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DEMANDING CHANGE / CHANGING DEMAND

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Abstract: It has become clear in recent years that traditional methods of forecasting and analyzing future demands for transportation infrastructure are largely out of step with the progression of many provincial and municipal agencies towards a more equitable, sustainable, and integrated transportation network that seeks to curb auto use and increase the use of transit and active modes. Estimating 'demand' to solely be the number of cars on the road and equating success with pushing more cars down that road is guaranteed to maintain the car as the dominant – and in some cases, only – choice. As the goals of the transportation system evolve to meet changes in policy, so too must our methods of forecasting and analyzing the demand for this system. This paper examines the changes that will be required to reposition transportation demand forecasts to serve the desired outcomes within the framework of new data sources, new transportation technologies and services, and an increasingly knowledgeable, nimble, and flexible travelling public. Important in all of this will be the evolution of practical and cost-effective solutions that are not restricted to academic research, but can be applied on real-world projects to help municipalities and provinces to achieve their policy goals.

1 INTRODUCTION

The forecasting of future demand for transportation infrastructure is undoubtedly one of the most important aspects of the transportation planning profession. This is what guides our investments in infrastructure and allows us to look beyond today's problems, peer into the future that we would like to see for the places where we live, and determine the path to achieving that future. As the principles of sustainable transportation and integrated mobility have taken hold in municipalities across Canada, it has become obvious that how we have traditionally gone about forecasting transportation demand – rooted very much in an auto-focused or auto-only approach – must evolve to provide a more complex, equitable, and realistic examination of the true drivers behind our transportation choices. As the options for travel continue to expand into the realms of the sharing economy, automated vehicles, smartphones, and other technological advances, our society is also experiencing cultural shifts away from a car-based society towards one that recognises the health benefits of active transportation, towards one where young people no longer want to live where they need a car, and one where higher order transit service is becoming more prevalent by the day. All of these aspects need to be better understood to allow us to provide our best estimate of what the future will bring, and create the multi-modal transportation system to meet it.

This paper is separated into five separate sections to allow us to discuss the major elements of such a wide ranging topic, these are:

- Input: Investigation of the changing needs and availability of travel data in light of the advent of GPS, smartphones, and other technologies

- Processes: Traditional modelling processes treat complex daily journeys as a series of disconnected events, but each trip is linked and relates to other choices made along the way.

- Detail: As the principles of sustainable transportation and integrated mobility have come to the fore, it is increasingly important to understand more about the people making the trip.

- Changes: Trends related to how people get around need more consideration in light of changing priorities, technologies, and disruptors like automated vehicles, on-demand ride and bike sharing, and technologies not yet considered.

- Output: The measures we apply in our analyses should be directly linked to the policy goals to allow for the city to evolve appropriately and cost-effectively.

2 INPUT: DATA NEEDS TO BE BETTER, DATA NEEDS TO BE BETTER UNDERSTOOD

As the rate of technological development increases, so too do its potential applications. The advent of smartphones, GPS technologies, and increasingly small and powerful computing hardware has created a new realm and scale of data collection not yet seen in the transportation planning industry.

Traditionally, transportation analysis has been limited by the amount of data on hand with which to understand the world. In large part, data was traditionally collected manually in the field, via surveys, or via the use of expensive hardware, all of which would typically be focused on the issue at hand for a limited time period and would also likely require significant time and effort to decode and understand the data. This is very quickly changing and, as the sheer amount of data available has increased, other issues have risen to the forefront such as: privacy, data access, data management, and data analytics. The catch-all term for this new ocean of data is *Big Data*.

The main difference between traditional data sources and Big Data can be summarised conceptually as: volume, velocity, and variety. That is, the sheer amount of data available (volume), the rate at which is collected, made available, and processed (velocity), and the range of sources and types of data (variety) all far outstrip traditional approaches. The difference is so significant that whole new professions have emerged in recent years related to processing and analysing large mountains of transportation data. No longer is a transportation engineer or planner someone who simply stands at the roadside with a clipboard and counts the cars as they pass; these days the terms ‘data scientist’, ‘programmer’, and the like are becoming more prevalent in the transportation industry.

2.1 The Inflection Point

It is interesting to consider why things are changing now. In part, this is due to the natural progression of technology, efficiency of communication, and increased integration of data collection. This has been an evolving process where several technologies have created a turning point in the realm of data collection.

The prevalence, pervasiveness, and constancy of smartphones and similar technologies in our lives have enabled data collection in a broader, more precise way than previously possible. This new data has resulted in an inflection point - data is now more real-time and passive in its collection and analysis, rather than deferred and active. In other words, it is now possible for massive quantities of data to be available more or less instantly rather than more traditional data collection means where data is actively collected, processed, and available months or even years later.

In some ways, the traditional problem with transportation data has been flipped on its head. Whereas before the problem was creating a focused data collection program to collect as much data as possible on your current issue and *expanding* it outward to represent the whole, now the issue is often *reducing* and understanding the information you need from the vast ocean.

Data collection can now be done virtually anywhere through anonymous GPS and smartphone tracking, rather than the traditional approach of utilizing human observation or more isolated ITS infrastructure, such as sensors on a highway for traffic monitoring. The capital and labour cost to the agency or consultant can be significantly reduced in the collection of the data. The investment comes, however, in the form of time and effort to understand the data and convert it to a useful and meaningful form. This has had the effect of creating a more robust data collection industry, where commercial firms develop ways to add value and services related to their data sources. This is an exciting and quickly expanding market in the transportation industry, as firms race to create better algorithms and even Artificial Intelligence (AI) routines to mine the data for more and more useful conclusions.

2.2 Cross-Platform Data Collection and Integration

An important consideration regarding big data sources, databases, and interactive user interfaces is that the data be ‘open’. Open data is data that is available in a portable digital format without restrictions on the ability to use, consume, or share the information. This does not necessarily mean “free” data, but open in the sense that data flows to where it’s needed - either for a fee or for free. This is critical to transportation model analysis and the need to increase of efficiency throughout transportation networks.

Although gathered data is largely proprietary, it must also be kept open and available to promote the integration of different data sources. The value of data is not the data itself. Data gains value in how it is aggregated, analyzed, and applied. Systems must be in place to perform data analytics and results must be communicated effectively. A non-open or proprietary system will limit the value of the data collected.

Encouraging the development and maintenance of open data is of utmost importance. But, how can open data sources be integrated cross-platform to provide the best value to end users? In contrast, if each big data company were to collected limited data in a siloed, gate-kept fashion, it would be of more limited benefit to end users. Through data standards and pipelines to integrate data sources, this enables a broader range of potential use cases for data application by end users.

2.3 Privacy Concerns and Data Ownership

To properly integrate data, standards need to be promoted and used, so that the data becomes useful to other parties. Data standards should encompass data formats, ethics, and privacy considerations.

Another consideration is data consolidation and reconciliation. For example, adjacent municipalities with the need to integrate and share data could address this at a base level with an agreed-upon data framework and/or a private consortium of member organizations. This could apply distributed consensus or blockchain technologies with a database being held by each consortium member.

A distributed, common database could be developed where everyone and nobody owns the data. In this way, a distributed and integrated network could be created to anonymize data based on specified rules at the source (i.e. smart contract algorithms), rather than navigate through each company’s own ethics and data sharing policies. A common ledger provides immutable proof of who created individual data records and could be maintained to settle payment and provide incentives for data collection.

Caution should be applied when exploring use cases for blockchain technology. For each potential use case, risk assessments and proof-of-concepts will need to be applied prior to any practical investment.

2.4 Importance of Detail and Data Management for a Bigger Picture

Smartphones have provided a level of location-based accuracy previously unattainable on such a large scale and have become a leading factor in the facilitation of big data collection. This has provided companies with a wealth of data and has made the management of data critical.

The level of detail in the data is vital when it comes to its distribution and analysis down the line. If appropriate detail is not collected at the source, this same data cannot be analyzed in depth at a later time. Big data collection has brought us into an age where it is finally possible to see a bigger picture of how people and goods are interacting and how best to promote their efficiency. This will provide a framework for greater value extraction by individual data source companies and enable the provision of a more detailed analysis for transportation engineers, planners, and modellers.

3 PROCESSES: DOING THINGS DIFFERENTLY

The traditional form of transportation demand modelling is typically referred to as Four-Step Modelling, as it has four general ‘steps’ - trip generation, distribution, mode choice, and assignment. This basic approach has been in practice for decades and is useful for examination of an auto-focused society. More recently, however, we have seen an increase in the use of tour-based, journey-based, and activity-based models, which look at how individual trips connect together. However, despite the increasing sophistication and complexities represented by newer types of models, how people travel has largely remained unchanged for the past century - walk, bicycle, transit, automobile, and trucks.

The fundamental question to consider within our model processes is whether or not they are still useful. For decades, the means by which people travel have fundamentally been the same and, thus, observing the trends over time was typically useful. However, with the imminent and ongoing paradigm shifts due to new technology (e.g., automated vehicles, ride sharing, bike sharing) and changing attitudes surrounding the use and design of urban space, the question is whether traditional processes are still useful.

To consider the new paradigm of models, a more useful term than “traffic model” or “transportation demand model” may be: *Mobility Model*. In essence, this is a blending of our traditional processes and experiences as professionals with new and emerging trends in transportation such as Mobility-as-a-Service (MaaS) and Integrated Mobility along with non-conventional modes of travel and services. This process should consider the mobility of *all people* who need to move through the city no matter their choice and represent the increasing fluidity between modes and choices as technologies and other transportation services become available. A Mobility Model will be a tool to help shape the future based on behavioural economics, demographics, technology, and policy.

3.1 Limitations of Traditional Four-Step Modelling

More traditional four-step models will continue to be useful in situations with less population density and fewer transportation options. However, for regions and municipalities that have more options, the usefulness of traditional four-step models is likely to be more limited. The approach taken to model processes will continue to be at the judgement and discretion of the professional in most cases.

We are at a crossroads in our approach to transportation models, which presents a bit of a “Catch 22” under current circumstances. The question is: when do forecasted trends from current models get dampened by changing attitudes and technologies? The answer to this is imprecise and not very predictable. On one hand, we are observing the emergence of new technologies and mobility options that are not yet fully commonplace which raises questions about the usefulness of current models and processes. Yet, we do not currently have the empirical data required to gain a full understanding or extent of the impacts these new technologies and mobility options will have.

Ultimately, while models will likely continue to be “wrong”, we must still adapt to ensure their usefulness over time. With increased real-life complexity and changing needs, our models must adapt to approximate this behaviour as simply as possible in order to optimize the effort required to develop those models.

3.2 Mobility Modelling Defined

A mobility model is defined as a model with the primary focus of moving people, regardless of travel mode, and has the ability to forecast infrastructure needs and impacts. The key assumption here is that fewer people will use a single mode choice in their daily travel.

Mobility models will include algorithms to capture travel elements and metrics, such as (but not limited to):

- Implementation of Mobility-as-a-Service or similar approaches to integrate travel modes;

- Implementation and effects of flex-route transit, mini-transit, and/or rider sharing for first/last mile trips; and
- Positive and negative effects of autonomous vehicle (AV) implementation (e.g. additional accessibility benefits vs. increased deadhead trip disbenefits).

In the current modelling landscape, there are many agencies that have already implemented more sophisticated modelling approaches, such as activity-based, journey-based, and tour-based modelling. To be sure, these approaches will continue to be utilized, especially by larger agencies that have invested in developing them. For these cases, it is a matter of implementing new and emerging algorithms that encapsulate mobility modelling concepts into their current model systems. Perhaps the greater challenge exists for small and medium sized agencies that have more limited resources, but wish to better understand mobility modelling concepts in the context of their transportation planning needs.

3.3 Forecasting with Mobility Models

The mobility modelling approach brings up a classic modelling problem - modelling and forecasting the behaviour for emergent or non-existent travel modes. For these emerging or theoretical travel modes, we likely have little to no empirical data to calibrate against. Therefore, in the short term, we need some creative approaches to forecast future conditions.

In this case, a sensitivity testing approach can be taken to model more theoretical travel choices using processes such as ensemble modelling. This is analogous to the modelling the future path range of a hurricane looking at the worst to best cases based on defined inputs and output metrics and selecting the most likely path from a large range of results.

While there is a need to address short term challenges in mobility modelling processes, we need to primarily look to longer term solutions and prepare for the time when empirical data for the mobility modelling approaches begin to flow. The intent is to iterate and refine our mobility modelling processes so that we have a solid foundation in place as theoretical assumptions transition to real-world data over time.

4 DETAILS: MOVING PEOPLE, NOT JUST CARS

Canada’s urban, suburban, and rural areas are made up of a fascinating variety of people, each of whom have their own thoughts, needs, preferences, and abilities related to moving around. So, it’s interesting to think about how that variety has been historically distilled in our transportation planning efforts to essentially look at only one type of person: the motorist. As a country – and planet – that is very rapidly urbanising and becoming more sophisticated and flexible in how we choose to get around, this myopic focus on one generic person moving via a single generic mode of travel to and from their single destination, is truly working ourselves towards failure and neglecting to recognize not only the variety of people, but also the variety of solutions available to us to keep our cities operating and growing smoothly.

It follows pretty directly, then, that we need to open up our thinking when trying to forecast future travel demand to not only represent a greater variety of *people*, but also better represent the increasing variety of *options* available to those people to get around.

4.1 Understanding the Population

Looking at the people first, we need to dig deeper into understanding who they are from a wider variety of elements that influence how, why, and when they travel. Traditionally, our knowledge would come from the Census or a manual survey and would be boiled down to a population number for a model zone and an understanding of typical household size and auto ownership. In reality, personal characteristics that determine our travel behaviour could be related directly or indirectly to a laundry list of criteria, such as: age, marital status, in-house dependents, education level, income level, occupation, and dwelling type.

Newer approaches to forecasting are pushing towards this with concepts such as agent-based simulation, which uses demographic information at the household and individual level to gain a better understanding of the individual. To do this, an agent-based simulation needs to rely on some form of population synthesis; that is, creating a more detailed understanding about the population from a range of sources, as data available from the Census and other surveys are necessarily aggregated for privacy or of limited sample size. This aggregated understanding needs to be fleshed out for the entire community.

To date, population synthesis (and thereby agent-based simulation) has typically been reserved for academic research and application, or for larger municipalities with the resources to tackle the coding necessary to create their own population synthesis approach. Some options are beginning to emerge for more general use, with some commercial and open source tools being released. Development of more practical, plug-and-play tools or implementation by commercial software vendors is necessary to allow agent-based methods to become more prominent and give us a better picture of the population.

Other approaches to population synthesis, at perhaps a less detailed level, are possible through the combination of census data with other data sources. There are vendors, for example, that have broken the demographic characteristics for all of Canada at a postal code level into many distinct groups based on their life stage, income, education, number of dependents, and other factors. Consideration of these categories with relation to trip-making behaviour and allowing the categorisations to shift over time could be a powerful tool in better understanding the shifting sands of travel behaviour over time.

An approach like this would reduce the level of effort required for municipalities to understand their population now and how that population will change over time. In essence, if you don’t understand who the people are, their needs, and their reasons for travelling, you will not be able to adequately plan your system to address or change that behaviour for the betterment of the city.

4.2 Understanding the Options

And likely just as important as who is moving around, we also need to do a better job at understanding how they move around their community amongst an increasing range of choices. As above, we have historically looked at this almost exclusively through a cars first (or cars only) lens. At best, the typical transportation model examines the use of cars, transit, and commercial traffic to determine our future transportation needs, which purposely ignores, or at best pays lip service to, the reality of an urbanising population that wants to walk and bike in increasing numbers, and altogether omits a rapidly changing market for alternative transportation service delivery through new sharing concepts enabled by smartphones and other technologies.

Not only are the options for travel increasing via newer concepts such as ride sharing, bike sharing, and car sharing, but the flexibility of moving between different modes on a single trip or between trips through the day is also increasing. The concepts behind Mobility as a Service (MaaS) are an attempt to bring together this increasing granularity and dexterity for travellers as they move through their community. MaaS is that umbrella that recognises that mobility needs can and should be able to change throughout a day, week, month, or season. The provision of seamless mobility ‘packages’ via MaaS that tie together elements like transit, biking, and car sharing demonstrate the evolution of mobility from a static one-time choice to a fluid reasoning of current needs. Some major *car* companies, for example, are currently investing heavily into becoming *mobility* companies. Our approaches to modelling travel behaviour need to evolve along with these concepts.

All of this means that our forecasting models need to better understand the mode choices available to people, build upon our increased knowledge of who they are and what they need to accomplish in a day, and give them the flexibility to move between modes as they would in reality. Each mode has certain characteristics that drive how they are used and how convenient they are for travellers.

5 CHANGES: TRENDS, DISRUPTORS, AND LESSER BULLIES

One of the main drivers of change in transportation is vehicle congestion. As the urbanization of areas continues to increase and intensify, new technologies, efficiencies, and modes of transportation are becoming necessary to accommodate them. Urbanization is one of the main drivers for Smart Cities, integrated mobility, and ITS, for example.

To promote the adoption of ITS and the coming disruptors (i.e. changes) to the current transportation system, services are being altered across the globe. Education campaigns to promote connected and autonomous vehicles (CAVs) are ongoing, and supporting infrastructure for these technologies is being constructed in order to accommodate the disruptive changes to transportation as they arrive.

5.1 Areas of Disruption

The premise and underlying tether for many areas of disruption in the transportation system lies in connectivity. Mobility-as-a-Service (MaaS), for instance, relies on the connectivity of various platforms to work together seamlessly. The concept of MaaS makes the case for shared mobility: ride-sourcing, micro-transit, shared parking, etc. Similarly with CAVs, vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications rely on communication protocols and standards, such as bluetooth, cellular, dedicated short range communications (DSRC), or wireless access in vehicular environments (WAVE).

In order to provide MaaS seamlessly, it will be important for authorities to ensure that the base infrastructure to support these services is there. For example, DSRC technology may need to be present in the right of way if that is the chosen means of communication. Educational campaigns will also have to be carried out to help abate natural distrust of these coming technologies by the public. Concerns with CAVs, for instance, center on the risk of possible technology failures, legal liability, and a vehicle's systems being hacked.

This connectivity will improve the efficiency of the transportation system. Dedicated CAV lanes, reserved solely for CAVs in platoon, would be especially efficient for trucking companies. Autonomous vehicles are classified by a 0-5 level of automation, where 0 is no automation and 5 is full. It is important to recognize that these changes to the transportation system will not happen overnight. There has been and will continue to be an incremental shift from manually operated cars, to CAVs, and everything in between.

Infrastructure to promote these changes is already being implemented and there will be an incremental shift toward CAVs, education campaigns, development of policy and legislation, and adjustment time for the public. The degree of adoption will likely increase over time as public trust is gained.

5.2 Modelling Non-Existent Travel Modes

One central issue that has arisen in the development of mobility models is the speed at which mobility changes are occurring. Forecasting methods have traditionally been based on historical data with little differences in specific modes of travel. However, it is becoming more necessary to represent behavioral changes that may not yet be present in empirical data. For example, there is little empirical data to calibrate these models against as CAVs and MaaS are still largely theoretical.

One potential way to approach this problem may be ensemble modeling. Ensembling is a technique of combining several algorithms to create a more robust system which incorporates the predictions from each algorithm. The resulting final decision is a more accurate, less biased solution. There are also disadvantages to this approach, for example, as conclusions can be more difficult to draw depending on the models chosen to create the ensemble and it can be time consuming to develop. Depending on the potential use cases a reusable framework may be a better approach.

Another approach may be a form of sensitivity-based modelling. A sensitivity analysis is a systematic method for examining how the outcome of an analysis changes with variations in inputs, assumptions, or methods. This could be applied in mobility models by combining various possible outcomes (i.e. best and worst cases) using multiple algorithms. An example of this is how weather patterns are predicted; or, how multiple models attempt to forecast a range of potential hurricane paths based on current conditions. The range of paths and likelihoods are analyzed to determine one of “best fit”.

Future modelling will likely involve more sensitivity testing of desirable and undesirable trends, rather than simply past historical data, to rapidly test a range of scenarios and potential outcomes. To provide the capacity to conduct these analyses, it will be necessary to generate base assumptions from a variety of sources, and improve these assumptions as more empirical data is available over time. A solid evaluation framework will need to be developed to report on likely ranges rather than definitive conclusions.

5.3 Looking Back to Look Ahead

In the process of forecasting, it may be challenging to utilize historical trends for modes of transportation that have yet to be observed, but it is the best information available at this time. By making educated assumptions as inputs to our models, they can still be useful in the interim. It is vital to determine how much weight current trends carry in making assumptions and monitor how these trends evolve over time.

Working from the end to the beginning, backcasting is a planning method that begins with defining a desirable outcome and then looking backward to define interim goals. This can be useful in arriving at a futuristic destination, but has obvious predictive limitations, especially when interim goals are not realized. A mix of forecasting and backcasting may be desirable in order to attain our future transportation visions, depending how these models are most useful to practitioners.

5.4 Integration

The mobility models needed to anticipate changes in our transportation systems will have to take into account inputs such as population segments (e.g. age, income, lifestyle, behaviours, etc.), generational shifts, and the impacts of improved travel choices and technology. The eras of data used to implement travel demand forecasting should be delineated so that future trends carry more weight in certain areas, such as pre/post smartphone, pre/post ridesharing, pre/post CAVs, etc.

Different jurisdictions will adopt travel options and shifts at different rates, based on any number of factors, such as income, political will, urban structure, regional policy, etc. For example, Montreal has an excellent bike network in place; therefore, preparation for the adoption of CAVs may be less of a focus.

Transportation demands will evolve at different paces in highly urbanized areas than in more rural areas. In order to facilitate the use of CAVs, the concern of where they are able to function will need to be addressed. Travel demands are also evolving at a different pace across the country. For example, the magnitude of Toronto traffic and congestion is hardly comparable to more rural areas.

As disruptors become part of the new normal, adaptable modeling processes that account for these integrations will need to be developed for use now and for when more empirical data begins to emerge. Individual jurisdictions will need to evaluate their needs and determine how mobility models can best be useful to them to plan for infrastructure investments.

The evolution of mobility modelling will likely be some balance between focusing on preferred outcomes (backcasting) and anticipating future trends from a wide range of unknowns (forecasting). Practitioners cannot simply ignore changing travel behaviour and may have the ability to influence the direction of CAV implementation through a more proactive approach, so long as they align themselves with current trends.

6 OUTPUTS: MEASURING PAINS AND GAINS

As discussed above, conventional transportation engineering philosophy steered transportation professionals towards design and operational decisions that prioritized the comfort of personal motorized vehicle users while lowering the comfort for other travel modes or discouraging their use altogether.

This prioritization affected many levels of transportation planning and design. We planned networks to “optimize” roads by maximizing auto capacity and minimizing auto travel time. We evaluated the Levels of Service (LOS) with measures such as delay, queue, and volume-to-capacity ratio, all of which are most applicable to vehicular traffic. And we also often planned and designed land use and transportation corridors independently, resulting in failed attempts at redevelopment and wide roads that are barriers between communities rather than parts of them. The impacts of decades of this thinking are present-day traffic congestion, primacy of the automobile, and entire cities built around driving.

However, the growing awareness of the link between health and physical activity, building support for sustainable cities, and increasing demand for downtown living has caused many stakeholders to challenge the priorities for street planning and design. This changing societal landscape has resulted in wide ranging municipal support for Complete Streets, a school of thought for street design that advocates for streets serving all modes of transportation rather than cars exclusively.

In this time of change, two major questions arise – how do we adequately measure changes to performance in the evolving landscapes of urban centres and how can we better examine street performance for all modes of transportation?

6.1 Multi-Modal Level of Service

Multi-Modal Level of Service (MMLOS) is an evaluation tool for measuring the level of service present on streets for *all modes* of transportation. Performance measures are assigned to each mode for safety, system efficiency, mobility, sustainability, etc. These measures are mode-specific – for example, a measure of mobility for automobiles might be a midblock volume-to-capacity ratio or travel time reliability, whereas a measure of mobility for pedestrians may be width of the sidewalk.

Of course, transportation professionals are constantly faced with the reality that the rights-of-way of streets in urban areas are limited. Few streets are capable of delivering a high level of service to every mode of transportation due to physical and/or monetary constraints. Therefore, we need trade-offs among level of service objectives for each transportation mode within an established right-of-way. With trade-offs, the prioritization of the modes depends on the context of the intersection, corridor, or network. We can make decisions on a case by case basis to prioritize certain modes and make compromises with others.

As of time of writing, the concept of MMLOS is still relatively new and there is no agreed-upon standard for performance measures, targets, or preferred trade-offs. On the one hand, this lack of precedent may present itself as a challenge to policymakers. However, not yet having an established industry standard also allows us to create a custom approach tailored to a municipality's unique goals. Ideally this leads to a sort of "municipal soul searching" where the community is able to work through a reasoned process towards an MMLOS system that helps them accomplish their policy goals.

MMLOS can allow a city to tailor their frameworks, measures, targets, and tradeoff decisions to be locally sensitive and reflect unique goals for all modes of transportation. That's why Canadian cities like Toronto, Ottawa, London, Edmonton, and Calgary have already made efforts to incorporate MMLOS into their Official Plans, Transportation Master Plans, and/or Complete Street guideline documents.

6.2 Evaluating Street Performance

For certain scenarios, mode priority is relatively obvious: you probably wouldn't make plans for extensive cycling infrastructure and a 3.0m wide sidewalk for a city bypass freeway. For others, such as for a bustling main street, the priority will depend on the city's vision for the street. But once priorities are established, how can we logistically evaluate the street's performance across the modes?

Transportation professionals can determine, tweak, and/or evaluate different performance measures at different stages: planning, design, and operation/maintenance. For instance, the decision to turn a corridor into a designated truck route, which could be a performance measure of a truck's environment, would be determined at the planning stage. Meanwhile, the design speed limit on an adjacent road can be utilized as a measure of the pedestrian mode's environment, a measure that can be changed as needed during design. And at the operation stage, providing transit signal priority at intersections could be a measure of safety for the transit mode.

Simply determining performance measures and then getting values for each measure is meaningless; we need to compare them to some form of rubric that can give an LOS "score" to each mode based on the values for each measure. And in fact, the aforementioned municipalities that already use an MMLOS framework do just that, though not all in the same way. And that's not necessarily a bad thing - a municipality's "rubric" can also be customized to reflect its unique objectives, goals, and vision. But having that “rubric” to consistently and efficiently screen planned transportation projects gives transportation planners and engineers the necessary targets for the best possible design.

6.3 Person Capacity

As we focus on building more progressive and inclusive cities, we should remain cognisant that our population is growing and more people are moving towards urban centres. Therefore, the efficiency of urban space is becoming more crucial and transportation professionals should be considering person capacity on streets. But with limited room between building faces and many cities already reaching or coming close to automobile capacity, how can we design streets to allow for this continued growth?

Person capacity is a rejection of the traditional definition of capacity as being the number of automobiles that can fit on a road and a move towards streets being designed for people. Person capacity measures the number of users of various modes that can fit on a given street. And when using person capacity to evaluate our streets, something quickly becomes obvious - a single street can fit more cyclists per square metre of space (and even more pedestrians) than drivers in cars since automobiles take up significantly more space than bicycles and shoes. And these comparisons vary by orders of magnitude.

The reality is that single-user vehicles are not an efficient use of space. Even buses, though larger than a single automobile, can fit more people per square metre than automobiles. Therefore, more people can be on a single bus at any given time than in cars. By focusing on person capacity and reducing delays for transit, we can create less person-delay per lane of buses than would have been possible with cars.

With the fixed amount of street space combined with the growing number of people, the need to shift to shared and active transportation modes becomes more prominent. Switching out a car lane for a transit lane on an existing street would reduce traditional automobile capacity, which we have been trained to think is undesirable and poor road design. However, with person capacity, while automobile capacity may be decreasing, by focusing on alternative modes, the overall capacity of the street would increase. And there is evidence that this is not just possible - it works. Toronto has added minimal significant auto capacity moving into the downtown core in the last 30 to 40 years but this has not hindered its growth - the city managed to triple the number of commuters in that same time period by increasing the transit (largely by rail), cycling, and pedestrian mode shares.

Of course, as a performance measure in an MMLOS framework, the concept of person capacity still requires refinement. We should also remain cognisant of designing for people. A utilitarian mindset of simply measuring throughput for a corridor may work for automobiles, trucks, and transit, but perhaps not pedestrians. And even the idea of just measuring number of people per square metre may be flawed. A number for capacity obtained through this method on its own does not consider the user’s abilities or street grades, for instance, which would affect the requirements of the pedestrian environment, let alone the presence of a mix of land uses and urban design considerations that make the space itself useful and attractive.

7 CONCLUSION

The above discussion presents an overview of some of the ways that the modelling of existing and future demands on our transportation networks will need to evolve to better serve the development of our cities. Just as it will be a challenge to help our cities evolve as they need to meet the demands of changing culture and technology in the coming years, it will be equally challenging to stay ahead of that curve and predict and direct where we are headed next.