Adopting Modular Integrated Construction for Affordable Sustainable Housing

Subjects: Construction & Building Technology

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The rise of offsite construction (OSC) techniques, especially modular integrated construction (MiC), has been evident. MiC's adoption in affordable sustainable housing (ASH) is still underdeveloped; however, due to various benefits of MiC over conventional construction methods, it is envisioned to be a significant emerging approach for tackling growing housing demand, and ASH in particular.

Keywords: drivers ; modular integrated construction ; affordable sustainable housing ; Total Interpretive Structure Modelling

1. Introduction

The ever-increasing global population necessitates housing to be delivered both at a rapid pace and with consideration of sustainability attributes [1]. Many regions are facing a housing crisis that has been exacerbated by the COVID-19 pandemic, through economic factors and the decreased pace of construction operations [2]. The pandemic has plummeted the economies and growth of various nations, and a drop has occurred in the construction of new housing across the globe [3]. Frequent pandemic restrictions have led to an adjustment of construction practices, to comply with social distancing protocols and safety of workers, which has contributed to a housing construction decline all over the world [4]. Due in part to ongoing concerns about the economic fallout caused by such pandemics, demand for affordable sustainable housing (ASH) has been further increasing [1]. The concept of affordable housing (AH) is the measure taken by government bodies to ensure that each group of income earners within the country can afford some form of housing, with the focus naturally on low- or moderate-income households [5][6][7]. The need for ASH is expected to become even more pressing in the near future, in light of currently unstable and fluctuating global economies [8].

Adequate housing is one of the primary and fundamental rights of human beings, as defined by the United Nations (UN) [9]. The UN's efforts in this direction are ongoing via sustainable development goals (SDGs), predominantly in the UN's SDGs #9 and #11 which are related to infrastructure and sustainable communities. The overarching aim of ASH is to deliver housing for different income groups in society in addition to maintaining social inclusion and minimizing environmental impact. While efforts are to provide ASH for all in both developed and developing countries, special attention is toward low- and middle-income residents [10]. In addition, uptake of ASH has been challenging within most developed countries such as the USA, UK and Australia [11]. The alarming need for more ASH has been highlighted by previous researchers who cite the growing population of the world which is speculated to rise from 7.9 billion in the year 2021 to 9.7 billion by the year 2050 [12]. Growing urbanization has also made it challenging for stakeholders of the construction industry to maintain a balance between demand and supply of ASH. The supply of ASH is often hindered, and may not meet requirements, as it is perceived to be low profit and thus of low interest for the private sector, which typically leaves the responsibility of developing ASH to government organizations and the public sector [13][14]. Consequently, there has been a lack of application of innovative technologies and solutions towards the development of ASH. The use of limited traditional methods of design and construction is a major barrier in achieving levels of sustainability, and is reported to be a contributor to the low deployment of ASH within communities [15][16]. More action is needed to adequately fulfil supply and demand for ASH while guaranteeing the product quality, but there is often a lack of interest among the stakeholders developing ASH.

2. Modular Integrated Construction

Modular integrated construction (MiC) can be defined as the process of planning, design, manufacturing, fabrication and preassembling of various building elements, components and modules in an enclosed environment, often called factory production, before their final installation on site to support a rapid permanent structure [17][18]. It is also referred to as other terms such as offsite construction, offsite manufacturing (OSM), offsite production (OSP), offsite fabrication (OSF), modern methods of construction (MMC), prefabrication, industrialized construction, volumetric, non-volumetric preassembly, component subassembly and panelized assembly in different countries [19]. **Figure 1** shows the literal meaning of each word in MiC as stated by Pan and Hon 2020 [20].

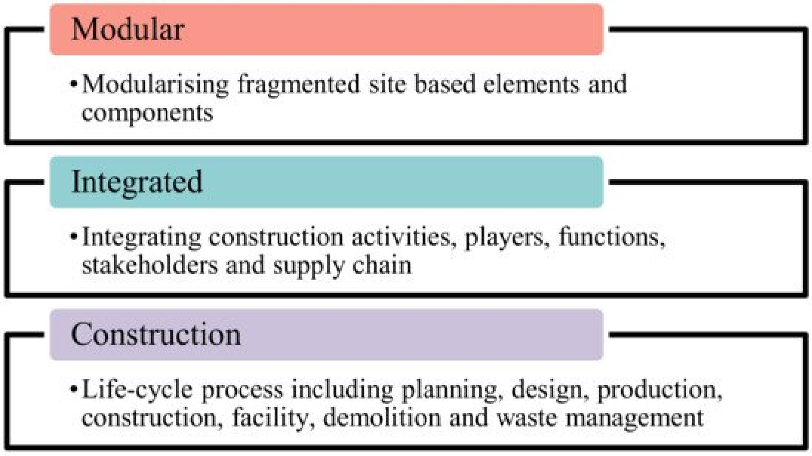

Figure 1. Breakdown of Modular Integrated Construction.

MiC came from the concept of modularity, which is to create pieces of a product in a secluded manner while still being configured or integrated to different systems utilizing similar engineering concepts. The process allows diverse configuration options for modules to achieve desired results [21]. MiC methods are derived from the theories of modularity and modularization, where modularity is defined as the disintegration of complex systems into smaller components that can interact based on specific standards and rules [22]. The simpler interface of a complex system makes modularity suitable for the construction industry as each element can be viewed in isolation and independently before integrating it into a complex building system. On the other hand, modularization is defined as the pre-making of a complex system involving large modules into smaller elements before transporting them to the site [23]. **Figure 2** reflects the process of typical MiC method including all the steps governed throughout different stages of the construction.

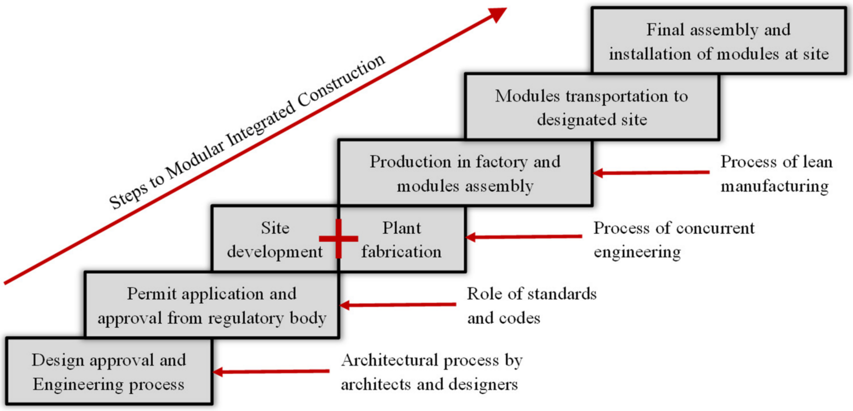

Figure 2. Steps of Modular Integrated Construction.

Similar to Lego brick assembly, the installation process of MiC is a stack of different modules placed on top of each other to complete the structure. The rise of MiC has been seen in recent years due to the vast benefits it offers in comparison with traditional construction methods. Kamali and Hewage [24] mentioned the lifecycle benefits of MiC and Wuni and Shen [25] documented the critical success factors of MiC projects in the construction industry. MiC methods have been used in various types of building projects such as houses, hospitals, hotels, offices, retail outlets, universities and supermarkets [17][26][27]. Several researchers believed that MiC is the future of the construction industry due to the vast benefits it possesses and mitigating the problems caused by the traditional methods of construction [28][29][30].

The design process of the MiC method follows an amalgamated methodology of Design for Manufacture (DfM) and Design for Assembly (DFA) theories. This approach eases the fabrication process to enhance the assembly process of modules generated within the timeline of the assigned schedule at a more rapid speed, lower cost, higher quality and with increased productivity. Meanwhile, the principles of concurrent engineering applied in MiC projects allow site development and plant fabrication at the same time, unlike stick-built construction methods [31]. The design of modules should comply with the local authorities' codes and standards as the MiC method does not have any specific standards [32]. Often, this stage requires the involvement of many stakeholders such as the client, contractor, supplier and fabricator. Collaboration, information and communication are the three most concrete pillars for achieving a successful MiC project. Note that MiC projects usually adopt steel frame, concrete or hybrid modules [33].

While the design process in MiC is a crucial stage, the offsite manufacturing, supply chain and logistics, and onsite assembly stages are also significant for a successful MiC project. The offsite manufacturing requires a factory production where bespoke modules or components are constructed [34]. This stage acts as a bridge between initial and final stages of MiC implementation. Although the success of this stage lies in effective collaboration and communication between project participants, suitable procurement strategies for materials, effective resource planning and scheduling and utilizing just-in-time methods for module production among others, there are certain risks factors that can affect this stage [35]. Dimensional conflicts between modules, defective design and information gaps, frequently changing orders from clients, inadequate inspection procedures, scheduling errors causing rework and low capabilities of manufacturers among other things, are some of the risk factors that hinder the factory production stage of the MiC method [36].

After the production of modules, delivery to the site is required. Although a straightforward process, it can be inundated with risks which are potentially impacting to successful logistics. Transportation restrictions in terms of size and weight, poor scheduling, inadequate marking and tagging of modules and defects due to damage/flexing/warping and manual handling of the modules, are some of the issues that have to be addressed for successfully accomplishing the logistics of delivering modules to site [37]. Finally, onsite assembly marks the end of MiC's stages in supply chain management. Critical factors at this stage include efficient path and layout planning of cranes, adequate buffer space for the modules and stability during module placements. As the site can be affected by weather disruptions, the just-in-time concept of module delivery is best suited to avoid unnecessary delays and risks in module settlement. Taking proactive measures against risks and applying optimization techniques at each of these stages, can lead to successful MiC project results. Further, integrating recent digital technologies at each stage of MiC not only makes the process faster and smoother, but also enhances the sustainability aspects of it [38].

3. Affordable Sustainable Housing

The word "affordable" is subjective and can carry different meanings to different parties. Contrasting views on the definition of AH are documented in previous studies [7][39][40][41][42]. Among various measures taken to define affordability, income is one of the top measures hence AH can be determined by the expenditure to income ratio. Some previous research states that in terms of income, affordable housing should not exceed more than 30% of the inhabitant's income. In addition, supply–demand hierarchy factors play a major role in defining affordable housing.

Amongst the different types of housing in the market, not many are affordable. Studies related to housing [7][39][40][41][42] have described the affordability in housing as a relationship between income and expenditure along with many other factors to consider. These factors include but are not limited to, finance cost structure, availability, occupation needs of relevant demographics, housing process distribution and government policies towards the requirements. Other than the financial affordability, the location and quality of a house should also be sufficient to be considered affordable housing [7]. While the idea of AH is to deliver houses to low- or moderate-income households, appropriate and cost-saving design and construction methods for AH have been dwindling, unable to meet the required upsurge in demand. That underpins the shortcomings inherent in the present processes of designing and constructing AH, and such a crisis is leaving stakeholders with little or no solutions. In light of such an AH emergency, the way in which AH is built should be transformed in a manner that makes it more financially practical as well as more environmentally friendly.

AH should be sustainable, as well as minimizing the living cost of residents. However, as Chan and Adabre [43] stated, "not all that is affordable can be counted as sustainable". Therefore, bridging that gap to add a sustainability aspect to affordable housing is critical, since the building sector accounts for 40% of energy consumption and constitutes 30% of carbon emissions to the environment [44]. Although there are a wide range of studies focusing on affordable housing, the integration of sustainable innovative methods has been missing [13]. A utilization of sustainable materials and methods during design, planning and operational stages, in addition to green practices, constitutes sustainable housing. Not only can such a sustainability aspect enhance the wellbeing of the residents living in these houses, but it will also reduce the environmental impact [16]. In addition to delivering habitable spaces, ASH should also prioritize consideration of the socio-economic development benefits it produces. Scrutinizing affordable housing through the lens of sustainable innovation is essential to the design of resilient urban spaces and durable housing for people [45]. However, an empirical consideration of innovative and modern techniques has not been adequately studied for ASH. Deploying innovative methods of construction with affordability and sustainability in mind, is crucial for developing inclusive and cohesive sustainable communities [16].

One of the UN's SDGs is to provide ASH to the entire relevant population that is in need of it, but at this stage achieving that target remains an aspiration [2]. Meanwhile, urbanization and the movement of people towards cities without a proper livable habitat, has resulted in the rise of slums or shanty houses in most developing countries [13]. As elucidated in a number of scholarly articles, the issue of slums remains a problem given the minimal development of strategies working towards achieving ASH [13]. Although continuous efforts regarding mandating and delivering ASH have been carried out by governments and relevant organizations, challenges remain.

The lack of a commonly accepted definition of ASH is fraught with many hurdles and is a contentious debate remains among stakeholders and in scholarly articles. It is important to include sustainability measures based on innovation, economic, social and environmental among others into AH to deliver low cost, high quality and durable dwellings to people. Several criteria for success [43][46] and barriers [47][48] toward achieving ASH have been reported by researchers in the existing literature. Moghayedi et al. [13] identified various critical success factors (CSFs) of ASH and divided them into environmental, social, technical and economic subcategories. In a similar study, Adabre and Chan [46] highlighted 30 CSFs of the development of ASH and subdivided them into developer enabling CSFs, household demand enabling CSFs, mixed land use CSFs and land use planning CSFs. Adabre et al. [47] categorized 26 critical barriers in ASH allocating them under social, economic, institutional and environmental barriers. Other barriers reported in previous studies include lack of knowledge towards sustainability and innovation, insufficient design capabilities, construction methods and efficient materials among others [49][50][51]. A few studies argued that innovation in all spheres has the potential to upgrade the development of ASH [13]; however, limited studies have explored such methods and innovations.

On the other hand, the growing demand for sustainability principles and societal needs calls for innovative practices of housing construction. Although housing is stated as one of the primary requirements by the United Nations, the problem of low or negligible delivery of adequate affordable housing exists among developed and developing countries [2]. According to a report by the UN in 2017, around 1.6 billion people reside in inadequate houses in unhygienic micro-environments [52]. The approach of delivering better households coupled with low price, high quality, better productivity and environment friendliness should be considered by housing policies and authorities. Low-income housing is often perceived to reduce existing property values within their neighborhoods, due to traditional views prevalent in the market such as NIMBY principles ("not in my backyard"). Such factors contribute to a shortage of low-income housing schemes such as affordable housing. These factors make it imperative to study drivers for adopting MiC as a strategy for ASH upliftment.

4. Application of MiC in Affordable Sustainable Housing

A significant housing shortage is an issue in many regions, as the demand for shelter for a growing population around the world remains unfulfilled [53]. MiC methods can fulfill this requirement by taking significantly less construction time. The application of MiC in ASH has been explored in a few studies highlighting the benefits and merits that MiC can have on the upsurge of ASH in both developing and developed countries. Nanyam et al. [54] suggested utilizing manufacturing methods such as last planner, lean and six sigma with offsite methods to augment the process of ASH. Along with manufacturing, some techniques related to Industrial Revolution 4.0 in the construction industry could also benefit the pressing issue of quick ASH delivery. Building Information Modelling (BIM), visualization tools such as VR, 3D printing and other enabling technologies have changed the process of design, construction and operation. The application of these digital technologies in the process of MiC can not only hasten the provision of ASH, but also progresses towards a brighter more sustainable future, in accordance with the UN's SDG goals of 2030.

Although MiC is considered to be the solution to such a housing crisis, its uptake is still low and lags behind in many countries due to an assortment of factors. However, following a few inactive years, a revolution in the MiC sector is rising due to the upsurge in digital technologies adopted in the Architecture, Engineering and Construction (AEC) field such as BIM and BIM-related visualization techniques which make the process of design and construction faster and easier to implement. As the construction industry is inundated with setbacks related to increasing its efficiency towards better quality and productivity, problems such as the sustainable nature of construction are increasingly scrutinized, since construction is one of the top industries responsible for a large contribution towards carbon emissions [55]. Although MiC is considered as one of the sustainable practices of construction and is deemed as the perfect methodology for depleting the housing crisis, the application of MiC towards ASH is still underutilized.

MiC and other offsite construction methods are proven to be a sustainable option for delivering ASH. For instance, Australian Engineers declared a climate and biodiversity emergency for engineering teams to actively support the transition of their industry towards a low carbon and more sustainable future [56]. Improvements can be made to sustainability, strengthening environmental, social and economic parameters, and also reducing the use of non-renewable sources and facilitating the recycling of materials [57][58]. This aspect of MiC favors the Circular Economy movement whereas the modules, materials and other items can be recycled and reused [59][60]. Although MiC and other offsite construction techniques have been around during the last 30–40 years, the advancement and more recent integrative options of different cyber-physical systems with MiC can open a new wider range of automation and innovative ideas for ASH construction [61]. BIM, internet of things (IoT) and other cyber-physical systems (CPSs) integrated with MiC can be a significant boost towards affordable and sustainable dwellings.

References

1. Mckinsey Co. The Next Normal in Construction. 2020. Available online: https://www.mckinsey.com/business-functions/operations/our-insights/the-next-normal-in-construction-how-disruption-is-reshaping-the-worlds-largest-ecosystem (accessed on 8 March 2022).
2. United Nations. Human Rights We Are All in This Together Human Rights Are Critical—For the Response and the Recovery. United Nations. 2020. Available online: https://www.un.org/sites/un2.un.org/files/un_policy_brief_on_human_rights_and_covid_23_april_2020.pdf (accessed on 10 March 2022).
3. Forbes. The COVID-19 Pandemic Has Fueled a Crisis in The Housing Market. 2021. Available online: https://www.forbes.com/sites/saibala/2021/04/27/the-covid-19-pandemic-has-fueled-a-crisis-in-the-housing-market/?sh=926e52a59287 (accessed on 10 March 2022).
4. Ayat, M.; Kang, C.W. Effects of the COVID-19 pandemic on the construction sector: A systemized review. Eng. Constr. Archit. Manag. 2021.
5. Ezennia, I.S.; Hoskara, S.O. Exploring the Severity of Factors Influencing Sustainable Affordable Housing Choice: Evidence from Abuja, Nigeria. Sustainability 2019, 11, 5792.
6. Marissa, P. Affordable Housing and Homelessness Challenges across the OECD. OECD Dir. Employ. Labour Soc. Aff. Backgr. 2019, 1, 1–18. Available online: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2019/06/OECD_Affordable-housing-and-homelessness_FINAL.pdf (accessed on 10 March 2022).
7. Leishman, C.; Rowley, S. Affordable housing. In The Sage Handbook of Housing Studies; Clapham, D., Clark, W., Gibb, L., Eds.; Sage Publications: London, UK, 2012; pp. 379–396.
8. Rogers, D.; Power, E.R. The global pandemic is accelerating housing crises. Int. J. Hous. Policy 2021, 21, 315–320.
9. De Schutter, O. The Right to Adequate Nutrition. Development 2014, 57, 147–154.
10. Powell, A.; Meltzer, A.; Martin, C.; Stone, W.; Liu, E.; Flanagan, K.; Muir, K.; Tually, S. The Construction of Social Housing Pathways Across Australia; Australian Housing and Urban Research Institute: Melbourne, Australia, 2019.
11. World Economic Forum. Making Affordable Housing a Reality in Cities. World Economic Forum. 2019, pp. 1–60. Available online: http://homeguides.sfgate.com/student-hous (accessed on 8 March 2022).
12. U. N. UNFPA. World Population Dashboard|United Nations Population Fund. Available online: https://www.unfpa.org/data/world-population-dashboard (accessed on 5 March 2022).
13. Moghayedi, A.; Awuzie, B.; Omotayo, T.; Le Jeune, K.; Massyn, M.; Ekpo, C.; Braune, M.; Byron, P. A Critical Success Factor Framework for Implementing Sustainable Innovative and Affordable Housing: A Systematic Review and Bibliometric Analysis. Buildings 2021, 11, 317.
14. Chava, J.; Newman, P. Stakeholder Deliberation on Developing Affordable Housing Strategies: Towards Inclusive and Sustainable Transit-Oriented Developments. Sustainability 2016, 8, 1024.
15. Yust, B.L.; Urness, M.; Mitchell, D.; Weber, W.G.; Loosen, A. A qualitative assessment of experiences with selected green technologies in affordable multifamily housing. Hous. Soc. 2015, 42, 239–249.
16. Atta, N.; Valle, A.D.; Campioli, A.; Chiaroni, D.; Talamo, C. Construction Technologies for Sustainable Affordable Housing within Fragile Contexts: Proposal of a Decision Support Tool. Sustainability 2021, 13, 5928.
17. Goodier, C.I.; Gibb, A.G. Future opportunities for offsite in the UK. Constr. Manag. Econ. 2007, 25, 585–595.
18. Goodier, C.; Gibb, A.; Ashley, D.; Taylor, M. Buildoffsite Glossary of Terms; DTI Buildoffsite: London, UK, 2006.
19. Khan, A.; Yu, R.; Liu, T. A Systematic Review of Risks in Modular Integrated Construction Practice. In Proceedings of the 44th AUBEA Conference, Geelong, Australia, 27–29 October 2021; pp. 344–354.
20. Pan, W.; Hon, C.K. Briefing: Modular integrated construction for high-rise buildings. Proc. Inst. Civ. Eng. Munic. Eng. 2020, 173, 64–68.

21. Winch, G. Zephyrs of creative destruction: Understanding the management of innovation in construction. Build. Res. Inf. 1998, 26, 268–279.

22. Baldwin, C.Y.; Clark, K.B. Design Rules; The MIT Press: Cambridge, MA, USA, 2000; Volume 1, Available online: https://mitpress.mit.edu/books/design-rules-volume-1 (accessed on 10 March 2022).

23. Navaratnam, S.; Ngo, T.; Gunawardena, T.; Henderson, D. Performance Review of Prefabricated Building Systems and Future Research in Australia. Buildings 2019, 9, 38.

24. Kamali, M.; Hewage, K. Life cycle performance of modular buildings: A critical review. Renew. Sustain. Energy Rev. 2016, 62, 1171–1183.

25. Wuni, I.Y.; Shen, Q. Critical success factors for modular integrated construction projects: A review. Build. Res. Inf. 2020, 48, 763–784.

26. Pan, W.; Gibb, A.G.F.; Dainty, A.R.J. Perspectives of UK housebuilders on the use of offsite modern methods of construction. Constr. Manag. Econ. 2007, 25, 183–194.

27. Ngowi, A.; Pienaar, E.; Talukhaba, A.; Mbachu, J. The globalisation of the construction industry—A review. Build. Environ. 2005, 40, 135–141.

28. Hampson, K.; Brandon, P. Construction 2020: A Vision for Australia's Property and Construction Industry; CRC for Construction Innovation: Brisbane, Australia, 2004.

29. Tam, V.W.; Tam, C.M.; Zeng, S.; Ng, W.C. Towards adoption of prefabrication in construction. Build. Environ. 2007, 42, 3642–3654.

30. Blismas, N.; Wakefield, R. Drivers, constraints and the future of offsite manufacture in Australia. Constr. Innov. 2009, 9, 72–83.

31. Wuni, I.Y.; Shen, Q. Towards a decision support for modular integrated construction: An integrative review of the primary decision-making actors. Int. J. Constr. Manag. 2022, 22, 1–20.

32. Wuni, I.Y.; Shen, G.Q. Fuzzy modelling of the critical failure factors for modular integrated construction projects. J. Clean. Prod. 2020, 264, 121595.

33. Li, C.Z.; Xue, F.; Li, X.; Hong, J.; Shen, G.Q. An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction. Autom. Constr. 2018, 89, 146–161.

34. Yazdani, M.; Kabirifar, K.; Fathollahi-Fard, A.M.; Mojtahedi, M. Production scheduling of off-site prefabricated construction components considering sequence dependent due dates. Environ. Sci. Pollut. Res. 2021, 1–17.

35. Wai, C.T.; Yi, P.W.; Olanrewaju, O.I.; Abdelmageed, S.; Hussein, M.; Tariq, S.; Zayed, T. A critical analysis of benefits and challenges of implementing modular integrated construction. Int. J. Constr. Manag. 2021, 1–24.

36. Wuni, I.Y.; Shen, G.Q. Exploring the critical production risk factors for modular integrated construction projects. J. Facil. Manag. 2021. ahead-of-print.

37. Wuni, I.Y.; Shen, G.Q.P.; Mahmud, A.T. Critical risk factors in the application of modular integrated construction: A systematic review. Int. J. Constr. Manag. 2019, 22, 133–147.

38. Hussein, M.; Eltoukhy, A.E.; Karam, A.; Shaban, I.A.; Zayed, T. Modelling in off-site construction supply chain management: A review and future directions for sustainable modular integrated construction. J. Clean. Prod. 2021, 310, 127503.

39. Dwijendra, N.K.A. Quality of affordable housing projects by public and private developers in Indonesia: The case of Sarbagita Metropolitan Bali. J. Geogr. Reg. Plan. 2013, 6, 69–81.

40. Thompson, N.; Yang, J. Developing Affordable and Sustainable Housing through Energy, Transport, and Building Utility Integration. J. Urban Plan. Dev. 2015, 141, 4014037.

41. Hamid, S.H.A.; Jamaludin, S.Z.H.S.; Mahayuddin, S.A. Achieving Sustainable Affordable Housing Scheme from the Perspective of Multi Eco-System. IOP Conf. Series Mater. Sci. Eng. 2018, 429, 12029.

42. Adabre, M.A.; Chan, A.P.C. The ends required to justify the means for sustainable affordable housing: A review on critical success criteria. Sustain. Dev. 2019, 27, 781–794.

43. Chan, A.P.; Adabre, M.A. Bridging the gap between sustainable housing and affordable housing: The required critical success criteria (CSC). Build. Environ. 2019, 151, 112–125.

44. Lucon, O.; Ürge-Vorsatz, D.; Ahmed, A.Z.; Akbari, H.; Bertoldi, P.; Cabeza, L.F. Chapter 9: Buildings in Climate Change 2014: Mitigationof Climate Change. In IPCC Working Group III Contribution to AR5; Cambridge University Press: Cambridge, UK, 2014; pp. 671–738.

45. Sunday, D.; Lim, N.H.A.S.; Mazlan, A.N. Sustainable Affordable Housing Strategies for Solving Low-Income Earners Housing Challenges in Nigeria. Stud. Appl. Econ. 2021, 39, 302–321.
46. Adabre, M.A.; Chan, A.P. Critical success factors (CSFs) for sustainable affordable housing. Build. Environ. 2019, 156, 203–214.
47. Adabre, M.A.; Chan, A.P.; Darko, A.; Osei-Kyei, R.; Abidoye, R.; Adjei-Kumi, T. Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective. J. Clean. Prod. 2020, 253, 119995.
48. Jamaludin, S.Z.H.S.; A Hamid, S.H.; Noor, S.N.A.M. Assessing the Challenges of Integration Affordable and Sustainable Housing from Economic Perspectives. IOP Conf. Series Earth Environ. Sci. 2020, 498, 12089.
49. Cho, Y.; Li, S.M.; Uren, L. Understanding Housing Affordability in Australia. Aust. Econ. Rev. 2021, 54, 375–386.
50. Adabre, M.A.; Chan, A.P.; Edwards, D.J.; Adinyira, E. Assessing critical risk factors (CRFs) to sustainable housing: The perspective of a sub-Saharan African country. J. Build. Eng. 2021, 41, 102385.
51. Adabre, M.A.; Chan, A.P.C. Modeling the Impact of Barriers on Sustainable Housing in Developing Countries. J. Urban Plan. Dev. 2021, 147, 5020032.
52. United Nations. Affordable Housing Key for Development and Social Equality, UN Says on World Habitat Day—United Nations Sustainable Development. 2017. Available online: https://www.un.org/sustainabledevelopment/blog/2017/10/affordable-housing-key-for-development-and-social-equality-un-says-on-world-habitat-day/ (accessed on 10 March 2022).
53. Housing—Housing is at the Root of many of the Rich World's Problems. Special Report. The Economist. 16 January 2020. Available online: https://www.economist.com/special-report/2020/01/16/housing-is-at-the-root-of-many-of-the-rich-worlds-problems (accessed on 8 March 2022).
54. Nanyam, V.N.; Sawhney, A.; Gupta, P.A. Evaluating Offsite Technologies for Affordable Housing. Procedia Eng. 2017, 196, 135–143.
55. Building Sector Emissions Hit Record High, but Low-Carbon Pandemic Recovery Can Help Transform Sector—UN Report. Available online: https://www.unep.org/news-and-stories/press-release/building-sector-emissions-hit-record-high-low-carbon-pandemic (accessed on 10 March 2022).
56. Australian Engineers Declare Climate and Biodiversity Emergency. 2019. Available online: https://engineersdeclare.org.au/ (accessed on 8 March 2022).
57. Abdelmageed, S.; Zayed, T. A study of literature in modular integrated construction—Critical review and future directions. J. Clean. Prod. 2020, 277, 124044.
58. Thai, H.-T.; Ngo, T.; Uy, B. A review on modular construction for high-rise buildings. Structures 2020, 28, 1265–1290.
59. Jansen van Vuuren, T.; Middleton, C. Methodology for Quantifying the Benefits of Offsite Construction; CIRIA: London, UK, 2020.
60. Buildoffsite. Buildoffsite Offsite Sector Response to COVID-19 Impact; Buildoffsite: London, UK, 2020; p. 30.
61. Le, A. The Benefits and Challenges of Automation in the Modular Construction Industry. 2021. Available online: https://digitalcommons.calpoly.edu/cmsp/455/ (accessed on 8 March 2022).