To: City of Bend Citywide Transportation Advisory Committee
Attn: Nick Arnis, Susanna Julber, and Eric King
From: Steve Porter and Michelle Porter, Residents of Bend
Date: July 9, 2018

Public Comment:

Evidence & Implications of Supply-Induced Demand in Transportation Systems

Dear Bend Citywide Transportation Advisory Committee:

We understand that you are in the process of forming plans for Bend's transportation system and that, as part of your work, you have been asked to develop proposals to "reduce congestion on major roads by expanding capacity" of vehicular roadways in and around Bend.

Due to what is known as "induced traffic," we advise against attempting to reduce congestion by expanding road capacity. It has been proven beyond any reasonable uncertainty that **adding roadway capacity does not relieve traffic congestion**. In the pages that follow, we explain this phenomenon, discussing the theory and empirical evidence relating to supply-induced demand with respect to transportation systems and the implications for Bend.

SUMMARY

- Induced traffic is roadway demand that is *self-generated* by road capacity expansion.

- Induced traffic consumes an average of 78% to 94% of any added road capacity and, depending on the particulars of expansion, induced traffic can consume more than 100% of new capacity.

- Because of the induced traffic effect, new road capacity does not decrease traffic congestion, reduce travel times, enhance travel time reliability, or accommodate new population growth.

- Expanded road capacity entails significant financial outlays for communities, both for initial infrastructure development and ongoing maintenance, as well as environmental costs. Since road expansion does not enhance traffic outcomes, the majority of these costs becomes waste.

- Reducing traffic congestion in Bend requires actions exclusive of adding roadway capacity; solutions emphasizing pedestrian, cyclist, and mass transit infrastructure enhancements should be prioritized since these do improve traffic outcomes.

SUPPLY-INDUCED DEMAND

Supply-induced demand (also called "induced demand") is a well known economic phenomenon under which a supply increase of a good or resource generates *its own* increase in the quantity of that resource which is demanded. That is, no factors other than the supply increase are necessary to provoke consumption growth.[1]

This phenomenon has been observed in roadway development across communities of various sizes both in the United States and abroad. Observations show that, if new road capacity is built, the induced demand effect consumes essentially all of the new capacity in a relatively short time frame. For these reasons, the induced demand effect is often referred to as "induced traffic" in the context of transportation systems.[2]

> The simple truth is that building more highways and widening existing roads, almost always motivated by concern over traffic, does nothing to reduce traffic. In the long run, it actually increases traffic. This revelation is so counterintuitive that it bears repeating: ***adding lanes makes traffic worse***.[3] (Emphasis added.)

Because the induced traffic effect associated with roadway expansion often approximately equals the volume of supply growth, additional roadway construction does not alleviate road congestion, reduce travel times, diminish fuel wasting, improve travel-time reliability, or accommodate new population growth. Rather, the increased volume of generated traffic simply consumes the new roadway capacity, and the initial states of road congestion, excess fuel burning, and travel times are unimproved, or worsened, following the supply investment. These effects are so well established by empirical study that researchers have called induced traffic and its negative consequences the "fundamental law of road congestion."[4]

The induced traffic effect is due to three key factors: 1) stimulation of so-called latent demand; 2) displacement of non-automotive transportation modes; and 3) land use changes.

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[1] Supply-induced demand is fully consistent with the Law of Demand as well as with the normal workings of supply and demand in economic markets. With respect to roadways, the general absence of an efficient price mechanism causes road consumption to take on characteristics associated with public or commons goods - i.e., oversubscription and depletion that cannot be reliably remedied by supply expansion. Induced demand can be depicted graphically. See the attached "Graphical Appendix."

[2] "Induced demand is the name for what happens when increasing the supply of roadways lowers the time cost of driving, causing more people to drive and obliterating any reduction in congestion." (Speck, J., *Walkable City*, North Point Press (2012).) Induced traffic also has been observed in connection with non-road automotive infrastructure development such as parking. (Shoup, D. *The High Cost of Free Parking*, American Planning Association Planners Press (2011).)

[3] Duany, A., et al., *Suburban Nation*, North Point Press (2000).

[4] Duranton, G. and M. Turner, "The Fundamental Law of Road Congestion: Evidence from US Cities," *American Economic Review*, Vol. 101 (2011).

Latent Demand

New road supply provokes behavioral changes among drivers that cause them to make less efficient use of roadways, an effect that is often called "latent demand" (also known as a "generative" effect).[5]

Key changes among drivers include:

- Reduced emphasis on trip and/or route planning, such that each vehicle trip is conducted along less orderly routes and thus consumes more road capacity;
- Diminished "grouping" of errands into single round-trip circuits, so that additional driving trips are made;
- Curtailed participation in ride-share and carpool programs, bringing additional vehicles to the roadways; and
- Slackened discrimination as to the timing of trips, causing more trips to be made during peak driving hours when the effects of congestion, fuel wasting, and travel time disruption are most salient.[6]

These behavioral changes collectively increase vehicle miles traveled ("VMTs") among existing drivers after road expansion. Notably, since the changes are not geared around value-enhancing trips, the average value of each VMT is lower following the expansion; that is, roadway usage efficiency declines, with more "empty miles" driven.[7]

Displacement

The displacement of non-driving transportation modes is a second type of behavioral effect and refers to the "crowding out" of non-automotive travel when transportation infrastructure tilts more heavily toward automotive transport (also known as a "redistributive" effect).[8]

Displacement causes people who would not have traveled by automobile *before* the installation of new road capacity to begin traveling by automobile *after* the installation. People who otherwise would have walked, cycled, or used mass transit become drivers following the roadway expansion.

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[5] Cervero, R., "Induced Demand: An Urban and Metropolitan Perspective," Paper prepared for Policy Forum: Working Together to Address Induced Demand (March 2001).

[6] Noland, R.B. and L. Lem, "A Review of the Evidence for Induced Travel and Changes in Transportation and Environmental Policy in the US and the UK," *Transportation Research Part D*, 7 (2002).

[7] Kooshian, C. and S. Winkelman, *Growing Wealthier*, Center for Clean Air Policy (2011).

[8] Cervero, R., "Induced Demand: An Urban and Metropolitan Perspective," Paper prepared for Policy Forum: Working Together to Address Induced Demand (March 2001).

Displacement occurs because, as additional roadways are developed, the ease, safety, and general attractiveness of walking, cycling, and mass transit decline. As illustration, consider the palatability of walking along or across a four-lane highway as opposed to a two-lane street. In a more general way, it can be stated that, as a region's transportation system becomes increasingly oriented around automotive transportation, the usage of non-automotive transport is less likely to be adopted.[9] Displacement thereby results in additional vehicle miles traveled by those who would have used non-driving modes but-for the incremental roadway construction.

A more subtle ramification of displacement is found in the distortion of consumer behaviors. People who would not have owned an automobile but-for the roadway expansions are motivated to purchase one afterward. Following acquisition of a vehicle, an increasing share of that user's trips will be made via car,[10] extending displacement.[11]

Substitutions from non-automotive transport to car travel have substantial implications for so-called "network effects" of non-driving modes in a transportation system.[12] As more people choose to drive (and as those motorists each drive more miles over more trips), it becomes less attractive - and statistically more dangerous - for other transportation system users to utilize non-driving modalities. It has been shown that the greater the share of trips in a transportation system made by pedestrians and/or cyclists, the safer the system is for all pedestrians and cyclists. As safety increases, more pedestrian and cyclist uptake is generated, engendering a virtuous cycle of increased safety, reduced automotive reliance, and diminished traffic congestion. However, when transportation network roadway development causes displacement, those network effect benefits are reversed, shunting would-be pedestrians and cyclists into cars in increasing volumes.[13]

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[9] Tovar, M., and Kilbane-Dawe, "Effects of 20mph Zones on Cycling and Walking Behaviours in London," Par Hill Research Ltd. (2013).

[10] Sunk cost claiming, for instance, would explain such effect.

[11] From an economic perspective, such purchase is unambiguously inefficient from both the purchaser's perspective and from society's perspective. The purchaser acquires the vehicle due to an actual or anticipated loss in effective mobility and/or safety (i.e., the purchase is an act of remediation), and it subjects buyers to debt accumulation and cash flow constraints associated with loss of financial durability. Society suffers because of the negative externalities associated with vehicle ownership and use including pollution and public health costs. Moreover, purchase of a vehicle typically leeches consumer spending and investment out of a local economy due to the economics of the automobile industry, with about 85% of dollars flowing out of the local economy (See: Speck, J., *Walkable City*, North Point Press (2012).). Since Bend's local economy does not substantially provide automobile parts or finished assembly manufacturing, Bend would experience such siphoning to its full extent.

[12] Liebowtiz, S.J. and S. Margolis, "Network Externalities (Effects),"

[13] As more people in a transportation network commute by walking or cycling, the statistical likelihood of death or injury among all pedestrians and cyclists declines. It becomes safer for each pedestrian or cyclists in the transportation system every time one additional person walks or cycles. This pattern is consistent with the economics of network effects wherein the value of something for each user increases every time a new user is acquired. As illustration, telecommunications equipment and social media platforms are well known for their network effects.

Jacobsen, P., "Safety in Numbers: More Walkers and Bicyclists, Safer Walking and Bicycling," *Injury Prevention*, Vol. 9 (2003).

The effects of displacement bear crucially on traffic flows during peak driving hours when pedestrians, cyclists, and mass transit riders are most helpful in reducing congestion.[14]

Displacement is particularly pronounced when infrastructure budgeting decisions require prioritizing either incremental roadways or incremental pedestrian, cyclist, and mass transit facilities. In the event roadway development is prioritized, the displacement effect is large and leads to a correspondingly large total induced traffic effect.

Land Use

The expansion or addition of roadways can alter land use patterns, which results in incremental driving, added dependence upon vehicles, and "lock-in" of traffic due to the structural nature of the effects of land usage.

Upon the expansion of roadways, residences and workplaces often relocate to utilize the newly added capacity. Residents and offices tend to migrate to places along the corridors of added road capacity, where the expected benefits of reduced commuting time will be enjoyed. Such change follows a logic of relocation from areas of relatively high density, where automotive transportation is less likely used, to areas of relatively low density, where driving is more likely necessitated.

This change in land usage is tantamount to a de-densification of residences and workplaces, which causes increased automotive utilization and engenders automotive dependence, an effect intensified through a feedback loop. Larger distances for everyday travel stimulate greater vehicle usage; greater vehicle usage deters non-automotive transport due to safety-related network effects; and the degradation of attractiveness for non-automotive transportation funnels more commuters into cars, even for shorter-distance trips.

Land use changes also cause traffic "lock-in" by virtue of structural effects on road use. That is, increased vehicle usage is non-discretionary once residents and workers have settled their homes and workplaces; they must commute to and from these destinations. As traffic becomes locked-in, drivers cannot adjust in the face of mounting traffic congestion as other factors of induced traffic are brought to bear. Accordingly, post-expansion

[14] Cass, N. and J. Faulconbridge, "Commuting Practices: New Insights into Modal Shift from Theories of Social Practice," *Transport Policy*, Vol. 45 (2016).

traffic congestion can exceed pre-expansion congestion levels, causing traffic to be *worse* after the roadway investment.[15]

The implications of land use changes on induced traffic can be difficult to model *ex ante* since it is not always known, nor can it often be reasonably predicted, what future developments may occur along expanded corridors or how those developments will affect transportation system user behaviors and traffic levels.[16] Because different types or scales of developments have dramatically different levels of traffic impact, this confounds accurate expectations of future traffic levels.[17] Notwithstanding this *ex ante* limitation, *ex post* empirical studies show land use effects can be substantial, with strong bearing on long-run induced traffic values.

Combined with latent demand and displacement effects, land use pattern changes bring about significant induced traffic levels following roadway expansion such that, on average, 78% to 94% of added capacity is consumed by induced traffic, leaving very little excess capacity to accommodate population growth or to reduce congestion.[18]

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[15] Rodier, C., et al., "Anatomy of Induced Travel: Using an Integrated Land Use and Transportation Model in the Sacramento Region" (November 2000).

Johnston, R., et al., "Applying an Integrated Model to the Evaluation of Travel Demand Management Policies in the Sacramento Region," Mineta Transportation Institute for Surface Transportation Policy Studies, College of Business, San Jose State University (September 2001).

"An Analysis of the Relationship Between Highway Expansion and Congestion in Metropolitan Areas: Lessons from the 15-Year Texas Transportation Institute Study," Surface Transportation Policy Project (November 1998).

Duranton, G. and M. Turner, "The Fundamental Law of Road Congestion: Evidence from US Cities," *American Economic Review*, Vol. 101 (2011).

[16] Such observation is consistent with analysis of "complex systems," which include systems comprised of individual agents whose responses to environmental stimuli affect other agents' responses, which in turn impact all agents' actions and, ultimately, alter the environment, leading to cascades of changes and responses that can unfold in unpredictable arrangements. For these reasons, modeling complex systems *ex ante* is known to be difficult.

Yaneer, B., "General Features of Complex Systems," *Knowledge Management, Organizational Intelligence and Learning, and Complexity*, Vol. 1 UNESCO EOLSS (2014).

[17] It has been thoroughly established that "statistical" resources used to estimate trip generation levels associated with different developments are based upon unreliable survey data, do not adhere to accepted standards of statistical rigor, and are often misapplied when used to estimate prospective traffic levels. The inadequacy of these resources compounds modeling problems.

Shoup, D. *The High Cost of Free Parking*, American Planning Association Planners Press (2011).

[18] The "Empirical Evidence" section of this report provides basis for these figures.

RAMIFICATIONS OF INDUCED TRAFFIC

Three significant ramifications stem from induced traffic, two of which have long-term financial implications and should thus be considered alongside any proposals for new roadway budgeting. The third effect is social in nature.

Financial Waste

The first consequence is that financial outlays used to expand roadway capacity go largely to waste. Owing to the induced traffic effect, roadway expansions generate their own increase in roadway demand, which causes the expansion to substantially fail at improving road congestion and travel times. That is, expansions do not generate meaningful societal benefit because induced demand effects consume most of the additional road supply. Investments financing capacity expansions are therefore principally wasted, with those outlays becoming irrecoverable losses.

In addition to financial losses associated with initial development costs, the ongoing outlays needed for the upkeep of additional roadway capacity also result in waste. Since maintenance of an expanded road system that has not improved traffic outcomes generates no societal benefit, the ongoing spending is misapplied. This is especially problematic for future budgeting discretion because maintenance costs represent continuing, required payments; inefficiency and waste become designed into future budgets.

Empirical evidence shows that, for every $1.00 spent on roadway expansion and added maintenance, approximately $0.78 to $0.94 becomes waste.[19]

Natural Resources Depletion

The second consequence is that expanded road capacity and its attendant induced traffic effects consume substantial natural resources, which would not have been consumed but-for the roadway expansion. These natural resource costs include land wasting, fuel wasting, air pollution, and water pollution, among others, all expended without any meaningful offsetting relief of traffic congestion. Accordingly, this expenditure of natural resources becomes a loss, since the increase in wasting and pollution that owe to the induced traffic effect reduces social welfare without mitigating benefit.

The corollary of these natural resource losses is that future financial investments will be required to recover land, air, and water quality that is deteriorated by the larger road system and higher traffic counts. Since it is more costly to damage and subsequently recover environmental quality than it is to conserve environmental quality in the first

[19] Basis for these numbers is detailed in the "Empirical Evidence" section of this report. In short, these waste figures reflect quantitative studies of the induced demand effect in transportation systems that show, on average, 78% to 94% of expanded road capacity is consumed by induced traffic within 3 to 4 years of the expansion.

place, this implies high future financial burdens for environmental recovery, or a permanently crippled environmental state, which presents its own costs.[20]

Social Welfare Loss

As road capacity is expanded and as more automotive traffic is induced to traverse the transportation system, several elements of social welfare are harmed. Mechanisms harming social welfare include:

- Visual intrusion, relating to the diminution of environmental aesthetic quality brought on by additional driven and parked cars as well as other new automotive infrastructure;
- Noise and vibration, spawned by additional automotive transportation, which is a main source of noise generation in urban and suburban environments;
- Loss of social spaces and loss of green spaces, brought about by the development of larger roadways that consume areas beneficial to social and health outcomes in the community;
- Collisions and loss of life, generated by greater automotive utilization that increases the statistical likelihood of driver, pedestrian, and cyclist loss of life; and
- "Severance," which is the social cost imposed on communities that become separated by enlarged and/or faster roadways.[21]

Here it is relevant to address another element of social welfare that could, at first glance, appear to offset certain of these losses but in fact compounds social welfare loss. It can be argued that a "revealed preference" for drivers to undertake less structured and less efficient roadway travel (e.g., by not grouping errands, taking more discrete vehicle trips, and traveling more vehicle miles) shows that increased road supply enhances those drivers' well being by allowing them to express this preference. Although this logic is facially appealing, it does not withstand scrutiny. For one, the tautological underpinnings of "revealed preference" have been refuted by findings from behavioral economics showing that, simply because a consumer undertakes an action (or purchases a good), that act does not *ipso facto* indicate the consumer has behaved in accordance with his or her best interest or stated preferences.[22] Simply put, people can and do make systematic mistakes.

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[20] Natural resources are generally recognized to confer economic and social benefits captured under the headings of "environmental services" and "ecosystem services." These include such things as carbon-dioxide capture, rainwater/runoff management, soil erosion mitigation, ecosystem support, habitats, etc. These benefits provide positive economic value that is lost when the resources are displaced. If the resources are not subsequently recovered through remediation efforts, those losses become permanent. If remediation efforts are undertaken, the environmental services value loss is curtailed, but remediation costs are realized. In either case, economic losses are incurred that exceed any "losses" associated with forgoing roadway development that generates no benefit.

[21] "Reclaiming City Streets for People: Chaos or Quality of Life?" European Commission, Directorate-General for the Environment (2004).

[22] Beshears, J., et al., "How Are Preferences Revealed?" Paper prepared for the Happiness and Public Economics Conference, London School of Economics (September 2006).

Second, Americans report that driving in an automobile is among the least enjoyable and most stressful elements of life, so it is unlikely that additional driving miles would substantially enhance drivers' well being.[23] If anything, incremental driving associated with induced traffic reduces social welfare among drivers, rather than enhances it, and thereby contributes to overall social welfare losses.[24]

This second point is supported by studies showing that modal substitution from vehicles to non-vehicle transport is highly sensitive to reductions in vehicle infrastructure or increases in non-vehicle infrastructure. This implies that drivers default to vehicle transportation for lack of viability in alternatives.[25] Indeed, Janette Sadik-Khan, chair of the National Association of City Transportation Officials attributes traffic congestion to "too many people driving without credible transportation alternatives."[26] Absence of reasonable choice generally harms social welfare.[27]

Finally, increases in lane-miles and VMTs are ***not*** indicative of increased economic activity. An inverse relationship exists between a region's road building levels and its employment levels,[28] and modal substitution from driving is associated with gains in productivity,[29] increased innovation,[30] and greater social connections[31] - all indicators of social welfare accrual that occurs when road expansion is stemmed, and all indicators of social welfare losses that amass when roads are expanded and higher VMTs are induced.

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[23] Or, more completely: It is unlikely that welfare losses from additional driving mileage would be sufficiently offset by welfare gains associated with less investment in errand planning.

[24] Krueger, A., et al., "National Time Accounting: The Currency of Life," in *Measuring the Subjective Well-Being of Nations: National Accounts of Time Use and Well-Being* (Krueger, A., Ed.), Chicago University Press (2009).

[25] Cairns, S., et al., *Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence*, Landor Publishing (1998).

Kruse, J., "Remove It and They Will Disappear: Why Building New Roads Isn't Always the Answer," Surface Transportation Policy Project Progress VII (March 1998).

Pucher, J. and R. Buehler, "Safer Cycling Through Improved Infrastructure," *American Journal of Public Health*, Vol. 106, No. 12 (December 2016).

Steer Davies Gleave, "Research into the Impacts of 20mph Speed Limits and Zones, (November 2014).

[26] Sadik-Khan, J. *Streetfight*, Viking (2016).

[27] This is a foundational economic concept. Constraints on choice, particularly when evidence shows that constrained options are preferred and generate positive externalities, are axiomatically reflective of harmed social welfare.

[28] Kruse, J., "Remove It and They Will Disappear: Why Building New Roads Isn't Always the Answer," Surface Transportation Policy Project Progress VII (March 1998).

[29] Kooshian, C. and S. Winkelman, *Growing Wealthier*, Center for Clean Air Policy (2011).

[30] Speck, J., *Walkable City*, North Point Press (2012).

[31] Appleyard, D., *Livable Streets*, University of California Press (1982).

EMPIRICAL EVIDENCE OF INDUCED DEMAND

Empirical studies of the induced traffic effect show that additional supply begets its own demand, thus leading to the negative consequences discussed above.[32] It is accordingly the case that increases in roadway capacity generate harms on financial, environmental, and social resources without any meaningful long-run benefit for traffic congestion, fuel efficiency, travel times, or travel-time reliability.[33]

The Hansen Study

One landmark study evaluating the induced traffic effect analyzes a set of panel data drawn from 14 metropolitan areas in California, covering 16 years. This study (the "Hansen Study") shows causality between road capacity growth and roadway demand, concluding that road expansion in metro areas, on its own, induces new traffic sufficient to consume *90%* of the added supply within four years.[34]

Summarily, separate and apart from any other factors that may affect roadway demand (such as population growth), the simple addition of road capacity is itself sufficient to incite *incremental driving that depletes 90% of the added capacity*. Only about 10% of any new capacity actually goes toward the reduction of pre-intervention traffic congestion or toward the accommodation of new population growth.

This finding translates into a *financial loss factor of nearly 90%* on any new capacity investments. For every dollar spent on new roadway capacity, about $0.90 of that dollar would be lost and irrecoverable, with no offsetting benefit. Additional losses would be represented by environmental and social costs generated by the expansion.

The Hansen Study's lead author summarizes his conclusions as follows (emphasis added):

> **New roads generate substantial new traffic** in metropolitan regions. A 1.0 percent increase in lane miles induces a 0.9 percent increase in VMT [vehicle miles traveled]...

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32 For simplicity, all elasticity values are reported in this section are shown in absolute value.

33 The empirical studies discussed here exhibit observed induced demand levels consistent with those found using computer simulation models developed to analyze and forecast demand patterns.

Rodier, C., et al., "Anatomy of Induced Travel: Using an Integrated Land Use and Transportation Model in the Sacramento Region" (November 2000).

Johnston, R., et al., "Applying an Integrated Model to the Evaluation of Travel Demand Management Policies in the Sacramento Region," Mineta Transportation Institute for Surface Transportation Policy Studies, College of Business, San Jose State University (September 2001).

34 Hansen, M. and Y. Huang, "Road Supply and Traffic in California Urban Areas," *Transportation Research*, Vol. 31, No. 3 (1997).

> With so much induced traffic, **adding road capacity does little to reduce congestion.**[35]

The STPP Study

A second study, conducted by the Surface Transportation Policy Project, analyzes 15 years' worth of data collected from 70 U.S. metropolitan areas by the Texas Transportation Institute (the "STPP Study").[36] The STPP Study includes the following summary of its findings (emphasis added):

> …**metro areas that invested heavily in road capacity expansion fared no better in easing congestion than metro areas that did not**. Trends in congestion show that areas that exhibited greater growth in lane capacity spent roughly $22 billion more on road construction than those that didn't, yet ended up with slightly **higher congestion costs per person, wasted fuel, and travel delay**.

The STPP Study is observational in nature and does not attempt to quantify the induced traffic effect directly. Nonetheless, the analysis demonstrates that *heavy investment in road capacity is not sufficient to cure traffic congestion*, and *worse traffic outcomes are more likely to be observed in regions with high roadway growth*.

Regions with higher road construction also suffer greater financial burdens than those with lower levels of construction. All these findings are consistent with the theory and other empirical evidence of a large induced traffic factor.

The UK Study

A third study was commissioned by the UK Department of Transport (the "UK Study") to evaluate the induced traffic effect for purposes of understanding the phenomenon and incorporating it into transportation system planning.[37]

Following an exhaustive evaluation of the theoretical and empirical evidence surrounding induced traffic, the UK Study concludes that the induced traffic effect substantially consumes new roadway capacity, leaving essentially no residual capacity for congestion relief or the accommodation of new population growth.

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[35] Hansen, M., "Do New Highways Generate Traffic?" *Access*, No. 7 (Fall 1995).

[36] "An Analysis of the Relationship Between Highway Expansion and Congestion in Metropolitan Areas: Lessons from the 15-Year Texas Transportation Institute Study," Surface Transportation Policy Project (November 1998).

[37] "Trunk Roads and the Generation of Traffic," Standing Advisory Committee on Trunk Road Assessment, UK Department of Transport (1994).

This study is sometimes called the "Goodwin" study or is known by the acronym for the Standing Advisory Committee on Trunk Road Assessment ("SACTRA").

The report identifies a "demand elasticity" for roadway consumption of approximately 1.0. Such an elasticity value indicates that, for every increase in road capacity, there will be an approximately equal increase in traffic – all brought on by the induced traffic effect – within a few years of the expansion's completion.

That is, the long-term result of any roadway capacity increase is expected to be *zero improvement in traffic congestion or travel time and zero accommodation of new population growth*.

All investment dollars would accordingly be total losses, and society would be made worse off (due to environmental and social costs) without any offsetting traffic benefits. On the basis of this study and others like it, the British have curtailed road-building budgets, and the Transport Minister has stated, "The fact of the matter is that we cannot tackle our traffic problems by building more roads."[38]

The Noland Study

A fourth study (the "Noland Study") reviews the statistical research conducted by more than a dozen quantitative analyses measuring induced traffic across a variety of time periods and geographies (i.e., both urban and rural, and both in the United States and the UK).[39]

According to this review, the observed average long-run (i.e., generally about 3 years) values for the induced traffic effect range from approximately 79% to 93%, indicating that very little traffic congestion benefit is attained from roadway capacity increases, despite the high costs of development and maintenance.[40]

These induced traffic effect values demonstrate that approximately *four-fifths to nine-tenths of all new road capacity is consumed by induced traffic* within a few years following the new installation, implying *financial waste associated with every dollar of capacity expansion investment in the range of $0.79 to $0.93*.

Accordingly, the Noland Study concludes that the financial, environmental, and social costs incurred to support new roadway capacity generate substantial wastage and losses.

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[38] Duany, A., et al., *Suburban Nation*, North Point Press (2000).

[39] These include the UK Study, the Hansen Study, previous work by Hansen ("Cervero/Hansen"), previous work by Noland ("Noland 1" and "Noland/Cowart") and a simulation model analysis ("Rodier").

Noland, R.B. and L. Lem, "A Review of the Evidence for Induced Travel and Changes in Transportation and Environmental Policy in the US and the UK," *Transportation Research Part D*, 7 (2002).

[40] This computed result of 79% to 93% is consistent with a review of research undertaken by the Victoria Transport Policy Institute, findings of which indicate a long-run range of 65% to 86%, using a slightly different methodology. (Litman, T., "Generated Traffic and Induced Travel: Implications for Transport Planning," Victoria Transportation Policy Institute (April 17, 2017).)

The Duranton Study

A fifth analysis (the "Duranton Study") was published in the prestigious *American Economic Review*.[41] This analysis evaluates city-level average annual daily traffic and roadway development data from the U.S. covering the period 1983 to 2003, subjecting the data to various econometric models to determine long-run demand elasticity values.

The Duranton Study concludes that *elasticities range from 0.67 to 1.03*, depending upon model specifications, with the study's authors indicating that *the upper range of calculated values is the "most defensible estimate" of the responsiveness of traffic to roadway expansion*. That is, for every one lane-mile of roadway added, the result is induced traffic that consumes as much as 103% of that additional capacity, exclusive of population growth or other factors.

The Duranton Study published after the Noland Study, so its results are not included in the Noland Study's review. When the Duranton Study's results are incorporated, aggregated estimates of economic analyses of the induced traffic effect range from 0.78 to 0.94, as shown in Figure 1.

Other Studies

Additional research efforts have been made to understand the mechanisms underpinning induced traffic and to quantify the effect, including those shown in Figure 1 but not separately discussed.

Certain studies have followed econometric methodologies similar to those used in the Hansen Study, the UK Study, and the Duranton Study (i.e., the Cervero/Hansen, Noland/Cowart, and Noland 1 studies). Others have utilized sophisticated computer simulation modeling (i.e., Rodier). While the various approaches have resulted in some modest diversity in findings, the most notable feature of the body of empirical work is its level of agreement: *induced traffic is a predictable, persistent, and significant result of lane-mile growth, regardless of the geography, population, or time period studied*.

Summary of Empirical Studies of Induced Traffic

The below table summarizes empirical results of analyses quantifying the induced traffic effect over long-run intervals.

Short-term studies (i.e., those estimating demand elasticity values over short-run intervals two years or less) are excluded from consideration here. Short-run evaluations, by their design and often by their authors' own admission, fail to completely capture the full effects of induced demand.

[41] Duranton, G. and M. Turner, "The Fundamental Law of Road Congestion: Evidence from US Cities," *American Economic Review*, Vol. 101 (2011).

Moreover, within the context of Bend's transportation planning initiatives, it is appropriate to consider only long-run effects since the capital investments made in any roadway expansion would be considered long-run investments. It would be improper to evaluate only the short-term effects of long-term projects.

Figure 1

Estimated Long-Run Demand Elasticity for Automotive Roadways
Summary of Empirical Studies

Analysis	Demand Elasticity Estimate Range: Low	High
UK Study	1.00	1.00
Hansen Study	0.90	0.90
Noland 1	0.70	1.00
Noland/Cowart	0.80	1.00
Cervero/Hansen	0.56	0.56
Duranton Study	0.67	1.03
Rodier	0.80	1.10
Average	**0.78**	**0.94**

Note:
Calculated demand elasticity average ranges include values from studies specifying long-run demand effects. All figures shown in absolute value.

The Induced Demand Effect and Non-Automotive Infrastructure

Induced demand also has been observed in connection with cycling and pedestrian infrastructure. For instance, one analysis (the "Pucher Study") considers the effects of bikeway expansions in U.S. cities on demand for bike trips. The Pucher Study calculates percentage increases in bikeways over periods as long as 15 years in 10 major U.S. cities. It then compares those supply increases with changes in bike trips made over the same period.[42]

In Minneapolis, Minnesota, for example, an increase in the bikeway network of 113% is observed, and the percentage growth rate of bicycle trips made in the city is 203%. The computed "sensitivity of bike trip demand to bike infrastructure growth" in Minneapolis is accordingly 1.8. For each one percentage point increase in the

[42] Pucher, J. and R. Buehler, "Safer Cycling Through Improved Infrastructure," *American Journal of Public Health*, Vol. 106, No. 12 (December 2016).

bikeway network, Minneapolis has seen a 1.8 percentage point increase in bike trips made in the city, a result that is slightly below average. In Washington, D.C., bike infrastructure was increased 101% and the city registered 384% growth in bike trips, an above-average sensitivity of 3.8. In Portland, Oregon, the sensitivity of bike trip demand to bike infrastructure growth is 7.4.

Across all 10 of the evaluated cities, the average "sensitivity of bike trip demand to bike infrastructure growth," a statistic similar in nature to induced demand, is a little over 2.5. In other words, the demand for bicycle trips appears highly sensitive to increases in bike network infrastructure.[43]

The Pucher Study summarizes (emphasis added):

> …**bicycle infrastructure can indeed help improve cycling safety and increase cycling levels**. That is clearly demonstrated by decades of evidence… More and better bicycle infrastructure and safer cycling would encourage Americans to make more of their daily trips by bicycle…

These findings support the notion that the induced demand effect in transportation systems applies as much to non-automotive modes as to automotive transport. On this basis, it can be stated that investments made in non-automotive transportation infrastructure can relieve automotive traffic congestion since, as people are provided viability in non-automotive transport, VMT demand evaporates.

This mechanism of VMT reduction can be detailed as follows. When additional people walk or cycle, those people undertake a simple substitution – walk or cycle rather than drive – and thereby reduce vehicle miles traveled in the transportation system. Each person who takes a trip on foot or bike equates to one fewer trip made by car, so the removal of cars (and VMTs) from the transportation system occurs in quantities commensurate with increases in walking and biking. It is through this mechanism that increased pedestrian and bicycle network infrastructure supply can result in lower traffic congestion, even in the absence of increased automobile infrastructure supply (and, indeed, perhaps most strongly in the absence of increased automotive roadway capacity).

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[43] This study makes no attempt to distinguish the effects of supply expansion from other factors that could influence demand for bike trips. Nonetheless, due to the breadth and duration of the analysis, as well as the large observed increases in bike trips, there is strong (if not statistical) evidence of a positive induced demand effect with respect to bicycle transport.

Other studies have developed statistical relationships between bicycle infrastructure and ridership, thereby illustrating induced demand effects. For instance, they have found that bikeway "connectivity and directness are important factors in predicting bicycle commuting after controlling for demographic variables and the size of the city." (See: Schoner, J., "The Missing Link: Bicycle Infrastructure Networks and Ridership in 74 US Cities," *Transportation*, Vol. 41, No. 6 (November 2014). See also: Krizek, K., et al., "Analyzing the Effect of Bicycle Facilities on Commute Mode Share Over Time," *Journal of Urban Planning and Development*, Vol. 135, No. 2 (June 2009).)

Notably, on a cost-per-mile basis, *new bikeway infrastructure can cost in the range of 95% to 99% less than new automotive roadway*.[44] Such cost differential, when considered in conjunction with induced demand effects, argues strongly in favor of non-automotive infrastructure expansion as means of reducing traffic congestion.

The below table summarizes the Pucher Study's findings and shows the calculated sensitivity level of bike trips vis-à-vis bikeway supply.

Figure 2

Growth in Bikeway Networks and Bicycle Trips
Pucher Study

City	Years	Growth in Bikeway Network (%)	Growth in Bicycle Trips (%)	Bicycle Trip Demand Sensitivity to Infrastructure Growth
Portland, OR	2000-2015	53%	391%	7.4
Washington, DC	2000-2015	101%	384%	3.8
New York, NY	2000-2015	381%	207%	0.5
Minneapolis, MN	2000-2015	113%	203%	1.8
San Francisco, CA	2000-2015	172%	167%	1.0
Cambridge, MA	2000-2015	27%	134%	5.0
Chicago, IL	2005-2015	135%	167%	1.2
Seattle, WA	2005-2015	236%	123%	0.5
Los Angeles, CA	2005-2015	130%	114%	0.9
Philadelphia, PA	2008-2015	17%	51%	3.0
Average				**2.5**

Source:
Pucher, J. and R. Buehler, "Safer Cycling Through Improved Infrastructure," *American Journal of Public Health*, Vol. 106, No. 12 (2016).

Note:
Bike Trip Demand Sensitivity to Infrastructure Growth calculated as Growth in Bicycle Trips (%) / Growth in Bikeway Network (%).

[44] Weigand, L., et al., "Cost Analysis of Bicycle Facilities: Cases from Cities in the Portland, OR Region," Portland State University Center for Urban Studies (June 2013).

Litman, T., "Whose Roads? Evaluating Bicyclists' and Pedestrians' Right to Use Public Roadways," Victoria Transport Policy Institute (December 2013).

REDUCED DEMAND

The economics of induced demand also work in reverse. If roadway capacity declines, then vehicle traffic falls. This is known as "reduced demand," and like induced demand, it is well known and empirically validated. In short, reduced demand is "what happens when 'vital' arteries are removed from cities. The traffic just goes away."[45] As summarized by a *Newsweek* article (emphasis added):

> …demand from drivers tends to quickly overcome the new supply; today traffic engineers acknowledge that **building new roads usually makes traffic worse**…[and] **closing roads can reduce congestion**.[46]

Reduced demand can be spurred by the closure of roads, reduction of lane-miles, and abatement of roadway capacity expansion. This strategy to reduce traffic congestion and improve transportation efficiency has been successfully undertaken in a variety of instances, including high-profile situations such as in San Francisco (at the Embarcadero Freeway, following its collapse and, additionally, at the Central Freeway), New York City (at Broadway near Times Square), Portland, Oregon (on Harbor Drive), Milwaukee (on the Park East Freeway), Madrid, Spain (at Rio Madrid), and Seoul, South Korea, where an expressway carrying 168,000 cars per day was removed.[47]

In all cases, system-wide traffic conditions improved and, due to well established inverse relationships between vehicle usage and land use/real estate values, general and sometimes substantive improvements in land use and real estate values were observed.[48] Additionally, broader measures of local economic activity have been found to

[45] Speck, J., *Walkable City*, North Point Press (2012).

[46] Summers, N., "New York City Embraces a Bold New Traffic Theory," *Newsweek* (February 26, 2009).

[47] Siegel, C., "From Induced Demand to Reduced Demand," Preservation Institute (2007).

Speck, J., *Walkable City*, North Point Press (2012).

Sadik-Khan, J. *Streetfight*, Viking (2016).

[48] Two effects explain changes in land use/real estate value in connection with vehicle usage. First, increased vehicle volume and speed are associated with particulate matter and noise pollution intensification that harm real estate value and hedonic states of land use. Second, pedestrian and cyclist usage and access, which rise and fall inversely with vehicle traffic, are associated with enhanced land uses and real estate values. Reductions in vehicle intensity give rise to non-automotive transport usage and thus enhanced real estate conditions.

Bateman, I., et al., "The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study," Scottish Executive Development Department (January 2001).

Pignier, N., "The Impact of Traffic Noise on Economy and Environment: A Short Literature Study," KTH Royal Institute of Technology (2015).

Ozdenerol, E., et al., "The Impact of Traffic Noise on Housing Values," *Journal of Real Estate Practice and Education*, Vol. 18, No. 1 (July 2015).

Bokhari, S., "How Much Is a Point of Walk Score Worth?" Redfin Housing Market News (August 3, 2016).

exhibit an inverse relationship with respect to vehicular infrastructure development. As more is spent on road development, local unemployment rates tend to increase, while the removal of lane-miles tends to boost local employment,[49] and productivity and innovation levels tend to increase.[50]

Empirical research quantifying the effects of reduced demand strategies on traffic counts has been conducted across dozens of locales. Two comprehensive studies demonstrate that, depending upon the particulars of the road closure strategy, 14% to 60% of traffic disappears from the transportation network following closures.

The first study indicates that, despite the typical "predictions of major traffic chaos [associated with road closure strategies]…examination of the evidence [shows] that the predictions rarely, if ever, prove accurate." When reduced demand strategies are employed, "prolonged, long-term gridlock is simply not restored." Rather, across a multitude of studied cases where road capacities were reduced in areas as a means to address traffic congestion, the approach resulted in "significant reductions in the total amount of traffic on the networks studied. On average 14-25% of the traffic that used to use the affected route, could not be found on neighboring streets."[51]

Separately, an empirical study observing 60 road closures determined that between 20% and 60% of driving trips disappeared, on net, from the transportation system.[52]

The mechanisms by which this traffic reduction occurs precisely mirror the processes that underpin induced demand: driver behavior changes to reflect the conditions by making more efficient use of vehicle trips and roadways; more people carpool and participate in ride-shares; marginal drivers switch modes to walking, cycling, or other alternative transit; and people choose to maintain or consolidate their housing and work geographies rather than increase their commute requirements. Reduced demand strategies are thus associated with increased efficiency in transportation systems - the elimination of "empty miles" and low-value vehicle trips characterized by over-reliance upon vehicle travel when induced demand effects play out are reversed when reduced demand approaches are used.

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[49] Moreover, by not spending funds to build futile lane-miles, city revenue can be spent on projects that do benefit the economic and life-quality outcomes of residents.

Kruse, J., "Remove It and They Will Disappear: Why Building New Roads Isn't Always the Answer," Surface Transportation Policy Project Progress VII (March 1998).

[50] Kooshian, C. and S. Winkelman, *Growing Wealthier*, Center for Clean Air Policy (2011).

Speck, J., *Walkable City*, North Point Press (2012).

[51] Cairns, S., et al., *Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence*, Landor Publishing (1998).

[52] Kruse, J., "Remove It and They Will Disappear: Why Building New Roads Isn't Always the Answer," Surface Transportation Policy Project Progress VII (March 1998).

CONCLUSIONS

Based on the foregoing, the following conclusions can be drawn:

1. Overwhelming evidence demonstrates that neither existing traffic congestion nor future population growth can be reliably addressed by adding road capacity. This is because of the induced traffic effect, which consumes the majority, if not all, of any new roadway supply in a short period.

2. The costs and waste associated with new road capacity, expanded road maintenance, and increased automobile utilization are staggeringly high in financial, environmental, and social terms.

3. Road capacity investments are self-defeating: The aim of road investments is ostensibly to improve the quality of life for people using and living near the transportation system; however, road capacity investments consign those who use and live near the transportation system to a lower quality of life due to reduced environmental and social conditions and no meaningful reduction in traffic congestion.

4. To the extent proposed roadway infrastructure projects do not properly incorporate induced demand effects (i.e., by recognizing that demand elasticity is large and increases over time), such projects will be systematically overvalued, and alternative arrangements (e.g., congestion pricing schemes or non-automotive transport networks) will be systematically undervalued, resulting in poor planning outcomes.

5. It is not advisable for Bend to increase its road capacity for automotive travel without properly accounting for induced demand.

6. Infrastructural developments prioritizing non-automotive transport are superior investments for Bend's future. Since supply-induced demand effects also apply to non-automotive modes, infrastructure growth supporting these alternatives would enhance their uptake and reduce automobile reliance. Capacity increases for non-automotive modes would alleviate road congestion efficiently, as use of these modes directly pulls VMTs from roads and improves social and environmental outcomes, while requiring relatively low investments.

7. The Citywide Transportation Advisory Committee should prioritize funding and infrastructure enhancements for non-automotive transport in Bend and should view with skepticism any promise of traffic congestion relief through roadway expansion.

Thank you for your consideration of this important topic as you proceed with making recommendations about the future of Bend's transportation system.

Steve Porter

Michelle Porter

GRAPHICAL APPENDIX

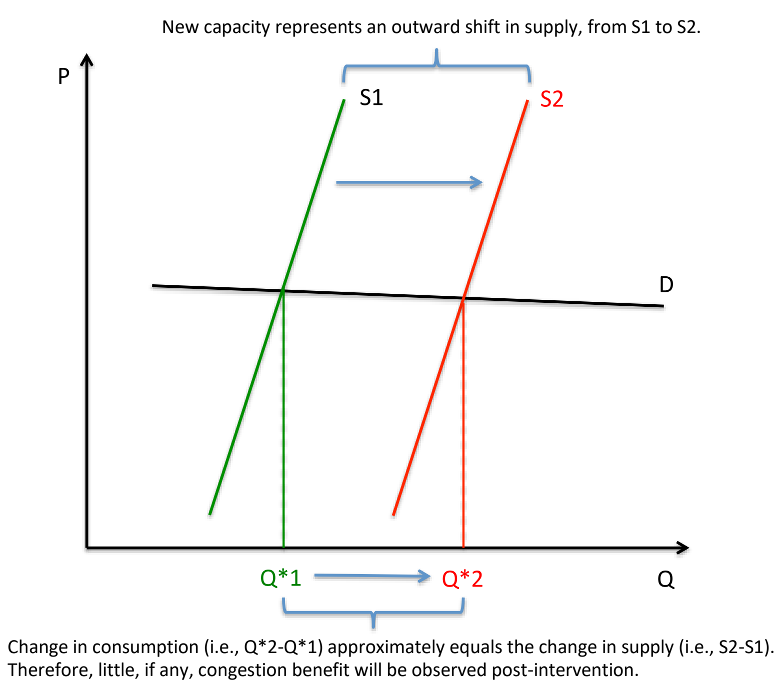
The induced traffic effect is entirely consistent with the typical workings of supply and demand within markets. Empirical research relating to induced traffic takes place within this framework, defining the "elasticity" (and thus deriving the slope) of the demand curve for roadways. While many may assume a perfectly inelastic (i.e., vertical) demand slope exists, empirical evidence shows that demand can be viewed as nearly perfectly elastic (i.e., flat).

Accordingly, the induced traffic effect can be graphically illustrated as follows, where:

D = Demand for roadways, typically "vehicle miles traveled." Evidence shows demand is highly elastic. The demand function shown represents existing demand; that is, it does not reflect any exogenous factors such as population growth, etc., which would be reflected in an outward shift of the demand curve.

S = Supply of roadways, typically "lane-miles." Supply elasticity does not bear on the outcome of the analysis shown here, so the supply curve's slope (i.e., whether lane-mile supply is highly inelastic or not) does not matter.

Q* = The "market clearing" consumption quantity of miles traveled (i.e., the point of supply and demand equilibrium).



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Steve is a recognized authority on economic analysis and valuation. He has provided expert testimony in high-stakes commercial litigation on topics including economics, valuation, statistics, econometrics, market definition, consumer choice, business strategy, and pricing, among others. He has consulted with Fortune 500 corporations on intellectual property licensing, asset transactions, and valuation issues, and he has conducted economic impact analyses, including work performed on behalf of the Los Angeles Superior Court. His articles have published in the *Journal of Legal Economics*, *les Nouvelles*, the *Patent, Trademark & Copyright Journal*, the *Journal of the Patent and Trademark Office Society*, and *Intellectual Asset Management*, among others. He also is co-author of *IP Strategy, Valuation, and Damages* (LexisNexis), a treatise on intellectual property economics. Steve has been an invited speaker before the Chicago Bar Association, the Attorney General's Office of the State of Arizona, and various law firms and corporations, where he has lectured on topics ranging from economic analysis and valuation to econometrics and game theory, and he has been quoted by and featured in the editorials section of the *Wall Street Journal*. Steve is a recipient of the William J. McKinstry Award in economics, the *Wall Street Journal* Scholar Award, the Micronomics Economic Research Award, and the IE Fund Leadership Scholar Award. He has served as a teaching assistant in economics at the Dolibois European Center in Luxembourg, an ad-hoc referee for the *Journal of Forensic Economics*, and as Co-Chair and an Executive Committee Member of Young Professionals Advisory Council at the Farmer School of Business. Steve graduated *summa cum laude* and with University Honors from Miami University in Oxford, Ohio, completing dual majors in economics and marketing. He was granted his MBA, with honors by the Dean and Board of Academic Affairs, from IE Business School in Madrid, Spain, graduating 5th in a class of more than 400. Steve holds the Series 65 securities license.

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