Institute of Transport Economics
Norwegian Centre for Transport Research

Summary

An assessment of the available simulation models for the planning and design of safe urban intersections for pedestrians and cyclists

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The Norwegian society faces a complex set of challenges in form of striking a balance between decreasing car usage and increasing usage of sustainable modes of transportation – public transport, bicycling and walking. A common denominator underlying all these growth trends is traffic safety, which needs to be filtered out and presented as one of the most important keystones for a balanced growth in the future. This necessitates a long term strategy which is aligned both with the transport structure and needs of future transport users. This report gives a systematic outlook on the relations that is considered important for make informed decisions on the design of urban junctions in the future.

Pedestrian modelling

A key overarching point is that pedestrian models are fundamentally different from vehicular models in that where road traffic can be defined as a stand-alone system with prescribed behaviours, formed by some system of links for instance, pedestrian movement is ‘free’. Pedestrian simulation models are therefore based upon the entire *area* available for walking, with origins, destinations, waypoints and various behaviours defined over relevant parts of the total area.

In addition to the accurate modelling of pedestrian ‘desire lines’ of movement, key aspects to be tested include the areas available for comfortable, safe movement of pedestrians along pavements and when waiting at crossings – together with potential delays and waiting times. Measures of walking times, waiting times, people counts, the use of space and densities of people per m² are outputs common to all pedestrian simulation models and form key metrics in the assessment of pedestrian experience at junctions. Video outputs, combined with vehicle micro-simulation models where relevant, can be powerful tools in demonstrating anticipated outcomes, problems and benefits to a wide range of stakeholders.

The following three theoretical models have driven the development of pedestrian simulation modelling till date:

Social Force modell

The model is based on the primary purpose of pedestrians being to accelerate towards making progress towards a destination at a desired speed. This primary goal is influenced by physical and social factors; agents will respond to ‘repulsive’ forces as a result of the boundary of physical objects (walls, other obstacles) and of the presence of other agents (i.e., people).

The Social Force Model was successful in recreating real-world 'emergent' behaviours such as the formation of lanes in opposing flows of people (at certain densities) and the 'shockwaves' that propagate through crowds of people at narrow openings and similar situations.

Legion / 'OMCA' modell

The model which is the basis for the software tool *Legion* was developed by Keith Still (Still, 2000) on the premise that a simpler mathematical approach than the Social Force Model could be used to create results that were just as well validated. The basis for this model is based on four key behavioural rules: Objective, Motility, Constraint, and Assimilation (OMCA). In more detail, these are described by Still (2000) as:

- *Objective*: Try to move to a desired or intended end point
- *Motility*: Try to maintain your optimum velocity
- *Constraint*: Try to maintain a minimum distance between yourself and the other objects in the environment
- *Assimilation*: Delay time taken to read and react to the environment.

Behavioural heuristics modell

More recently, the cognitive science approach taken by Moussaïd et al (2011) seeks, as with the Legion model, to simplify the mathematical basis of the movement model. Specifically, a model based on the distance of obstructions in agents' 'line of sight' is proposed, which uses two simple heuristics (simple cognitive procedures and rapid decision making).

Bicycle (and vehicle) modelling

The three main elements of vehicle micro-simulation modelling, which would also apply in some form to bicycle modelling, are:

- Car-following models describe the interaction between a vehicle and the vehicle in front
- Lane-changing models describe the timing and urgency of changing lane
- Gap-acceptance models determine the timing and safety of movements at intersections.

The algorithms to perform these functions vary by software tool, and have various strengths and weaknesses in different circumstances, but the broad concepts are common.

State of development of bicycle models

A key differentiator for bicycles is their width, and the associated more complex lane behaviour. Generally speaking, model development for bicycles is therefore in the process of moving from simplistic lane adherence that is appropriate for motor vehicles to more advanced modelling of 'lateral' movement appropriate for bicycles (and their interaction with motor vehicles). When combined with the ability to model dedicated bicycle lanes, this additional capability should provide the basis for modelling the majority of conceivable bicycle routes. This is a step change from past modelling of bicycles, which considered them only nominally, based purely on the vehicle model.

The industry as a whole is not there yet. Different tools are at different stages of development. However, the overall direction is towards suitable adaptations to the car-following models to enable relatively sophisticated and accurate modelling of bicycles. PTV Group are currently notably strong in this area.

Key considerations for junction design

Simulation of junction designs with a focus on pedestrians and cyclists – both to accommodate large numbers of those users and to provide optimal, safe route choices for them – requires various capabilities of the modelling software. A summary of key considerations are given below, to be used as a basis for assessment and comparison of the different software tools.

These considerations are given further context by giving a brief overview of some trends in the US, the Netherlands and the UK – with a particular focus on bicycle use; arguably the least well understood and provided-for user group.

Key considerations for software tools

General

- *Model validation:* Technical and real-world validation of model outputs to ensure outputs are a credible representation of the situation modelled and therefore have the potential to form an accurate basis for decision-making (including applicability to pedestrians, cyclists and vehicles).
- *Fully integrated interactions between modes*: Exchange of position and speed data between pedestrians, cyclists and motor vehicles at each time step.
- *Integration with signal timing software:* Ability to optimise signal timings is critical, through fixed and vehicle actuated timings, as well as LISA+, RBC, SCATS, SCOOT, Siemens VA, VS-Plus, etc.
- *Quality and clarity of outputs:* Options to produce both high-level and detailed numerical and graphical outputs suitable for not only technical assessment and conclusions but also stakeholder communication (e.g., to include 3D rendering).
- *Cost:* Indicative costs of software licences and training, together with broad appreciation of modelling time/cost.

Cyclists

- *Road position and overtaking:* Ability to model vehicles using road space 'freely' (not restricted to one vehicle per lane) to enable realistic modelling of cyclists in particular (thus having the potential to have an appropriate impact on junction layout/geometry in the design process). To include interaction between bicycles and other road users (e.g., a car and bicycle sharing a lane) and dedicated cycle paths.

- *Classification of speed and acceleration:* Ability to take account of the wide range of speed and acceleration characteristics of different bicycle user types, in the context of surface gradient.
- *Dealing with obstructions*: Ability to take account of obstructions that may have a direct bearing on cyclist behaviour and knock-on impacts in relation to movement and capacity (e.g., narrowing of route, bus stops etc).
- *Behaviour at traffic signals:* Ability to simulate waiting behaviours in 'forward stop zones'; encroachment on pedestrian crossings[1]; the use of cycle-specific signal timings; and red-light violations (full violation or early start), especially for right turns.

Pedestrians

- *Route choice flexibility*: Combination of modelled shortest-path choices and imposed navigational routes required with sufficient control to model the pedestrian environment effectively.
- *Realistic pedestrian model*: Appropriate mathematical basis to recreate pedestrian behaviours relating to individual movement and aggregate, crowded movement.
- *Conflict areas*: Ability to define (freely) areas of conflict between pedestrians and vehicles, to include modelling crossings at places other than formally marked crossings. Flexibility is required to ensure that the modelling reflects real-world 'desire lines' of movement for pedestrians (including for planned schemes such as extended central reservations).
- *Crossing behaviour*: Capability to model realistic behaviours of pedestrian crossing choices (gap acceptance, right of way, etc) and vehicle responses
- *Response to traffic signals:* Control over pedestrian adherence to signal timings and 'jaywalking'.

Simulation modelling tools overview

A brief overview of relevant simulation tools is given for context and to illustrate potential future developments. The most promising are identified for specific assessment, against the key considerations described.

The information given here is based on a combination of information from suppliers, use of trial versions and review of relevant material (e.g., other publicly-available research/project work that has used a particular tool).

Paramics / UAF

Summary: Micro-simulation vehicle model with sophisticated pedestrian module ('Urban Analytics Framework' or UAF) allowing for full interaction between vehicles and agents. Note that two 'versions' of Paramics software exist (stemming from the same original software) – one owned by Quadstone Paramics / Pitney Bowes and the other by SIAS.

1 encroachment on pedestrian crossings means cycles blocking pedestrian crossings (which they are not meant to do but sometimes take advantage of that space)

Given the inclusion of UAF within the Quadstone product, it is that software tool that is considered here.

Key benefits

- Autodesk and GIS integration.
- Proven micro-simulation vehicle model.
- High-quality pedestrian module.

Key limitations

- Bicycles modelled only as another vehicle type similar to motor vehicles; lacks detail of within-lane movement and related behavioural characteristics. No information on planned development of lateral movement modelling.

InControl Pedestrian Dynamics

Summary: Sophisticated pedestrian simulation tool, but currently lacking integration with a vehicle micro-simulation tool.

Key benefits

- Sophisticated pedestrian simulation with dynamic route choice based on emerging pedestrian conditions.

Key limitations

- Currently not integrated with a vehicle simulation tool.

Aimsun / Legion

Summary: Proven micro-simulation model by TSS, paired with pedestrian simulation module using Legion.

Key benefits

- Proven micro-simulation vehicle model with fast run times.
- Ability to build hybrid vehicle simulation – mesoscopic model of larger area, micro-simulation of smaller area of key interest.
- High-quality pedestrian module.
- Integrated model: Allows for assessment of interaction between vehicles and pedestrians.

Key limitations

- Bicycles not currently modelled with lateral movement (though actively in development).
- No Norwegian language option (English supported).

Vissim / Viswalk

Summary: Established micro-simulation vehicle model.

Key benefits

- All-in-one solution to model vehicles, bicycles and pedestrians.
- Bicycles modelled with lateral movement and greater level of development overall for bicycles, including recent developmental project experience in Copenhagen. Parameter settings identified (albeit research/revision for Norwegian context might be required).
- Much-improved pedestrian module which allows complex algorithmic basis to be relatively well controlled.
- Potential to model detailed scenarios involving complex behaviours of both bicycles and pedestrians.
- PTV have a strong record of innovation and research (e.g., Kretz, 2014).

Key limitations

- Pedestrian module remains complex mathematically, though a competent practitioner should be able to produce reliable results.

Commuter / InfraWorks 360 Traffic

Summary: Innovative all-in-one solution considering person-trips as the primary basis for analysis, rather than being mode-led.

Key benefits

- Potential to be a sophisticated multi-modal tool, including dynamic mode choice and 'layering' of walkways/roads/crossings to allow for complex priorities and crossing behaviour.
- Non-lane based modelling of vehicles and bicycles – allows for vehicles to pass where there is sufficient width (e.g., including bicycles overtaking stopped buses).
- Potential to incorporate the influence of public transport modes on junction design, e.g., a rush of pedestrian demand from people disembarking from a bus or train close to junction.

Key limitations

- Currently in beta testing following takeover by Autodesk; undergoing integration into the InfraWorks tool.
- Release plan not yet public.

MassMotion

Summary: Sophisticated natively 3D pedestrian simulation tool, but currently lacking integration with a vehicle micro-simulation tool.

Key benefits

- Advanced control over pedestrian class types, with unique 'agendas' en route.
- Autonomous agent route choice.
- Ability to plot line-of-sight of agents, demonstrating their field of view when walking.

Key limitations

- Currently not integrated with a vehicle simulation tool.
- Requires Autodesk Softimage.

Massive Insight

Summary: Advanced simulation tool based on 'artificial intelligence'.

Key benefits

- Potential to implement different type of mathematical model from the more typical vehicle and pedestrian models.

Key limitations

- Not yet available for commercial use; development appears to have stalled since 2009 beta testing programme.

Software assessed in greater detail

On the basis of the state of the market at the time of writing, the following tools are further assessed in this report:

- *Aimsun / Legion*
- *Vissim / Viswalk*
- *Commuter / InfraWorks 360 Traffic*

Conclusions and recommendations

In recent years, the development of micro-simulation tools has been rapid and complex multi-model environments have been modelled. Specific high-profile projects such as Oxford Circus in London, together with in-depth studies such as the Copenhagen bicycle modelling study, have shown that it is feasible to assess complicated junction design for all road users.

That said, because these developments are new – and on-going – there remain challenges in refining some model features and behaviours (notably for bicycles), and not all software developers are at the same stage of development, despite moving towards similar goals.

The recommendations given below are therefore presented in the context of our best understanding of both the current and future position of the software market. We anticipate that these timings could have a bearing on the most appropriate software choice, depending on the precise requirements and timescales of forthcoming projects.

Recommendations: Software tool selection

Based on our understanding of the requirement, trends in junction design for pedestrians and cyclists, and the review of simulation tools presented in this report, we recommend the possible use of three software tools. They are presented here in priority order based on *current functionality at the time of writing*. Note that the relative merits of these software tools may change substantially within the next 12 months, given our understanding of the development priorities and broad timescales of the software developers.

1. **Vissim/Viswalk (PTV)**
    - Excellent integration of vehicles, bicycles and pedestrians. Allows testing of features such as bicycle lanes/paths; signal timings, including 'green scramble' and 'green waves'; forward stop zones, including feeder bicycle lanes; narrowing lanes; and a range of priority and gap acceptance behaviour for vehicles, bicycles and pedestrians.
    - Most developed bicycle model, incorporating lateral movement and including recent developmental experience in Copenhagen.
2. **Aimsun/Legion (TSS)**
    - Currently almost as capable as *Vissim/Viswalk*, but lacking lateral movement for bicycle modelling. Also slightly more complex integration between vehicles and pedestrians because of separate companies' collaboration.
    - Within approximately the next year, likely to have developed lateral movement (based on a specific, major, funded project) and become a relatively even competitor for *Vissim/Viswalk*.
    - Potential efficiencies given existing use of *Aimsun* by the Norwegian Public Roads Administration and City of Oslo.
3. **Commuter/InfraWorks (Autodesk)**
    - Not currently commercially available.
    - However, is multi-modal from conception and would offer (arguably) the greatest flexibility of the three recommended tools.
    - Early indications suggest that conflict between vehicles, bicycles and pedestrians may be the better implemented of the tools (though note the more limited information freely available).
    - Potentially well integrated with Autocad CAD and BIM tools.
    - Proven in a range of past projects, though currently unavailable during integration with InfraWorks.