Extended Abstract

Conceptualising the Recursive Relationship among Urban Development, Physical Activity, and Health Using Agent-based Modelling

Keywords: Active travel and non-communicable diseases, Urban planning and development, 15-minute City or 20-minute Neighbourhood, Population health and health equity, Complex systems theory, Agent-based modelling

1 Introduction

Extant literature highlight the positive impact of physical activity to non-communicable diseases (NCDs) such as type 2 diabetes as well as obesity, hypertension, coronary heart disease, stroke, cancer and depression (WHO, 2010). Many existing studies also indicate the impact of built environment and air quality on physical activity (PHE, 2016), a relationship between type 2 diabetes and socio-economic deprivation (Marmot, 2010; PHE, 2018), and socio-economic status and physical activity (PHE, 2016).

As a response, urban development and planning initiative of 15-minute city (or 20-minute neighbourhood (20mN)) are increasingly being pursued by local and regional governments as a pro-health and pro-environmental policy agenda (Moreno et al., 2021). The aim of the 20mN concept of each citizens reaching essential functions within 20 minutes of walking or cycling (or via multimodal transport including public transport) is expected to encourage active travel and reduce air pollution.

However, despite the close linkages among the urban decision-making (e.g., policymaking, investment and development towards 20mN), travel behaviour, physical activity, NCDs, and health equity, there is a gap in the literature in examining these holistically. To address this, this research examines these interlinkages using complex systems theory and agent-based modelling (ABM), through a case study of Greater Manchester.

2 Literature review

Risk factors of NCDs have been associated with urbanisation and lifestyle changes and particularly in terms of physical inactivity, unhealthy diet and harmful use of alcohol and tobacco (WHO, 2010b, Wagner and Brath, 2012). In England, there has been increased exposure to low physical activity and high body mass index (BMI) which have been suggested as areas of improvement (Schmidt et al., 2020).

This research's literature review on the recursive relationship between physical activity and NCDs is summarised in Table 1, which is used to inform the relationship rules in the ABM. Similar literature review was conducted regarding the relationship among air quality, NCDs, physical activity, and reduction of car use.

Table 1. Recursive relationship between physical activity and NCDs.

Changes in physical activity leading to changes in NCDs	Source
5 kJ.kg^{-1}.d^{-1} increase in physical activity (equivalent to a 20-minute brisk walk) → 11% decreased odds of **type 2 diabetes** (BMI adjustment included)	Strain et al., 2023
+2500 steps per day for obese participants (with body mass index (BMI) between 25 and 45 kg/m2) for 36 weeks → **Obesity**: Body weight (-4.5 kg), BMI (-1.6 kg/m^2), percent body fat (-3.2%)	Katzmarzyk and Lear, 2012
Low to high walkability movers → Crude **hypertension** incidence rate of 18.0 per 1,000 person years reduced to 8.6 per 1,000 person-years	Chiu et al., 2016
WHO recommended physical activity levels (at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity physical activity) → 17% decreased risk of **cardiovascular conditions**, 23% decreased risk of **cardiovascular mortality**, and 26% decreased incidence of **type 2 diabetes**	Wahid et al., 2016
Exercise vs control → **Depression**: standardised mean differences = -0.37 (p < .001)	Conn, 2010
Changes in NCDs leading to changes in physical activity	
Participants with chronic disease (aged 40+) participated in 9% less moderate activity and 11% less vigorous activity than participants with no chronic disease	Barker et al., 2019

3 Methods and data

Among complex systems approaches, we ABM and the platform NetLogo as a particularly suitable method for modelling the recursive relationships among urban development (20mN), physical activity and NCDs which captures the travel behaviour of heterogeneous actors and their interactions with the urban environment (xxx, 2020). ABM is also chosen to reveal complex non-linear and recursive patterns emerging at the system-level, i.e., land/building use changes and mobility culture changes in this research.

We chose Greater Manchester (GM) as a case study to set the policy bearing on the 20mN initiative the GM Combined Authority (GMCA) and Transport for GM (TfGM) under the ‘Streets for All’ strategy. The research question is set as ‘What is the outlook for post-covid building use change towards 20mN in GM, and what are the implications for residents’ travel behaviour, physical activity, NCDs and health inequality?”

Repurposing an existing land use-transport interaction ABM developed by the author (xxx, 2020), this study established a conceptual framework of two feedback loops that can enable a virtuous cycle for population health in NCDs. One is where the citizens’ switch from car to non-car modes increases physical activity and air quality, leading to better health and further encouraging active mobility. The other is where more mode switch and more consumer/user demand for carless urban environment leads to pro-health urban development in the aspect of land/building use change towards 20mN, which would facilitate further mode switch away from car (Fig. 1).

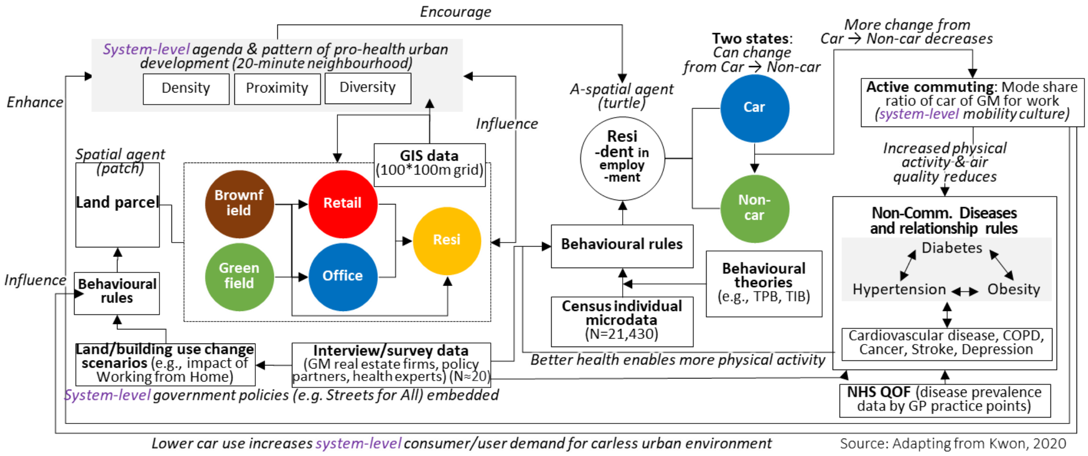

Fig. 1. Conceptual framework of the ABM.

As for population data, this study used the 2011 UK census individual micro-data with real-life socio-economic/travel characteristics of 21,430 working residents in GM. This study focused on 'active commuting' as the UK census asks question on main mode of transport only for work, and also to directly link to the GM partners' particular interest in the post-covid changes of building use and travel patterns caused by increased work from home, which is closely linked to the socio-economic inequality. These individual characteristics (e.g., age, deprivation, health, no. of children, distance to work, occupation, work from home) were used to set the behavioural rules for car to non-car mode switch based on the theories of planned behaviour and interpersonal behaviour along with the 20mN variables within the 2km radius of each resident agents calculated within NetLogo based on real-life spatial data. Social norm is also captured by having the mode share of car of neighbouring residents as a key variable for switch.

As for built environment and neighbourhood characteristics data, we prepared various spatial data in 100*100m grids, such as the building use maps (residential, retail, and office) by building height, multiple deprivation map and air quality map of GM.

For health data, we used the NHS Quality and Outcomes Framework (QOF) data which contains various NCD's disease prevalence (%) by GP practice points. Voronoi polygon maps were created for each of the eight disease types related to physical activity including obesity, coronary heart disease, heart failure, hypertension, chronic obstructive pulmonary disease, cancer, diabetes, depression and mental health issues.

The abovementioned data, corresponding to 'turtle (residents)' and 'patch (land parcel)' attributes, were loaded on NetLogo using CSV and GIS extensions as in Fig. 2. This study randomly assigned the disease prevalence to the 'turtles' under a process with justifications.

In addition, this study conducted around twenty first-hand interviews and surveys on real estate firms, policy partners, and health experts in GM to cross-check and improve the behavioural rules for residents' travel mode switch, land/building use change scenarios, 20mN policy scenarios, and the rules for the expected impact of increased physical activity on the improvement of the prevalence of different NCDs.

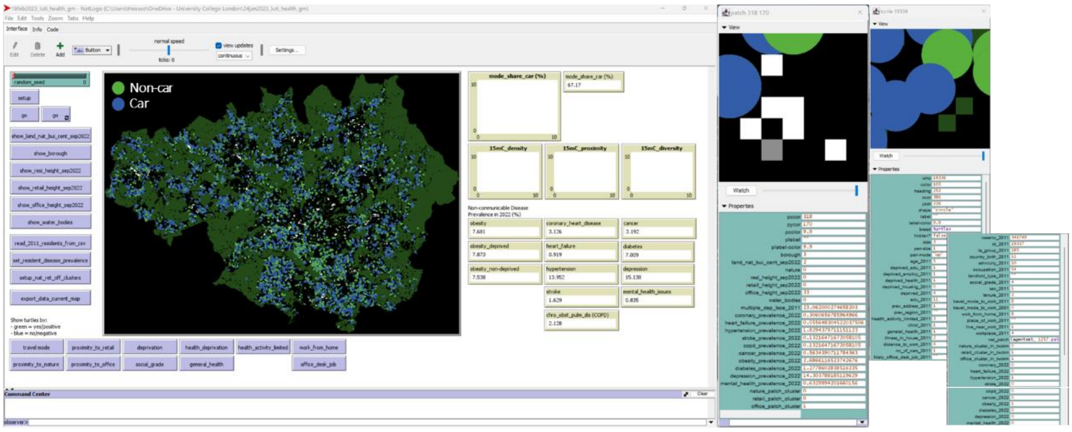

Fig. 2. Model interface on NetLogo (left), patch properties (middle), and turtle properties (right).

4 Expected findings and future work

With the release of the 2021 census microdata, this model is to run from 2021 until 2040 to test the likelihood of GM achieving its vision for 50% mode share of walking, cycling and public transport, i.e., how likely that the mode share of car currently at 67% would be lowered to 50%, under three work from home scenarios and three 20mN policy scenarios. The impact on the prevalence of different NCDs will be the focus of analysis along with spatial analysis of health inequality to explore whether the building use change and 15mN policy scenarios are likely to exacerbate the existing inequalities and which neighbourhoods are likely to require particular policy attention.

The analysis of simulation results will enable the generation of some top-down and bottom-up policy implications for behavioural change for both residents' pro-health travel decisions as well as real estate and planning actors' pro-health urban development decisions with regards to pursuing the vision of 20mN with health and health equity considerations in the centre stage.

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