CASA: A MATSim-Based Platform for Investigating Methods to Reduce Traffic Emissions

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Abstract. Finland has some of the cleanest air in the world yet still suffers from approximately 2 000 pollution related, premature deaths a year. In Helsinki, traffic is the most significant local contributor to the concentrations of fine particles ($PM_{2.5}$) that are the most detrimental to human health, and produces 20 percent of the city's CO_2 emissions. Reducing the adverse health effects of particles and cutting CO_2 emissions require a change of behaviour on individual level, as well as structural changes on a city-wide scale. Using MATSim, agent-adaptivity, atmospheric modelling and AI methods on various scales, we present a platform to test and create incentive-based policies that encourage populations of urban centres to take more climate sensible transport modes, with quantifiable impacts on emissions and atmospheric composition.

Keywords: Traffic, Emissions, Policy-Creation, Incentives, Adaptivity

1 Introduction

Air pollution is a significant contributor to urban mortality across the world. Finland has some of the cleanest air in the world yet still suffers from approximately 2 000 pollution related, premature deaths a year [5]. There have been a number of approaches to reduce urban air pollution with incentives: tax-credits for electric car purchases, ride-sharing, purchase and use of bicycles. However, due to cultural and structural differences, these approaches are not easily transferable to other urban systems - at least not with identical outcomes. Several of these approaches rely on encouraging the population to change their behaviours through incentives and positive reinforcement. As one of the more unusual examples, an initiative in Bologna employed beer and ice-cream to encourage citizens to walk or use bicycles instead of driving [1].

By encouraging individuals to make climate-aware travel decisions, we can create a bottom-up approach to reducing urban pollution that does not require significant investment or time in infrastructure. To this end, we propose CASA

(**C**ity **A**ir **S**imulation with **A**gents)[3], a scalable, city-agnostic platform for testing and creating incentives to reduce CO_2 and $PM_{2.5}$ emissions and related health effects. Our goal is to provide a unified platform for city-planners and urban stakeholders to design incentives and methods for improving air-quality that utilize societal constructs. CASA is itself designed to be extensible.

2 Proposed Approach

CASA shares some similarities with other MATSim based frameworks, such as those in [7, 2]. However, with respect to emissions and atmospheric modelling, we couple the traffic simulation with a Gaussian finite line source dispersion model CAR-FMI [3] developed by the Finnish Meteorological Institute and here enhanced with AI based Random Forest. This combination allows us to simulate direct vehicle emissions from an open road network and the atmospheric dispersion of the emitted concentrations. A further advantage of using an agent-based model is that we can map the movement of individuals, which, alongside with the modelled particle concentration field, enables a more accurate study of population exposure to air pollution. The true novelty in our approach is that with adaptive agents, we are also able to quantify the change in emissions and resulting concentrations when (an incentivized) change in agent behaviour occurs.
Currently, CASA provides tools for pre-processing data, configuring a MATSim simulation, extracting certain data, and analyzing output. In addition, we have created three extensions for our framework so fa, namely, *CASAVolumesAnalyser*, which produces more detailed counts information for CAR-FMI, *CASAPTPassenger*, which determines the number of passengers on public transit per hour per link, which enables emissions modelling to produce more realistic results, and *CASAPT2MOptimiser*, which is a tool to find the optimal configuration for pt2matsim for a particular schedule and network.
Calculating the emissions is done by coupling simulated traffic volumes, traffic fleet (fractions of different vehicle types), and road type information with emission factors that are determined on a national level considering different parameters (vehicle type, vehicle age, road type etc.). We quantify aggregate emissions for each link, and model the dispersion of emitted concentrations. The dispersion model relies on meteorological data and an analytical solution for atmospheric dispersion. The final result is hourly concentrations in each pre-determined receptor point or a grid of points, which can be displayed on a map depicting the spatial variation of dispersed traffic-originated particle concentrations.

Incentivizing a Population

The most significant and novel component of our framework is the 'incentives layer' called *CASAIncentives*. *CASAIncentives* serves two main purposes: firstly, it aims to determine the viability and success of a set of incentives with the goals of reducing emissions and premature mortality in a city, and secondly, it aims to generate a new set of improved incentive parameters. To accomplish this,

[3] Available at https://github.com/AIPSE

data from a MATSim execution is sent to *CASAIncentives*, which incorporates emissions modelling, complex systems analysis methods, amongst others. *CASAIncentives* is designed to be extendable so that each urban system expert can design methods unique to their city.

An *Incentive* is a set of rules designed to influence a sub-population's mode choice. These rules include the incentive or reward a person receives, the type of population that it initially effects, e.g. people that live in a certain zone or receive a monthly income below a certain threshold, and the mode trade-off that gives the person the reward. In addition, the transmission medium, such as social network or television, is selected. Finally, the rule states the goal that is meant to be achieved, which informs the analysis tools on which features need to be optimized.

Through multiple iterations, CASA aims to determine the optimal set of incentives and parameters of reaching the goal of improving air-quality. However, we also consider determining effective deployment and transmission paths, which directly affects the policy's distribution when implemented into the real city.

Agent-Adaptivity

We implement agent adaptivity using *jill* [6]. We consider that an agent is able to alter their mode selection based on their perception of social media feeds, IoT sources, weather, location, and desired activity. This builds upon existing works by considering that a person's selection of mode can be influenced by social and governmental interactions in addition to weather, traffic, and activity factors.

Our study not only involves how agents adapt to an incentive in their mode-selection and behaviours over the course of day, but also how populations adapt to incentives over extended time-periods. This allows urban planners to consider long-term ramifications of a particular incentive, such as when does an incentive become an integral part of urban mobility and can the reward be phased-out?

Transferability

A key design feature of CASA is that it can be deployed to examine and test incentives for other cities. This city-independent approach is crucial as reducing emissions is a global problem and that many different incentive styles exist. Following the approaches shown in [4, 7], we strive to use only open-data sources. Each city is likely to have a different survey structure and questions, and in some cases, multiple surveys are required to build up a quality representation of the population. To aid in incorporating this data into simulations, CASA provides a set of Java classes to assist in converting and aggregating survey data for use.

Our initial case study is for the city of Helsinki. While not a dense city, Helsinki has a large number of public transit and non-car based travel options. The Helsinki transit authority, HSL, contributes heavily to GTFS and OSM, which therefore gives our initial CASA case study a highly accurate network and transit schedule. However, our initial population is based on a data from an agency performed survey, that was provided to us on request.

3 Initial Experiments

At this early stage of CASA's development, our experiments are limited to verification and validation, and standard MATSim executions. Our initial population is constructed from private survey data collected by HSY, which represents approx. 5% of the total population. The network is collected from OSM, public transit data from GTFS, and counts provided by the City of Helsinki and is publicly available. Currently, an initial execution of CASA for 24 hours in Helsinki on a machine with an i7-7700K CPU, with 22GB of RAM, takes roughly 31 hours, with the main runtime contributor being CAR-FMI at 22 hours.

4 Conclusion & Future Work

CASA is designed to be a a scalable, city-agnostic platform for testing and creating incentives to reduce emissions and mortality. Our initial work has shown that we can use CASA as a city-agnostic platform for emissions and mortality study. In addition to further work with the Helsinki case-study we will prove the effectiveness of our simulation approach, by targeting cities from Europe, Canada, and Brazil. Our primary focus now is two-fold. Firstly, continued development and testing of the *CASAIncentives* component which will enable us to study mode-selection based methods to improve urban air quality, and secondly, developing more sophisticated adaptive agent models. Future work here involves incorporating TASHA [2] and social behavioural models.

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