenecks are challenges in the construction industry in Africa. This is evident from rigid procurement practices and bureaucratic delays, especially in various approval processes in the industry; extended tender processes and administrative encumbrances are hindering progress in the construction industry. Many property developers are tied down, along with their projects, due to archaic mechanisms along the entire construction project supply chain, which is further complicated by lazy and non-digitised bureaucratic methods. There is a need to unbundle the various African construction firms, automatically easing the supply chain. This can be achieved via digitalisation and sustainable practices.

The Way Forward

Proffering solutions to the challenges mentioned above is a core duty of the Sustainable Human Settlement and Construction Research Centre (SHSCRC). In the last 10 years, the research centre's publications have focused on developing practical solutions and frameworks to the challenges, while mitigating the effect of the difficulties, as they hinge on the survival of humankind. Therefore, we propose seven revitalisation solutions to the various challenges bedevilling the African construction industry. These revitalisation solutions encompass managerial, economic, social, ecological, and technological perspectives. This revitalisation focuses on solving past challenges and safeguarding the future of the African construction industry.

The first recommended solution is to unbundle bureaucratic bottlenecks surrounding procurement processes, supply chain mechanisms, contract issues, and payment sophistication between construction stakeholders, especially on government-funded projects. This is predominantly seen in the efficiency of the construction supply chain. African construction stakeholders need a common front on standardising and simplifying the construction supply chain, which will unravel bottlenecks across the board. Some of the causes of these bottlenecks are inefficiency and unnecessary processes, inadequacy surrounding the implementation of different contract forms, over-dependence on a single individual or department regarding specific and critical construction processes, non-utilisation of relevant project management practices and methodologies, poor inventory management, non-digitalisation of relevant processes, opaque and confusing bills of quantities, poor earned value management, poor change management, poor materials handling, archaic procurement laws in different African countries, and long approval times for building permit processes in the region. Therefore, construction stakeholders, government regulatory agencies, and construction firm owners need to rethink their various bureaucratic processes, which are currently deleterious for the growth of the African construction industry.

Unbundling bureaucratic bottlenecks can be done via process assessment in the various departments to weed out unnecessary processes and processes that can be digitalised, removed, or merged with others. Frameworks such as capability maturity model integration (CMMI), Business process improvement (BPI), Six Sigma, and relevant ISO standards can be used for process assessment to unbundle, decongest, and simplify bureaucratic bottlenecks. This will lead to enhanced project delivery without the challenges of the tripod project constraints. It will increase efficiency in pre-construction, construction, and post-construction activities. It will also ease the productivity of material take-off, material handling, and inventory management. It will reduce unnecessary red tape on construction projects. It will increase construction firms' profitability, reputation, and performance metrics. Also, from the government's point of view, a simplified bureaucratic process in the construction industry will positively stimulate the economy in terms of increased employment opportunities, foreign direct investment, human capital development, and technology transfer.

Another urgent solution is the need for skill revamping in the African construction industry. All construction personnel within the African construction industry must undergo overwhelming and optimal reskilling and compulsory fourth industrial revolution (4IR)-oriented upskilling. Construction activities often answer to the forces of skill supply and demand, which are influenced by globalisation. We now have more exposed clients and creative architects and designers, demanding new skills. Also, propagating smart cities, climate-resilient structures, and retrofitting buildings for sustainability calls for a new skills approach. Therefore, construction firms must boost their organisational capital by meeting the global construction markets' expectations, trends, and changing tastes. An unskilled workforce aligned with contemporary reality leads to a degenerating construction organisation. Also, construction companies without contemporary project portfolios have no competitive advantage in the national, regional, and global markets. Moreover, construction project managers and workers are seeing the need for reskilling and are thus opting to go to organisations working on trending and sophisticated projects, which in the long run will force the construction industry to either sit up or fold up. Consistent reskilling and necessary upskilling in line with digital and sustainability trends are the currency of a globalised construction market.

Therefore, construction firms and stakeholders should channel their strengths in upskilling and reskilling along the following lines: Building information modelling (BIM), Robotics, Digital Twin technology, 3D printing, Green building, climate resilient structures, energy efficiency in buildings, identification, production, utilisation and control of renewable & sustainable materials, environmentally friendly construction processes and methods, Internet of Things (IoT) utilisation in construction projects, alternative building technologies (ABT), alternative building materials, innovative building technologies (IBTs), robust building systems, net zero buildings, retrofitted buildings, Green construction, sustainable buildings, blockchain technology, prefabrication and modular construction, utilisation of project management software, Drone technology, Virtual Reality technology, utilisation of Artificial Intelligence-oriented administrative, bureaucratic and inventory management processes, and biomimicry technologies, among others. However, reskilling and upskilling must be tailored toward the supply and demand of construction projects, skills, processes, methodologies, architecture, designs, materials, and technologies in the respective African countries. Moreover, the Sustainable Human Settlement and Construction Research Centre (SHSCRC) at the University of Johannesburg is ready to partner with construction firms, institutions, and stakeholders in this needed, urgent, and essential journey of skills revamping in the African construction industry, as we have developed competency, capacity, and a knowledge reservoir over the last 10 years.

Developing and revitalising the African construction industry is a collaborative journey and cannot be done in isolation. There must be collaboration, cross-pollination of ideas, and allogamy between large and small construction firms. The word "collaboration" is a common, cherished, and sweet word in the mouth of construction stakeholders, but there is little to show for it. Hence, there is a need for a structured collaboration and a clear departure from the conference workshop-like talks without actions, and passions without fruits. The Quintuple Helix model of innovation offers us a structured collaboration model in the African construction industry. The Quintuple Helix model offers interaction among universities, industry, government and societal organisations, and the natural environment. The model mobilises different types of capital to achieve set objectives: economic capital, natural capital, human capital, legal capital, information capital, and political capital. Therefore, in the context of the African construction industry, the Quintuple Helix model will lead to the alignment of different interests, identification and removal of bottlenecks, and accelerate growth in the construction industry. Collaboration must exist among the following stakeholders in the African construction industry: Higher Educational institutions (HEIs) and research institutions offering construction-related programmes, construction companies, contractors, professional associations, construction professionals, government regulatory agencies, government policymakers on construction related activities, civil society organisations, non-governmental organisations, community leaders within the built environment and construction industry, and environmentalists.

However, this raises questions about who should lead the collaboration effort. Without prejudice, as an academic institution, academics who are the custodians of knowledge should take the lead via workshops, conferences, seminars, and webinars. They have been doing this but have little to show for it, evidenced in the state of the construction industry and the lacunae in various construction curricula across the continents. Hence, as custodians of knowledge, they should bring together the various actors in the quintuple innovation model, which will catalyse construction discourse into achieving sustainable construction growth. This will lead to the following benefits: a competitive construction market in Africa, innovative construction methods, localised technologies, quick diffusion of construction 4.0 technologies among construction firms, accelerated economic growth in the region, boosted and encouraged confidence of investors, timely upskilling and upskilling mechanisms among construction firms, enhancement of project productivity, profitability, delivery and efficiency, efficient manpower planning, optimised resource allocation, preventive response to risks, adequate, cost-effective and less severe risk mitigation plan, improved and informed decision-making processes, a safe working environment and conditions, and a profitable business environment for construction activities.

Furthermore, there are many fragmented, isolated, and idle infrastructural plans within the African construction industry in each African country and region. These many plans have contributed little and have absorbed many resources within the continent, leading to abandoned projects. Yes, according to the African Development Bank, we need to close the infrastructural gap in Africa, which is about 200 billion USD. However, we must solve the recurring 80% failure rate of infrastructure projects in Africa. The most significant way is the alignment of scope management of the many plans, optimising the strategic synergies of the plans, and mitigating their trade-offs. It is incumbent upon stakeholders in the built environment in each African country to champion this alignment of plans per their country's priorities, developmental challenges and stages, information management scenarios, political landscapes, and cultural dynamics. Achieving this amalgamation of infrastructural plans will ensure resource optimisation, prevent duplication and waste of efforts, ensure identification of priority projects, ensure cooperation of strategies rather than competition, create harmonious urban planning, lead to integrated transportation systems, boost a resilient African economy, contribute to regional integration, reduce the environmental impact from waste residue and climate change, birth localised green technologies, encourage local content development, attract financial and technological investments, provide econometrics statistics for socioeconomic planning, and usher in economic opportunities in the short term and long term. We must think outside the box, beyond repetitive plans and idle visions. We must forge all our plans for a better future beyond the contemporary generation.

The construction revitalisation needs a catalyst and a success-driven enzyme. This can be achieved via digital transformation. Our research centre propagated the concept of Construction 4.0, which is the application of 4IR technologies. We did so to chart a new paradigm and innovative pathways for the construction industry. Therefore, embracing digital transformation via Construction 4.0 technologies is the way forward. This includes building information modelling, 3D printing, additive manufacturing, blockchain technology, smart contracts, virtual reality, augmented reality, artificial intelligence, digital twins, robotic technologies, drone technology, and cyber-physical systems, among others. We have addressed the need for skill revamping alongside digital transformation; however, construction companies should utilise competitive strategies and acquire these technologies. Construction firms in the African construction industry should invest in Construction 4.0 technologies and use these technologies on different construction projects.

In the 21st Century and the 4IR era, there must be a distinctive and clear departure from obsolete construction methods and processes. Yes, these technologies may be expensive; however, firms must weigh the investment in different financial models to determine the extent of productivity, the return on investment (ROI), and the profitability dynamics. We cannot just say "No" to technological investments without modelling them into financial models. The result of these models will enable a firm to consider the cost-benefit analysis and determine alternative sources of finance. Also, two or more firms may come together in the spirit of cooperation and make joint investments in any of the Construction 4.0 technologies. African construction firms must know that utilising digital technologies in administrative processes is necessary but insufficient. The more we disinvest and show a combination of complacency and investment ignorance on Construction 4.0 technologies, the more we open the door for foreign construction companies to take up big, profitable complex infrastructures and construction projects, of which the multiplier effect is detrimental to the progress of the construction industry. We cannot afford to live in fear; we must embrace, invest, and acquire these technologies, thereby reducing capital flight, increasing the propensity for reskilling and upskilling, increasing African-oriented technological sophistication, and revolutionising the construction industry for African prosperity, given its multidimensional and reverberating effect on every aspect of our economy.

In addition, there is a need for a change of approach to construction activities in safeguarding humanity. We cannot use digitalisation and all other recommended solutions to propel development in the African construction industry, and then use unsustainable construction activities to negate the gains. It would be a case of pouring water into a basket. The adoption of green practices offers a double-gain approach to African construction—protection of gains from other solutions and protection of humans from unsustainable activities, environmentally adverse materials, and unsustainable practices (i.e., resource extraction, waste generation, greenhouse gas emissions, high energy consumption, deforestation, water pollution from run-off, inefficient buildings, utilisation of non-renewable materials, and unplanned urban sprawl). Hence, for the revitalisation of the African construction industry, we must adopt green practices in terms of the green supply chain, climate-resistant structures, green maintenance practices, circular economy business models, building retrofitting, the building of energy-efficient buildings, water–energy–food nexus-oriented building design and infrastructure design, preference for brownfield sites over greenfield sites, utilisation of energy efficient windows, usage of biomimicry buildings, incorporation of renewable energy like solar energy into facilities and infrastructure, installation of rainwater harvesting systems, constructing water efficient landscaping, use of sustainable and recyclable materials, installation of green and blue roofing, utilisation of low volatile organic compounds (VOC) materials, and promotion of sustainable practices.

Therefore, construction companies within the African construction industry and built environment must make conscious decisions in adopting and systematically adapting these green practices to ensure growth in the industry. As a research centre, we are aware of the low capacity to implement these green practices and are ready to guide.

Furthermore, the African construction industry has adopted different public–private partnership (PPP) arrangements for various construction projects. These range from Build – Operate – Transfer (BOT), to Build – Own – Operate (BOO), Build – Transfer – Operate (BTO), Design – Build – Finance – Operate (DBFO), Design – Build – Finance (DBF), Management contracts, Concession contracts, and Service contracts. However, these PPP arrangements have been subjected to government corruption, political opposition, cost overruns, bureaucratic bottlenecks, currency transferability, irregular foreign exchange rates, tax regulation changes and inconsistent government policies, contractual variation, operational changes, and changes in the construction market. This has led to the failure of many construction projects. However, for the industry's growth, we cannot do without PPP; therefore, as a research centre, we propose a Blockchain oriented public–private partnership. The features of Blockchain technology can and will address the challenges of PPP. It will lead to efficiency in project execution, solve at least 55% of the causes of PPP failure, promote the trustworthiness of PPP collaboration, ensure accountability and transparency, transfer contractual obligations into smart contracts for optimal performance, enhance construction data integrity and security, enhance effectiveness, efficiency and trust of efficient payment systems, enhance the optimality of the construction supply chain, simplify compliance, promote the tokenization of assets, and drastically reduce construction disputes. Hence, construction firms and government agencies should introduce Blockchain technology into their partnership irrespective of the type of PPP.

Conclusion

The Sustainable Human Settlement and Construction Research Centre (SHSCRC) at the University of Johannesburg has comprehensively examined the African construction industry, identified its challenges, and proposed revitalisation solutions. Through collaborative efforts, multidisciplinary research, and a transdisciplinary mindset, we present seven revitalisation solutions to optimise the industry's competitive value in the global construction market. These solutions encompass addressing bureaucratic bottlenecks, upskilling to meet global market demands, implementing the Quintuple Helix model of collaboration, consolidating infrastructural plans, embracing Construction 4.0 technologies, adopting green practices, and integrating blockchain technology into public-private partnerships. By applying these encompassing solutions, we firmly believe that the construction industry and built environment in Africa will be revitalised, acting as a catalyst to achieve the Sustainable Development Goals (SDGs) for Africans, given the multidimensional and multiplier effects of these solutions.

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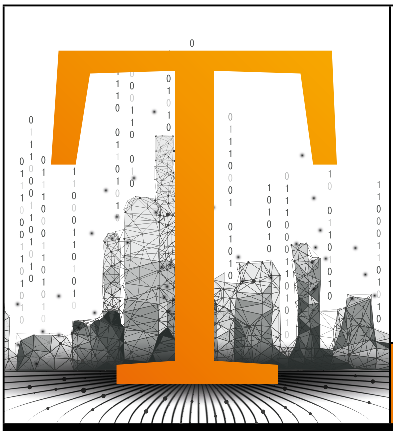

The Circumference of the Built Environment

Dr David Love Opeyemi

The SHSCRC operates within the built environment. The research from the research centre encompasses everything within the built environment, with the principal aim of protecting and safeguarding the built environment using technological innovations and sustainability practices. This raises questions on the breadth of our research: What is the built environment? Does it include the construction industry or more than the construction industry? Is it an amalgamation of the construction industry and the environment? What are the features of a built environment? Do we have an urban or rural built environment? This piece seeks to modify your thoughts and your thought process on the built environment.

The built environment began from man's need for survival by cultivating land, manufacturing tools, developing shelter, and harnessing fire from the environment. This then metamorphosed into modifying the environment for safety, comfort, and productivity via the design of structures, technological sophistication, manipulation of space, segmentation of landscape, demarcation of boundaries, and beautification of surroundings. All these human activities morphed the built environment—what man has built within his environment. To protect the built environment from the built environment, man is looking at untapped natural systems to shape the built environment further. It is an endless cycle in which the SHSCRC intervenes in safeguarding the built environment from the built environment.

According to Bartuska (2004), the built environment is *"everything humanly made, arranged or maintained to fulfil human purposes (needs, wants, and values); to mediate the overall environment; with results that affect the environmental context"*. According to the author, the built environment emerged in the 1980s and was popularised in the 1990s and was further cemented in 2003 by the International Federation of Landscape Architects. The author states that the components of the built environment include products (tools, materials and machines), interiors (workroom, living room, stadiums, etc.), structures (housing, schools, factories, bridges, highways, etc.), landscapes (parks, courtyards, farms, national forests, malls, gardens, etc.), cities (districts, neighbourhoods, towns, etc.), regions (groupings of cities), and the Earth. The research of De Valence (2018) posits that the built environment comprises all that is needed to deliver every aspect of the construction industry. The author opined that in a typical construction project, *"consultants provide design, engineering and cost planting, and project management services. There are also inputs from urban planning, transport, finance, and legal services"*, which signifies the broadness of the built environment. According to the United States Environmental Protection Agency (2023), the

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built environment *"touches all aspects of our lives, encompassing the buildings we live in, the distribution systems that provide us with water and electricity, and the roads, bridges, and transportation system we use to get from place to place"*. Also, the Construction Industry Council (CIC) of the United Kingdom considered that the built environment *"encompasses all forms of buildings (housing, industrial, commercial, hospitals, schools, etc) and civil engineering infrastructure, both above and below ground and includes the managed landscapes between and around buildings"*. This aligns with the perspective of the Centre for Digital Built Britain, which defines the built environment as *"all forms of building (residential, industrial, commercial, hospital, schools), all economic infrastructures (above and below ground) and the urban space and landscape between and around buildings and infrastructure"*. The South African Council for Built Environment Act posits that the built environment is a conglomeration and practice of the architectural profession, project and construction management professions, engineering profession, landscape architectural profession, property valuers' profession, and quantity surveying profession. Bekchanor, Wijayasundra, and De Alvis (2022) considered that the built environment includes man-modified surroundings, including buildings and infrastructure such as telecommunication systems, transportation, energy, waste management systems, and water systems. Patterson et al. (2020) refer to the built environment as a physical environment constructed to support the needs and lifestyle of residents. In Kaklauskas & Gudauskas (2016), the built environment is referred to as *"human-made surroundings that provide the setting for human activity, ranging in scale from buildings and parks or green space to neighborhoods and cities that can often their supporting infrastructures, such as water supply or energy networks. The built environment is a material, spatial and cultural product of human labor that combines physical elements and energy in forms for living, working, and playing"*. Furthermore, Lampropoulous et al. (2020) and Benis & Ferrao (2018) described the following systems and infrastructure as constituents of the built environment: water distribution systems (pipes, valves, sewers and sanitary systems' drainage & treatment), coastal storm surge infrastructure (dams, seawalls, levees), drought infrastructure (desalination plants, reservoirs & rainwater detention infrastructure), green water infrastructure against wetlands & riverbanks, stormwater drainage systems, irrigation infrastructure, water retention infrastructure, heat pumps in structures, distributed energy generation systems, the electric transport system in the environment, underground thermal energy storage, smart grids, food storage systems, urban food systems, and food accessibility systems and routes.

These descriptions, definitions, and perceptions of the built environment reflect the Indian story of the six blind men and their description of an elephant, which are true when put together. The built environment encompasses all that can be built within the environment or that affects the environment: buildings (residential, commercial, industrial, schools, hospitals, utility, farms, etc), bridges, roads, transportation systems, landscapes, infrastructure, telecommunication systems, energy systems, waste management systems, technological systems, water systems, food systems, parks, monuments, and every system built for the survival, productivity, and leisure of man and other environmental inhabitants. Hence, the modus operandi of the SHSCRC research encompasses all aspects of the built environment.

Moreover, technological innovations and speedy advances in technology as evidenced in the fourth industrial revolution for productivity, efficiency, and effectiveness, are reshaping the built environment as seen in the concept of smart city development, 3D buildings, prefabricated buildings, drones mounted with 3D printers for building repairs, drone surveillance, robotic buildings, robotic architectures, and robotic fabrications.

In addition, there are laws and regulations that shape the nature of the type of structures allowed within a geographical space, and that have modified the perspectives of the built environment. The laws that structured the built environment in the United States differ from those that structured the built environment in South Africa. Owing to geographical homogeneity, there are laws, regulations, treaties, and conventions that structure the built environment within geopolitical regions, such as the Programme for Infrastructure Development in Africa (PIDA), the EU-African Infrastructure Trust Fund, the European Fund for Sustainable Development, the European Union Global Gateway, and China's Belt and Road initiative, among others.

Also, the impact of climate change and the diminishing resources on planet Earth is leading to changing dynamics in the built environment, such as green buildings, net zero buildings, blue roofs, sustainable materials, green roofs, climate resilient designs, structures and buildings, resilient infrastructures, retrofitting buildings, sustainable buildings, eco-friendly buildings, and energy-efficient buildings.

Moreover, with the recent efforts of Man in inhabiting space, the built environment may include anything built outside planet Earth, evidenced in concepts such as space architecture, orbital architecture, the international space station, lunar architecture, and planetary surface construction.

The built environment is multi-disciplinary, trans-disciplinary, and inter-disciplinary, involving different stakeholders and moving towards trans-planetary. The built environment also differs across regions, countries, geographical locations, geopolitical culture and planetary bodies. The realities of the built environment in West Africa are different from the realities in the European Union. Even within a homogenous society, Johannesburg city's-built environment realities differ from realities on the East Rand, all within the Gauteng province of South Africa. Also, in a heterogeneous country like South Africa, built environment realities in Limpopo province differ from the realities in KwaZulu-Natal province. This also leads to the fact that population dynamics and concentration, cultural heritages, educational exposure, historical perspectives, and migration effects influence the realities of the built environment. Also, irrespective of the influencing factors, geographical disparities, and concepts that shape the built environment, all culminate into urban and rural built environments. The urban built environment covers the externalities of an urban setting that shape the structure, technological applications in structures, material usage, building patterns, types of social amenities, landscaping designs, and climate change-influenced designs in an urban area. Also, the rural built environment deals with the realities of a rural setting, which shapes the type of building, the economic influence of building designs, connectivity factors, family heritages, farmlands, historical perspectives, and economic settings in the rural area.

Therefore, the totality of the built environment, whether urban or rural, and irrespective of geospatial influence, geopolitical colouration, and geo-economic tendencies, encompasses all forms of construction activities, structures, projects, infrastructure, and digital technology as they relate to man's residency and settlements, climate change-influenced buildings and structures, space-induced structures, and systems that affect man's residency and settlements such as energy, telecommunication, water, agriculture, engineering, urban and rural development, transportation, landscaping, information, and space systems, policy-making initiatives for man's settlements, and factors that influence man's movement and settlements. Hence, the research of the SHSCRC encompasses everything within the totality of the built environment as expounded earlier, as we collaborate with professionals, academics, and policymakers in different fields of study to ensure a sustainable and digitally built environment that is safe, humane, conducive, and friendly for all inhabitants in both the short and long terms. Hence, our motto: Shaping Tomorrow's Built Environment Today.

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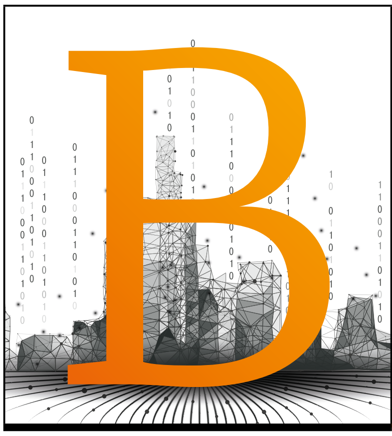

Blockchain Technology and the Revolution of the Construction Industry

Dr. Opeoluwa Akinradewo

Introduction

Blockchain technology, the backbone of cryptocurrencies like Bitcoin, has emerged as a disruptive force across multiple industries. Its immutable, decentralised, and transparent characteristics have made it an attractive technology for various applications beyond cryptocurrencies. The construction industry, with its complex supply chain, fragmented data systems, and payment processing challenges, is one such industry that could potentially benefit from blockchain technology.

What is Blockchain technology? Blockchain is a distributed digital ledger that can record transactions reliably, openly, and permanently. Each block in the chain contains a unique cryptographic code that links it to the previous block, creating an unbreakable chain of records as depicted in Figure 1. This technology enables trust and accountability in peer-to-peer transactions, eliminating the need for intermediaries such as banks, lawyers, or other third-party services. The characteristics that make blockchain technology unique are its immutability, decentralisation, and transparency. Blockchain technology has been applied to various industries such as finance, healthcare, supply chain management, and gaming. In the finance sector, for example, blockchain-based cryptocurrencies like Bitcoin and Ethereum have disrupted traditional financial systems by enabling peer-to-peer transactions without intermediaries.

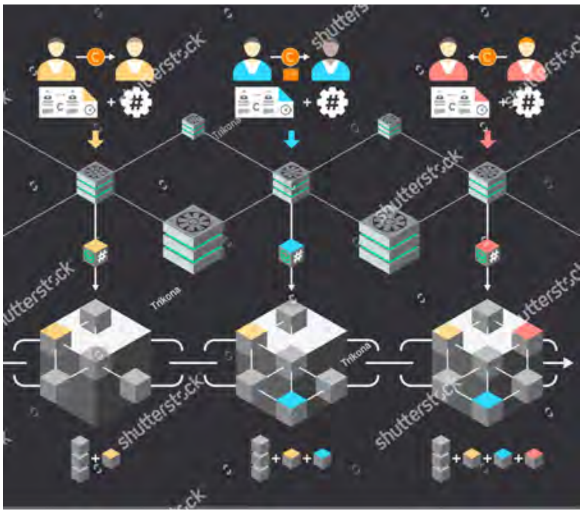

Figure 1: Blockchain Architecture (www.shutterstock.com)

Applications of Blockchain in the Construction Industry

There are various applications of blockchain technology in the construction industry today. These include, but are not limited to:

— Smart contracts for construction project management: A smart contract is a computer program that automatically enacts the terms of a service agreement between the parties involved.

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Smart contracts have the potential to streamline construction project management by automating contract execution, reducing administrative overheads, and improving efficiency.

— Enhanced supply chain management through blockchain-based tracking of construction materials and equipment: Blockchain-based tracking of construction materials and equipment could increase transparency and accountability in the construction supply chain. This technology could enable real-time tracking of the construction materials' movement, ensuring that they are ethically sourced, and reducing the risks of fraud and counterfeiting.
— Increased transparency and accountability in payment processing through blockchain-based solutions: Blockchain-based payment processing solutions could improve payment processing efficiency and reduce the risk of fraud. Payments can be automated, eliminating the need for intermediaries, reducing transaction fees, and enabling faster payment processing.
— Improved collaboration and data sharing between project stakeholders through blockchain-based platforms: Blockchain-based platforms could enable secure and transparent sharing of project data between project stakeholders, improving collaboration and reducing the risk of data breaches.

Benefits and challenges

— **Benefits**: Numerous benefits have been reported regarding the adoption of blockchain technology in the construction industry. It is reported that the implementation of blockchain technology in the construction industry could lead to increased efficiency, reduced costs, and improved transparency. The technology could streamline construction project management, supply chain management, and payment processing, leading to faster completion of construction projects, lower costs, and fewer disputes.
— **Challenges**: Implementing blockchain technology in the construction industry is currently being faced with challenges such as high implementation costs, technical expertise, regulatory challenges, and resistance to change from industry stakeholders.

Typical Applications of Blockchain Technology in the Construction Industry

There have been successful blockchain-based projects in the construction industry, such as:

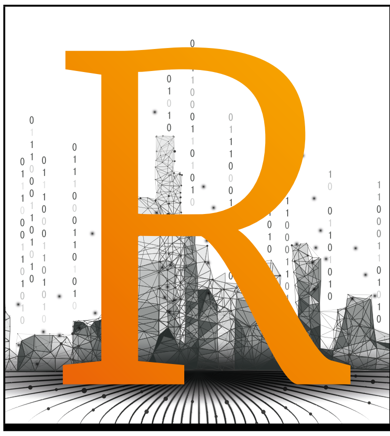
— **Proxeus**: This is a blockchain-based platform that can be used in construction projects to streamline and automate administrative tasks such as document management, project tracking, and communication between stakeholders. It is a very useful tool for construction project management.
— **VeChain**: This is a blockchain-based platform that can be used to track the entire lifecycle of construction materials, from production to delivery and installation. By using VeChain's blockchain technology, each material can be assigned a unique digital identity that can be tracked and verified at every step of the supply chain. This ensures that the materials used in construction projects are of high quality, sustainable, and ethically sourced.
— **Elastos**: This is a blockchain-based platform that provides a secure and decentralised environment for building dApps. It can be used in the construction industry to store and manage construction information securely and transparently, ensuring that all stakeholders always have access to the same data.

Future Trends and Opportunities

The construction industry could benefit from emerging technologies such as artificial intelligence and the Internet of Things in conjunction with blockchain technology. The combination of blockchain technology and artificial intelligence could enable automated decision-making processes for construction project management, reducing errors, and increasing efficiency. Similarly, the integration of the Internet of Things with blockchain technology could enable real-time tracking of construction materials and equipment, ensuring their authenticity, quality, and safety.

Conclusion

Blockchain technology has the potential to revolutionise the construction industry by increasing efficiency, reducing costs, and improving transparency. Blockchain-based applications such as smart contracts, supply chain management, payment processing, and data sharing could streamline construction project management, leading to faster completion of projects and fewer disputes. While implementing blockchain technology faces challenges such as high implementation costs, technical expertise, and regulatory issues, the benefits of blockchain technology outweigh the challenges. Hence, organisations in the construction industry should explore the potential of blockchain technology and collaborate with other stakeholders to develop and adopt blockchain-based solutions.



Retrofitting Designs of Existing Commercial Buildings for Net Zero Energy Use

Ms Keamogetswe Maluleke

Introduction

Buildings have a large influence on energy use and the environment. Commercial and residential buildings consume over 40% of primary energy and 70% of electricity in the United States (EIA, 2005). The energy consumed by the construction industry continues to rise because new structures are built quicker than old ones. Electricity usage in the commercial building sector doubled between 1980 and 2000, and it is anticipated to rise by another 50% by 2025 (EIA, 2005). Commercial building energy consumption will continue to rise unless buildings can be built to create enough energy to balance the rising energy demand of these structures. To that aim, the United States Department of Energy (DoE) has set an aggressive target of developing the technology and knowledge foundation for cost-effective zero-energy commercial buildings (ZEBs) by 2025.

Building Performance Metrics

According to the US DoE, a zero-energy building is defined as a building that produces enough renewable energy to meet its own annual energy consumption requirements (US DoE, 2015) According to the European Union Article 2, a nearly zero-energy building is a building that has a very high energy performance, where low energy is required by the building, which should be covered to a very significant extent from renewable sources, including sources produced on-site or nearby (European Commission; Energy). There are several metrics that define the performance of buildings, such as the net-zero site energy building, net-zero sources energy building, net-zero energy cost building, and net-zero energy emission building.

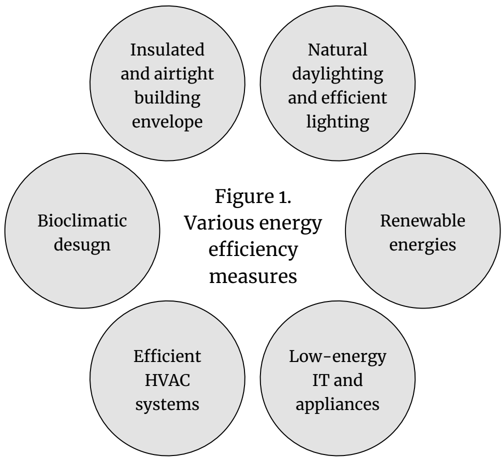


Figure 1. Various energy efficiency measures

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Table 1. Summary for zero energy building

TYPE	DEFINITION	ADVANTAGE	DISADVANTAGE
Site NZEB	A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.	Easy to implement. Verifiable through on-site measurements. Conservative approach to achieving ZENB Easy for the building community to understand and communicate. Encourages energy-efficient building design.	Requires more PV export to offset natural gas. Does not consider the utility costs. Not able to equate fuel types. Does not account for non-energy differences between fuel types.
Source NZEB	A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.	Able to equate energy value of the fuel types used at the site better model for impact on national energy system. Easier ZEB goal to reach.	Does not account for non-energy differences between fuel types. Source calculations are too broad. Does not consider all energy costs. Need to develop site-to-source conversion factors.
Emissions NZEB	A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.	Better model for green power. Accounts for non-energy differences. Easier ZEB to reach.	Need appropriate emission factor.
Cost NZEB	In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.	Easy to implement and measure. Allows for control. Verifiable from utility bills.	Requires net-metering agreements. High volatile energy rates make for difficult tracking over time. Net metering is not well established, often with capacity limits and at buyback rates lower than retail rates.

Principles to Achieve Net-Zero Energy Building Design

Utilising passive heating or cooling techniques like solar chimneys and direct heat gain through south-facing glazing and/or isolated gain or sunspace; thinking through all possible exterior wall construction that avoids thermal bridging; increasing the R-value in all roof construction; utilising efficient lighting systems; utilising daylighting sensors and occupancy sensors; and finally using energy-efficient office equipment for workstations, are all important considerations that should be made together. The designer should then incorporate a life cycle analysis, a net-zero water and energy system, and optimise the design in accordance with occupancy levels.

Three guidelines can help to create a net-zero energy building design:

A. **Building envelope measures**

The structure should be positioned to reduce HVAC loads, but it should also include screens and overhangs to block direct sunlight. There are several choices, including plants, awnings, and roof overhangs. Avoid glazing on the east/west façade if you want to limit heat input through windows. Increased insulation on opaque surfaces, the use of glass with low solar heat gain coefficient values, the use of double-skin façades, and modification of the building envelope to meet the environmental conditions, are other ways to limit heat gains.

B. **Energy efficiency measures**

This may be done by modelling the design using simulation, predicting the optimal needs, and applying safety factors in accordance with ASHRAE Standard 90.1 to appropriate baseline circumstances. To be effective when employing variable volume systems, variable speed drives, variable capacity boilers, variable capacity chiller systems, variable capacity pumping systems, and part load performance should be taken into account in the simulation. In addition, a high-efficiency lighting and control system should be used by the designer, for example, LED lighting, high-performance ballasts, dual-circuited task lighting, occupancy sensors, and daylighting dimming sensors.

Electric loads should be switched at times of high demand by the designer to save energy usage. Some suggestions for reducing HVAC loads include the use of heat recovery chillers (Lin B, Li X, 2011), underfloor air distribution systems (Shehadi M, 2018), high-efficiency chillers (Dong H, et at., 2010), passive cooling (Li G, 2011), phase-change materials (PCMs) for thermal storage (Gellings CW, 2009), combined heating and power (CHP), and natural ventilation (Shehadi M, 2019). After construction is complete, commissioning is an essential stage to make sure the facility is operating as planned and accomplishing its goals. The building's energy-related systems are installed, calibrated, and tested during the commissioning phase to ensure they are operating in accordance with the owner's project requirements, design principles, and construction documentation. The HVAC systems and controls, lighting and daylighting controls, the domestic hot water system, and any renewable systems like wind and solar should all be included in the commissioning phase. Building commissioning may increase occupant productivity while lowering energy consumption, operating expenses, and contractor callbacks. Energy efficiency may be increased by 5–10% when the commissioning procedure is implemented successfully.

C. **Renewable energy measures**

The first two methods for maximising energy sources are the building envelope, which promotes the use of less energy, and the efficient utilities and equipment measures. Renewable energy measures are more expensive than these two measures, thus designers should begin with the first two steps and optimise their design to lower the energy consumption in this stage. Solar, wind, biomass systems, and other alternative energy sources are available. Roof-mounted solar collectors heat a fluid that is then used to heat water stored in a cylinder in solar water heating systems. There are two types of collectors that are often used: flat plate and evacuated tube. Flat plate collectors are often less expensive. Solar water collectors either directly or indirectly heat the water that would be stored in a cylinder by heating another fluid that would heat the water. Photovoltaic systems may be utilised to store energy and shift peak demand. Wind systems generate electricity at a very low cost if the wind is continuous and constant, and the speed is greater than 10 mph (4.47 m/s), although it is preferable to be greater than 25 mph (11.2 m/s).

Conclusion

Net zero buildings offer a transformative solution to the environmental challenges we face. By combining energy efficiency, renewable energy generation, and innovative design, these buildings have the potential to revolutionise our approach to construction, reduce greenhouse gas emissions, and mitigate climate change. Embracing net zero building practices on a global scale can not only create a sustainable future but also contribute to economic growth and improved quality of life for generations to come. It is our responsibility to support and invest in this sustainable revolution to shape a brighter and greener world.

Sustainable and Innovative Construction Material: Blue Roof

Mr Mpingana Wanda

The blue roof is a novel and sustainable construction material that has garnered widespread acclaim because its advantages are too numerous to overlook. Hence, Foster et al. (2011:11) strongly believe that blue roof controls, blocks, or stores stormwater and permits on-site storage or discharge for purposes other than hygienic ones. Additionally, Shafique and Luo (2019:476) posit the view that the blue roof is an environmentally friendly approach that aims to capture rainwater runoff by utilising temporary storage layers with different depths, allowing for controlled detention over a specific duration. Before delving into the blue roof technology, it is necessary to look at the observed advantages.

Foster et al. (2011:11) argue that the rainwater stored in blue roofs can reduce urban heat by splashing the water onto the roof, improving the cooling effect via evaporation. Eagle (2017) also indicates that blue roofs offer improved temperature control, resulting in lower energy usage and enhanced water availability. Lastly, the implementation of blue roofs not only improves the natural water cycle in urban environments but minimises the adverse effects of urbanisation and provides a cost-effective solution for sustainable stormwater management (Shafique et al., 2018:760).

To mitigate potential risks such as leakage, ponding, water damage, infiltration, and structural failures in the long term, proper design and construction of blue roofs are crucial (Eagle, 2017). The blue roof infrastructure normally contains various temporary storage layers that retain the rainwater runoff (Shafique and Luo, 2019: 476). Consequently, Rey-Mahia et al. (2022) argue that the blue roof consists of four main layers, namely a waterproof membrane to prevent water seepage, a drainage layer to direct rainwater to a retention layer, and a growing medium layer that supports vegetation growth, allowing for the temporary storage of rainwater in the retention layer before gradual release into the surrounding area.

Furthermore, the water harvested from blue roofs can be released into sewer systems at a regulated flow rate, replenished into groundwater via infiltration systems, or used on-site for non-potable purposes and irrigation (Foster et al., 2011:11).

Blue roofs play a crucial role in mitigating the effects of climate change. The process of urbanisation disrupts the natural hydraulic system by replacing permeable surfaces with impermeable ones, leading to a heightened risk of flooding and environmental issues (Miller et al., 2014:60). Due to this ecological disturbance, there is a loss of green spaces and natural biodiversity in urban areas. The urban heat island effect can arise as a result of creating more frequent and intense heat waves (Gunawardena et al., 2017). Hence, Almaaitah et al. (2021:224) argue that blue roofs can mitigate the urban heat island effect by providing shade, absorbing heat through vegetation, and lowering the overall

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temperature of urban areas by radiating longwave energy. Furthermore, blue roofs can also assist in reducing the risk of flooding and soil erosion due to intense storms through the temporary storage and stormwater management of rainwater (Almaaitah et al., 2021:226). Brears (2018) also argues that blue roofs enable the integration of trees and vegetation into the growing medium layer, allowing for the absorption of carbon dioxide and other air pollutants and ultimately leading to enhanced air quality.

Blue roofs play a crucial role in sustainable development in urban areas. This innovative construction material has the potential of being the driver of Sustainable Development Goal 11 related to sustainable cities and communities (Russell, 2018:33). Blue roofs can ensure that local communities can address the effects of climate change caused by rapid urbanisation by reducing the risks of flooding and the urban heat island effect, and improving air quality, thereby ensuring sustainable communities (Rey-Mahia et al., 2022). In this way, the needs of the future will not be compromised by the effects of climate change and urbanisation; the population of people living in urban areas is predicted to be two-thirds of what it is now in 2050 (Russell, 2018:31). The blue roof technology has the potential of being a driver in the sustainable cities goal, being at the forefront of innovative construction materials in the industry.

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Sustainable and Innovative Construction Material: Carbon Fibre

Tanga Tambwe

Every human action, including construction activities, affects the natural world we live in. A certain amount of impact can be absorbed by the environment without causing long-term harm, but it is evident that current human actions routinely go beyond this limit, degrading the quality of the environment in which we live and endangering the health of generations to come (Ashby, 2011).

For instance, the construction industry, by its actions, produces high carbon emissions that contribute to health damage and negative consequences resulting from construction actions (Soliman et al., 2022). However, Soliman et al. (2022) have suggested that innovative construction material technologies may contain answers to numerous problems encountered by the construction sector, such as high carbon emissions and low energy efficiency. One of the activities undertaken by most companies involves the creation and use of innovative and sustainable construction materials such as carbon fibre. This carbon fibre usage is on the rise, particularly for structures that are vulnerable to harsh environmental conditions (Zhang et al., 2022). In addition, Huson et al. (2014) explained that fiscal constraints are undoubtedly driving an intense interest in carbon fibre materials from the aerospace industry and are predicted to have a related impact in the general sectors (construction, automotive), where these materials have been used to strengthen old infrastructure such as beams, bridges and columns. Pusch and Wohlmann (2018) supported this by naming a few applications of carbon fibre-reinforced polymers (advanced carbon fibre with cohesive matrix) in various sectors that include aerospace and defence, wind turbines, sport and leisure, and civil engineering, which is part of the construction sector. Frigione and Aguiar (2020) propose that carbon fibre can offer effective substitutes for traditional construction materials (concrete, steel, aluminium). This implies that structures built using carbon fibre can be designed to be lighter and more efficient, without sacrificing strength or durability. Huson et al. (2014), Zhang et al. (2022), and Holschemacher (2022) reported that this carbon material's light weight can lead to more cost-effective transportation, installation and maintenance processes, high strength, recyclability, chemical resistance, and low density. Furthermore, carbon fibre is resistant to corrosion, making it an ideal material for use in severe environments, such as industrial settings (Pusch & Wohlmann, 2018; Zhang et al., 2022, Holschemacher, 2022). Carbon fibres, according to Pusch and Wohlmann (2018), are simply fibres with a carbon content of not less than ninety percent. They are created through the thermal conversion of lower organic carbon content fibres (renewable resources), which make them sustainable. These renewable resources include polyacrylonitrile (PAN), which has thousands of filaments with diameters between 5 and 10 μm.

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Zhang et al. (2022) explained that the flexible nature of carbon fibre provides an advantage to the construction industry, which encourages its implementation. This is because carbon fibre is a perfect material for use in intricate building projects since it can be shaped into a variety of shapes and sizes (flexibility). Because of this flexibility, designers and architects can experiment with cutting-edge ideas that would be impossible to realise with conventional building materials. Prefabricated panels for use in building façades are one application of carbon fibres in the construction industry. The aforementioned panels cannot only be made thinner and lighter, allowing energy saving, but can also allow natural airflow, which eliminates the requirement for mechanical cooling systems (George et al., 2013; Zhang et al., 2022). Another application of carbon fibres is the use of carbon-reinforced concrete (CRC) where carbon-based meshes, frequently blended with solid carbon fibre-reinforced polymer bars, are used as reinforcement in concrete members. However, the implementation of this CRC in the construction sector strongly relies on, and requires frequent production of, new technologies, which is a challenge (Holschemacher, 2022)

Conclusion

The environmental challenges that the world is facing have pushed the construction sector to combine ideas from different perspectives to come up with innovative and sustainable approaches. One approach incorporates the use of carbon fibre, which offers a great substitute for traditional materials for constructions that need to be strong, resilient to the elements, and durable. Its adaptability also makes possible complicated constructions and imaginative designs that other materials would not be able to support. Employing carbon fibre in the construction sector may help lower greenhouse gas emissions, increase energy efficiency, and encourage sustainability.

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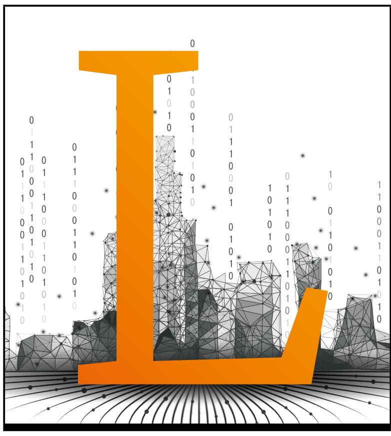

Local Content Development: Perspective on the African Construction Industry

Dr Babatunde Fatai Ogunbayo

In simple terms, local content refers to using materials and local skills and/or maintaining an asset or service using locally sourced skills and materials. In any developing economy, the key components of local content include local employment and skills development, local procurement of goods and services, and enhancing the capacity of local suppliers and contractors in the local industries. Like any other industry or sector, the construction industry in Africa plays a vital role in the economic growth of countries (Masoetsa et al., 2022). In the same vein, this contribution varies from country to country. The political instability and economic pressures in some African countries, and the impact of the COVID-19 pandemic, have significantly affected this sector. It is relevant that the construction industry heavily relies on conventional construction materials, leading to a high carbon footprint. However, many existing local and waste materials are greatly overlooked and under-utilised in the African construction industry sector (Abdalqader et al., 2022). However, the construction industry in Africa plays a notable role in the economy, indicating how well the economy is doing (Baloyi & Bekker, 2011). Inappropriate use of the available local content includes construction materials, which contributes to many local skilled workers being unemployed, and the poor use of locally sourced construction materials, including cement and aggregates.

If the local content is well positioned, the African construction industry, like any other industry, can assist in achieving countries' national development and UN sustainable development goals (SDG) in the continent. One effective way to achieve this is by replacing traditional construction materials sourced outside the continent with more sustainable, locally sourced ones. The significance of local content (construction materials) in African development cannot be overemphasised. This is because the poor development of the African construction industry is affected by inappropriate usage of the available local content in the continent. It is pertinent to note that the construction of new structures with local content, through public or private efforts, brings new jobs, increases local spending, creates jobs for locals, leads to neighbourhood improvements, and, most especially, the encouragement of using locally sourced construction materials. Local content, as defined by Warner (2011), "*is a composite value contributed to the national economy from purchasing bought-in goods and services, including wages and*

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benefits, materials (construction materials), equipment and plant, subcontracts, and taxes." In the construction industry context, local content refers to construction materials and products made in a country instead of those imported for construction purposes. However, there is an increasing interest in using construction materials sourced locally for construction products to support local economies and provide jobs. Using local materials for construction purposes in developing economies, including Africa, is also seen to improve national sustainability performance and develop greener buildings (Maponga, 2021). As a result, many countries are developing policies that promote local content usage for construction purposes.

In many African countries, the procurement of local materials has been identified as essential for supporting local economic growth (Stephenson, 2013). Local content can be described as the number of national workers employed within a total workforce or as a proportion of procurement expenditure allocated to local suppliers (Veloso, 2006). In the national development context, the rationale of local content requirements is the attempt to extract the full benefits of job creation for most African countries. This rationale can further narrow the gap in local expert capability and construction market opportunities between developed and African countries. Typically, firms in developed countries have mature technologies but struggle to sell them in saturated markets, whereas African countries have immature technologies and offer new market opportunities through their available local construction raw materials. The logic behind local content usage for construction work is to increase domestic content production in the receiving countries and reduce the foreign country's output in its home country. The requirement for local content usage in Africa's economy, including the construction industry, is that the national government intends to correct a perceived gap between the private and social costs and benefits of the investment (Veloso, 2006). Recently, many African countries have enacted local content laws. However, implementing these laws and policies has not always been successful due to frequent bottlenecks in government bureaucracy (Corkin, 2012). This might also be due to the non-explicitly targeted local material for construction work. It might also be due to existing national construction practices that do not support local content considerations. However, it is important to note that local construction materials used for construction purposes have different benefits and values to the African construction industry.

For instance, importing construction materials and other construction products for the African industry construction industry from outside the continent will involve payment with scarce foreign exchange. In most African countries, foreign exchange required for imported construction products is limited. In such circumstances, using locally sourced construction materials and developing other local capabilities to meet the construction industry's needs will free up valuable foreign exchange for vital construction products and equipment that may have to be imported. Thus, the local economy will gain economically. Also, local product manufacturers of construction materials and tools can reduce delivery times and improve the predictability of supply by avoiding transport logistics and bureaucracy, such as import permits, related to importing construction materials that can be found locally. The risk involved in the supply line of construction materials, especially hoarding of construction within the construction industry, can also be avoided through local quantities of products stocked at the warehouse and readily available, as additional stock can be more easily ordered and delivered.

In the same vein, continued encouragement of using local construction materials within the local content policy will lead to a closer physical relationship between product manufacturers, installers, and users. This helps local designers and producers understand how their products are used. It will also lead to local product improvement, usage, and outlook. However, locally produced construction materials and products may not achieve the same levels of quality as imported goods. Nonetheless, using local construction materials through a closer physical relationship between the manufacturers and professionals might lead to further research among African material testing institutions toward achieving quality standards for local products. In most African countries, manufacturers of local construction materials and products cannot produce construction materials and products in the quantities required or for their national quotes expected for large-scale projects (Corkin, 2012). Thus, meeting and avoiding this shortage requires proper planning, good legislation, and the incorporation of lead times to enable local manufacturers to scale up production and stockpile the materials and products required (Warner, 2011).

Moreover, local manufacturing of construction materials and products means that the materials used and skills involved in producing these products were sourced locally and will be available in the long term to carry out repairs and maintenance when needed. Thus, this will enable repairs and maintenance to be executed more rapidly and cost-effectively, with the country losing nothing in foreign exchange. The easy maintenance and repair of locally sourced construction products will also mean that waiting times and costs associated with imported products are avoided. This will reduce operational downtime and improve the African construction industry's operations and process efficiencies. However, limited competition among local producers of construction materials and products in Africa has resulted in locally produced materials being more expensive and unresponsive to market needs. The diversity in construction components can be used in developing a wide range of small and medium enterprises (SMEs) linked to manufacturing different construction materials and products to provide a platform for competition among manufacturers. Through this means, the resulting local economic and industry diversity is more resilient and better able to weather economic downturns than when product is imported from larger employers from developed economies. Moreover, producing and fabricating construction materials and products for the African construction industry through local content will support local businesses and create employment opportunities. Income and tax revenue from these businesses can be used to improve other sectors of the economy, such as education and health, improve quality of life, and increase economic competitiveness (Gu & Yabuuchi, 2003).

In conclusion, it is pertinent to know that local content has not been pursued widely as an objective in construction materials and product specification, nor has it been successfully implemented in most African construction industries. Thus, governments at the national and local levels should enact policies that guide the adoption of local content, especially toward developing the construction materials and products that will be guided by local content standards in line with obtainable international standards and codes such as ISO 9000. Ministries, Departments, and Agencies (MDAs) of African countries should organise frequent training for manufacturers on quality, and on ways and methods of improving local content products, including construction materials and products. This is because manufacturers of construction materials and products in Africa can benefit from local content production and application in the construction industry through sustainable production of construction products from readily available local materials. Developing local content for construction materials and products for the African construction industry could improve the sustainable performance of the construction industry, create jobs, and support the local economy. Local content for construction materials is also relatively easy to implement for African construction. It should be prioritised to improve the economic power block of Africa, making it an ideal way to stimulate the local economy and create more sustainable construction materials and products. Finally, governments, non-governmental organisations, academic and building material research institutes, and manufacturers of construction materials and products within the African continent, should collaborate in local content development and usage in the construction industry toward meeting national development and UN sustainable development goals.

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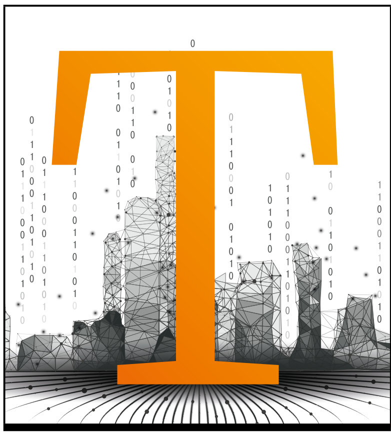

The Digitalisation of the Construction Industry and the Fourth Industrial Revolution

Dr Samuel Adekunle

Introduction

The traditional way of doing things (reliance on paper-based documentation, manual processes, and limited data utilisation) is characterised by a paper-based workflow. This has been observed to be prone to human error and less productivity. Generally, this is experienced in diverse sectors of the economy, although some sectors were able to make significant transitions to better approaches compared to others. Other sectors are observed to be early adopters of technology compared to the construction industry[1]. Consequently, the construction industry loses a lot of revenue due to this approach, despite the numerous advantages of improved benefits and productivity[2]. Other challenges facing the construction industry include low productivity, fragmented processes, safety concerns, and environmental impact.

Due to the nature of trying to solve problems and get better, humans have naturally tried to better previous achievements and conquer new territories through innovations and inventions. To this end, men have transitioned various industrial revolutions from the first to the fourth industrial revolution (IR), and gradually, the 5th revolution is being ushered in. Each of these IRs has its peculiar characteristics. Figure 1 presents the various IRs. The diverse IRs aim to progress and promote the efficiency of human endeavour. In the current IR, the connectivity of data and interdependency of humans and machines is becoming prevalent. This is heavily underpinned by an array of technologies and innovations (see Figure 1).

Various sectors have adopted the emerging technologies in the 4IR, albeit at different paces. For the construction industry, it has been tagged a latecomer to the technology adoption party. The 4IR in the construction industry has been tagged construction 4.0, which means the adoption of emerging technologies and innovations in the 4IR to the context of the construction industry. The impact of the 4IR is extensive on the construction industry process, people, and products. This is due to the disruptive nature of the technologies affecting every facet of the industry[3]. The fourth IR's centrality is the digitalisation of the construction industry. Consequently, 4IR is characterised by the breaking down of silos and connecting the physical, digital, and biological spheres in the construction industry (see Table 1).

These technologies and innovations are adopted at various construction phases: design and planning, construction execution, operations, and maintenance —throughout the facility lifecycle.

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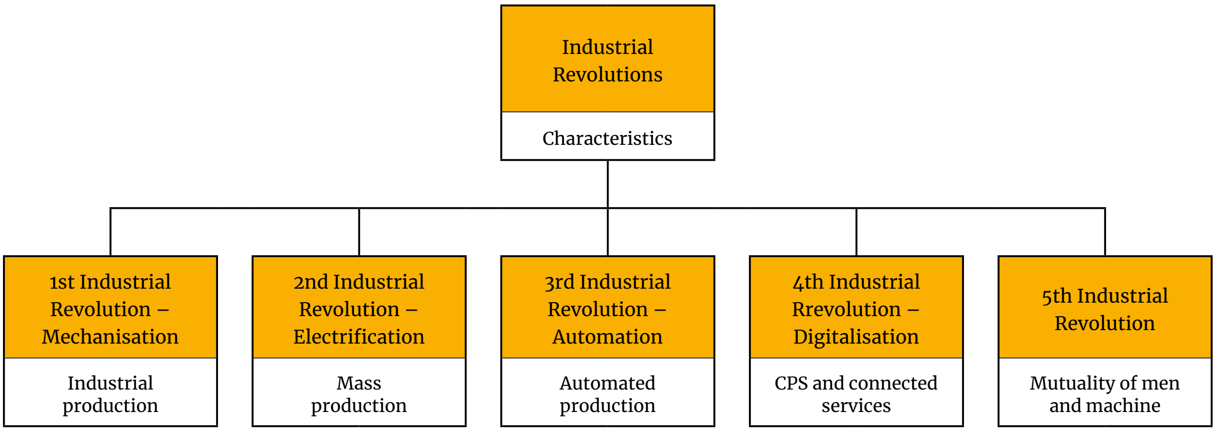

Figure 1. IRs

Table 1. Some 4IR technologies/innovations

Technologies/innovations	
Building Information Modeling (BIM)	3D model-based process for design, construction, and operation
Artificial Intelligence (AI)	Machine learning, data analytics, automation for tasks like predictive maintenance, design optimisation, and safety monitoring
Internet of Things (IoT)	Sensor-connected devices for real-time data collection and analysis
Robotics and Automation	Automated equipment and robots for dangerous, repetitive, and labour-intensive tasks
Virtual and Augmented Reality (VR/AR)	Immersive technologies for visualisation, training, collaboration, and remote monitoring
Big Data	Analysing large datasets to improve decision-making, identify trends, and predict outcomes
Digital twin	A virtual representation that serves as the real-time digital counterpart of a physical object or process
Prefabrication	Practice of assembling components of a structure in a manufacturing site or factory, and then transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located
3D printing	Process of making three-dimensional solid objects from a digital file
Drones	Providing aerial surveys, monitoring project progress, and enhancing safety

[1] Obuks Ejohwomu et al., "Construction and Fourth Industrial Revolution: Issues and Strategies," in *The Construction Industry: Global Trends, Job Burnout and Safety Issues.*, ed. PhD (Editor) Emmanuel Adinyira, PhD (Editor), Kofi Agyekum, First (Nova Science Publishers, 2021), https://doi.org/https://doi.org/10.52305/JDFM1229.

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Benefits of Digitalisation for the Construction Industry

Some of the general benefits of the 4IR and its attendant technology and innovations are listed below. These benefits apply to the construction industry at the micro, meso and macro levels.

- Increased productivity and efficiency.
- Improved project outcomes: cost reduction, waste minimisation, and schedule adherence
- Enhanced safety and working conditions
- Reduced environmental impact
- Increased collaboration and communication among stakeholders
- Improved decision-making through data-driven insights

Barriers to Implementation of Digitalisation in the Construction Industry

The key challenges and barriers to broader adoption of digitalisation in construction include[4]:

- Lack of awareness and understanding of new technologies
- Fragmentation of the industry and resistance to change
- High initial investment and running costs for technology implementation
- Lack of interoperability and data standardisation across different platforms
- Cybersecurity risks and data privacy concerns
- Lack of trained personnel

Potential Strategies and Solutions to Overcome these Challenges.

- Government initiatives and support programmes
- Industry collaboration and knowledge sharing
- Standardised data formats and open platforms
- Education and training programmes for workforce development

Future Trends and Outlook

- Integration of AI and machine learning for autonomous construction
- Development of collaborative robots and human–robot interaction
- Blockchain technology for secure data sharing and transparency[5]
- Sustainable construction practices enabled by digital technologies
- Ethical considerations and data privacy concerns

The Potential Long-term Impact of Digitalisation on the Construction Industry

- Increased competitiveness and global market opportunities
- Transformation of the workforce and emergence of new skills[6]
- Greater focus on sustainability and environmental responsibility
- Improved quality of life through smart and resilient infrastructure[7]

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Conclusion

The construction industry needs to catch up in the adoption of technology and innovations over the years and, by extension, industrial revolution. The construction industry in the light of the IR has been highlighted, albeit through a cursory view. The different aspects of the 4IR were identified. The challenges and strategies to complete the construction industry's complete digitisation were also identified. It is important to note that achieving the 4IR is a prerequisite for achieving the 5IR, as it provides the necessary technological adoption. Therefore, it is pertinent that the construction industry stakeholders strive to be proactive in adopting digital technologies to ensure a more efficient, sustainable, and resilient construction sector.

Teasers

Mr. Otasowie Kenneth

1. I can be open, but I never let anything in. What am I?
2. I open and close but I am not a door. I let in light but keep out the elements. What am I?
3. I am always on top of things, but sometimes I am upside down. I can be made of wood, metal, or even stone. What am I?
4. I am taken from a mine, and shut up in a wooden case, from which I am never released, and yet I am used by almost every person. What am I?
5. What comes in different sizes and shapes, but is often made of stone? It can be used to construct buildings, monuments, and sculptures. It's a common material for roads and pathways. People skip them across water for fun. What is it?
6. What is something that can be cracked, made, told, and carried, but also needs to be supported?
7. What has a heart that doesn't beat, a mouth that doesn't eat, and a wall that cannot be breached?
8. What is something that can be nailed, sawed, and drilled, but can't be touched or held?
9. What is something that can help you build a structure, but is not a tool or a material?
10. What is made up of a series of triangles, but is strong enough to support buildings, bridges, and other structures?
11. What is something that keeps a building standing strong, but can also mean to walk with confidence and pride?
12. I go up and down without shifting position. What am I?
13. "Afonidunto" is a part of a building that supports the weight of the structure.
14. Anxvteacoi: is a process carried out before prior to construction
15. Pemituneq can be used for various purpose in construction

Answers

1. Window
2. Window
3. Roof
4. The answer is a nail. Nails are commonly made from metal that is mined from the earth and are often sold in wooden cases. Once a nail is used, it remains in place and is never released, yet nails are used by almost everyone for various purposes such as construction, woodworking, and hanging pictures.
5. Stone
6. The answer is a beam. A beam can be cracked under too much pressure, made by assembling pieces of wood or metal together, told by describing its properties and uses, carried by construction workers or machines, and it also needs to be supported to bear weight and prevent collapse.
7. A house! The walls of a house cannot be breached, and the house itself has a heart (the fireplace), and a mouth (the chimney) that don't actually beat or eat.
8. The answer is: a "joist". A joist is a horizontal structural member used in construction to support floors, ceilings, or roofs. It can be nailed, sawed, and drilled during the building process, but once it's installed, it can't be touched or held.
9. A scaffolding.
10. A truss! A truss is a framework made up of a series of interconnected triangles that is commonly used in construction to provide support and stability to structures.
11. A strut! In the context of a building, a strut is a structural component that helps to support and reinforce the structure, keeping it standing strong. As for the other meaning, to "strut" means to walk with confidence and pride, often accompanied by a swaggering or self-important demeanour.
12. An Escalator
13. Foundation
14. Excavation
15. Equipment

Construction Puzzle

B	F	M	S	P	A	R	U	D	E	U	C	D	U	C	L	B	B	J	P	L	U	D	P	L	Z	C	H	X	Y
V	M	A	T	P	R	O	M	U	Z	X	F	W	Q	H	E	R	U	O	B	A	L	L	P	E	Y	R	P	V	W
E	N	H	O	O	C	T	V	R	S	J	H	O	R	R	S	M	C	P	D	E	Y	D	F	S	J	O	Y	S	K
D	X	X	U	E	U	A	W	O	A	D	W	Q	S	L	J	C	E	T	O	H	C	J	P	I	H	W	M	R	D
Y	T	T	S	S	H	V	E	P	A	T	P	C	O	R	N	Y	R	N	P	P	Y	A	E	H	A	B	E	O	Q
E	E	E	U	D	I	A	K	B	X	K	J	V	N	W	O	G	C	E	T	U	V	I	K	C	F	A	O	X	S
R	K	W	N	B	Q	C	N	Y	C	O	N	T	R	A	C	T	O	R	W	E	H	A	M	M	E	R	H	D	P
M	F	H	F	D	I	X	R	G	F	N	A	A	W	T	D	G	A	Q	R	D	P	B	H	L	O	E	D	B	Y
S	E	F	C	F	E	E	S	X	R	S	K	F	C	O	K	S	B	V	A	U	R	R	B	L	O	C	K	L	J
P	Q	M	G	J	N	R	O	O	G	L	W	A	P	M	L	S	N	V	A	I	T	I	L	O	V	Z	A	L	O
G	V	H	Z	I	Q	X	I	W	C	C	X	E	T	N	F	T	A	M	I	C	Q	R	V	M	A	G	I	H	A
O	C	B	H	S	A	W	J	N	O	P	G	R	Z	I	T	O	O	H	U	F	X	X	Z	E	Z	B	P	O	M
U	Q	C	R	R	L	H	C	I	G	P	Z	O	Y	U	C	N	H	R	O	L	S	E	R	S	R	I	B	K	V
N	A	L	M	N	O	E	D	A	O	R	V	O	K	C	I	E	G	L	M	X	O	Y	A	W	L	I	A	R	R
M	B	T	Y	S	S	T	D	G	N	V	O	L	G	X	S	B	M	R	C	R	G	C	Z	W	E	L	T	Q	S
S	Y	G	F	A	K	D	N	G	Q	B	W	F	E	Z	H	V	S	K	E	T	F	I	L	K	R	O	F	M	T
K	Z	V	W	R	R	T	B	A	E	J	O	G	W	O	V	M	Y	Z	B	L	V	A	R	I	Z	D	T	W	F
C	Z	J	A	V	L	G	M	L	L	H	V	W	G	I	K	D	O	S	R	F	W	D	W	P	E	Y	N	Y	K
I	K	G	Q	O	J	O	G	O	R	P	A	W	U	D	C	D	O	S	I	D	P	K	J	F	O	T	E	P	H
R	L	N	N	N	O	J	M	W	E	R	D	M	K	D	L	R	R	Q	D	J	Y	T	E	T	R	C	M	Z	J
B	O	Y	J	R	I	L	F	H	I	W	K	T	M	L	F	E	A	U	G	S	W	R	V	L	E	N	P	D	Y
U	X	T	H	I	D	C	K	O	I	Q	A	P	U	E	I	G	F	N	E	I	C	U	R	L	H	M	I	Q	P
Q	Q	T	C	D	K	E	Y	P	G	F	B	B	Z	L	R	B	S	M	E	B	J	C	V	S	C	D	U	S	R
O	A	H	X	A	R	W	R	E	N	C	H	F	P	K	W	B	M	I	R	H	F	K	F	D	N	R	Q	A	X
B	L	B	K	E	P	N	O	I	T	A	V	A	C	X	E	V	J	Z	C	W	U	K	K	J	E	I	E	A	U
E	V	E	G	M	D	M	D	D	V	M	N	Y	P	L	F	E	C	J	Y	L	O	A	D	E	R	L	W	U	E
P	U	U	V	A	Z	G	O	K	Z	R	M	V	O	G	N	A	J	B	N	T	U	J	B	Q	T	L	E	K	S
M	A	U	M	E	Q	K	W	C	M	Y	H	K	R	X	L	N	K	J	R	M	I	N	P	W	N	P	R	J	S
G	M	D	J	A	L	K	W	J	U	X	X	V	I	L	C	F	H	Z	M	F	R	W	X	B	M	N	B	R	Q
K	Z	X	U	J	D	Z	L	N	U	E	E	I	Y	N	L	K	W	A	J	B	P	F	V	T	I	N	L	W	U

Excavator, Bulldozer, Loader, Crane, Truck, Paver, Forklift, Compactor, Trencher, Auger, Hammer,
Screwdriver, Drill, Saw, Tape, Level, Chisel, Pliers, Wrench, Sledgehammer, Crowbar, Router,
Excavation, Columns, Floor, Bathroom, Block, Cement, Stone, Sand, Labour, Plant, Equipment,
Machinery, Contractor, Tendering, Bridge, Dam, Railway, Excavators

Construction Puzzle

R	J	T	B	Y	S	L	D	E	P	S	X	R	V	W	H	M	R	E	J	P	A	Z	O	U	Y	H	T	W	M
P	E	X	H	T	C	X	I	R	M	L	W	R	V	E	X	O	X	T	P	F	X	K	T	D	E	M	M	A	R
S	E	E	A	Z	Z	N	C	A	Y	A	A	M	F	E	O	C	N	O	I	T	A	D	N	U	O	F	S	T	E
E	N	I	N	A	Z	Z	E	M	N	W	R	S	E	D	A	Q	Q	R	L	M	H	Z	Z	E	A	O	J	E	I
T	R	C	L	I	V	X	P	U	Z	O	A	F	T	V	R	P	W	G	G	L	J	C	N	H	N	A	C	R	N
S	C	W	I	S	G	B	L	Y	Q	K	S	L	A	E	Y	N	O	C	L	A	B	J	P	R	K	C	A	P	F
R	C	E	N	N	A	N	Z	X	I	M	U	T	L	A	R	Q	F	F	O	Q	C	A	Y	H	M	R	V	R	O
H	A	W	T	T	T	Y	E	I	U	S	I	V	O	L	L	I	F	K	C	A	B	B	M	K	S	Q	F	O	R
I	A	Y	E	I	J	K	R	T	J	O	B	I	A	Z	X	L	N	T	V	V	H	N	E	M	C	Z	H	O	C
I	K	M	L	M	H	Q	L	G	N	B	Y	Q	B	O	P	E	I	G	X	Y	F	G	K	A	P	A	L	F	E
D	O	F	M	P	O	C	L	R	G	Y	E	X	N	W	I	C	B	O	C	C	U	T	S	S	M	O	A	I	M
J	M	I	I	E	K	B	R	C	N	S	L	X	R	C	R	E	P	N	I	Y	D	X	S	F	O	Q	J	N	E
L	O	S	B	Q	R	V	L	A	I	G	O	Y	C	L	T	I	G	A	I	T	E	U	H	Y	I	I	W	G	N
Q	N	I	X	R	P	A	U	L	B	M	H	A	C	E	Q	F	T	M	S	X	R	A	I	C	R	A	N	E	T
S	U	K	S	Z	L	P	B	V	M	C	W	R	R	I	N	S	U	L	A	T	I	O	N	E	R	K	M	M	L
N	K	W	S	T	Z	E	P	N	U	S	Y	C	O	R	T	Z	R	Q	A	E	T	Y	G	Y	J	V	K	G	P
X	U	H	H	B	T	L	D	I	L	D	N	U	S	T	J	Q	T	D	N	G	E	S	L	Q	H	J	N	E	N
Y	J	E	X	L	I	E	X	S	P	O	U	P	B	O	C	V	S	O	G	U	V	S	E	B	I	I	L	L	E
W	V	F	E	R	J	V	M	T	C	E	I	L	I	N	G	A	T	E	H	I	A	N	Q	D	D	R	L	B	O
B	A	C	F	F	U	A	B	A	Q	Z	S	R	E	Z	B	W	R	P	O	L	B	G	Z	A	N	X	E	A	Y
D	R	B	J	U	W	T	Y	L	U	G	N	N	B	W	H	R	J	T	J	S	K	R	R	T	H	I	L	G	R
C	Y	C	C	I	O	I	F	B	F	S	C	A	F	F	O	L	D	I	N	G	G	G	O	K	R	G	L	F	N
Y	P	F	N	U	O	O	D	O	V	E	N	T	I	L	A	T	I	O	N	O	N	C	R	J	R	L	F	W	M
G	Q	D	H	O	H	N	O	M	P	N	I	T	H	W	F	H	X	Y	S	J	C	L	C	J	O	V	S	Q	U
R	O	Z	S	Q	C	R	D	G	E	J	U	Y	G	H	M	B	H	L	S	V	N	B	T	N	Y	L	Y	E	A
W	S	D	Q	D	Q	O	F	X	G	H	C	A	P	Q	Y	Z	P	L	H	E	G	N	U	Y	E	L	Z	V	J
N	W	N	P	L	X	X	M	V	E	U	L	Z	N	U	A	N	A	Z	O	C	I	J	Y	S	V	V	M	I	Z
L	Z	B	O	Z	D	M	N	N	T	N	G	O	O	Q	A	B	H	N	X	D	S	L	A	T	R	V	Y	W	H
E	E	S	C	C	T	W	L	E	O	J	J	V	R	W	N	H	P	S	Q	X	E	W	R	M	U	H	B	N	K
W	Z	I	B	Y	S	G	E	J	D	C	W	X	I	K	A	L	J	C	K	C	D	Q	X	J	S	I	C	R	K

Architect, Design, Concrete, Crane, Drywall, Elevation, Excavation, Foundation, Frame, Gable, Grading, Insulation, Joist, Lintel, Masonry, Mezzanine, Nail, Plumbing, Roof, Scaffolding, Plastering, Shingle, Slab, Stucco, Subcontractor, Surveyor, Truss, Ventilation, Beam, Waterproofing, Window, Backfill, Engineer, Strut, Door, Ceiling, Hammer, Reinforcement, Stairs, Balcony.

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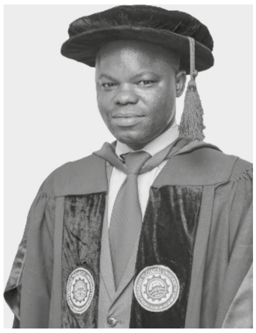

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