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Research Article

# Revisiting the built environment: 10 potential development changes and paradigm shifts due to COVID-19

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ABSTRACT

This study explores potential development and paradigm shifts in two main sectors of construction and the built environment due to COVID-19. These development changes are discussed based on evidence from previous pandemics, current and expected impacts on both industries, and how they are likely to shape the next policy, practices, and perspectives. By assessing the primary areas of both sectors through an expert-led analysis, this study suggests 10 potential development changes that we could expect in the post-COVID time. These potential changes are discussed as possible new practices, empowered regulations, or adaptive measures; and eventually towards paradigm shifts. A total of 50 participants contributed to the selection, identification, and assessment of these potential changes. The findings from this study feed into the assessment of ongoing and forthcoming changes as a result of the current pandemic, specifically on two sectors of 'construction' and 'the built environment'. These will include paradigm shifts in architecture practices, civil engineering practices, project management, and urbanism. Some of the suggestions in this study may harness shared practices, and some may simply develop into new forms of development practices in both sectors.

## 1. Introduction

As the world is facing the challenges of a major outbreak, the impacts become more than just the initial public health (Campion et al., 2020; Foletti, 2020; Sharma & Bhatta, 2020) and economic factors (Bougheas, 2020; Muhammad, 2020; Rashid et al., 2020). Much of the impacts are expected to happen in struggling economies (Mamun and Ullah, 2020; Zandifar & Badrfam, 2020) as well as the highly infected countries. The already social and economic challenges (Kopnina & Blewitt, 2018) are those that are expected to be affected more in the coming months and years. As part of the happenings of these recent months, a range of divergent emerging strategies is proposed to tackle the current challenges (Puri et al., 2020). These could also be utilized for the preparation of cities and communities for any potential waves of the outbreak (Bischof & Prewitt, 2020; Kim, 2020; Webster, 2020). The adversities as they grow will encompass multiple sectors, making some of our systems more vulnerable than before. This is similar to the broader understanding of the vulnerability sector proposed by Smith et al. (1996), and those that could be seen in context-specific examples (Kaushik & Guleria, 2020; Watanabe, 2020). During the COVID-19 pandemic outbreak, the deficiencies of our main systems have become more visible and vulnerabilities are extended beyond just the economic system. The same applies to the cases of natural disasters (Guo et al., 2016). The

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many debates on current and future changes are mostly narrowed down to economic issues that are expected to last longer than expected (Cheshmehzangi, 2020b), similar to previous pandemic cases (Maynard & Bloor, 2009).

Some sectors face new challenges and these would result in the development of new policies – even if temporary - and practices. The paradigm shifts in practices will include – but are not limited to – architecture practices, civil engineering practices, project management, and urbanism. As Mouard (2020, pp. 1–5) argues certain changes change us or become the new norms and altered realities of the future. However, such factors may simply differ from context to context (Petracca et al., 2020). In general, some of the temporary policies and practices may develop into potential paradigm shifts that would then be interesting to debate further. Thus, it is valid to argue that we anticipate development changes in two overlapping sectors of construction and the built environment. The moving to health (M2H) paradigm shift was suggested by Drewnowski et al. (2018), which was aimed to develop more connections between health and the built environment. The reason to move towards a more health-oriented approach, or at least the studies of health and the built environment, has never been as strong in the last century or so. Previously, even the impacts of climate change and pollution on human health has never taken a strong standpoint in the built environment.

While the main international UK-based bodies of the Royal Institute of British Architects (RIBA), Royal Institution of Chartered Surveyors (RICS), Royal Town Planning Institute (RTPI), and Chartered Institute of Building (CIOB) share the same concerns regarding the larger impact of COVID-19 on the civil engineering, construction, and the built environment industries (RIBA website, April 16, 2020), we see signs of an ever-changing picture in these important sectors (Cheshmehzangi, 2020b; Kammerbauer, 2020). The impacts are likely to be beyond the current debates on maintaining operations and businesses and protecting the workforces, or those that are relevant to supply chain effects (Ivanov, 2020) and loss of businesses (Koonin, 2020). Beyond these ongoing and potentially increasing impacts, there are possible major and minor development changes that may reshape our industries for a long time. Such development changes may turn into new practices or empowered regulations or adaptive measures that lead to new laws and guidelines, and some may just form into adaptive measures (Carnevale & Hatak, 2020; Cheshmehzangi, 2020a, pp. 1–10; Forsido et al., 2020; Sheridan et al., 2020). These are similar to adaptive planning approaches (Alterman, 1988; de Roo et al., 2020, chap. 5) that are applicable for the management of disasters and emergencies (Schmidt-Thome et al., 2015; Hudson, 2020; Stagrum et al., 2020). These are likely to form new best practices (Allen et al., 2020; Bergman, 2020; Kissinger, 2020; Lumpkin & Lim, 2020; Sharfuddin, 2020), such as for design guidelines, updated regulations, project management pathways, adaptive measures, rethinking paradigms, resilience ideas, enhancement opportunities, etc. (Agarwala & Vaidya, 2020; Cheshmehzangi, 2020b; Djalante et al., 2020; Habli et al., 2020; James et al., 2020; Malegaaonkar, 2020; Manurung, 2020; Mawani, 2020; Parahanj & Vaidya, 2020; Rawaf et al., 2020; Rogers et al., 2020; Toh & Webb, 2020; Valentin Ribeiro et al., 2020). For instance, as Habli et al. (2020) suggest, the scientific argument should be developed to become scientific claims, which could then lead to policy argument and policy development. Hence, the extent to which decision-making processes could occur depending on the multiplicity of processes. Hence, we can argue that some of these new best practices may harness shared practices and some may simply develop into new forms of development practices in both sectors of construction and the built environment.

To take these potential development changes into a full spectrum, this study highlights not only those expected impacts on the named sectors but also explores foreseeing paradigm shifts. These shifts could potentially change our current building engineering and design paradigms. The immediate response from experts highlights the main impacts, through which this study aims to fill the gap by demonstrating some of the potential development changes. Some of these changes may stay with us for years to come and some may simply change our current practices.

## 2. Methods

This study benefits from expert-led opinions from two sectors of construction and the built environment. This is conducted by the active participation of relevant stakeholders (Sun et al., 2020), including 25 experts for each sector – i.e., a total of 50 experts for the study. In between the two sectors, the experts are from a wide range of backgrounds, including 10 academics (AC), 5 governmental agencies (GA), and 10 practitioners (PR) in the field (see Fig. 1). From an initial pool of 87 requests, 50 experts (i.e., n-count, as a cutoff point for selection) agreed to participate in this expert-led assessment exercise. In this regard, a specific selection procedure is made to ensure a balance between three key groups of stakeholders is met (i.e., 10 AC, 5 GA, and 10 PA as shown above). From the initial feedback, we note some divergence and convergence in the opinions of different groups of experts. For instance for divergence, as anticipated, the academic (AC) respondents mainly favored their selection on 'perspectives', governmental agencies on 'policy', and practitioners (PR) on 'practice'. For convergence that occurred among experts, however, there was a consensus on the selection of primary areas (step 1 as shown in Fig. 1), and partly on the eventual sector selection. Also, another convergence occurred in terms of selection in the built environment sector, which included more votes for 'practices' than 'policies' and 'perspectives'. This was even more visible across the majority of non-practitioner participants (i.e., in AC and GA groups for the built environment sector). On the contrary, for the construction sector, there was a balance between the selections across all three groups.

The expert-led approach is used for two reasons, (1) for the selection of specific areas, through which the top six primary areas of both sectors are picked; and (2) for the identification of top five main factors for the consideration of post-COVID development changes that are agreed by all 50 participants in part 1, and final rating by 25 participants in each sector in part 2 (Fig. 1).

While we aimed to open for opinions across various fields and people of various experience and expertise, the qualified survey was selected based on the participants' experience equal to and over three years only. This is intended to maintain consistency in opinions and suggestions gathered from the conducted survey (for details, see Supplementary Document – Appendix A). For the construction sector, 3 participants had over 10 years of experience, 14 participants had 6–9 years of experience, and 8 participants had 3–5 years of experience (total of 25 participants). For the built environment, 7 participants had over 10 years of experience, 12 participants had 6–9 years of experience, and 6 participants had 3–5 years of experience (total of 25 participants) (Table 1). As indicated in the interview protocol package (see Appendix A), the study is conducted through three main questionnaire packages, inclusive of (1) general questions, consisted of five questions, which are used for qualifying or disqualifying the responses, as well as identifying the range of participants following the requirements of the study - i.e., based on participants' background and experience; (2) Selection of primary areas and main factors, involving sector-based participants in step 1, and all participants in step 2/part 2; and (3) rating questions, which are conducted separately for each sector. Details of the questionnaire packages are provided in Appendix A. The details of the survey steps are explained in detail in the following, including expert participation, expert-led weighting, selection, and rating.

By conducting the expert-led approach, we provide a questionnaire for the participants to pick their top six primary areas from both sectors. In this part, 25 participants from each field select the primary areas from the provided list of 12 areas, i.e., half of the given range. Then, based on the accumulated weighting analysis, the top six primary areas are selected. The results are shown in Tables 2 and 3 for both construction and the built environment sectors, respectively.

The second part involves two sets of expert opinions involving all 50 participants from both sectors. This is done in this way to ensure consistency in the results of both sectors and their respective analyses. The first set of opinions decide the top five factors that should be taken into consideration. From the results, the top five factors are 'resilience', 'health', 'policy', 'practices', and 'perspectives'. These are selected from a set of 20 factors, i.e., a quarter of the given options are then weighted and finalized accordingly. The ones selected with the top reoccurrence in the selection are finalized without any specific order. The second set of opinions decide on the weighting of each factor against the primary area. In this part, only 25 participants specific to their sector are involved in weighting and rating the identified factors in each of the six primary areas. The rating is done similar to a Likert rating system with only three rating options, 1 for 'low', 2 for 'medium', and 3 for 'high' importance for each factor against each primary area. In doing so, the highest rating is 75 (i.e., if all 25 participants give a rating of 3 or 'high'), and the lowest rating is 25 (i.e., if all 25 participants give a rating of 1 or 'low'). The final selection of rating is then selected based on the accumulated figures, i.e., the total of 25–41 is ranked as 'low importance', 42–59 is ranked as 'medium importance', and 60–75 is ranked as 'high importance'. The results are then shown in the form of a matrix in Tables 2 and 3

After the selection and identification stages are completed, 10 potential development changes and paradigm shifts are provided. This is conducted in two steps. First, through the literature review and ongoing development changes; and second, through confirmation from the 10 practitioner experts of each sector. In doing so, the suggestion is first made and further comments are requested by the experts. If there were any general disagreements, the recommendation was replaced with another recommendation. Each sector is then

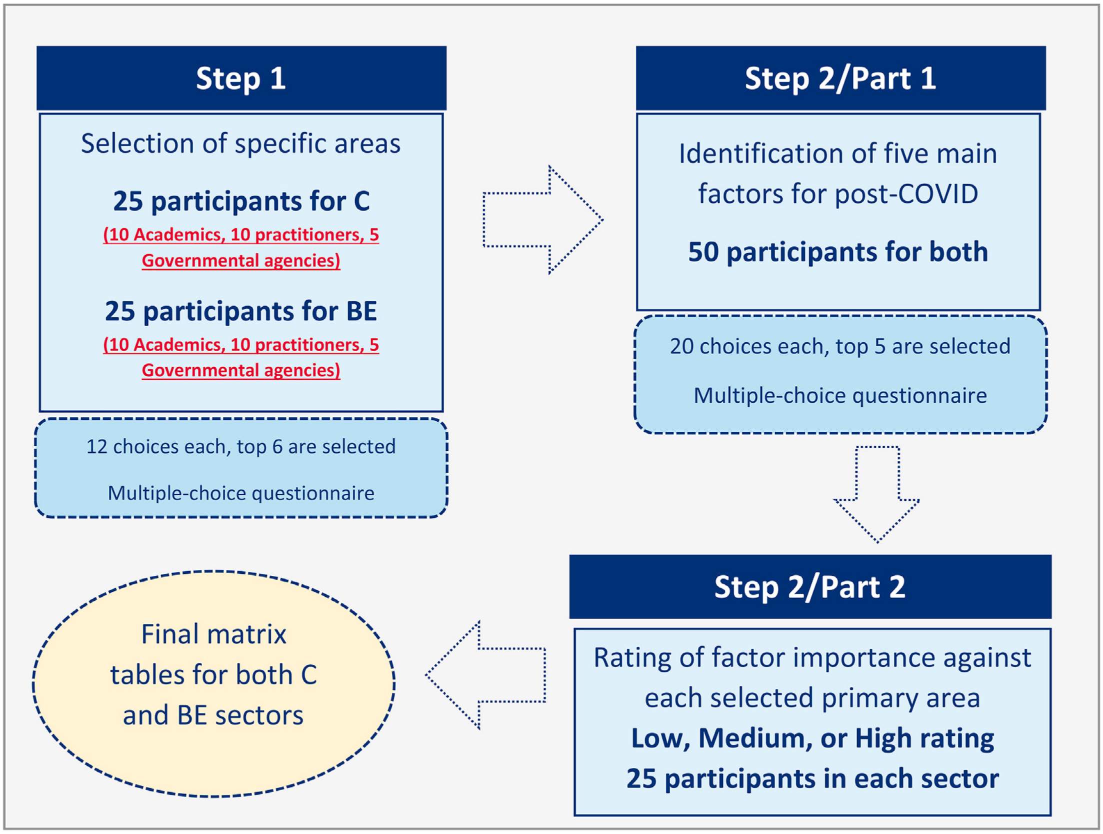


Fig. 1. – The methodology package for selection and identification stages in the study.

**Table 1**
The summary of distribution of all 50 participants across all three expert groups, their numbers, and years of experience.

| Sector | Expert Groups | Number | Years of Experience | Number |
|---|---|---|---|---|
| **(1) Construction** | Academic Experts (AC) | 10 | ≥ 10 years of experience | 1 |
| | | | 6–9 years of experience | 5 |
| | | | 3–5 years of experience | 4 |
| | Governmental Agencies (GA) | 5 | ≥ 10 years of experience | 0 |
| | | | 6–9 years of experience | 3 |
| | | | 3–5 years of experience | 2 |
| | Practitioners (PR) | 10 | ≥ 10 years of experience | 2 |
| | | | 6–9 years of experience | 6 |
| | | | 3–5 years of experience | 2 |
| | **TOTAL EXPERTS** | **25** | **≥ 10 years of experience** | **3** |
| | | | **6–9 years of experience** | **14** |
| | | | **3–5 years of experience** | **8** |
| **(2) The Built Environment (BE)** | Academic Experts (AC) | 10 | ≥ 10 years of experience | 3 |
| | | | 6–9 years of experience | 7 |
| | | | 3–5 years of experience | 0 |
| | Governmental Agencies (GA) | 5 | ≥ 10 years of experience | 2 |
| | | | 6–9 years of experience | 1 |
| | | | 3–5 years of experience | 2 |
| | Practitioners (PR) | 10 | ≥ 10 years of experience | 2 |
| | | | 6–9 years of experience | 4 |
| | | | 3–5 years of experience | 4 |
| | **TOTAL EXPERTS** | **25** | **≥ 10 years of experience** | **7** |
| | | | **6–9 years of experience** | **12** |
| | | | **3–5 years of experience** | **6** |

finalized with five recommendations that are deemed to be either a potential development change or paradigm shift. It is important to note that this participant engagement is conducted online and by selecting experts from different locations. The process is suggested in this way to ensure no biased decision making in the selection and recommendation stages. Finally, after summarizing the 10 recommendations, the study provides a brief discussion and concluding remark.

## 3. Foreseeing development changes

So far, it is evident that two mainstreams of health and resilience are likely to develop faster than before, in particular concerning main sectors of construction and the built environment (CBE). These two ranked the highest amongst all provided factors, which were assessed and selected by our 50 participants. Apart from these two mainstreams, the results also indicate three main factors of policy, practices, and perspectives; the three P's that are likely to play a major part in the CBE industries. Here, we address these in a matrix by weighting the relevance of all five factors (namely resilience, health, policy, practices, and perspectives) against 12 primary CBE areas, including six in the construction sector and six in the built environment sector. The selection is done based on the given explanation in section 2 of the study, and is ranked against each sector specifically. This is conducted through step 1 of the methodology package.

### *3.1. Development changes in the construction sector*

Here, the assessment is based on six primary areas in the construction sector, namely: (1) Construction Engineering (CE), (2) Construction Technology (CT), (3) Structural Engineering (SE), (4) Transport Engineering (TE), (5) Infrastructure Engineering (IE), and (6) Building/Construction Management (BCM). As described in step 2 of the methodology package, the rating is approached by the accumulated weighting of 25 participants per sector. The results are summarised in Tables 2 and 3, indicating the importance levels (i.e., low, medium, and high) for primary areas and top factors that are expected to be taken into consideration in CBE sectors. For each area, a maximum of two ratings is allowed across all five factors, to ensure consistency and level of importance are distributed evenly. This is monitored during the rating approach by the experts in each sector.

**Table 2**
The matrix of 6 primary construction areas and five main factors.

| | CE | CT | SE | TE | IE | BCM |
|---|---|---|---|---|---|---|
| Resilience | Low | Low | Low | High | High | Low |
| Health | Low | Low | Medium | Low | Medium | High |
| Policy | Medium | Medium | High | Medium | Low | High |
| Practices | Medium | High | High | Low | Medium | Medium |
| Perspectives | High | Medium | Medium | High | High | Medium |

**Table 3**
The matrix of 6 primary built environment areas and five main factors.

| | BE | ARC | UD | UP | LA | ID |
|---|---|---|---|---|---|---|
| Resilience | High | Low | High | High | High | Medium |
| Health | High | High | Medium | Medium | Low | High |
| Policy | Medium | Low | Low | High | Medium | High |
| Practices | Medium | Medium | High | Medium | Low | Medium |
| Perspectives | Low | Medium | Medium | Low | Medium | Low |

### *3.2. Development changes in the built environment sector*

Here, the assessment is based on six primary areas in the built environment sector, namely: (1) Building Engineering (BE), (2) Architecture (ARC), (3) Urban Design (UD), (4) Urban Planning (UP), (5) Landscape Architecture (LA), and (6) Interior Design (ID). The same methodology (as explained above) is applied to this selection and rating.

In the following section, 10 potential development changes and paradigm shifts are provided. First, the selection is based on the literature review which is then verified by ongoing development changes or debates across the globe. The selected recommendations are then passed to 10 practitioner experts of each sector as discussed in section 2. These are then confirmed through this process to ensure no biased or subjective decisions are made as part of the recommendations in this study.

## 4. Summarizing 10 possible development changes

By reflecting on the initial assessment, as shown above, the following two sub-sections highlight 10 possible development changes comprised of five in the construction sector and five in the built environment sector. Each of these is backed up by literature and confirmation by the selected experts from the practice, who are not from one geographical location. This is believed to diminish any biased or subjective selection and recommendation.

### *4.1. Construction development changes*

#### *4.1.1. Decline in car-based transportation infrastructure*

The replacement of car-based transportation infrastructure by bicycle paths (Weast & Stamatiadis, 2020) and walking opportunities, particularly in central urban areas, is likely to one of the development changes. The changes in car use in everyday life (Maxwell, 2020) indicate an opportunity to alter perceptions in our transportation mode (Lättman et al., 2020). The motives and habits of our car use (Sucha et al., 2018) are likely to change as cities are planning to invest more in non-car based infrastructures. The most remarkable case is the City of Milan and its ambitious aim to share green recovery and to reallocate street space after the crisis. This means a gradual shift from cars to cycling and walking, which was announced in April 2020 (The Guardian, 2020). If more cities follow the same idea, then we may see more cities investing in the restructuring of the transportation infrastructure in urban environments. If so, cities and communities may have new construction sites with some changes in the current transportation infrastructure, and an opportunity towards more sustainable modes of transportation. This is dependent on work-from-home initiatives and based on the understanding of challenges of the virtual working (Russell, 2019), the digital transformation of the workplaces (Savić, 2020), and the continuation of this current working environment arrangement (Bick et al., 2020), even if partly in the future.

#### *4.1.2. A push for information-based construction management methods*

By reflecting on methods that the construction industry could embrace data science (Callagan, 2020; Cheshmehzangi, 2020b), we expect to see growing popularity in the use of digital techniques and technologies, especially those that lead to information-based management (da Casa et al., 2020) and modeling (Markowsky, 2020) methods. These methods are likely to become more popular at multiple scales of building construction (Afkhamiagha & Elwakil, 2020; Gamil et al., 2020; Yan, 2020) to larger city-level projects. The implementation of faster construction methods has pushed for digital information-based platforms that could be encouraged more in the construction sector (Alashmori et al., 2020). If so, the push towards information-based construction management is likely to be just at the beginning.

#### *4.1.3. Increase in off-site construction and engineering*

As off-site construction (OSC) is already proven to be popular in recent years (Jin et al., 2019), we expect increasing OSC projects and innovations in construction strategies that require less time on construction sites. This is based on the increasing use and availability of data that could be systematically used in the construction sector (Mather & White, 2020) as well as the growing demand that reflects on some of the main challenges of OSC (Hou & Yan, 2019). It is possible that with new materials and construction methods, we could change some of the existing development patterns. For instance, rapid shelter construction (Yan and Yang, 2020) or other emergency constructions (Yan, 2020) push for an opportunity to explore more of the OSC methods and engineering. At least for a temporary period, this could boost innovation that includes the exploration of new materials and methods of construction.

#### 4.1.4. Increase in lightweight structural systems

With the possibility for more individual internal units and the need for shorter beam spans for internal spaces, we anticipate an increase in popularity in lightweight buildings and lightweight structural systems. This possible development change depends on the new demand for new internal layouts of less shared spaces (such as shard offices), more individual units, and smaller communal spaces. These are, for now, suggested as safety measures and preparation of workplaces by the governmental officials and reports (The UK Government, 2020; US Chamber, 2020). According to extended construction guidelines provided by the Pennsylvania Government (Department of Labor and Industry, 2020), the safety requirements are expected to be the highlight of any construction method. For lightweight construction and structural systems, much of what has been happening in recent months are adapting to the conditions of the pandemic, such as office space layout rearrangements (Koppikar, 2020; ZD Net, 2020) or new internal layouts that suggest less compact working environments (Wilson, 2020) but allocated spaces for individuals. These are in line with the already increasing demand for lightweight construction as Knorra (2016) highlighted a few years ago. If the current adaptive methods continue to develop as trends of development, depending on the market demand (Marketplace, 2020) then methods of optimizing buildings and internal layouts are very likely (Center for Active Design, 2020). If so, then the safety of users will be highlighted as a priority and hence tailor-made spaces become high in demand.

#### 4.1.5. Opportunities for new materials for performative insulation

The variety of lightweight constructions (Sobek, 2016) and disadvantages it may have in regards to fire safety and sound-proof protection are those that would pick up the most in the development of new materials in construction. Furthermore, as the lockdown measures had an impact on people's well-being and quality of life, particularly in multi-storey buildings, it is expected one of the development changes could relate to new material development and enhanced construction methods for better sound insulation and much-enhanced building performance (Langdon et al., 1981; Koetz, 1988; Constable, 2002; Jeon et al., 2010). The immediate impacts on construction materials are mainly on risk exposure and price impacts (GEP, 2020), which are then likely to shift towards as the supply issues are eventually fulfilled. In a short-to-midterm, however, the focus is likely to be on enhancing the safety of buildings and spaces (Gauzy, 2020), which will be centered on the safety and wellbeing of people as the users. Considerations such as new material composites (Mahapatra & Patnaik, 2009), new material for airborne virus filtration (Wang, 2013), possibly from other sectors (Tiliket et al., 2011), are likely to be on top of the list for the development and use of new materials in the construction practice. The innovations here are expected to be associated with both construction and the built environment sectors.

### 4.2. Built environment development changes

#### 4.2.1. Revisions in density and compact design

The failures of larger and more compact cities are likely to enable us to rethink the issues of density in cities and city environments. It is already evident that high population densities could, in fact, catalyze the spread of COVID-19 (Rocklöv & Sjödin, 2020; Sjödin et al., 2020) with density-related delineations (Wu et al., 2020) and various variables (Kuchler et al., 2020) such as income, poverty rate, etc. This is also studied from the perspective of city size (Desai, 2020; Stier et al., 2020) and well as the city's capacity for preparedness and responsiveness (Cheshmehzangi, 2020b). The post-COVID time will include new definitions of compact design or compactness, which are likely to suggest changes to density considerations, urban layouts, and urban morphologies. The recent changes in high-rise development policies in China (CNN news, 2020) indicate signals for the 'new era for architecture'. The afterward suggestions, as has already started, would mean reduction of density levels, new height restriction measures, and new urban layout planning and design. These will likely form from new analytical and modelling methods that suggest evolving urban patterns and development.

#### 4.2.2. Spatial planning considerations

It is likely to see more adaptive measures in spatial planning from placemaking strategies to public place design (Cheshmehzangi, 2020a, pp. 1–10). Previous examples of spatial data mining indicate approaches to support or enhance pandemic preparedness (Bailey-Kellogg et al., 2006), suggest emergency management planning has been successful in previous pandemic events (Gould & Wallace, 1994; Avery et al., 2008). The understanding of spatial dynamics from the evaluation of the impacts from the pandemic events (Eggo et al., 2011) would form into better spatial planning suggestions and evolutions (Mensua et al., 2009), such as hygiene development and spatial use. In doing so, we are likely to see new urban design guidelines, new requirements for primary and secondary access points, gathering areas, etc. The spatial planning considerations are expected to be developed at multiple levels of the built environment, some that may potentially change the way cities are planned, at least at the fundamentals.

#### 4.2.3. Smaller and individual internal layouts

Similar to the earlier discussion in sub-section 4.1.4, we anticipate major changes to internal layouts of public buildings, commercial buildings, retail, and offices. The changes are positioned in the face of emerging trajectories of interior design practice that would impact the production of "*new urban interiors and interiorities*" (Attiwill, 2020). As Young Cho and Suh (2020) put it well, the act of creation that is embedded in interior design is an enabling tool to make our daily life safe and healthy amongst the many other benefits that can be offered through quality interior spaces. Hence, as Berk (2020) suggests, individual spaces are likely to push for healthy design, something that also emerged from the movement in the mid-to-late 19 h century for changes in bathroom design after the Cholera outbreak in London. The impact was also seen in internal spaces of housing and where there were causes of disease spread (Tomes, 1999). In fact, as Budds (2020) suggests it is evident that throughout history, "*we design and inhabit physical space* [that] *has been a primary defense against epidemics*". The redesign of physical spaces is the immediate reflection of how spaces should become safer and healthier for users. The likelihood for the post-COVID internal layouts is to see inconsistent measures across different building typologies and more attention to those populated or overcrowded interior spaces.

#### 4.2.4. A push for meso scale strategies at the neighbourhood/community level

As prevention and safety procedures are proven to be more effective at the meso scale (Cheshmehzangi, 2020b), we anticipate growing attention to this spatial level of the built environment. Existing studies related to the COVID-19 meso-scale include modelling analysis of spatio-temporal dynamics (Kergaßner et al., 2020), which support decision-making processes and effective measures at the community level. In doing so, the strategies are suggested at a more manageable scale (Kergaßner et al., 2020). It is also evident through previous pandemics that communication and provision of support are more effective at smaller scales (Krill & Ayvaz, 2007). This could also end up with better community participation (Marston et al., 2020) and mitigation methods that have historically worked well in maintaining public health in communities (Morens et al., 2009; Sutton, 2020). The design of communities is likely to be given more attention at the urban design level (Cheshmehzangi, 2020a, pp. 1–10). This means more consideration of green spaces, green park design, community-level communal spaces, local amenities, etc.; as well as accessibility to them. This is likely to change our perceptions of walkable catchments to local services and amenities and promote home-office plans, local community design, and community-level infrastructure planning.

#### 4.2.5. New opportunities for non-centralized building systems

From the building engineering perspective, we are likely to see more effective integrated systems and non-centralized building systems. This comes from the understanding of air distribution patterns in the interior spaces of the buildings (Zhimei, 2020) as well as the applicability of air purifiers and air quality monitory systems (Panicker et al., 2020) during the pandemic. As part of the extended report by Deaves (2020), there are many health and environmental aspects that require reflective attention. As imposed by many local governments in China that led to the prohibition of centralized building systems such as air-conditioning units (Cheshmehzangi, 2020b), we see gradual changes to rethink large scale building systems that are integrated with several rooms. Hence, such measures are likely to help the development of future building codes (Milberg, 2020; Rozgus, 2020), new technologies (Xiao, 2020), and enhanced methods for the optimization of building design and spatial arrangements (Cheshmehzangi, 2020a, pp. 1–10). In doing so, there are potential policy changes that may have a larger impact on our building system design, architectural engineering, and architectural solutions. Many of the existing solutions in this area are suggested by the industry rather than scholarly research.

## 5. Discussions and conclusion

The golden age of architecture, engineering, and construction (AEC) industries are likely to continue based on emerging data-driven and information-based techniques and digital technologies. Nevertheless, the paradigm shifts are still debatable and it would depend on the longevity of the outbreak. As it has been indicated, the current outbreak has slowed down development progress and is likely to bring along some tangible changes to our policy, practices, and perspectives. The focus on resilience, health, and/or safety are the ones that are expected to develop further. For instance, the use of data science is likely to shape new approaches to information-based modeling, new material design, spatial planning, and integrated design solutions. The COVID-19 outbreak suggests potential new paradigm shifts that are likely to change our patterns of development, particularly from both construction and the built environment sectors. Our decision-making for a new design is expected to depend on new parameters and innovative design and engineering considerations, if not solutions. We are expected to revisit the planning strategies of our cities and their densities, question whether the compact design is essential. And the question of whether any further urbanization is viable, especially that we see most of our daily work and operations could be done remotely. As shown in the shreds of evidence in this paper, these changes have altered our everyday operations, and for some, we have managed just to have the alternative mode of operations. With the rapid progress in technologies, we are likely to opt for new methods that are likely to enhance our resilience and health in cities and communities, as well as in buildings and spaces that are constantly used for various functionalities. Nevertheless, the scholarly work on the built environment is yet to expand further, and lessons from the industry reports could help to achieve that at a faster pace.

Furthermore, this study only provides several – but key - examples of possible development changes in both construction and the built environment sectors, those that are likely to have an impact from the ongoing outbreak. Based on our expert-led assessment of primary areas, the verification of these potential changes proves to be possible from the industry perspective, but are also associated with specific contexts, too. Due to expected economic impacts that are generally widespread and across multiple sectors and systems, we anticipate new paradigms in both engineering and design of the built environments. Perhaps, the shift may become more digital, but in reality, the practices would adopt new methods of design and development. Some of these paradigms will appear in the form of smart development or resilient development, and some are likely to be in the hybrid form of smart-hybrid models. It is also important to note that the suggested potential changes are likely to be contexts-specific and not necessarily global. While we argue the directions may be similar to some extent, the pace of progress towards such development changes and paradigm shifts could differ depending on the contextual conditions and level of development.

As a hypothesis, for more developed cities (regardless of their size), we anticipate a faster push towards digitization and digitalization modes (Cheshmehzangi, 2020b). For instance, for the construction sector, the developed cities are likely to push towards '*information-based methods*' (sub-section 4.1.2), '*off-site construction strategies*' (4.1.3), and '*the use of new materials*' (4.1.5). The other two recommendations on '*car-free transportation infrastructures*' (4.1.1) and '*lightweight structural systems*' (4.1.4) are more likely to be ubiquitous. The former is expected for smaller cities, while the latter is more suitable for high dense mid-to-large scale cities. For the built environment sector, the recommendation on '*density and compact design*' (sub-section 4.2.1) is likely to apply more specifically to larger cities in both developed and developing contexts. The two recommendations of '*smaller and individual internal layouts'* (4.2.3) and '*non-centralized building systems*' (4.2.5) are likely to appear in more developed and richer cities. However, the other two recommendations of '*spatial planning considerations*' (4.2.2) and '*meso-scale strategies*' (4.2.4) are expected to be ubiquitous. The former will be more relevant to all sizes of cities, while the latter is more relevant to mid-to-large size cities.

Through the examples of potential development changes in this study, we can argue that some changes are likely to be gradual and some may shift in a rapid turn. Those that are expected to be gradual will form from the development of new practices and perspectives, and those that are likely to be sudden are expected to happen through policy changes or updates that are very likely, too. Finally, the suggestions from this study are mainly to be considered as food-for-thought for what we expect to be potential development changes in the built environments.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jum.2021.01.002.

## References

Afkhamiagha, M., & Elwakil, E. (2020). Preliminary modeling of Coronavirus (COVID-19) spread in construction industry. *Journal of Emergency Management, 18*(5).
Agarwala, P., & Vaidya, H. (2020). *Can COVID-19 fill the void of city governance for urban transformation?* UN Habitat and National Institute of Urban Affairs.
Alashmori, Y., Othman, I., Rahmawati, Y., Amran, Y. M., Sabah, A. A., Rafindadi, A. D. U., & Mikić, M. (2020). BIM benefits and its influence on the BIM implementation in Malaysia. *Ain Shams Engineering Journal*. https://doi.org/10.1016/j.asej.2020.02.002
Allen, J., Burns, N., Garrett, L., Haass, R. N., Ikenberry, G. J., Mahbubani, K., Menon, S., Niblett, R., Nye, J. S., Jr., O'Neil, S. K., Schake, K., & Walt, S. M. (2020). The Coronavirus pandemic will change the world forever. Foreign Policy. https://foreignpolicy.com/2020/03/20/world-order-after-coroanvirus-pandemic/.
Alterman, R. (1988). Adaptive planning. *Cognitive Science, 12*, 393–421.
Attiwill, S. (2020). Urban interiors and interiorities. In *book: Cultural, theoretical, and innovative approaches to contemporary interior design*. IGI Global Publishers of Timely Knowledge. https://doi.org/10.4018/978-1-7998-2823-5.ch002.
Avery, G. H., Lawley, M., Garrett, S., Caldwell, B., Durr, M. P., Abraham, D., & Kopach-Conrad, R. A. (2008). Planning for pandemic influenza: Lessons from the experiences of thirteen Indiana counties. *Journal of Homeland Security and Emergency Management, 5*(1).
Bailey-Kellogg, C., Ramakrishnan, N., & Marathe, M. V. (2006). Spatial data mining to support pandemic preparedness. *ACM SIGKDD Explorations Newsletter, 8*(1), 80–82.
Bergman, M. M. (2020). The world after COVID. *World, 1*, 45–48.
Berk, B. (2020). Life after COVID-19: How interior design will change. Online source available from: https://bobbyberk.com/life-after-covid-19-how-interior-design-will-change/.
Bick, A., Balndin, A., & Mertens, K. (2020). *Work from Home after the COVID-19 outbreak*, working paper 2017 for federal reserve bank of dallas, 20pp. available from: https://www.dallasfed.org/-/media/documents/research/papers/2020/wp2017.pdf.
Bischof, E., & Prewitt, E. (2020). Looking to the future to prepare for covid-19's second wave. *NEJM Catalyst Innovations in Care Delivery, 1*, 3. https://doi.org/10.1056/CAT.20.0106
Bougheas, S. (2020). The economy on ice: Meeting the economic challenges during and after the COVID-19 crisis. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3563536
Budds, D. (2020). Design in the age of pandemics. available at: Curbed website at: https://www.curbed.com/2020/3/17/21178962/design-pandemics-coronavirus-quarantine.
Callaghan, S. (2020). *COVID-19 is a data science issue, patterns* (Vol. 1). Editorial, Cell Press Open Access. https://doi.org/10.1016/j.patter.2020.100022
Campion, J., Javed, A., Sartorius, N., & Marmot, M. G. (2020). Addressing the public mental health challenge of COVID-19. *The Lancet Psychiatry*. https://doi.org/10.1016/S2215-0366(20)30240-6
Carnevale, J. B., & Hatak, I. (2020). Employee adjustment and well-being in the era of COVID-19: Implications for human resource management. *Journal of Business Research, 116*, 183–187.
Center for Active Design. (2020). 5 ways to optimize buildings for COVID-19 prevention. https://centerforactivedesign.org/5-ways-to-optimize-buildings.
Cheshmehzangi, A. (2020a). *10 adaptive measures for public places to face the COVID 19 pandemic outbreak* (pp. 1–10). " *City & Society*, special issue. https://doi.org/10.1111/ciso.12282
Cheshmehzangi, A. (2020b). *The city in need: Urban resilience and city management in disruptive disease outbreak events. "* Singapore: Springer.
CNN news. (2020). No taller than 500M, no plagiarism: China signals 'new era' for architecture, CNN style article on 7th of june 2020. available from: https://edition.cnn.com/style/article/china-new-era-architecture-skyscrapers-intl-hnk/index.html.
Constable, J. E. R. (2002). Transmission of sound between neighbouring rooms in a brick building. *Proceedings of the Physical Society (1926-1948), 51*(No. 1). originally published in 1939, available from: https://iopscience.iop.org/article/10.1088/0959-5309/51/1/307.
da Casa, F., Garcia, R., Echeverria, E., D'Amico, F. C., Nope, A., Domínguez, P., & Chías, P. (2020). BIM for sustainable management in existing hospitals BIM for sustainable management in existing hospitals. *IOP Conference Series: Earth and Environmental Science, 503*, 1–7.
Deaves, R. (2020). International COVID-19 penetration determinants: An exploratory analysis of cultural, economic, political, health and environmental factors across 96 countries (june 4, 2020), 26pp, Available at: SSRN: https://doi.org/10.2139/ssrn.3618947.
Department of Labor and Industry (DLI). (2020). Construction guidance during COVID-19 FAQs, by Pennsylvania government. available from: https://www.dli.pa.gov/Individuals/Labor-Management-Relations/bois/BOISFAQs/Pages/Construction-Guidance-COVID19.aspx.
Desai, D. (2020). Urban densities and the covid-19 pandemic: Upending the sustainability myth of global megacities. *ORF Occasional Paper, 244*(4).
Djalante, R., Shaw, R., & DeWit, A. (2020). Building resilience against biological hazards and pandemics: COVID-19 and its implications for the sendai framework. *Progress in Disaster Science, 6*, Article 100080.
Drewnowski, A., Arterburn, D., Zane, J., Aggarwal, A., Gupta, S., Hurvitz, P. M., … Rosenberg, D. (2018). The moving to health (M2H) approach to natural experiment research: A paradigm shift for studies on built environment and health. *SSm – Population Health, 7*, Article 100345.

Eggo, R. M., Cauchemez, S., & Ferguson, N. M. (2011). Spatial dynamics of the 1918 influenza pandemic in England, Wales and the United States. *Journal of the Royal Society Interface, 8*(55), 233–243.

Foletti, A. (2020). *Some biophysical perspectives on the COVID-19 health challenge, at the Conference on the mechanism of COVID-19 virus protein spikes interaction with host cell membrane and its age-dependency*. Yerevan, Armenia: UNESCO/UNITWIN Interregional Network on "Biophysics, Biotechnology and Environmental Health control, March 20th 2020.

Forsido, S. F., Abddisa, F. M., Lemessa, F., Ejeta, T. T., Belew, D., Yadessa, G. B., … Eneyew, A. (2020). *COVID-19 probable impacts on Ethiopian agriculture and potential mitigation and adaptation measures: No food-No health-No life*. Research Project. April 2020.

Gamil, Y., Alhagar, A., Hussein, T., & Malaysia, O. (2020). *The impact of pandemic crisis on the survival of construction industry: A case of covid-19, preprint paper*.

GEP. (2020). The impact of COVID-19 on building materials. online article available from: https://www.gep.com/mind/blog/the-impact-of-covid-19-on-building-materials.

Gould, P., & Wallace, R. (1994). Spatial structures and scientific paradoxes in the AIDS pandemic. *Geografiska Annaler Series B Human Geography, 76*(2), 105–116.

Guardian, The (2020). Article on "Milan seeks to prevent post crisis return of traffic pollution" Accessed on 2 May 2020, available from: https://www.theguardian.com/world/2020/apr/21/milan-seeks-to-prevent-post-crisis-return-of-traffic-pollution. (Accessed 21 April 2020).

Guazy. (2020). Creating safe, sustainable spaces: How building materials will evolve post COVID-19. online article available from: https://www.gauzy.com/creating-safe-sustainable-spaces-how-building-materials-will-evolve-post-covid-19/.

Guo, J., Zhou, Q., & Zhang, Z. (2016). Long impact of earthquake on post-traumatic stress disorder. *Advances in Psychological Science, 24*(10), 1534–1543.

Habli, I., Alexander, R., Hawkins, R., Sujan, M., McDermid, J., Picardi, C., & Lawton, T. (2020). *Enhancing covid-19 decision-making by creating an assurance case for simulation models. 2005.08381*. arXiv preprint arXiv. preprint paper.

Hou, L., & Yan, Y. T. (2019). Challenges of off-site construction: A critical review. In K. Papadikis, C. S. Chin, I. Galobardes, G. Gong, & F. Guo (Eds.), *Sustainable buildings and structures: Building a sustainable tomorrow, proceedings of the 2nd international conference in sustainable buildings and structures (ICSBS 2019), october 25-27, 2019, Suzhou, China* (p. 6).

Hudson, P. (2020). The affordability of flood risk property-level adaptation measures. *Risk Analysis, 40*(11), 1151–1167.

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case. *Transportation Research Part E: Logistics and Transportation Review, 136*, Article 101922.

James, P., Das, R., Jalosinska, A., & Smith, L. (2020). Smart cities and a data-driven response to COVID-19, dialogues in human geography, article commentary. https://doi.org/10.1177/2043820620934211.

Jeon, J. Y., Ryu, J. K., & Lee, P. J. (2010). A quantification model of overall dissatisfaction with indoor noise environment in residential buildings. *Applied Acoustics, 71*(10), 914–921, 2010.

Jin, R., Gao, S., Cheshmehzangi, A., & Abogye-Nimo, E. (2019). A holistic review of off-site construction literature published between 2008 and 2018. *Journal of Cleaner Production, 202*, 1202–1219.

Kammerbauer, M. (2020). Corona and the built environment, article published on 20th March 2020. available from: https://www.toposmagazine.com/corona-and-the-built-environment/, 1-3.

Kaushik, M., & Guleria, N. (2020). The impact of pandemic COVID -19 in workplace. *European Journal of Business and Management, 12*(15), 9–18.

Kergaßner, A., Burkhardt, C., & Lippold, D. (2020). *Meso-scale modeling of COVID-19 spatio-temporal outbreak dynamics in Germany, preprint paper*. https://doi.org/10.1101/2020.06.10.20126771

Kim, A. S. (2020). *Transformed time series analysis of first-wave COVID-19: Universal similarities found in the group of twenty (G20) countries*. https://doi.org/10.1101/2020.06.11.20128991. Preprint.

Kissinger, H. (2020). The Coronavirus pandemic will forever alter the world order. *Wall Street Journal*. https://www.wsj.com/articles/the-coronavirus-pandemic-will-forever-alter-the-world-order-11585953005.

Knorra, U. (2016). Lightweight construction is gaining momentum. *Lightweight Design, 9*, 3. https://doi.org/10.1007/s35725-016-0087-8

Koetz, W. D. (1988). Noise control in buildings in practice—what values for the indoor noise insulation are provided in new buildings? *ZWS Zeitschrift für das gesamte Sachverstaendigenwesen*, 117–146 (in German).

Koonin, L. M. (2020). Novel coronavirus disease (COVID-19) outbreak: Now is the time to refresh pandemic plans. *Journal of Business Continuity & Emergency Planning, 13*(4), 298–312.

Kopnina, H., & Blewitt, J. (2018). *Sustainable business*. Routledge, London (Chapter 4, 23pp).

Koppikar, S. (2020). How office spaces are adapting to the COVID-19 reality. commentary article from: https://www.moneycontrol.com/news/india/how-office-spaces-are-adapting-to-the-covid-19-reality-5432671.html.

Krill, S. J., & Ayvaz, M. (2007). *Communicating pandemic influenza risk to individuals, families and communities, at the international emergency management society (TIEMS) annual conference, march 2007*.

Kuchler, T., Russel, D., & Stroebel, J. (2020). *The geographic spread of COVID-19 correlates with structure of social networks as measured by Facebook (No. w26990)*. National Bureau of Economic Research.

Langdon, F., Buller, I. B., & Scholes, W. W. (1981). Noise from neighbours and the sound insulation of party walls in houses. *Journal of Sound and Vibration, 79*, 205–228.

Lättman, K., Friman, M., & Olsson, L. E. (2020). Restricted car-use and perceived accessibility. *Transportation Research Part D: Transport and Environment, 78*, 102213. https://doi.org/10.1016/j.trd.2019.102213

Lumpkin, M. M., & Lim, J. C. W. (2020). Pandemic best regulatory practices: An urgent need in the covid-19 pandemic. *Clinical Pharmacology & Therapeutics*. https://doi.org/10.1002/cpt.1932

Malegaaonkar, M. (2020). *Post-pandemic urbanization - cities in the COVID-19 world*. preprint paper.

Mahapatra, S. S., & Patnaik, A. (2009). Study on mechanical and erosion wear behavior of hybrid composites using Taguchi experimental design. *Materials & Design, 30*(8), 2791–2801.

Mamun, M. A., & Ullah, I. (2020). COVID-19 suicides in Pakistan, dying off not COVID-19 fear but poverty?–The forthcoming economic challenges for a developing country. *Brain, behavior, and immunity, 87*, 163–166. https://doi.org/10.1016/j.bbi.2020.05.028

Manurung, H. (2020). *COVID-19 and the dynamics of business cities*. https://doi.org/10.13140/RG.2.2.15574.68163. preprint paper.

Markowsky, G. (2020). *Modeling and battling COVID-19*. https://doi.org/10.13140/RG.2.2.13108.07042. preprint paper.

Marston, C. A., Renedo, A., & Miles, S. (2020). Community participation is crucial in a pandemic. *The Lancet, 395*(10238). https://doi.org/10.1016/S0140-6736(20)31054-0

Mather, A., & White, G. (2020). Designing with data: A systematic approach for offsite construction. *Proceedings of the Institution of Civil Engineers - Civil Engineering, 173*(2), 78–84. https://doi.org/10.1680/jcien.19.00002. May 2020.

Mawani, V. (2020). *Vulnerability and public space governance in the post-covid city*. https://doi.org/10.31219/osf.io/aj9bz. preprint paper.

Maxell, S. (2020). Negotiations of car use in everyday life. In D. Millers (Ed.), *Car cultures* (Chapter 9), 20pp.

Maynard, A., & Bloor, K. (2009). The economic impact of pandemic influenza. *BMJ, 339*, b4888. https://doi.org/10.1136/bmj.b4888

Mensua, A., Mounier-Jack, S., & Coker, R. (2009). Pandemic influenza preparedness in Latin America: Analysis of national strategic plans. *Health Policy and Planning, 24*(4), 253–260.

Milberg, E. (2020). *Coronavirus pandemic creates challenges for building departments*. Smart Brief Industry News. available from: https://www.smartbrief.com/original/2020/04/coronavirus-pandemic-creates-challenges-building-departments/.

Morens, D. M., Taubenberger, J. K., Folkers, G. K., & Fauci, A. S. (2009). An historical antecedent of modern guidelines for community pandemic influenza mitigation. *Public Health Reports, 124*(1), 22–25.

Mouard, A. (2020). *We are changed: COVID-19, the new norms and altered reality*. perspective document.

Muhammad, F. (2020). COVID-19 pandemic: A global economic challenge. *Hormozgan Med Journal*, Article e104280 (in press).

Panicker, D., Kapoor, D., Thakkar, B., Kumar, L., & Kamthe, M. (2020). Smart air purifier with air quality monitory system. *International Journal for Research in Applied Science and Engineering Technology, 8*(5), 1511–1515.

Parahanj, S., & Vaidya, H. (2020). *The urban dimension of COVID-19 in India: COVID outbreak and lessons for future cities* (pp. 1–9). Report Document.

Petracca, F., Ciani, O., Cucciniello, M., & Tarricone, R. (2020). *Harnessing digital health technologies during and after the COVID-19 pandemic: Context matters*. https://doi.org/10.2196/preprints.21815. Preprint.

Place, Market (2020). Article on "*How will office spaces change after COVID-19?*". available from: https://www.marketplace.org/2020/04/22/how-will-office-spaces-change-after-covid19/.

Puri, S. U., Bhimanwar, A. A., & Vaidya, M. M. (2020). A review: Divergent emerging strategies to tackle challenging covid-19. *Journal of Drug Delivery and Therapeutics, 10*(3-s), 251–255. https://doi.org/10.22270/jddt.v10i3-s.4117

Rashid, H., Afonso, H., Pitterle, I., & Vergata, S. (2020). Commodity exporters face mounting economic challenges as COVID-19 pandemic spreads. *Policy Brief No, 60*, 1–4. April 2020.

Rawaf, S., Yamamoto, H. Q., & Rawaf, D. (2020). Unlocking towns and cities: COVID-19 exit strategy. *EMHJ, 26*(5), 499–502.

RIBA Website. (2020). *Working with the RICS, RTPI and CIOB to ensure the concerns of members are heard.* " Available at: https://www.architecture.com/knowledge-and-resources/knowledge-landing-page/joint-institute-response-to-covid-19. (Accessed 23 May 2020).

Rocklöv, J., & Sjödin, H. (2020). High population densities catalyse the spread of COVID-19. *Journal of Travel Medicine, 27*(3). taaa038.

Rogers, D., Herbert, M., Whitzman, C., McCann, E., Maginn, P. J., Watts, B., … Novacevski, M. (2020). The city under COVID-19: Podcasting as digital methodology. *Tijdschrift voor Economische en Sociale Geografie, 111*(3), 434–450. https://doi.org/10.1111/tesg.12426

de Roo, G., Rauws, W., & Zuidema, C. (2020). Adaptive planning and the capacity to perform in moments of change. In G. de Roo, C. Yamu, & C. Zuidema (Eds.), *Handbook on planning and complexity, Research Handbooks in Planning series*. Elgar Publishers. https://doi.org/10.4337/9781786439185 (Chapter 5).

Rozgus, A. (2020). Will a pandemic change building codes?. online source available from: https://www.csemag.com/articles/will-a-pandemic-change-building-codes/.

Russell, S. (2019). How remote working can increase stress and reduce well-being [ONLINE] Available from: https://theconversation.com/how-remote-working-can-increase-stress-and-reduce-well-being-125021. (Accessed 18 June 2020).

Savić, D. (2020). COVID-19 and work from home: Digital transformation of the workforce. *Grey Journal, 16*(2), 101–104.

Schmidt-Thome, P., Nguyen, T. H., Pham, T. L., Jarva, J., & Nuottimäki, K. (2015). Climate change adaptation measures. In *Climate change adaptation measures in vietnam. SpringerBriefs in earth sciences*. Cham: Springer.

Sharfuddin, S. (2020). The world after covid-19, *the round table*. *The Commonwealth Journal of International Affairs, 109*(3), 247–257.

Sharma, S., & Bhatta, J. (2020). Public health challenges during the COVID-19 outbreak in Nepal: A commentary. *Journal of Health Research*. https://doi.org/10.1108/JHR-05-2020-0124

Sheridan, G. A., Boran, S. A. M., Taylor, C., O'Loughlin, P. F., & Harty, J. A. (2020). Pandemic adaptive measures (PAMs) in a major trauma centre: Coping with covid-19. *Journal of Patient Safety, 16*(2). https://doi.org/10.1097/PTS.0000000000000729

Sjödin, H., Wilder-Smith, A., Osman, S., Farooq, Z., & Rocklöv, J. (2020). Only strict quarantine measures can curb the coronavirus disease (COVID-19) outbreak in Italy. *Euro Surveillance, 25*(13), 2000280.

Smith, J. B., Huq, S., Lenhart, S., Mata, L. J., Nemesová, I., & Touré, S. (1996). Summary of results by vulnerability sectorJ. B. Smith, S. Huq, S. Lenhart, L. J. Mata, I. Nemesová, & S. Touré (Eds.). . In *Vulnerability and adaptation to climate change* (Vol. 8, pp. 49–68). Cham: Part of the Environmental Science and Technology Library book series (ENST.

Sobek, W. (2016). Ultra-lightweight construction. *International Journal of Space Structures, 31*(1). https://doi.org/10.1177/0266351116643246

Stagrum, A. E., Andenæs, E., Kvande, T., & Lohne, J. (2020). Climate change adaptation measures for buildings—a scoping review. *Sustainability, 12*, 1721.

Stier, A., Berman, M., & Bettencourt, L. (2020). *COVID-19 attack rate increases with city size*. Mansueto Institute for Urban Innovation Research Paper Forthcoming, 20 March 2020.

Sucha, M., Viktorova, L., & Risser, R. (2018). *Car use: Motives and habits, conference: ICTCT workshop vancouver 2018, at Vancouver, Canada*. March 2018.

Sun, J., Cheshmehzangi, A., & Wang, S. (2020). Green infrastructure practice and a sustainability key performance indicators framework for neighbourhood-level construction of sponge city programme. *Journal of Environmental Protection, 11*(2), 82–109.

Sutton, H. (2020). Reframe how to serve your community in the midst of a pandemic. *Campus Security Report, 17*(3). https://doi.org/10.1002/casr.30670, 3-3.

The UK Government. (2020). *Working safely during coronavirus (COVID-19)*. updated on 24 June 2020 (initially published on 11 May 2020). Culture, Media and Sport: from Department for Business, Energy and Industrial Strategy, and Department for Digital. available from: https://www.gov.uk/guidance/working-safely-during-coronavirus-covid-19.

The US Chamber. (2020). Coronavirus *(COVID-19): Workplace tips for employees*, 2pp, available from: https://www.uschamber.com/sites/default/files/coronavirus_workplace_tips_for_employees_031620.pdf.

Tiliket, G., Le Sage, D., Moules, V., Rosa-Calatrava, M., Lina, B., Valleton, J. M., … Lebrun, L. (2011). A new material for airborne virus filtration. *Chemical Engineering Journal, 173*(2), 341–351.

Toh, C., & Webb, W. (2020). The smart city and COVID-19. *IET Smart Cities*. https://doi.org/10.1049/iet-smc.2020.0024, 3pp.

Tomes, N. (1999). *The gospel of germs: Men, women, and the microbe in American life*. Cambridge, MA: Harvard University Press.

Valentin Ribeiro, H., Sunahara, A. S., Sutton, J., Perc, M., & Hanley, Q. (2020). *City size and the spreading of COVID-19 in Brazil*. preprint paper.

Wang, J. (2013). Preparation and characterization of the anti-virus and anti-bacteria composite air filter materials. *Science China Technological Sciences, 56*(1), 48–52.

Watanabe, M. (2020). The COVID-19 pandemic in Japan. *Surgery Today*. https://doi.org/10.1007/s00595-020-02033-3

Weast, J., & Stamatiadis, N. (2020). Improving bicycle infrastructure with the use of bicycle share travel data. *Transport Findings*. https://doi.org/10.32866/001c.12801. Article 12801.

Webster, N. (2020). Africa and the third wave of COVID-19. available from: https://www.globalpolicyjournal.com/blog/25/03/2020/africa-and-third-wave-covid-19.

Wilson, M. (2020). Our offices will never be the same after COVID-19. Here's what they could look like, commentary article from:. https://www.fastcompany.com/90488060/our-offices-will-never-be-the-same-after-covid-19-heres-what-they-could-look-like.

Wu, X., Nethery, R. C., Sabath, B. M., Braun, D., & Dominici, F. (2020). *Exposure to air pollution and COVID-19 mortality in the United States. medRxiv*.

Xiao, Y. (2020). *10 technology trends to watch in the COVID-19 pandemic*. World Economic Forum. available from: https://www.weforum.org/agenda/2020/04/10-technology-trends-coronavirus-covid19-pandemic-robotics-telehealth/.

Yan, Z. (2020). *Emergency hospitals for COVID-19: Construction and operation manual*. World Scientific Publishers. https://doi.org/10.1142/11903 (in press), 124pp.

Yan, Z., & Yan, G. (Eds.). (2020). *Fangcang shelter hospitals for COVID-19 construction and operation manual*. World Scientific Publishers. https://doi.org/10.1142/11904 (in press), 124pp.

Cho, J. Y., & Suh, J. (2020). Spatial color efficacy in perceived luxury and preference to stay: an eye-tracking study of retail interior environment. *Frontiers in psychology, 11*, 296. https://doi.org/10.3389/fpsyg.2020.00296

Zandifar, A., & Badrfam, R. (2020). Fighting COVID-19 in Iran: Economic challenges ahead. *Archives of Iranian Medicine, 23*(4), 284.

ZD Net. (2020). Could COVID-19 change the look of the office as we know it?. online opinion article by Almee Chanthadavong, available from: https://www.zdnet.com/article/could-covid-19-change-the-look-of-the-office-as-we-know-it/.

Zhimei, W. (2020). Air distribution analysis of clean air conditioning in operating room of hospital. *IOP Conference Series: Earth and Environmental Science, 512*, Article 012105. https://doi.org/10.1088/1755-1315/512/1/012105