System Dynamics Evaluation of Traffic Safety Policy: An Exploratory Study

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Overview

• Traffic Safety as a Wicked Problem

• System Dynamics for Traffic Safety

• Case Study

• Discussion
Purpose

• To assess the strengths and weaknesses of system dynamics methodology in the context of road safety policy analysis

Wicked Problems

• “The search for scientific bases for confronting problems of social policy is bound to fail, because … [they] are ‘wicked’ problems…”

• Rettel and Webber (1973)
Wicked Problems

- no enumerable set of potential solutions
- no stopping rule
- planner has no right to be wrong
- unique
- can be explained in numerous ways
- no opportunity to learn by trial-and-error
- symptom of another problem
- no immediate and no ultimate test of a solution
- no definitive formulation
- not true-or-false, but good-or-bad

Traffic Safety is Wicked!

- Fatality Rate
  - Driver behaviour
  - Safety of vehicle
  - Safety of roads
- Enforcement Education
- Encourage sale of ANCAP rating
- Frequency of maintenance
Traffic Safety is Wicked!

If fatality rate increases…
the real reason is always debatable

Policy resistance may occur!
A set of modelling tools to facilitate understanding of the real world

- Emphasise interactions or feedback between agents/components across time

- MIT - Forrester (1961)

- Applied in:
  - Climate change (LTG Meadows et al. 2004)
  - Supply chain
  - Ecology
  - Marketing
  - Public health
  - Project management
  - Strategic planning
  - Public policy
  - ...
SD Method (Sterman 2000)

1. Problem and scope
   - Theme selection
   - Key variables
   - Time Horizon
   - Reference modes

2. Dynamic hypothesis
   - Hypothesis
   - Endogenous focus
   - Mapping (causal loop diagram etc.)

3. Formulation
   - Stocks and flows simulation (structure, decision rules, parameters, relationships, initial conditions)

4. Testing
   - Compare with reference mode
   - Extreme conditions
   - Sensitivity analysis

5. Policy design and evaluation
   - Scenario specification
   - Policy design
   - What if...
   - Sensitivity analysis
   - Cross policies analysis

SD in Transport Policies

- Growing interest
  - ASTRA project in Europe (1997-2000)
  - Environmentally Friendly Urban Transport System (Han et al. 2010)
  - Impact assessment in the automotive industry (Walther et al. 2010)
  - Land use transport interaction modelling (Pfaffenbichler et al. 2010)
SD in Traffic Safety Policy

• **Traffic Safety → Policy taker**
  – An externality dealt with after implementation of transport policy

• **Possible applications of SD**
  – Understand effect of transport policies on traffic safety
  – Analyse policy scenarios for traffic safety policies

Safe System

• **Fundamental Objectives**
  – making the road transport system more forgiving of human error
  – minimising the level of unsafe road user behaviour

• **System Dynamics facilitates safe system**
  – Bigger picture view; multiple stakeholders view
  – Allows trial and error and theorising about possible effects
  – Not a silver bullet
Case Study

- Case study is a platform for discussion
- Hypothetical case study
  - Policy goal: Increase the average ANCAP rating of passenger cars on the road to 4-star by 2020
  - Key Assumptions:
    - Only 3-star and 5-star cars
    - Only network effect and price effects

Group Model Building

Cavana and Adams 2010
Qualitative Models

Amalgamation of mental models

System Dynamics Simulation

- Qualitative models are translated into quantitative model

- Most useful when there are large number of effects
  - Relative strength of effects is unknown
  - Complex inter-dependencies are likely
  - Robust regression equations or expert opinions are available
Stocks

3-Star Cars


5-Star Cars


9,000,000.00 Cars

Initial 3-Star Cars

3-Star Cars
Flows

- 136,156.81 Cars/month (New 3-Star Cars)
- 75,000.00 Cars/month (3-Star Cars)
- Scrap 3-Star Cars

Outflow

- 3-star mean lifetime: 120.00 mo
- 75,000.00 Cars/month (3-Star Cars)
- Scrap 3-Star Cars

'3-Star Cars'
'3-star mean lifetime'
Inflow – Network Effect

136,156.81 Cars/month

New 3-Star Cars → 3-Star Cars

Reinforcing Loop

Market_share_3-star Attractiveness_3-star

9.49

Effect of 3-star stock on attractiveness

Social norm, “3-Star cars are good enough, no need to buy 5-star”

Based on Sterman (2000, 394)

8,000,000.00 Cars

Threshold_For_Network_Effects

2.00

Effect of 3-star stock on attractiveness

[Sensitivity \times \left( \frac{N_{3\text{-star}}}{\text{Threshold}} \right)]
3-Star Cars

Three-Star Cars

- Initial 3-Star Cars
- New 3-Star Cars
- 3-Star Cars
- Scrap 3-Star Cars

Sensitivity Analysis

Sensitivity analysis - variation of 'Average Star Rating' with normally distributed 'Threshold for network effect' (10% std. dev.)

- 50% confidence bound
- 90% confidence bound
Policy Experimentation

Threshold For Network Effects

Govt tax on 3-star (%)

Govt subsidy on 5-star (%)

Sensitivity to size of car population

Policy goal: To increase the average star rating to 4.0 at the end of 10 years

Non-commercial use only!

Average Star Rating of Passenger Cars

- No Intervention
- 20% tax & subsidy
- 45% tax & subsidy
Cost-Benefit Analysis

Discussion

- System dynamics has significant potential
  - Allows modelling of soft variables ("behavioural economics")
  - Ability to represent wicked problems and facilitate trial and error
  - Collaborative approach
• Level of Analysis
  – More suitable for high level (macro or meso) analysis

• Validity
  – Rigorous validity is impossible to achieve in wicked problems
  – Key question is usefulness in solving wicked problems

• Size of model
  – Blackbox effect can occur if model is too complex
  – Replicate-the-real-world approach has to be avoided
  – Capture key dynamics and levers
Any Questions?
Thank you!

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