ENERGY CONSTRAINT MODELS FOR SUSTAINABLE TRANSPORT

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ABSTRACT
Energy use is an essential element of transport systems. Energy in transport is largely supplied from finite resources, mainly from crude oil. Because of this, transport energy will be subject to supply constraints. Current transportation models available to engineers do not include energy constraints. To integrate energy constraints into transportation models systems engineering will be applied to energy in transport systems and it will be shown that all dimensions of sustainable transport systems are underpinned by energy. This master’s thesis aims to develop new transport energy models to assist in planning for functional continuation of transport systems within energy constraints that are conjointly related to pollution and spatial constraints. Research will look at transport modes and energy to spatial layout relationships within a defined time interval for a specific trip purpose.

RESUMO
O uso de energia é um elemento essencial dos sistemas de transporte. A energia em transporte em grande parte é fornecida por fontes finitas, principalmente de reservas petrolíferas. Por causa desta energia de transporte pode estar sujeito a limitações futuro. Os modelos atuais de transportes não incluem limitaçãos de energia. constraints de energia a modelos de transporte, A teoria de sistemas de controle será aplicado para introduzir as limitações de energia em sistemas de transporte e será mostrado que todas dimensões de sistemas de transporte sustentáveis são apoiar-se em energia. Este mestrado tese busca desenvolver novos modelos de energia de transporte para ajudar planejadores planejamento para continuação de sistemas de transporte dentro das limitações de energia que são relacionou com a poluição e limitações espacial. A pesquisa examiná modos de transporte e energia espacial relacionamentos dentro de um intervalo definido de tempo para um propósito específico de viagem.

1. INTRODUCTION

Energy use is an essential element of transport systems. The spatial separation of human activities creates the need for energy use for travel and goods transport (Nix, 1983). The transport system exists to serve activity systems, and people as social beings are continually involved in activities. Activities serve basic human needs and higher social needs. Participation in activities requires transport energy relative to the spatial organization of the built environment. Food and goods are a primary transportation requirement for households. Work and recreation activities of individuals also commonly require energy for travel.

There is a growing realisation that current energy sources are finite (Nix, 1983). Combustion of fuels is also the major cause of pollution in transport systems and is directly responsible for hydrocarbons, particulates, and sulphur and nitrogen oxide emissions (National Institute of Water and Atmospheric Research *et al.*, 1998) resulting in poor air quality in many urban areas (Whitelegg, 1993). The Kyoto protocol has outlined that the rate of carbon dioxide pollution is too high for ‘the world’ to environmentally cope. The world view of energy availability and pollution acceptance is changing and transport planners will need to change their focus as a result. “Planning has always changed its central concerns and approaches in response to the state of the world with which it has had to deal. The significant fact is that each of these views of planning can be related to a predominant vision of the world at that time.”(Hall, 1983).

Transport planners are becoming more concerned with sustainable transport systems. Sustainable systems in other fields are defined as being able to continue to *function* within the ecological environment (Tainter, 1988). Functional continuation of transport systems requires the rate of use of renewable resources to not be greater than the rate of regeneration and the rate of pollution emission to not exceed the capacity of environment (Whitelegg, 1993). To ensure functional continuation of transport systems within the ecological environment, transport planners must design the system to meet activity functions within environmental requirements and energy supply limitations.

There are few historical examples in developed countries of transportation energy having a limited availability, or a *hard constraint,* not subject to the economics of supply and demand. This is taken as evidence that *the market* is effective at supplying the fuel demand. One exception was the case of petroleum and diesel supplies being constrained by the government in Canada during the 1980's oil crisis. This policy required Canada to maintain a 'transport energy cap' at a set level which was implemented because of the inability of market forces to cope with matching demand to supply (Nix, 1983).

The current state of the art transport models that include energy are elaborate holistic models with transport-energy as a sub model. These models are used to assess affects of traffic management strategies, such as ramp metering and priority lanes (Nix 1983). However model users have reservations about the abilities of these elaborate transport-energy models in assisting policy development. The real concern is that current energy models do not have the ability to provide information to policy makers for energy as a hard constraint. No models were, or are currently available to assist planners with policies requiring a hard constraint such as experienced in the 1980's oil crisis. There is a need for research into th is area so that future energy and pollution constraints can be appropriately considered in transport planning.

This research aims to develop energy constraint models as a sustainable transport modelling tool. There are two types of constraints, soft and hard constraints. A soft constraint is not an actual defined 'limit' but constrains by creating increased friction as the 'limit' is reached and surpassed e.g. market forces. A hard constraint sets a physical limit that cannot be exceeded. The model developed in this research will aim to consider energy as a hard system constraint. Relationships between energy, mode use and spatial separation of specific trips will be studied and a new model that represents these energy relationships developed. The model will be designed to show the sensitivity of changing modes and spatial separation of specific trips.

2. SCIENTIFIC BACKGROUND

Energy is related to spatial layout and quality of life, and energy constraint will affect functionality and activity at many levels. Pollution is a result of energy consumption and energy consumption is required to bridge spatial separation of activities. Therefore an energy constraint will affect spatial layout and pollution. However an energy constraint need not be detrimental to quality of life. When activities that add to quality of life are spatially separated and require energy to bridge this separation, energy consumption adds value to quality of life. However if these activities can be reached with less energy, or the spatial separation is reduced, thus reducing energy requirements, quality of life need not be harmed. In fact, policies to constrain car use in city centres are generally not detrimental to the economic viability of city centres (Wegener, 2001). In addition these policies generate a reduction in air pollution which improves quality of life.

Because of the causal link between energy and pollution, there is a need to integrate transport and environmental policies. In particular there is a need to contain growth of traffic demand, especially road transport, and develop a sound economic principal based on polluter pays (Whitelegg, 1993). A common approach to the "polluter pays" policy is to add a pollution tax to fuels. Pollution has been more effectively reduced through controlling traffic volumes and speeds, which also has a direct impact on energy consumption.

Energy consumption correlates directly to the spatial layout of activities, and thus to land-use systems. It is inferred that the history of decreasing energy costs has facilitated increasing distance of spatial interactions, leading to more dispersed settlement systems creating more trips over longer distances. This is an unsustainable trend in transport (Wegener, 2001) on several levels. Abundant energy availability, or cheap energy, is seen to be one cause of transport sustainability issues (Warren Centre, 2001). Increasing costs of energy use in transport is seen as a way to control or effect spatial layout of settlement systems. However, cost is a soft constraint and the effect of using market forces to control energy use is not clearly understood.

Hard energy constraints will, by definition result in a decrease in fuel consumption. The Kyoto protocol is aimed to bring this constraint to transport systems in consideration of environmental impacts. There are other transport system constraints currently used and recognized as hard constraints by transport engineers, such as population and employment constraints. Extending these constraints to include energy would make it possible to also incorporate pollution, land-use, spatial layout and other energy related constraints. This implies a large role for suitable methods of modelling (Harris, 1983).

Systems engineering is employed by mechanical and aerospace engineers for highly complex systems with hard constraints. The transport energy system requirement would be for functional continuation of the transport system within energy constraints that are conjointly related to pollution and spatial constraints. In a system many variables may be affected by a constraint through their direct or indirect relationships. In the case of a transport energy constraint, it is related to mode use, pollution emissions and spatial separation of trips. The sensitivity of these variables to energy will differ, and this sensitivity is one aspect that the research will focus on, through defining of the model.

3. RESEARCH METHOD

To develop models that can suitably deal with energy constraints, research will need to be carried out to determine the relationship between energy use, mode use distribution and spatial distribution within a defined time interval for all trip purposes. The following are specific areas to be studied:

i) The effect that transport mode has on energy consumption
ii) Energy to distance (trip distribution) relationship for each transport mode
iii) Frequency of trips being made from origin to destination during a defined time interval

The aim of research into these separate areas is to determine overall energy consumption for trip purposes, which will be dependent on a combination of these relationships.

The strategy for the thesis is to model one specific trip purpose and develop a coupled trip distribution and energy model. The overall goal is to structure the model so that the energy constraint can be set as an input to yield spatial land use patterns. The trip purpose studied is for food from the source to household and will include combined energy consumption for both freight and individual trips.

4. CURRENT STATE OF RESEARCH

This thesis has only just begun and the current focus is on research into the methods required to begin model estimation. It is expected that existing computer simulation tools will be used to link mode distribution to spatial distribution for the specific trip purpose. Several trials will be completed with different modelling software packages (not necessarily transport); then the most effective tools will be selected to produce and develop the energy models. Difficulties are expected when combining mode distribution and spatial trip distribution for a defined time interval to produce overall energy consumption for the trip purpose. In addition the combination of freight and individual trips into the energy model should prove challenging.

5. CONCLUSIONS

Current transport models are unable to treat energy as a hard constraint. Energy constraints will affect relationships between spatially separated activities and mode use. The benefit of having energy constraint modelling tools available is that it will allow planners to make informed decisions when facing the reality of current and future energy, spatial and pollution constraints.

When considering quality of life factors good neighbourhood design is important. Communities offering the highest quality of life have activities and services that are not largely spatially separated and do not require a large amount of transport energy to reach them. Energy constraint modelling tools may assist planners in more effectively planning urban areas to require less energy use.

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