A System Dynamics Approach for Quantifying Wider Impacts of Sustainable Mobility Policy

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1. Background and Objectives

- The Scottish Government has a legally binding target to reach net zero by 2045 [1]
- Transport accounts for 36% of Scotland's emissions, posing a significant barrier [2]
- In response, Scottish Government policy outlines a modal shift away from car travel towards public transport and active travel, with a supporting equitably accessible public electric vehicle (EV) charging network
- This work develops a policy interrogation tool using System Dynamics (SD) and Bayesian Networks (BN) to explore wider impacts of such initiatives

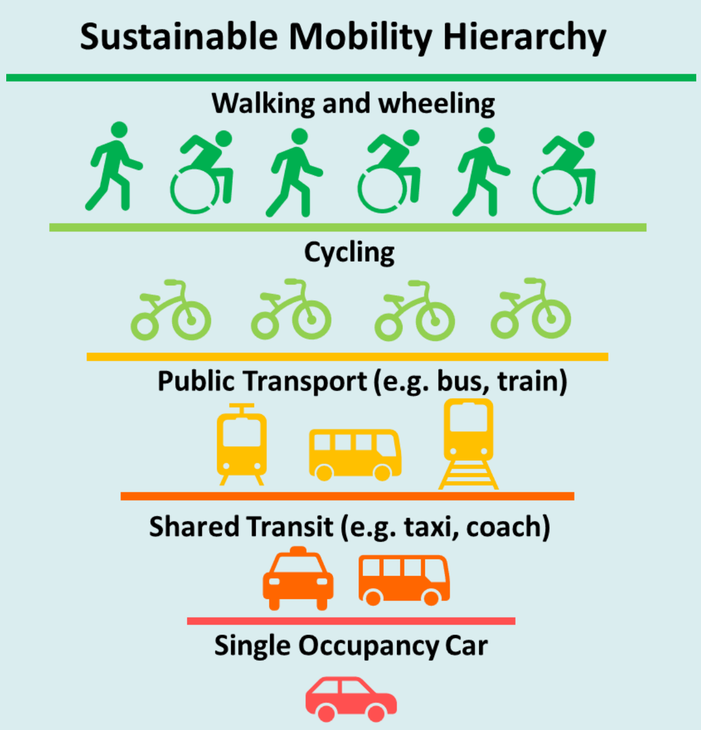

Figure 1: Adapted from National Transport Strategy [1] which outlines prioritisation of active travel and public transportation

2. System Dynamics

- SD allows for holistic, time-based modelling through analysis of cause and effect relationships between key variables, represented in causal loops, a basic example of which is shown in Figure 2

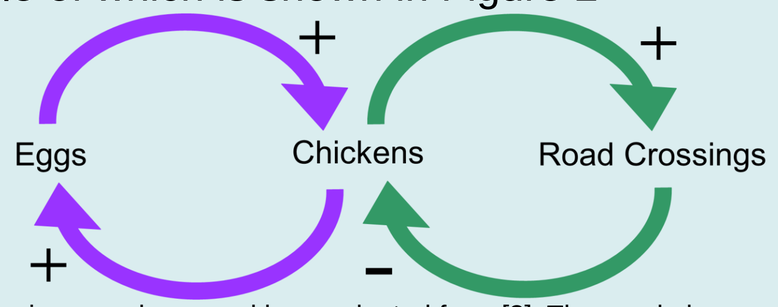

Figure 2: Basic exemplar causal loop, adapted from [3]. The purple loop on the left represents that the number of chickens and eggs increase together; the green loop on the right represents that the number of chickens and road crossings increase together but as the number of road crossings increases, the number of chickens decreases

- Figure 3 shows a causal map as a precursor to an SD causal loop diagram, modelling a realistic system, capturing road transport in Scotland, 2019
- This demonstrates how charging infrastructure and power network elements can be incorporated and related to the transport system

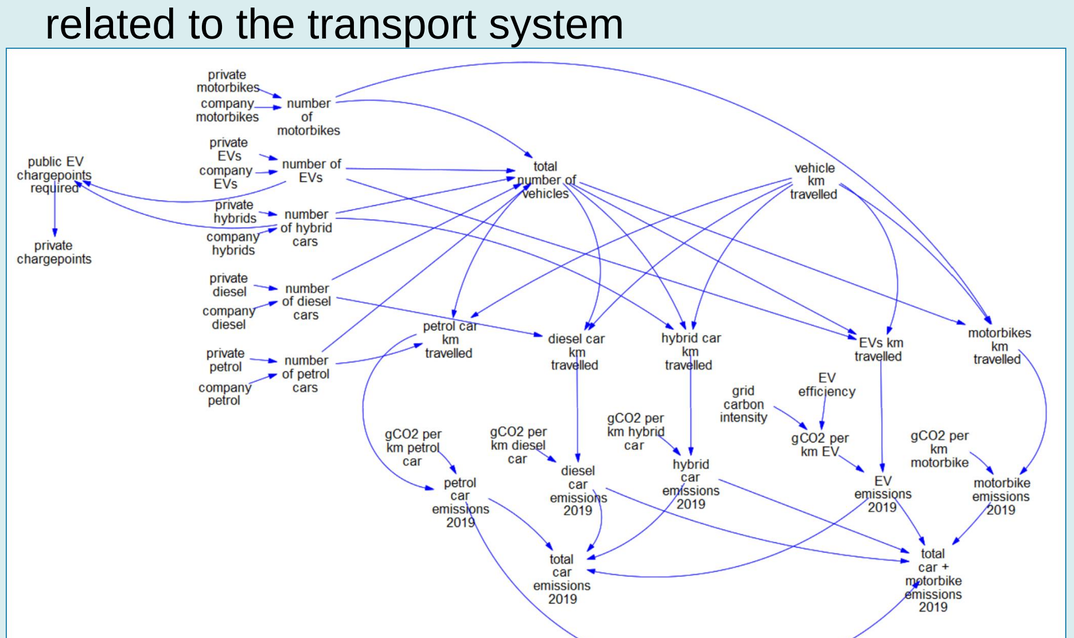

Figure 3: Causal map modelling car and motorbike emissions in Scotland in 2019, also capturing public EV charging requirements for this year as set out in the EU Directive on Deployment of Alternative Fuels Infrastructure [4], will form the basis of an SD model

3. Bayesian Networks

- BN are probabilistic – i.e. their output is the probability an event (e.g. a chicken making it safely to the other side of the road) occurs
- Figure 4 shows an example BN that predicts the likelihood an individual will buy an EV based on their perception of several factors
- BN require a conditional probability table (CPT), usually informed by recorded data, literature or expert opinion, is input for each node

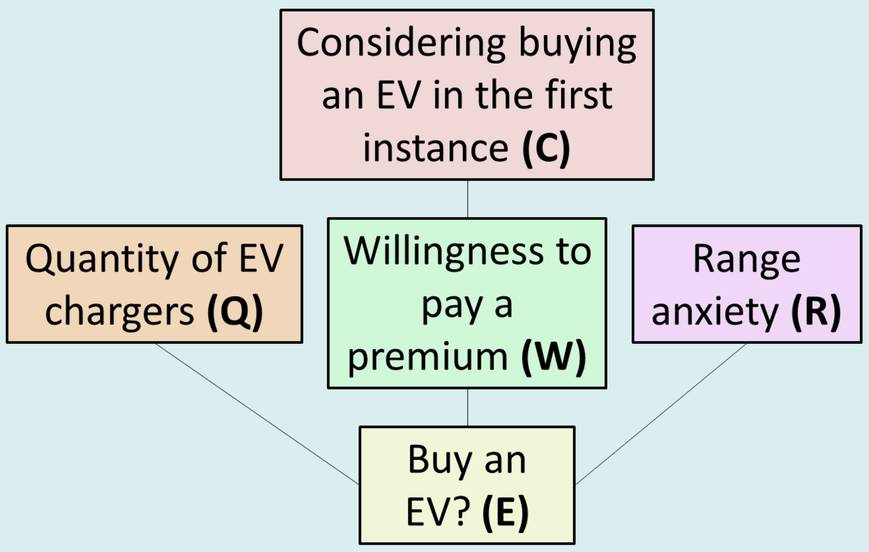

Figure 4: BN predicting whether an individual will buy an EV based on different factors, namely whether the individual is initially considering buying an EV, if they are willing to pay a premium for an EV, and if they perceive the EV range and quantity of public chargers to be a barrier or incentive

4. An Integrated Systems Approach

- Use BN to inform particular variables in SD model
- The strengths and limitations of BN and SD are complementary – BN can effectively manage uncertainty, gaps in data and incorporate expert opinion as a data source; SD can capably model complex, dynamic and nonlinear relationships between diverse variables

5. What Now?

- The preliminary causal map model outputs a value of 8.4 $MtCO_2$ for the emissions resultant of car travel in Scotland, 2019
- Despite the simplifications and assumptions associated with this early stage basic model, the output is reasonably within range of the reported value of 5.3 $MtCO_2$ [2]
- Next steps of this work are to develop the SD model and integrate BN to certain variables to allow the uncertainty associated with the impact of Scottish Government transport policy to be captured
- International governments are likely to adopt similar policy approaches, evidenced by the Ireland's National Sustainable Mobility Policy [5], demonstrating the pertinence of this work

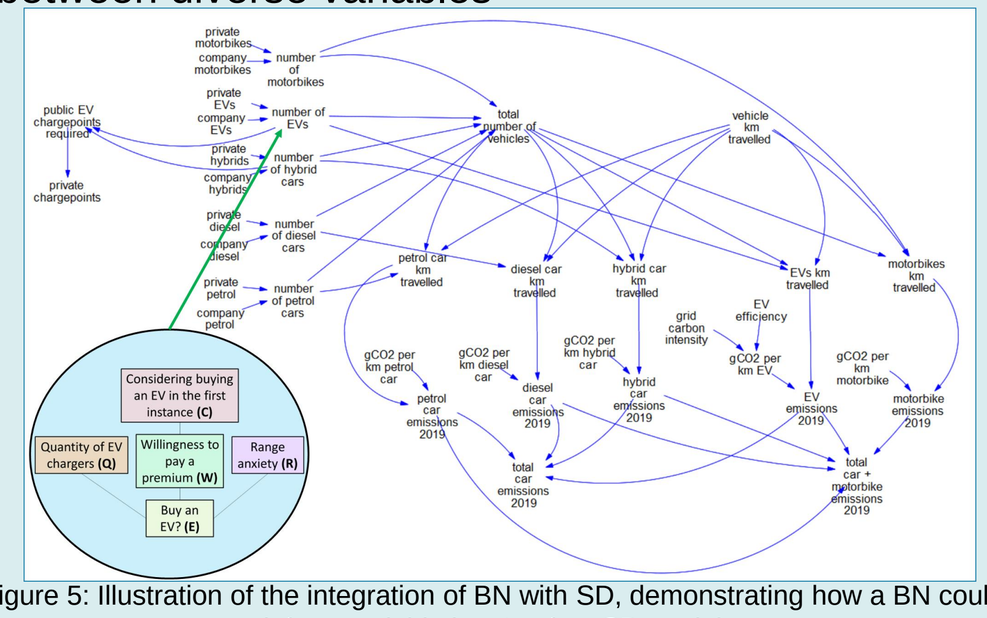

Figure 5: Illustration of the integration of BN with SD, demonstrating how a BN could inform variable inputs of an SD model

References

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