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Traffic modeling: micro-analytical meets micro-simulation

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TRB Standing Committee - Traffic Simulation (ACP80)

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Abstract

Powerful concepts have been developed and used in traffic modelling for a long time. These apply to key elements of analytical models and are related to methods used in microsimulation models. This presentation recommends that formal procedures are developed for cross-verification (benchmarking) and calibration of analytical and microsimulation models using the well-established micro-analytical and microsimulation concepts. This effort should aim to provide model transparency which is essential for the model users to understand the model output that software generates. The presentation discusses a number of key concepts that apply to analytical and microsimulation models. These include the importance of lane-based modeling, lane use at intersection approaches and midblock lane changes, acceleration - deceleration, definitions and measurement methods for consistency of traffic performance variables, environmental objectives, capacity analysis, near-saturated and oversaturated conditions, queue discharge, gap-acceptance, arrival headway distributions and bunching models, and lane blockage and capacity constraint in networks.

Reference

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PRESENTER's Notes

Authoring Language: English (United States)

Slide	Notes
1	**PRESENTATION TITLE**
2	Presentation Contents
3	**SECTION 1 - The Big Picture**
4	***Wikipedia*** (https://rb.gy/byz802): " *… the underlying message is to* ***question the apparent certainty of anyone who only has one source of information. The man with one watch has no way to identify error or uncertainty*** *(although at surface level, the adage emphasizes the consistency that arises when information comes from a single source and points out the* ***potential pitfalls of having too much conflicting information****).*"
5	For my **credentials** to talk about microsimulation! **Two models of very different nature**, and from different times and places (same person!), give almost the same result. **Capacity estimate is useful to check** if the delay estimate makes sense. **TNS**: Traffic Network Simulation.
6	Work during 1990s.
7	The study found that "***Cycle average queue estimates of the two models were within one vehicle of field measurement*** *" and suggested that* "***Resources (i.e. labour and software) used to develop and run SIDRA models were substantially less***" compared with the resources allocated for developing and running microsimulation models. It was estimated that **microsimulation required three to five times more resources than SIDRA**. Comment by Ian Espada (first author of the report): "*At the time we were doing research on models, the* ***skill of the modeler*** *became a very important factor to ensure that different modelling techniques reach the same conclusion. A bad SIDRA modeler and a bad VISSIM modeler will not get agreement.*"
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9	The hourly, daily, weekly, yearly changes in travel demand and operating conditions make the analysis complex – **even changes within an hour** can have significant effect. **Non-linearity** is an important characteristic of the performance of traffic and transport systems. **Sensitivity and uncertainty of operating conditions** increase at a high rate when demand approaches and exceeds the capacity of the system. The **human element** adds greatly to the variability of the system as drivers, riders and pedestrians adapt to varying conditions. For example, aggressive vs relaxed behavior will depend on traffic conditions. **The diversity of traffic engineering practice** around the world and the emergence of new practices over time add to the complexities.
10	In the USA and Canada, it is very common to use **All-Way Stop Control** at intersections but not Yield (Give-Way) Control. I believe the opposite applies to Australia, New Zealand and UK: It is very common to use **Yield (Give-Way) Control** at intersections but **not All-Way Stop Control.** These control types have different driver characteristics which affect the capacity of unsignalised intersections.

11	The **Multimodal approach** aims to manage demand rather than capacity by way of shifting demand to modes that demand less road space. An example of this is the **Movement and Place** practice in Australia.
12	As an example of the application of the **Movement and Place approach**, this is a shopping strip in Melbourne with low speed limits, and curbside parking. The purpose is not to provide road capacity through this place but facilitate shopping, other activities, safer pedestrian movements, and so on.
13	**SECTION 2 - Model Cross-Verification (Benchmarking)** We need to pay attention to **compatibility** between **microsimulation** methods and established **analytical (micro-analytical)** techniques used in traffic modeling. This can be achieved by establishing a process of **cross-verification (benchmarking)**. This idea has been recommended and actually applied in practice to some degree, even a quarter of a century ago. General definitions: An **analytical model** uses direct mathematical computations to determine system states. A **simulation model** uses various rules (mostly in the form of mathematical equations) for movement of vehicles in a system (individually or in platoons).
14	We should look at this from the **model user's perspective**. What's a good, smart, wise modeler? Signs of a **smart modeler** include **knowledge and experience**, **understanding** of model concepts, model assumptions and input data limitations, understanding the model as a tool, and useful feedback to researchers and software developers towards model improvements.
15	**Cross-verification** of analytical and simulation models will help with **transparency** of the models. Reading Brian Christian's words about "*systems optimized for appearance of explanation*", I thought of inexperienced model users watching animation. Even if it is a perfect replication of the real-life conditions, **watching an animation** does not reveal those laws to a modeler who does not have adequate knowledge based on concepts developed by decades of **traffic science**. Brian Christian's words that follow the quote in the slides are "*Such systems could wield this ability deceptively; we may find we have optimized for virtuosic bullshit artistry.*"
16	Our past papers (available for download on our website) discuss analytical modeling and microsimulation modeling in some detail.
17	This relationship shows that **microsimulation and analytical models** have a common basis. I came across this during my PhD, and later used it in our freeway research. This shows the derivative of speed relative to concentration as a function of speed and density (concentration). By choosing the ***m* and *l parameters***, many known analytical fundamental speed - flow - density equations are generated from the equation. Then, the microsimulation user could ask what fundamental traffic flow (analytical) models are generated by the microsimulation model used. This is an example of a **cross-verification question**.

18	Microsimulation models emulate **individual vehicle movements**. Analytical models employ algorithms based on **more aggregate and measurable "traffic movement" characteristics** representing the interactions of vehicles in a traffic stream.
19	**SECTION 3 - Key Model Elements** The process of **cross-verification (benchmarking)** recommended to measure the **compatibility** between microsimulation and analytical models used in traffic engineering require paying attention to **details of model elements**.
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21	Important subjects like effects of **road geometry**, **short lanes** and **signal timings** were not included in the discussion due to the presentation time limitations.
22	SIDRA is a **fully lane-based model**, i.e. the input, modeling process and output are lane-based. Various movement-based input exists, and output for movements are calculated according to the effective use of lanes by movements. As a lane-based model, the **SIDRA "micro-analytical" model matches the microsimulations models** that are lane-based as needed for emulating lane use of vehicles. This is not common to analytical models. The **HCM** roundabout capacity model is lane based, but l**ane groups and movement groups** are used for signalized intersections and stop sign control.
23	Lane-based models require determination of approach **lane flows** at intersections. Therefore, a **lane choice model** which allows for **lane under-utilisation** is needed. This allows determination of implied **midblock lane changes** by the analytical model. Comparison of approach lane flows and midblock lane changes estimated by micro-analytical and microsimulation models is recommended as a basic element of cross-verification. Approach lane flows are a key factor in determining intersection **performance (delay, queue, etc.) estimates**.
24	Modeling of **acceleration-deceleration** and **stop-starts** at intersections is very important. This is not included in the HCM.
25	Two very important aspects of this cross-verification are **definitions** and **measurement methods**. These are important for **consistency for all performance variables and all control types** (signals, roundabouts, two-way stop control, etc.). **Back of queue** is important for **upstream lane blockage** in networks and **short-lane capacities** at intersections (to model how the short-lane fills up and overflows into the adjacent lane). An example is **large differences in queue length** according to the definition used and how it is measured. HCM uses the back of queue for signals, but it uses cycle-average queue for roundabouts and sign control. SIDRA uses back of queue for all intersection types. Does the well-known formula **Cycle-average Queue = Average Delay x Arrival Flow Rate** work for oversaturated conditions?

26	The **relation between delay and queue** (e.g. very long delay while queue is very short, or very short delay while the queue is very long) requires an understanding of the queue definition. SIDRA models **stops** including **multiple stops in queue** (queue move-ups). This is not included in the HCM.
27	The **definition of delay** is particularly important for **oversaturated** conditions. There is a major difference between analytical (HCM, SIDRA) models and microsimulation models for these conditions. Analytical models include all delays experienced by vehicles left in the queue at the end of the analysis (simulation) period until they depart **after the analysis period**. A microsimulation would need to model the consecutive periods to match the analytical model estimates.
28	Visit: https://www.sidrasolutions.com/software/sidra-intersection/features/environmental-analysis/environmental-assessments and https://www.sidrasolutions.com/software/sidra-intersection/features/environmental-analysis/fuel-consumption-and-emission-models
29	**Capacity** is a key parameter in estimating **performance measures** (delay, queue, stops, travel time, average speed). Development of an agreed method for **measuring capacity in microsimulation models** is important for cross-verification.
30	In **near-saturated conditions**, delays, queues, and stop rates increase quickly. The **two-term performance models** used in the HCM and SIDRA analytical models explain this condition. For example, for delay at signals, the **first (uniform) delay term** is due to red time effects, and the s**econd (random) delay term** is due to **overflow queues** resulting from random variations in cycle-by-cycle arrival flow rates. **Overflow queues** occur in the cycles when the arrival flow rate is larger than capacity (**cycle failure**) while the average flow rate is less than capacity. This is the reason for **non-linearity** when the average arrival flow rate approaches capacity.
31	The figure in this slide shows the difference between average values of two simulation points for low and high v/c ratios (degrees of saturation). This is important since the effect of **randomness in arrival flow rates** increases as the arrival flow rate approaches capacity. The capacity may also change cycle-by cycle. This explains the **need for multiple runs in microsimulation modelling** for obtaining performance estimates representing average conditions. In particular, multiple runs in microsimulation modelling are essential for **oversaturated conditions**. Running longer simulation times is not the correct action in this case since the residual queues would keep growing with longer simulation time.
32	Cross-verification of modeling of **queue discharge at intersections** should address questions regarding the **car following model** used for queue discharge conditions, the resulting **acceleration profiles**, and the observance of **saturation speed** behavior.
33	**Queued vehicles** accelerate to a **saturation speed** while negotiating the intersection area rather than accelerating to the **speed limit** directly. This is shown in the example in the slide. Steady **saturation headway** (**h_s**) and **saturation speed** (**v_s**) indicate the existence of steady **saturation spacing** (**$L_{hs} = h_s v_s$**) of vehicles during queue discharge.

34	Cross-verification should investigate the values of **critical headway and follow-up headway** parameters (used by analytical models) corresponding to the **conflict zone method** used by some microsimulation models. **Follow-up Headway**: The average queue discharge headway time (seconds) between successive opposed (entry) stream vehicles entering a gap available in the opposing (circulating) traffic stream. The Follow-up Headway (seconds) is a saturation (queue discharge) headway: **Saturation Flow Rate (veh/h) = 3600 / Follow-up Headway**. **Critical Headway (Gap)**: The minimum headway time (seconds) between successive vehicles in the opposing (circulating) traffic stream that is acceptable for entry by opposed (entry) stream vehicles.
35	The HCM roundabout capacity (analytical) model based on US research is a good one, However, it does not have the effect of various **roundabout geometry parameters** (inscribed diameter, entry radius, etc.) on capacity. The SIDRA model has a model calibrated for US conditions and has the effect of the geometry parameters as well as various other features which can be used as **extensions to the HCM model**.
36	**Arrival headway distributions** have a significant role in traffic modelling. They are not discussed enough. Cowan's M3 "**bunched exponential**" headway distribution model is used for most applications in SIDRA. This model is particularly useful for **gap acceptance capacity modellin**g, e.g. for modeling of roundabout circulating streams.
37	Refer to the LinkedIn discussion: https://www.linkedin.com/in/rahmi-akcelik-4b403524/recent-activity/all/
38	The photo from Sydney shows a **lane blockag**e case: signals are green but the upstream intersection vehicles cannot depart from the queue, or the queue discharge is slow with long departure headways, and therefore the **saturation flow rate is much reduced**.
39	**SECTION 4 - Conclusion**
40	Smart modelers are those who **understand the methods and concepts** used by the models they use. Cross-verification of micro-analytical and microsimulation models will lead to these two modeling approaches supporting each other; thus, it will help the modeling profession greatly.
41-42	**REFERENCES** ✓ Available for download from https://www.sidrasolutions.com/publications
43	**ABSTRACT**
44	**PRESENTER**
45	**END OF PRESENTATION**

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