Assessing impacts reduction and transition-oriented planning in sustainable mobility policies: a System Dynamics approach

1 Background and problem description

Transport related airborne pollution is one of the main causes of respiratory diseases and associated increase in morbidity in densely populated areas (Vimercati, 2011; WHO, 2006). The link from air pollution to both severe health problems and high traffic volumes is well known and thoroughly researched (WHO, 2006). However, an unsustainable transportation system not only causes health issues, but also massive costs in terms of reduced productivity, freight delay, increased energy and fuel consumption or vehicle losses and damages, for example (Li-Zeng, Hong-Ge, and Li-Ren, 2012). The impacts of transportation and, particularly, urban mobility range from environmental pollution and its effects on human health and ecosystem stability to social and economic costs, as has been reviewed. Therefore, there is an urgent need for change in the mobility system, towards sustainable solutions that reduce the pressures on the environment and society.

To address all these issues, policy packages or simultaneous enforcing of different policies are needed, because of the complexity involved in effectively reducing mobility impacts (Garcia Sierra, 2014, ch. 3, p. 45). However, regulation cannot be designed without evaluating the caused impacts — too many resources and possible negative outcomes would be at stake. Policy assessment from the systems thinking perspective is, thus, a key issue to develop, due to the difficulty of dealing with entire systems, their internal dynamics and the emergent systemic behaviour patterns, such as feedback loops, rebound effects and hidden causalities. In this regard, the field of System Dynamics can help capture such structures and cause-effect chains (Hjorth and Bagheri, 2006). The holistic nature of system dynamics models can also help achieving an integrated assessment framework for urban mobility policies, by delivering information on a set of several indicators, at the environmental, social and economic levels.

On the other hand, policy development in the field of transportation has been mainly focused on two paths, according to Köhler et al. (2009): (a) efficiency increasing measures, through incentives for technological enhancements (e.g. better engines or fuel mixes) and more stringent pollution limits and (b) behavioural change management, i.e., measures aimed at modal shift — encouraging people to shift from private cars to public transport, for example. Both approaches, albeit successful to some extent, have not delivered the expected results so far, due to the high inertia and stabilisation mechanisms inherent to the current dominant regime for transportation: internal combustion engines cars-based mobility. Social backlash from abrupt changes, as well as industrial pressure to maintain support for the current business/social model are among the reasons for the partial success of mobility policies, with technological niches such as electric vehicles still not sufficiently developed or economically viable for the majority of the population (Geels et al., 2012; Nykvist and Whitmarsh, 2008).

However, a third way is possible, when it comes to policy design for sustainable mobility: transition management oriented policy. Its approach entails adopting a longer term thinking mindset (usually one or several generations), multi-level and multi-domain thinking, maintaining support for a large set of solutions and with a focus in system *innovation* alongside system improvements (Rotmans, Kemp, and Asselt, 2001). Moreover, flexibility in the objectives of policies is encouraged, as well as a more qualitative perspective to policy goals. All these characteristics configure a policy design mindset that could be the key to unlock a true game change in urban mobility, by drifting the focus from efficiency measures to a transition and innovation vision, where something more than technological progress is harnessed to achieve a sustainable transport system in the future.

2 Purpose and definitions

As much as a holistic evaluation framework is needed to assess the impacts reduction or increase resulting from policies in the mobility system, policy makers should also focus on the transition management perspective of said policies. In order to understand the status of a transition towards a sustainable mobility system, an analysis of the current and future policies is needed. Taking all of this into account, the research question that the thesis addresses is: *"How can mobility policies be designed to achieve effective impact reductions and, at the same time, support a transition to a more sustainable urban mobility system?"*

In order to answer the stated research question, this thesis aims to *explore a method for system-wide evaluation of urban mobility policies, with regards to environmental, social and economic impacts and the status of a sustainable transition, used in the assessment of mobility policies.* Developing and applying such an evaluation framework helps the analysis of the current set of policies to understand to which extent the mobility system is transitioning to a more sustainable state.

The set of objectives designed to fulfil the aim of the thesis are:

(a) *Identify* the important variables, impacts and system structures affecting mobility in urban areas, as well as the drivers and lock-in mechanisms of a potential transition towards a more sustainable transport system.
(b) *Design* a conceptual model for the mobility system, including the previously identified social, environmental, economic and structural aspects.
(c) *Quantify* the relations of the conceptual model to enable a more in-depth policy analysis, with respect to impact assessment.
(d) *Validate* the model by performing tests to increase the confidence level of the model, as suggested by Forrester and Senge (1978) and Qudrat-Ullah and Seong (2010).
(e) Carry on a *case study*, reviewing and assessing mobility policies under the perspective of transition management theory, to understand the differences and potential for improvement in mobility policy design.

3 Method description

The chosen tool for the conceptual modelling step is the *causal loop diagram* (CLD), probably followed by *system dynamics* modelling in the quantification step, although this is still not clear[1]. The models obtained using this technique are easy to understand by a majority of stakeholders, they quickly convey the interrelations of the main components of a (dynamic) system and, finally, they are useful to highlight the feedback structure of the modelled system (Ghosh, 2015). A more detailed plan of the methodology consists in:

(a) Design a *conceptual CLD*, linking different components in the transport system. To achieve a highly comprehensive model, iteratively expand the system boundaries of the CLD by including other aspects that affect or are affected by the transport system, with the insights provided by the literature research. The necessary data and knowledge about the diverse transportation system components will be collected on the basis of a *literature review*.
(b) Using the previously gathered information and complementing it with appropriate quantitative data, fit as many *equations* as possible for the links in the CLD model.

[1] The final decision between implementing the quantification step through *system dynamics* or *agent-based modelling* will be based on literature research and a thorough justification of the strengths and weaknesses of each method.

The quantification is done in three steps:

i. Identify and define the quantifiable links between *core components* of the system.
ii. Quantify "external" links dealing with social issues, such as healthcare or accident costs, if enough data is available.
iii. Quantify the links from the core components of the system to the transition management assessment level.

(c) Validate the evaluation model through a set of structural, behavioural (model behaviour) and policy implication tests, dealing with sensitivity, adequacy and consistency.

(d) Evaluate a series of mobility policies, with respect to the expected impacts and transition potential through a *case study* in Barcelona, assessing the city's mobility plan.

4 Disposition

The preliminary document structure for the thesis report is based on a traditional research outline, due to the investigative nature of the thesis:

1. Introduction
    1.1. Background
    1.2. Aim and objectives
2. Methods
    2.1. Methodological framework
    2.2. Causal Loop Diagrams
    2.3. System Dynamics modelling
    2.4. Transition Management assessment
3. Results
    3.1. The conceptual model
    3.2. The System Dynamics model
    3.3. Mobility plan assessment
4. Discussion
    4.1. Model calibration and limitations
    4.2. Transition management for mobility policies
5. Conclusions

5 Detailed schedule

A detailed version of the proposed thesis schedule can be seen in Figure 1 and Table 1. The phases that were outlined in the Thesis Synopsis document have been broken down into more specific tasks, which amount the same number of work days as the preliminary suggestion. The most important changes are:

- The model development phase (PH2) is now split up between a conceptual modelling task and a quantitative modelling one. Iterations in the conceptual mapping step will be used to develop the environmental, social and economic modules of the CLD model. The quantitative modelling phase is also split between the identification of stock and flow variables and the quantification of the dynamics of such.
- The model benchmarking phase (PH3) consists of a model formal validation step and a case application, in which a policy framework will be assessed using the developed model.

Table 1: Thesis detailed schedule. The same information is presented in a Gantt chart in Figure 1.

Task	Objective	Start date	Finish date	Duration (work)*
PH0 Topic definition	–	Jan 16	Jan 20	5d
PH1A Background literature review	(a)	Jan 23	Feb 3	10d
PH1B Planning report writing	–	Jan 30	Feb 3	5d
Planning report	–	–	Feb 3	**Milestone**
PH2 Model development	(b), (c)	Feb 6	Mar 31	40d
Conceptual modelling	(b)	Feb 6	Mar 3	20d
System boundaries definition	–	Feb 6	Feb 6	1d
Identification of indicators	–	Feb 7	Feb 10	4d
I1 Iteration 1 - Environmental	–	Feb 13	Feb 17	5d
I2 Iteration 2 - Economic	–	Feb 20	Feb 24	5d
I3 Iteration 3 - Social	–	Feb 27	Mar 3	5d
Quantitative modelling	(c)	Mar 6	Mar 31	20d
Flows and stocks identification	–	Mar 6	Mar 10	5d
Flows and stocks quantification	–	Mar 13	Mar 31	15d
PH3 Model benchmark	(d), (e)	Apr 3	Apr 28	20d
Model validation & calibration	(d)	Apr 3	Apr 14	10d
Case application	(e)	Apr 17	Apr 28	10d
PH4 Report writing	–	May 1	May 26	20d
Introduction	–	May 1	May 5	5d
Methods	–	May 8	May 10	3d
Results & analysis	–	May 11	May 17	5d
Discussion	–	May 18	May 24	5d
Conclusion & abstract	–	May 25	May 26	2d
Thesis report	–	–	May 26	**Milestone**
PH5 Presentation preparation	–	May 29	Jun 6	7d
Final presentation	–	–	Jun 6	**Milestone**

* Only *work* days are included in the duration specification – weekends are excluded from the calculation. Therefore, 20 days correspond to 4 full weeks (a month) worth of work.

Name	Work
PH0 Topic definition	5d
PH1A Background literature review	10d
PH1B Planning report writing	5d
Planning report	
PH2 Model development	**40d**
Conceptual modelling	**20d**
System boundaries definition	1d
Identification of indicators	4d
I1 Iteration 1 - Environmental	**5d**
I2 Iteration 2 - Economic	**5d**
I3 Iteration 3 - Social	**5d**
Quantitative modelling	**20d**
Flows and stocks identification	5d
Flows and stocks quantification	15d
PH3 Model benchmark	**20d**
Model validation & calibration	10d
Case application	10d
PH4 Report writing	**20d**
Introduction	5d
Methods	3d
Results & analysis	5d
Discussion	5d
Conclusion & abstract	2d
Thesis report	
PH5 Presentation preparation	7d
Final presentation	

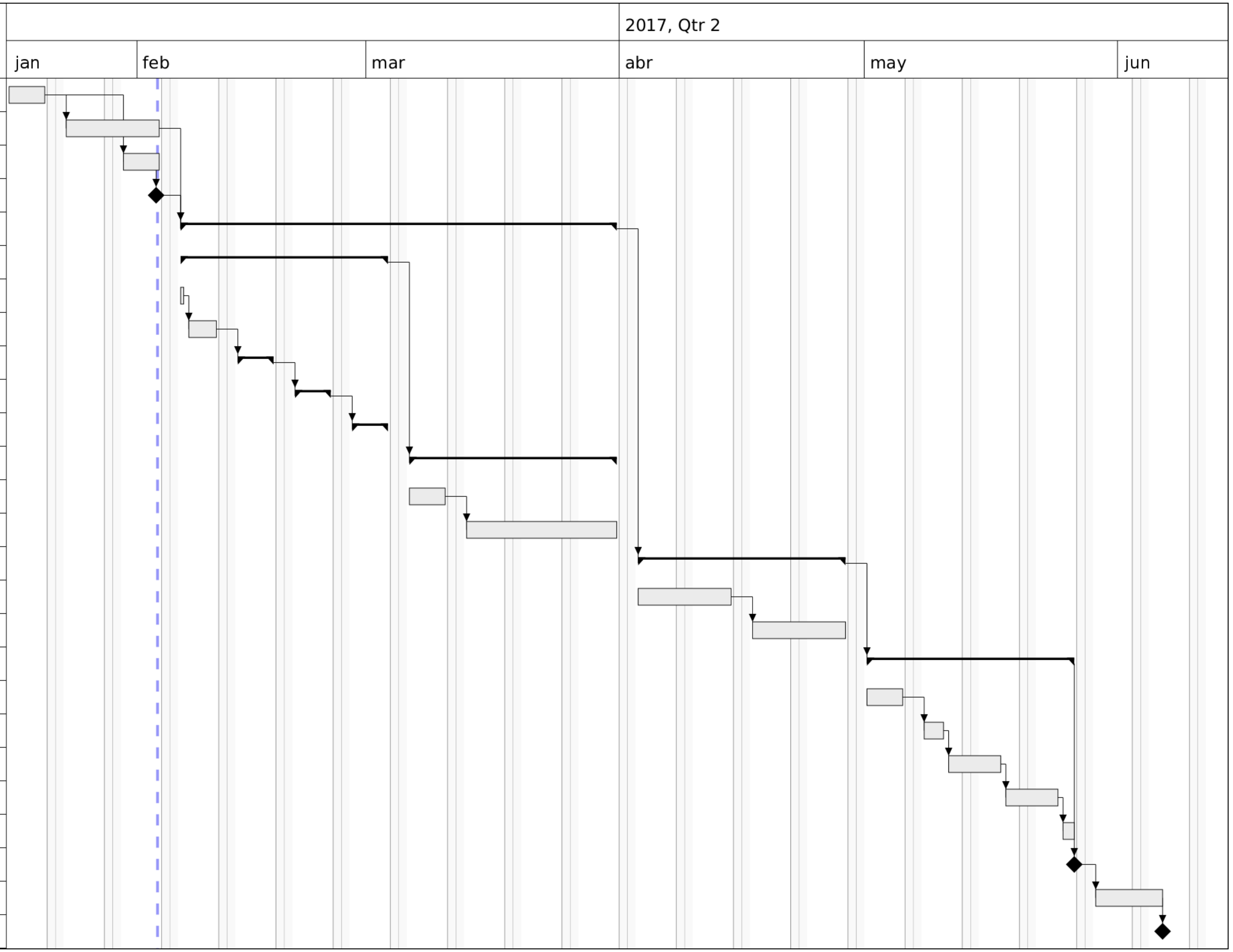

Figure 1: Detailed Gantt chart of the thesis schedule. Milestones are marked with a ⧫ symbol.

6 Risk analysis

Several risks have been identified with respect to the proposed thesis, considering the chosen methodology and objectives. The list of risks is presented in Table 2, where a subjective likelihood level indicator (with possible values: 1, 3, 9) is included, as well as a summary of the consequences of incurring in every detailed risk. Alternative action plans are also included in the table, which would be put in place if the thesis project was deviating from its normal course due to any of the identified risks.

Table 2: Risk analysis of the thesis. Alternative action plans are detailed for each identified risk.

Risk	Likelihood	Consequences	Action plan
Too ambitious scope	9	The thesis is not complete, regarding the list of objectives.	A thorough model quantification is skipped. The thesis focuses on qualitative discussion of the system's causal structure instead.
Unavailable data	3	The model is incomplete, at a conceptual or quantitative level.	The limitations of the model are deeply discussed. The focus is put on model validation and example use.
System Dynamics quantification is the wrong choice	3	The use of System Dynamics to quantify the model does not capture the flexibility in the model structure needed to evaluate transition management policies.	Another modelling technique, such as agent-based modelling is chosen and implemented. If there is no time to do so, the quantification step is skipped and details of the decision are provided in the final report.
The results are too normative	1	The thesis is regarded as too normative and the results are not accepted as valid, due to the normative bias.	The discussion section is lengthened to argue for the normative focus of the thesis. Results are put in context to avoid being too biased.
The results are inconclusive	1	The model does not capture the reality of the system and the aim is not fulfilled.	Useful results are highlighted and an explanation and analysis is given about the reasons why the modelling phase was unsuccessful.

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