Journal of Transport & Health xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

Understanding bicycling in cities using system dynamics modelling

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ABSTRACT

Background: Increasing urban bicycling has established net benefits for human and environmental health. Questions remain about which policies are needed and in what order, to achieve an increase in cycling while avoiding negative consequences. Novel ways of considering cycling policy are needed, bringing together expertise across policy, community and research to develop a shared understanding of the dynamically complex cycling system. In this paper we use a collaborative learning process to develop a dynamic causal model of urban cycling to develop consensus about the nature and order of policies needed in different cycling contexts to optimise outcomes.

Methods: We used participatory system dynamics modelling to develop causal loop diagrams (CLDs) of cycling in three contrasting contexts: Auckland, London and Nijmegen. We combined qualitative interviews and workshops to develop the CLDs. We used the three CLDs to compare and contrast influences on cycling at different points on a "cycling trajectory" and drew out policy insights.

Results: The three CLDs consisted of feedback loops dynamically influencing cycling, with significant overlap between the three diagrams. Common reinforcing patterns emerged: growing numbers of people cycling lifts political will to improve the environment; cycling safety in numbers drives further growth; and more cycling can lead to normalisation across the population. By contrast, limits to growth varied as cycling increases. In Auckland and London, real and perceived danger was considered the main limit, with added barriers to normalisation in London. Cycling congestion and "market saturation" were important in the Netherlands.

Conclusions: A generalisable, dynamic causal theory for urban cycling enables a more ordered set of policy recommendations for different cities on a cycling trajectory. Participation meant the collective knowledge of cycling stakeholders was represented and triangulated with research evidence. Extending this research to further cities, especially in low-middle income countries, would enhance generalizability of the CLDs.

1. Introduction

Increasing urban bicycling as a transport mode in cities has established net benefits for human health across a range of social, physical and mental outcomes (de Hartog et al., 2010; Woodcock et al., 2013, 2009; Lindsay et al., 2011; Macmillan et al., 2014). These include increasing physical activity, enhanced neighbourhood social connection and fairer, low-cost access to health promoting education, employment, goods and services. In addition, when bicycling replaces motor vehicle use for transport trips, there is significant potential to decrease transport's contribution to climate change, air pollution, and road traffic injury.

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http://dx.doi.org/10.1016/j.jth.2017.08.002
Received 19 December 2016; Received in revised form 8 July 2017; Accepted 9 August 2017
2214-1405/

Previous research to understand cycling in cities represents a body of disparate evidence about influences and outcomes. Analysis of travel data has contributed to an understanding of individual factors that are associated with cycling, such as age, gender and socioeconomic status (Walking, 2013; Steinbach et al., 2011; Yang et al., 2010). Survey research has concentrated on perceived barriers to cycling, including fear of injury, trip distance, weather and topography (Daley et al., 2008; Fishman et al., 2014; Goldsmith, 1992; Winters et al., 2010; Parkin et al., 2007). Significant weight in research has also been given to the role of behaviour change programmes in promoting cycling, in contrast to changing the cycling environment (Yang et al., 2010). More recently, a body of research is emerging based on natural experiments to understand environmental factors that influence individuals cycling (Goodman et al., 2014; Wardlaw, 2014; Sahlqvist et al., 2015; Heinen et al., 2015; Keall et al., 2015; Goodman et al., 2013). These studies have demonstrated modest increases in cycling from small-scale infrastructure interventions. Overall, it can be concluded from this body of evidence that high quality infrastructure may be a promising route to achieving mass cycling, while behavioural interventions alone are unlikely to achieve sustained cycling growth. Establishing robust epidemiological evidence about the effectiveness of interventions to improve and encourage cycling is limited by methodological difficulties and expense, reinforcing the importance of modelling for understanding future implications of cycling policies (Macmillan et al., 2013; Mulvaney et al., 2015).

Perhaps as a result of these disparate sources of evidence, there is disagreement amongst transport decision-makers about how to change the shape of trends in cycling (e.g. from decline into growth) and achieve a sustained growth in cycling, whether the context is a car-dependent city with very low levels of cycling, or a city where bicycling is already a major mode of transport. For example, in the Australian National Cycling Strategy (Austroads, 2010), cycling promotion is the first priority, while in New Zealand the top priority is investment in urban cycling infrastructure to improve cycling safety (Transport Agency, 2015), despite these countries having similar cycling mode shares and urban environments. There is evidence of policy uncertainty about the relative importance of behaviour change interventions; targeting; investment in cycling-specific infrastructure; and the role of land use and urban design (Wardlaw, 2014; Noland and Kunreuther, 1995; Buehler and Pucher, 2011; Pucher and Buehler, 2008). Furthermore, the above examples demonstrate there is debate about the order of policy implementation to successfully achieve sustained growth in bicycling.

Procedural issues also make an effective transition to cycling growth more difficult, particularly in cities where policies that support motor vehicle use are dominant. Transport policy-making, on the whole, continues to be characterised by technocratic processes and strong interests vested in the status quo, with little meaningful collective input from wider stakeholders (including "would-be" cyclists) to understand the complex influences on transport patterns or debate pathways for reaching desired outcomes of policy (Bickerstaff et al., 2002, 2005; Booth and Richardson, 2001; McAndrews and Marcus, 2015).

The complexity of cycling as a policy issue, uncertainty about policy effectiveness and procedural issues in transport policy all suggest that novel ways of considering cycling policy are needed. We suggest these should synthesise expertise from policy, community (including existing and "would-be" cyclists) and research stakeholders to develop a shared understanding of cycling, reflecting recommendations from research about decision-making in complex areas such as urban planning for health and sustainability (Macmillan et al., 2014; Bickerstaff et al., 2005; Beall and Ford, 2010; van den Belt, 2004; Vennix, 1999). As has previously been argued, methods should also aim to incorporate the dynamic complexity of influences and outcomes that determine trends in cycling (Macmillan et al., 2014). In this paper, we use participatory system dynamics (SD) modelling to address these evidential and procedural challenges. Participatory SD modelling involves a range of stakeholders in a collaborative learning process to develop a shared theory about the causes of trends over time in a complex system, and the policies that are likely to have a desired influence on observed trends (Beall and Ford, 2010; van den Belt, 2004; Vennix, 1999).

In high income countries of the global west, we postulate that four groups of cities or countries may be placed at different points on a theoretical trajectory towards cycling being a common mode of transport: a group where cycling is already a widely used mode, with a vision to further increase; a group where cycling has been growing and contributes between 5% and 10% of all trips, a group where cycling has seen a small amount of growth and is between 1% and 5% of trips, and a group where cycling is almost non-existent (around 1% of all trips) and has been that way for a significant period of time. It is likely that different influences take prominence at different places along this trajectory and therefore the most effective policies will vary.

A dynamic causal theory about cycling has previously been developed using participatory SD modelling in Auckland, New Zealand, a city with longstanding low levels of cycling and high levels of car use. This theory centralised cycling injury and perception of safety to explain the main influences on cycling over time. However, it is unclear whether the insights developed in this research can be generalised to other cities.

The aim of this research was therefore to use a collaborative learning process to build on the initial causal model for cycling developed in Auckland. We aimed to test the generalizability of the causal model for cities in the groups described above, and to enhance understanding of the system across stakeholder groups. By building consensus across cities about the causal theory, we aimed to develop agreement about the effective policies for achieving a sustained increase in urban cycling for transport while simultaneously benefiting health and environmental outcomes.

2. Methods

2.1. Participatory system dynamics (SD) modelling

We used participatory SD modelling to elicit a qualitative causal model of the influences and outcomes of cycling. We based this research on the following SD modelling principles (Forrester, 1969, 1980; Sterman, 2006, 2000; Richardson, 2011).

1. Complex systems include many interacting variables that change over time