Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Rethinking the health implications of society-environment relationships in built areas: An assessment of the access to healthy and hazards index in the context of COVID-19

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HIGHLIGHTS

- Health vulnerability *and* exposure to features of urban landscapes impact COVID-19 contagion.
- Traditionally 'healthy' landscape features may promote risky social interaction.
- The AHAHI and similar indices need to be revisited in the context of COVID-19.
- Society-environment interactions must evolve to match changing host-virus dynamics.

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ABSTRACT

Urban environments have been evolving to mitigate threats to the health and wellbeing of societies for thousands of years, including establishing open spaces to combat bubonic plague, improving waste management in the 20th century, and more recently retrofitting urban landscapes with green space to promote physical exercise. In the context of the current COVID-19 pandemic there is a need to rethink how societies interact with space in built environments to prevent contagion at the same time as facilitating health behaviours, such as exercise. Previously, we examined the spatial relationship between features of urban landscapes that are commonly considered to be 'hazardous' and 'healthy' and unusual clusters of COVID-19 cases in the East Midlands of the UK using ambulance data. Here, we consider the nature of social engagement that these features of urban landscapes facilitate and identify society-environment interactions that may increase risk of exposure to the virus. In some cases, spaces that are commonly thought to promote health behaviour may increase exposure. Contagion hot-spots occur at the nexus of exposure and underlying susceptibility. The viral-host dynamics of infectious disease are changing. Now, as in past eras, societies are required to evolve and adapt to the new challenges presented by emerging infectious diseases in the modern world.

1. Introduction:

Built environments, particularly cities, have a long legacy of development and renewal in response to outbreaks of infectious disease, including the establishment of open space during the Renaissance to combat bubonic plague in dense urban areas, and urban design to

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improve waste management in the 20th century (Megahed & Ghoneim, 2020). More recently, urban planners have embraced social science narratives about the links between sedentary lifestyles and health conditions, and the benefits of interactions with natural environments (Wolch et al., 2014). To this end, contemporary shifts in built environments include retrofitting urban areas with 'green space' and 'blue space' to facilitate wellbeing and physical exercise (Raymond et al., 2016). In this commentary we consider the need to rethink dominant paradigms about features of the built environment that facilitate healthy compared to hazardous behaviours in the United Kingdom in the context of the COVID-19 pandemic. Our prior research (Moore et al., In Press) has evaluated urban landscape characteristics that elucidate unusual clusters of severe cases of COVID-19 in the East Midlands of the UK. We observed that ordinary indicators of healthy landscapes are less clear-cut predictors of cluster hot-spots. Here, we suggest that contemporary Western societies have become unaccustomed to planning for outbreaks of infectious disease. Rather, the focus of urban planning and policy in recent times has been on preventing non-communicable diseases associated with sedentary lifestyles. In light of the ongoing COVID-19 pandemic, there is a need to reintroduce planning for contagious disease to the collective psyche of urban planners, policy makers, and wider societies. Understanding the social dynamics of society-environment interactions is central to this purpose; in some instances, 'healthy' social behaviour in ordinary circumstances, such as accessing public green spaces for exercise and psychological wellbeing, may be at odds with 'healthy' behaviour during a pandemic. Hence, we make some recommendations for the direction in which urban planning needs to evolve to keep pace with the evolution of emerging contagious diseases.

2. Reimagining urban landscapes:

According to Lieberman (2013), the need to continually renew and reimagine urban landscapes stems from a paradoxical 'mismatch' between the evolutionary needs of the human body and the lifestyles that individuals within societies have adopted; societies are the healthiest at any time in human history, while at the same time being faced with new chronic, and importantly, *preventable*, non-communicable diseases including mental health conditions, type II diabetes, and some cancers. Thus, cities reflect the complex history of emerging health problems associated with society-environment interactions, and successive efforts to mitigate risks (Jackson, 2003). One of the next big challenges for the design and redevelopment of built environments is to tackle the dual risk of emerging contagious diseases, such as COVID-19, on the one hand, and preventing the further escalation of health concerns related to sedentary and other health behaviours on the other. In the context of the current pandemic and transmission mitigation methods, including 'lockdown' and physical distancing, there is the danger of exacerbating non-communicable diseases in an effort to control contagion (Hall et al., 2020).

In our recent study we analysed spatial data representing more than 10,000 ambulance 999 calls related to suspected severe cases of COVID-19 in the East Midlands of the UK between March 2nd and May 11th. Ambulance data reflect more severe cases of contagion requiring emergency attention and has been shown to be an accurate measure of transmission of respiratory disease (Mostashari et al., 2003). We used a Kulldorff spatial scan (Kulldorff et al., 2005; Kulldorff, 1997) to identify 13 unusual clusters of contagion, as well as to explore factors related to built environments that predict the location of contagion clusters (Moore et al., In Press)[4]. Using the UK Access to Healthy Assets and Hazards Index (AHAHI) (Daras et al., 2019), we identified 12 indicators that predict clusters of contagion, including measures of distance (kms) from 'healthy' and 'hazardous' features of built environments. We used the AHAHI database at lower super output area (LSOA)[5] scale to analyse the spatial characteristics of high-risk regions. The results of our analysis revealed that contagion clusters occur within close proximity to pubs, bars and clubs (p/b/c), off licenses[6], blue space (such as lakes and water features) and passive green space (such as commons and parks). In comparison, cases of COVID-19 that did not occur in clusters were more likely to be located within close proximity to fast food outlets, tobacconists, GPs, hospitals with accident and emergency (A&E) departments, and pharmacies. Here we make two observations about the relationship between human health and built environments based on the findings of our analysis and reflect on how pre-COVID-19 understandings of healthy landscapes may need to change in the face of contagious disease outbreaks.

3. Two observations about evolving health dynamics in built environments:

Our first observation is regarding the spatial relationships between the features of built environments included in the AHAHI. With the exception of passive green space, retail, health service facilities and environmental features tend to be located close together. This is true of the locations examined in our earlier study of suspected COVID-19 cases (Moore et al., In Press), as well as throughout the UK more widely, as demonstrated in Fig. 1 which reports the correlation between distance (km) from the central point of LSOAs and each retail, health, and environmental feature included in the AHAHI. We found that the spatial relationship between features of built environments at locations with suspected COVID-19 cases in the East Midlands is a good representation of wider relationships in landscapes across the UK; the direction and strength of correlations between locations and 'hazardous' and 'healthy' features of landscapes are the same, or very similar between the UK dataset and the COVID-19 dataset published by Moore et al. (In Press). There is a moderate to strong positive correlation between the distance between most 'healthy' and 'hazardous' retail, health, and environmental characteristics of built environments which indicates that these features tend to cluster together. The one exception, distance from passive green space, is negatively correlated to all other features, indicating these spaces are located further away from other landscape features. This suggests that COVID-19 hot-spots are occurring in *ordinary* built landscapes. Cluster hot-spots do not vary from wider characteristics of the UK in terms of access to outlets, services, and natural features that are traditionally considered to be 'healthy' or 'hazardous' for communities.

Our second observation is that regions with clusters of severe COVID-19 cases *and* regions with cases occurring more randomly are both located close to 'hazardous' and 'healthy' outlets and services. However, the social characteristics of these landscape features vary considerably between areas with hot-spot clusters and areas without hot-spots. Hot-spot clusters are located near to both 'hazardous' retail outlets, and 'healthy' features of natural landscapes that facilitate or encourage social interaction, while cases outside hotspots are located near outlets and services that are more indicative of individual or household-scale activities. For example, clusters are located nearby 'hazards' including pubs, bars and clubs (p/b/c) and off-licenses, the latter being listed as an 'essential' store in March 2020 after supermarkets experienced extraordinary alcohol sales (Hockaday, 2020). While many of these outlets were closed during the first national lockdown, social activity in the weeks preceding lockdown, particularly the 'rush to pub' in the nights before business closure (Tahir, 2020) almost certainly influenced

[4] The methodology, data, analysis, and results that precede the observations outlined in this commentary are explained in full in Moore et al. (In Press) in this special edition.

[5] Lower Super Output Area (LSOA) refers to population size rather than geographic size. Each LSOA is characterised by a population between 1000 and 1,500.

[6] An 'off license' is a shop licensed to sell alcohol for consumption elsewhere.

	1	2		3		4		5		6		7		8		9		10		11		12		13	
1. GP	-	.42	.29	.7	.7	.79	.69	.67	.64	.66	.67	.61	.66	.49	.45	.47	.45	.51	.58	.22	.17	-.10	-.2	.46	.42
2. A&E	-	-		.43	.28	.40	.31	.49	.29	.45	.27	.41	.30	.52	.38	.52	.51	.55	.27	.19	.08	-.12	-.17	.26	.24
3. Dentist	-	-		-		.74	.73	.77	.78	.73	.82	.65	.76	.55	.53	.52	.45	.56	.67	.22	.21	-.11	-.20	.45	.44
4. Pharmacy	-	-		-		-		.69	.69	.68	.69	.64	.67	.49	.51	.46	.37	.50	.58	.22	.21	-.09	-.18	.49	.51
5. Gambling	-	-		-		-		-		.79	.86	.69	.76	.64	.60	.59	.47	.67	.80	.22	.19	-.12	-.21	.42	.40
6. Fast food	-	-		-		-		-		-		.75	.78	.62	.58	.58	.44	.65	.78	.23	.22	-.11	-.20	.39	.43
7. Pubs/clubs/bars	-	-		-		-		-		-		-		.54	.53	.52	.48	.55	.69	.23	.21	-.10	-.18	.39	.42
8. Leisure	-	-		-		-		-		-		-		-		.64	.46	.62	.60	.16	.17	-.12	-.19	.33	.35
9. Off-license	-	-		-		-		-		-		-		-		-		.59	.46	.18	.12	-.12	-.21	.31	.36
10. Tobacconists	-	-		-		-		-		-		-		-		-		-		.21	.18	-.12	-.23	.33	.36
11. Blue Space	-	-		-		-		-		-		-		-		-		-		-		-.07	-.14	.14	.16
12. Green Space (p)*	-	-		-		-		-		-		-		-		-		-		-		-		-.07	-.14
13. Green Space (a)*	-	-		-		-		-		-		-		-		-		-		-		-		-	

*Green Space passive (p); Green Space active (a)

Fig. 1. A comparison of correlations between characteristics of the built environment, including health services, retail outlets and environmental spaces, that contribute to the Access to Healthy Assets and Hazards Index for: a) the national data set (unshaded), and b) the COVID-19 dataset published in Moore et al. (in press) (grey shading). All correlations are significant ($P < .01$).

case rates in the months that followed.

Clusters are also located near 'health' assets including blue space and passive green spaces. The announcement of the COVID-19 pandemic, and successive policies and guidelines to promote physical distancing occurred at the beginning of spring in the UK (the period over which our COVID-19 was collected) and continued through summer. A report prepared by the Office of National Statistics about use of outdoor spaces during the first national lockdown noted, "While bedrooms have become offices, gardens – and the areas within walking distance of home – have become wildlife-watching spots and gyms." (Office of National Statistics, 2021). This trend continued as the pandemic progressed and lockdown was eased; media outlets reported a rapid rise in people visiting parks, commons, village greens and beaches (e.g., Binding, 2020; Wright & Cole, 2020; Shaw, 2020). By comparison, we found that cases occurring outside of contagion hot-spots were located near outlets and services that were less reflective of socialising behaviour, including 'hazards' such as fast food outlets and tobacconists, and 'healthy' services such as GPs and pharmacies; tobacco tends to be purchased for personal use, take away meals are often purchased in substitution of home-cooked meals (Mallinson et al., 2016), and doctors and pharmacies tend to be visited by individuals or families rather than social groups. Further, most doctors and pharmacies imposed, and continue to impose, strict limits on the number of people entering their facilities.

Taken together, these observations suggest that areas with more acute cases of COVID-19 requiring emergency medical attention occur in regions that reflect the 'ordinary' dynamics of healthy and hazardous features of urban environments. However, hot-spots of severe COVID-19 cases occur within close proximity to retail outlets and environmental assets that *facilitate social engagement*, while cases occurring randomly are located closer to outlets, services and assets that are more likely to be utilized by individuals or household units. Thus, there is a need to rethink the health risks associated with urban landscapes. Previous efforts to conceptualize health risks, such as the AHAHI (Daras et al., 2019) have focused on features of landscapes that contribute to the prevalence of many non-communicable diseases, such as diabetes and cardiovascular conditions, which in turn increase *underlying susceptibility* to severe illness from contagious diseases such as COVID-19. For example, access to fast food outlets is associated with diabetes and obesity (e.g., Babey et al., 2008; Bodor et al., 2010). These underlying health conditions have been found to increase susceptibility to severe COVID-19 (Dietz and Santos-Burgoa, 2020). Our research suggests that severe, acute cases of COVID-19 may also be related to characteristics of landscapes that increase *exposure* to the virus, as opposed to *underlying susceptibility*.

4. Rethinking society-environment relationships:

While many characteristics of COVID-19 are similar to other respiratory viruses, such as SARS, MERS, ordinary influenza, and the novel influenza A (H1N1), there are some distinctive epidemiological features of COVID-19 that make the virus particularly suited to transmission via social interactions, thus increasing *exposure*. For example, compared to influenza, COVID-19 is more contagious, has a longer incubation period, infected individuals are more likely to be asymptomatic, and the virus is most contagious before symptoms present (Zayet et al., 2020). Recently, Seitz et al. (2020) proposed that "our own social strategies, the features that define much of what it is to be human, make us a prime target for viral exploitation." (p.27768). We echo this sentiment, and additionally suggest that the viral-host dynamic may be exacerbated by urban landscapes that encourage our extraverted tendencies. The severity of the current pandemic is the combined result of e*xposure* as well as *underlying susceptibility*.

The way that society-environment relationships are conceptualized, including the frameworks, data, and indices used to analyse health risks, have shaped the direction of planning and development in built environments for hundreds of years. The AHAHI highlights the importance of links between features of these built environments and underlying health conditions that precipitate widespread 'epidemics' of non-communicable diseases in societies. In the UK and elsewhere, underlying health vulnerability is almost certainly a contributing factor to the high level of contagion and mortality associated with COVID-19 (Jordan et al., 2020). The relationship between urban density and exposure to contagious disease is well recognized. However, in recent times in developed regions like the UK, there has been much less planning focus on characteristics of urban landscapes that drive exposure compared to factors that influence underlying health conditions and biological vulnerability. This is understandable given that until very recently, contagious disease outbreaks had become 'a thing of the past'.

5. Some recommendations for research and urban planning:

In the context of highly urbanized regions such as the UK, the focus of urban planning has long since shifted from managing contagion outbreaks associated with poor hygiene and sanitation, such as cholera, to a focus on preventing non-communicable diseases associated with sedentary lifestyles, such as obesity and diabetes. The AHAHI captures the dynamics of built environments that influence non-communicable disease and underlying health vulnerabilities. Equivalent ways of analysing landscapes are required that reflect the risks associated with emerging contagious diseases in the 21st century, particularly the relationship between normative social behaviour, exposure to contagion in social spaces, and high rates of transmission reflected in contagion clusters. Our research is a stepping-stone towards elucidating the complex mosaic of interactions between societies and the environments that have given rise to localized outbreaks of COVID-19 in the UK. Future research directions, and considerations for urban planning include the following:

- Localized outbreaks occur at the nexus of underlying susceptibility *and* exposure. Conceptual frameworks and spatial indices are needed

that consider these factors together. This may involve revisiting current approaches, or developing alternative versions of existing indices, such as the AHAHI. Frameworks and indices that integrate risks associated with underlying health conditions as well as exposure to contagious diseases would be well placed to inform approaches to localized 'lock-downs' in the short-term. In the long-term, such approaches could also inform efforts to redesign urban spaces to promote health behaviour, such as exercise, while simultaneously mitigating contagion transmission;

- The AHAHI reflects potential access to features of built environments. However, spatial closeness does not necessarily reflect behaviour. On the one hand, hot-spots of severe COVID-19 may indicate increased social activity in retail outlets like pubs, and green spaces like commons, in the weeks and days immediately preceding the first national lockdown, and subsequent transmission within households and communities. On the other hand, factors related to the socio-economic characteristics of communities may also have influenced cluster location. For example, lower-income jobs were more likely to continue 'in person' compared to higher-income jobs which were more likely to shift to online platforms. Thus, new datasets are needed that compile indicators of social behaviour, including when and where people access retail outlets, health services, and environmental assets. Producing behavioural datasets requires careful consideration of the ethical and moral implications of mapping and recording social activities in a way that does not impeach on the individual freedoms of people or breach General Data Protection Regulation (GDPR). Pandemic researchers could draw on methods developed for other areas, such as behavioural sciences. For example, health nutrition researchers often use supermarket sales to evaluate nutritional intake (e.g., Hamilton et al., 2007). Similar data could be used to investigate social behaviour during a pandemic, such as food and alcohol sales from pubs, bars, and off-licenses;
- Behaviour is influenced by risk perception. Multiple studies have examined the association between perceptions of disease risk and protective behaviour during the COVID-19 pandemic (e.g., Wise et al., 2020). A useful extension of this research would be to consider whether risk perceptions of built environments have shifted as a result of COVID-19, and whether place-based risks are driving protective behaviour in terms of accessing social spaces;
- The meaningful application of research about society-environment interactions and contagion for urban planning requires genuine interdisciplinary collaboration within academia and between researchers, planners, and policy makers. Expertise and research methods from the behavioural sciences could help translate big data into urban planning;
- A new built environment research agenda towards designing and developing urban spaces that addresses the dual needs of contemporary societies; promoting health behaviours to address rising rates of non-communicable disease, including physical and mental health conditions, while preventing the transmission of EIDs. Urban planners and policy makers face the challenge of future-proofing urban infrastructure to ensure societies can maintain the meaningful social relationships that are so essential for wellbeing at the same time as safeguarding against future outbreaks of contagious disease in urban areas.

In 1854 physician John Snow identified the relationship between the location of water pumps and localized cholera outbreaks in London. The infamous Golden Square dot-map became a symbol in recognition of the critical connection between landscapes and the health of societies. Snow brought to light the importance of linkages between urban infrastructure and biological health. Understanding linkages between social structures and biological health are of equal importance in the context of the current pandemic. It is likely that societies will be faced with the challenge of mitigating emerging contagious diseases for some time. As Hall et al. (2020) suggest, this is more accurately a challenge of mitigating two pandemics – biological contagion as well as the lifestyle diseases that may become more prevalent as societies progress through uncertain phases of ordinary activity and 'lock-down' situations. Urban planning and design may offer some avenues for incentivising active lifestyles while mitigating the transmission of emerging infectious diseases. However, we may also need to reconsider our perception of built environments, and the way we conduct ourselves in those environments. The viral-host dynamics of infectious disease are changing. As in past eras, societies, and the built environments they inhabit, are now once again required to evolve and adapt to the new challenges presented by emerging infectious diseases in the modern world.

CRediT authorship contribution statement

Harriet Elizabeth: Conceptualization, Formal analysis, Methodology, Writing - original draft, Writing - review & editing, Data curation, Project administration. **Bartholomew Hill:** Conceptualization, Software, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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