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A CONCEPTUAL APPROACH FOR ESTIMATING RESILIENCE TO FUEL SHOCKS

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ABSTRACT

This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

We examine a conceptual approach to the estimation of resilience of transport systems to fuel shocks, i.e. a severe and long lasting reduction in the availability of fuel for motorised transport. Adaptive capacity is an element of resilience and is defined in the paper. There is currently no indicator of adaptive capacity of individuals in small geographies sensitive to a variety of policy measures, such as those affecting fitness, obesity, bicycle availability and bicycle infrastructure, whose impacts (at least in the short term) are on a smaller scale than large-scale land use and urban morphology change. We propose a conceptual approach for designing a method to quantify this indicator. The indicator shows the proportion of the population of areas who would have the capacity to commute to work principally by bicycle or walking following the shock. It assesses capacity grounded in current data and avoids as far as possible the need for speculation about the future. We believe this makes progress towards producing a good indicator with relatively un-controversial, transparent simplifying assumptions. The indicator can compare the resilience of different areas and can be updated over time.

Keywords: Resilience, adaptive capacity, sustainability, indicators, walking, cycling, peak oil, resource scarcity, disruption, system change, indicator functions

1 INTRODUCTION

There are finite limits to resources (Meadows et al., 1972). There are finite limits to fuel available for transport (Hubbert, 1956). Rockstrom et al., (2009) argue that certain natural resources have already been exploited beyond critical thresholds where there are likely to be consequences to which society will have to adapt. Peak-oil may lead to a gap between demand and supply of fossil fuels for transport (for example see Aftabuzzaman and

Mazloumi, 2011). This means that there are a number of situations in which it is possible that fuel supply for [passenger] transport could be suddenly and dramatically reduced.

We are interested in the assessment of resilience to inform transport policy about sustainable futures. A resilient transport system is one which can continue to provide some social and economic benefits within the environmental limits imposed by a fuel shock. The question we will address is: how resilient is our current pattern of travel and transportation provision to such a sudden and unpredictable fuel shock?

The focus of this paper is the development of the conceptual design of a method for assessing resilience. The conceptual design is necessary firstly in order to inform methodology and data selection and secondly as part of the communication of what to measure and why. These elements are pre-requisites of applying the methodology to an indicator which is instrumentally sound and applicable to policy and decision making. (Gudmundsson, 2010; Lyytimäki and Rosenström, 2008). In section 2 of this paper we first consider the definition of resilience, its importance and the need for indicators of resilience to inform sustainable transport policy. Then we go on to show that current indicators are not able to give a complete measure of the adaptive capacity element of resilience. Adaptive capacity being the ability to continue making journeys post shock. Particularly there are no existing indicators that are sensitive to a variety of policy measures affecting fitness, obesity, bicycle availability and bicycle infrastructure whose impacts (at least in the short term) are on a smaller scale than large-scale land use and urban morphology change. Sections 3 and 4 construct the conceptual approach by defining scope and the indicator design respectively.

Section 3 outlines the scope of the indicator proposed. For purely practical reasons the indicator is based upon a model of adaptive capacity the ‘morning after’ a shock which happens tomorrow. Whether this is a short term disruption to fuel supply or a permanent reduction in availability there is a ‘morning after’: a day after the shock when the population needs to attempt to carry on with life. On the ‘morning after’ the shock, the number of ways in which people can adapt is likely to be limited to changing modes. For example, people are unlikely to be able to move home to a better location or get a new job the morning after, nor can land-use and location of jobs and services be changed instantly. The ‘morning after’ is chosen not for policy reasons, but for the practical reason that a calculable, relatively non-controversial, and transparent indicator can be produced for this point in time. We provide a baseline for further work. Section 4 outlines the indicator designs. The factors considered are explained and examples are given of the type of existing data which could be used to populate the model. Section 5 summarises issues addressed developing a method which can be applied to calculating an indicator. Section 6 covers conclusions and further work.

2 BACKGROUND

Resilience in this paper is defined as the persistence required of the social, economic and environmental systems for sustainable development. Sustainable development in this paper means economic and social systems functioning within finite ecological and resource limits. There is much debate over the definition of sustainable development used in transport (for a summary see Ramani et al., 2011). Resilience has several elements which will be defined below including adaptive capacity and transformation (Folke et al., 2010). Specified resilience (Carpenter et al., 2001) is the resilience of one system in response to specific changes. Using specified resilience is a simplification which may make analysis tractable. We pick as our system of interest the transport system. In this context we can examine the resilience of people to a fuel shock in the transport system. Adaptive capacity in this context is the ability of people to keep making journeys [primarily by walking and cycling] post shock, so that they can continue to have a 'way of life'. This holds if we assume that people need to make journeys in order to have any form of 'way of life'. People need to access goods, services, other people, education and employment wherever they exist.

Resilience as defined above is important to achieving sustainability. More precisely it is part of sustainability defined within an eco-centric worldview or as ecological economists would call it "Strong sustainability" (Daly, 1994). There is agreement that resilience is an aspect of strong sustainability (Teigão dos Santos and Partidário, 2011, Gunderson and Holling, 2002, Lebel et al., 2006). Within the transport literature there is support for strong sustainability underpinning the development of transport policy (e.g. Banister, 2008, Gudmundsson and Höjer, 1996, Schiller et al., 2010). There is then a clear justification for attempting to increase adaptive capacity to transport fuel shocks.

Active modes are key to resilience to fuel shocks. Adaptive capacity in this context is the ability of people to keep making journeys [primarily by walking and cycling] post shock focussing on "small" scale factors influencing individuals in small geographies. The UK guidance on indicators for transport appraisal does not directly consider resilience of people to a fuel shock in the transport system as we define it in Section 2.1 (DfT, 2007). The current indicators used in appraisal of the environment objective do assess effects on physical fitness. This is a factor of adaptive capacity but on its own it cannot give a measure of adaptive capacity. Current mode share does not indicate capacity for people to use active modes post shock. It would appear from the literature that other countries do not explicitly examine resilience. For example Mihyeon-Jeon and Amekudzi, (2005) give examples of indicator sets used in economically developed nations and international bodies and Miranda and Rodrigues da Silva, (2012) in Brazil. The indicator sets examined do not collect the range of information which would be needed to give a measure of adaptive capacity to transport fuel shocks. For example they do not collect the fine grained information about people's capacity to travel by bicycle such as ownership at small geographies and individuals' ability to propel a bicycle.

Proposed indicator sets for sustainable urban mobility, such as those suggested by Litman and Burwell (2006) or Toth-Szabo and Várhelyi, (2012) include some indicators which measure some factors of adaptive capacity but it is not considered explicitly. For example Marletto and Mameli, (2012) consider walkability and cyclability as measures of the propensity to use active modes under current conditions. These measures do not give an adequate measure of adaptive capacity after a shock. Accessibility statistics and indicators use assumptions about trip length by active modes based upon current circumstances and behavioural preferences. Dodson and Sipe, (2007) suggest an indicator of vulnerability of the populations of different areas to fuel price rises in Australian cities. It identifies areas which may have to change if there are price rises. It does not measure the capacity of the individuals there to adapt.

Rendall et al., (2011) provide an indicator of resilience as defined above. They use the notion of active mode accessibility to suggest changes to urban morphology and land-use to increase adaptive capacity in the event of a reduced supply of fuel due to peak-oil. The mitigation strategies considered changes to land-use which are high level changes. These are useful mitigation strategies to be implemented in anticipation of a shock. Other land use and transport interaction models would also be suitable for examining high level mitigation strategies. However we believe that there are also non land-use “small” scale factors which influence the ability of individuals to adapt after a shock. As Table 2 states, indicators need to be sensitive to policy measures. Different indicators are needed at different scales. For example; land-use focussed indicators are too high level to examine localised, individual and community oriented interventions. It would not pick up the effects of policy interventions aimed at changing obesity or bike availability on adaptive capacity.

There is currently no indicator which shows adaptive capacity of people to transport fuel shocks which would be sensitive to policy interventions at the scale of interest.

To summarise our position so far: Our definition of transport resilience illustrates its importance. Indicators are essential to represent issues in transport policy. This justifies a need for indicators of resilience and the subset we are interested in – adaptive capacity indicators of “small” scale factors that is those not involving large scale land-use and urban morphology change which influences individuals in small geographies. There is a lack of suitable indicators which justifies the production of a new indicator. This application requires development of a method of calculation.

3 INDICATOR SCOPE

The indicator we shall subsequently define uses a fairly simple idea, commonly found in transport planning. We calculate the adaptive capacity of the area now. That is, we consider a shock which happens tomorrow and the adaptive capacity immediately after the shock. Then we suppose: what if a particular policy intervention had been implemented before the shock – what would the current adaptive capacity be? For pragmatic reasons we choose to concentrate on a hypothetical situation on the first day after a sudden shock, i.e. before society has had any opportunity to make a ‘post-shock’ adaptation. We can offer evidence from the current situation to suggest adaptive capacity at this point. If our measure is calculated some weeks or longer after the shock we have no evidence of how people may change. In reality a shock might not be so sudden. This indicator gives a clear simplification rather than speculating about how rapid the onset of the shock would be. We wish to avoid speculation where possible. The indicator is then sensitive to policy interventions before a shock. These policies affect the adaptive capacity immediately after the shock.

We hypothesise that the adaptive capacity ‘the morning after’ at a local scale will affect longer-term and larger scale adaptive capacity and overall resilience. Thus, while predicting the longer-term adaptive capacity is beyond the scope of our work, we believe our calculated measure to be a useful indicator for both the shorter and longer term.

It is important to state that the guiding approach of this work is to produce an indicator of capacity to adapt rather than a predictive model. Calculating capacity tells us an upper bound of what might be possible. This is clearly a rather artificial situation but it is a clear simplification and captures a key aspect of resilience of the present transport system, and the journey to work is a journey type that is easy to understand. The indicator used existing secondary data for ease of production, cost effectiveness and a wide area of coverage. The purpose of the indicator is to assist in decision making by firstly assessing the effect that specific policy interventions would have on adaptive capacity to fuel shocks, and secondly by fulfilling discursive functions (Boulanger, 2007; Gudmundsson, 2010). The scope of the indicator is tightly focussed on transport fuel shocks, but the consequences could be wide. Ramani et al., (2011) suggest that indicators which affect generic sustainability issues are more important than those only relevant to a specific domain such as transport.

As the indicator is quantifiable it is more easily used in existing appraisal frameworks. The indicator could be used in a Multi-Criteria Analysis (MCA) where a weighting is given to achieving resilience objectives. The nature of the indicator means it could also be monetised. This means it could also be utilised in a Cost Benefit Analysis (CBA) based appraisal framework.

4 INDICATOR DESIGN

The indicator is designed to measure the effect of interventions which could be made before a shock which would improve adaptive capacity after a shock.

Indicators are a trade off between realism and simplicity. The aim is to make non-controversial simplifications and assumptions which are transparent and easy to understand. Simplifying assumptions we made in the design of our indicator are shown in table 1:

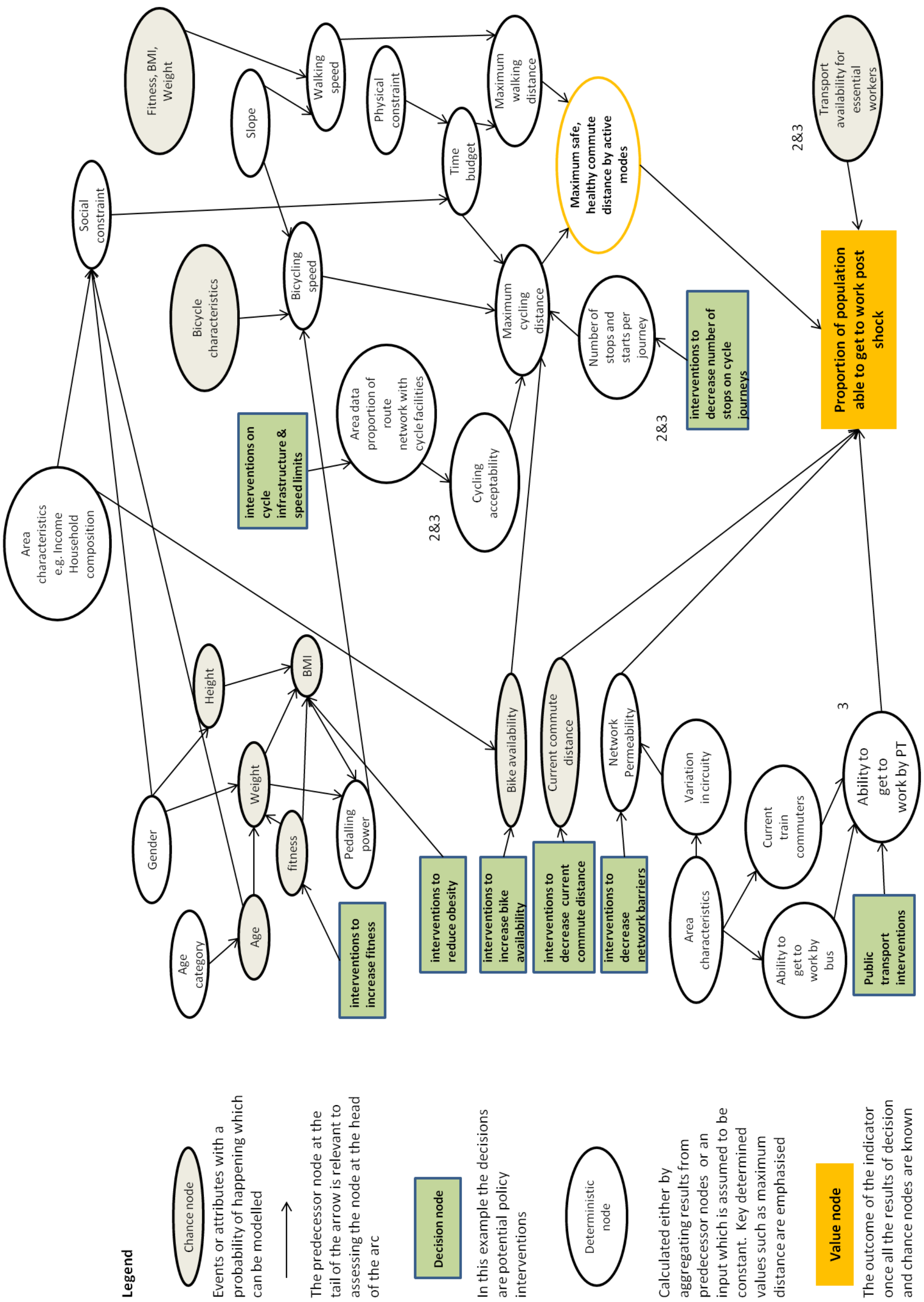
Table 1 simplifying assumptions

1.This is an indicator of adaptive capacity immediately after a shock.
2. The health and age characteristics are the same as the current population.
3. Post shock – walkers and cyclists can use all of the road network in situation 1 but have to share with motor vehicles in situations 2 and 3.
4. Cyclists are free flowing and not subject to congestion or delays at junctions.
5. The population could achieve the level of adaptive capacity proposed by the indicator safely and without risk to health.
6. Spatial distribution of activities does not change the morning after the shock.
7. People cannot migrate or change jobs the morning after the shock.
8. A policy has to lead to safe and healthy outcomes. It cannot encourage or direct people to behave in an unhealthy or unsafe way. For example; estimates of how far people can walk and cycle should not be based on work rates [whilst walking or cycling] and time budgets which lead to illness and injury.

This indicator is given as the proportion of an area's population which could maintain their current commute by changing to active modes. It is an indicator of one form of adaptive capacity following a fuel shock. The calculation of the indicator is based on four groups of factors. Firstly, individuals have a maximum capacity to walk and cycle based upon their physical characteristics. Secondly, location features such as topography affect this physical capacity. Thirdly the supply of resources such as bike availability and the permeability of the transport network due to barriers and infrastructure also affect the maximum distance which individuals can walk or cycle. Finally individuals have constraints on the time they can spend commuting.

The conceptualisation of the indicator was made using influence diagrams. The reason for using an influence diagram is to clearly define the relationships between variables in the indicator in an easily understandable way (Clemen, 1991). A summary of the key factors influencing the indicator is given below. The identification of the factors which influence the indicator mean the effects of policies on the indicator value could be tested. Policies which could be tested include interventions to increase fitness, reduce obesity, increase bicycle availability or reduce network barriers

Figure 1: Influence diagram – factors and relationships modelled in the indicator. Personal physical characteristics such as fitness influence pedalling power. Environmental factors such as slope, supply factors such as bike availability and constraints such as time budget affect the maximum distance people can travel by active modes. Maximum travel distance is compared to an individual's current commute distance to determine whether they can make the journey to work Maximum distance an individual can travel is also dependent upon the fuel situation and whether the journey can be made by motorised modes.



5 THE METHOD APPLIED TO AN INDICATOR

In this section we summarise issues which have been addressed in developing a method which can be applied to calculating an indicator. We reflect upon indicator design in Table 5. Marsden et al 2006 propose criteria for good indicators. Table 2 shows the criteria and the progress made.

Table 2: The design of the indicator follows the criteria set for good indicators shown in table.

Criteria for good indicators	**Steps towards fulfilling criteria**
1. Usefulness	Indicator can have calculation and discursive functions. Trial use with stakeholders would further refine the functions. Indicators can measure the resilience to fuel shocks. The issue of resilience to transport fuel shocks is a specific example of the generic issue of resource scarcity threatening sustainable development.
2. Clarity	We have tried to be clear in terms of definitions of terms and presentation of the design.
3.Non-corruptibility	Users would have to be clear about what data is input to the model. As the journey to work is used in the indicator, areas with high unemployment could artificially increase the adaptive capacity. This has to be accounted for in construction of the indicator.
4. Controllability	It is not possible to totally isolate transport systems from other real world systems so simplifications have to be made.
5. Measurability	A quantifiable indicator of adaptive capacity is produced. Speculative assumptions are avoided as much as possible. Relationships between factors rely on established relationships evidenced in literature. Simplifications have had to be made, such as assuming that the social constraints on time budget remain the same immediately after the shock rather than speculating how it might change. We also assume relationships from sports science literature which determine the link between level of physical activity reported in a survey and the pedalling power.
6. Responsivity / comparability	The indicator shows the response that particular interventions would have on the indicator value. A do minimum calculation of the indicator can be made for the current time. Next year if updated data are collected a do minimum calculation could be made. This would give the opportunity to show progress. However not all data sets would be updated annually such as the census. The indicator is spatially responsive: The indicator is comparable between locations.
7. Understandability	The indicator is intended to be straightforward: The output units can be understood by non-specialists. The influence diagram goes some way to making the factors modelled understandable to a non-specialist. However this could be made clearer. The functional relationships between variables and the data sources do require more explanation and may be difficult to convey to non-specialists. Trial use with stakeholders will help determine how understandable the indicator is.
8. Cost effectiveness	This first iteration indicator uses existing nationwide secondary data sets. If the indicator were developed further by collecting new primary data it would be more difficult to establish the cost effectiveness of this indicator over the first iteration.

6 CONCLUSIONS

The importance of considering resilience and particularly adaptive capacity to fuel shocks is explained. Transformation before a shock or adaptive capacity at the point of shock are required to avoid negative consequences. Adaptive capacity would be required to maintain options for sustainable development after a shock. We explain the need for indicators of resilience and the subset we are interested in – those sensitive to a variety of policy measures affecting fitness, obesity, bicycle availability and bicycle infrastructure whose impacts (at least in the short term) are on a smaller scale than large-scale land use and urban morphology change. We demonstrate a lack of suitable indicators which justifies the production of a new indicator. The conceptual framework allows assessment of the impact of policy interventions which could influence adaptive capacity such as health and fitness, bicycle availability and reduction of network barriers. The indicator illustrates generic issues of sustainability and are not limited to the transport domain.

A number of choices were available in developing this conceptual framework, principal of which was estimating capacity rather than attempting to predict future behaviour. This was driven by the need of indicators to be uncontroversial in the assumptions used in their calculation. The decision to estimate adaptive capacity immediately after a shock avoids the need for controversial assumptions about attitude and behaviour change (or not) resulting from shocks. The choice of model scale was made because the literature points to an absence of indicators sensitive to the policies of interest. As explained above we felt it important to give a full explanation of the conceptual framework for this method of estimating the adaptive capacity element of resilience to transport fuel shocks. Because it is a pre-cursor to model development and application as an indicator the next steps in further work are clear.

In the longer term further work may include development of data sets to enhance the model, and evaluation of the usefulness of the indicator amongst policy makers and practitioners. The model might also be usefully expanded to look at the movement of freight by active modes following fuel shocks. The integration of this indicator into suitable indicator frameworks also presents an opportunity for further work.

We feel that the most important application of this indicator is to address issues of resource scarcity. However we notice that the indicator could be used to assess adaptive capacity to other transport shocks and disruptions caused by other events such as geo-political crises and natural disasters.

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