Economics of Transportation 4 (2015) 135–146

Contents lists available at ScienceDirect

Economics of Transportation

journal homepage: www.elsevier.com/locate/ecotra

Traffic management: An outlook

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ARTICLE INFO

Article history:
Received 10 April 2014
Received in revised form
23 March 2015
Accepted 23 March 2015

Keywords:
Traffic control
Road management
Value of time
HOV
HOT
Congestion pricing
Managed lanes
Autonomous vehicles
Integrated corridor management

ABSTRACT

Traffic congestion is caused by inefficient road operations and by excess demand. Inefficient traffic control is pervasive. Most urban streets and freeways do not have an adequate traffic sensing infrastructure, so one does not know how much congestion there is, its cause, or whether congestion mitigation projects have met the expected improvement. In the absence of adequate information, neither road operators nor travelers can gauge how poorly the road system is operated. Because the traffic changes randomly, the road system should be managed by effective feedback control of signals at intersections and at on-ramps. These control techniques are well known, and they have been successfully adopted in isolated road networks in different parts of the world. The investment in sensing needed to implement these control techniques is trivial compared to the benefits of an efficiently operated road system. But management is not able to quantify road system performance or how much improvement is possible and at what cost. Excess demand can be eliminated by appropriate incentives, including pricing. But empirical analysis of popular approaches such as HOV and HOT lanes suggests that they are ineffective unless the freeways are also efficiently managed. New ITS technologies, such as 'integrated corridor management' systems, while promising in theory, are likely to fail in the absence of a comprehensive traffic measurement system. More valuable might be initiatives that seek to shift modes away from private auto, adding bicycle and bus lanes, ridesharing, and telecommuting. Most of the data used in this analysis is from California.

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1. Context

Urbanization is accelerating: in 2013 22% of the world's population lived in cities with more than 1M people, up from 18% in 1990 (http://wdi.worldbank.org/table/3.12). There are 527 such cities today (www.citypopulation.de/world/Agglmoerations.html). The increase in the urban population is accompanied by an even faster growth in automobile ownership. World vehicle sales hit a record 82.8M, expected to reach 85M in 2014 and 100M in 2018. While China will account for a third of the new vehicles by 2018, much of the growth will come from auto markets such as India, Russia, and Brazil (http://www.cnbc.com/id/101321938). Since vehicle ownership grows twice as rapidly as income in the $3000–$10,000 per capita range (Dargay et al., 2007), growth in emerging, growing economies is predictable.

In both advanced and emerging economies cities are experiencing worsening congestion as transportation authorities confront the task of maintaining (let alone improving) the performance of their existing road networks. With very rapid growth in the demand for personal transport and freight, the challenge in emerging economies is more severe. Automobile pollution is endangering health, and the environment may be unable to withstand this deterioration.[1] But in the face of the growing desire for automobile ownership governments may be unable to curtail its growth.

US congestion: The Texas A&M Transportation Institute (TTI) Urban Mobility Report finds that congestion has forced urban Americans to travel 5.5 billion hours more and waste 2.9 billion gallons of fuel at a cost of $121 billion in 2011 (Lomax et al., 2003). Fig. 1 shows a trend and congestion share by road type. Thanks to the recession, the 2011 congestion is below the 2005 peak, but it is higher than in 2000 and will increase as the economy improves. Congestion cost rose from $24 billion in 1982 to $94 billion in 2000 (2011 dollars), and will likely increase 40% by 2025.

The TTI report emphasizes that "*the best speed data is combined with the best volume information to produce high-quality congestion measures*," but it places no confidence bounds on these measures. This is unsurprising: TTI combines speed data from a private company and

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http://dx.doi.org/10.1016/j.ecotra.2015.03.002
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[1] A widely-quoted 2013 paper (Chen et al., 2013) estimates that total suspended particulates in the air will reduce the life span of 500M in Northern China by 5 years. The particulate estimates in the study are from coal burning, but both gasoline and diesel vehicles emit particulates and GHG.

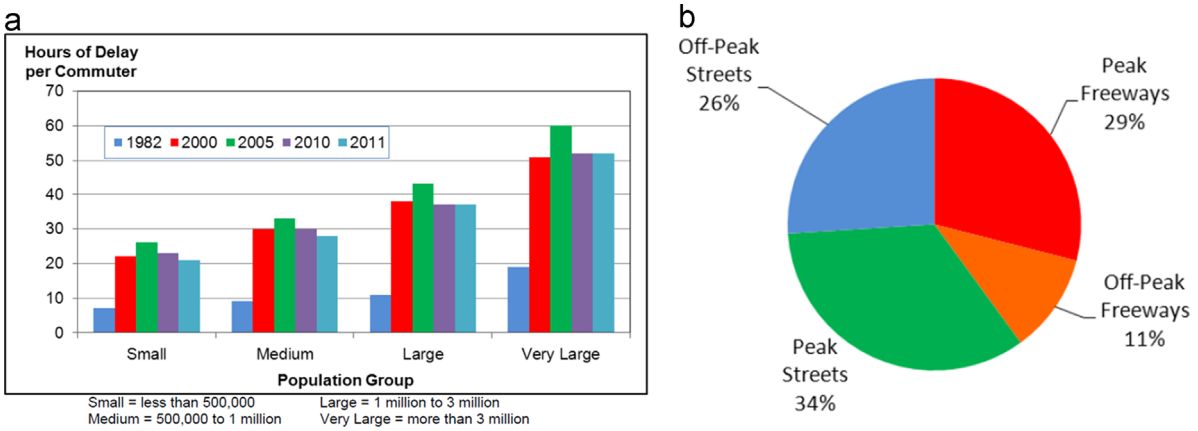

Fig. 1. Congestion statistics: (a) congestion trend; (b) percent of delay by road type.
Source: Lomax et al. (2003).

volume data from Highway Performance Monitoring System (HPMS) files assembled by the Federal Highway Administration (FHWA). The two sets of data are obtained at different times and from different locations, neither providing error estimates, and as TTI does not have the raw measurements, it cannot calculate any confidence bounds.

We know of no city that systematically (say once a month) measures traffic volume, occupancy and speed (VOS) on its main streets. With the exception of a few states like California, most states do not have dense freeway VOS measurement. So when local, state and federal transportation agencies discuss the magnitude and causes of congestion, they lack a reliable empirical basis. Agencies and the press merely selectively quote the TTI Report, and no one remarks on the absence of reliable measurements.[2]

The absence of reliable traffic measurements means that no one knows how much congestion there is (or whether it is getting worse) in their neighborhood, city or state, which hinders awareness and reduces citizens' motivation to denounce or applaud a transport agency's performance. For example, in 2006 California voters approved 61% to 39% a $20B bond measure (Prop 1B) for projects "to relieve congestion, improve the movement of goods, improve air quality, and enhance the safety and security of the transportation system." While one can readily find online descriptions of Prop 1B-funded projects, it is not possible to learn how much congestion relief these projects have provided.[3]

Another damaging consequence of the absence of traffic measurements is that it obstructs accurate diagnosis of the causes of congestion in a particular time and place, and thwarts effective design and implementation of congestion relief projects and reliable project evaluation.

2. Excess demand or poor traffic management

In its online publication "Describing the Congestion Problem (http://www.fhwa.dot.gov/congestion/describing_problem.htm)" the US Federal Highway Administration (FHWA) notes that "the process of congestion relief begins by understanding the problem," and asserts that "highway congestion, very simply, is caused when traffic demand approaches or exceeds the available capacity of the highway system." It also offers a different definition of congestion as 'performance reduction": "congestion … represents the difference between the highway system performance that users expect and how the system actually performs." The congestion delay in the TTI report and in the California freeway performance measurement system (PeMS) (http://pems.dot.ca.gov) are calculated as the additional vehicle hours spent traveling below a nominal or free flow speed, e.g. 45 mph. Thus, both use 'performance reduction' as congestion measures.

The Joint Transport Research Centre of the Organization for Economic Cooperation and Development (OECD) offers three definitions (Joint Transport Research Centre, 2007): (1) it "is a situation in which demand for road space exceeds supply"; (2) it is "the impedance vehicles impose on each other, due to the speed-flow relationship"; and (3) it "is linked to the difference between the roadway system performance that users expect and how the system actually performs". Evidently, (1) and (3) coincide with FHWA's two definitions, whereas (2) is a quantitative gloss on definition (1) via the speed–flow relationship.

FHWA and OECD both agree that congestion is measured by performance reduction. They also claim that excess demand causes performance reduction. We call this the 'excess demand' hypothesis. We propose 'poor traffic management' as an additional hypothesis. Empirical evidence suggests that poor management is pervasive. The cure for congestion will depend on its cause: poor management should be replaced by better traffic control, and excess demand should be reduced by demand management.[4] We first consider freeway and then arterial congestion.

2.1. Freeway congestion

Consider Fig. 2 (left). It is a scatter plot of vehicle-miles traveled (VMT) on the *x*-axis vs. delay in vehicle-hours on the *y*-axis, calculated for a nominal speed of 45 mph. Each point represents one hour of each workday in November and December of 2013 for vehicles traveling the 45 miles of Interstate 880 South in the San Francisco Bay Area, from Oakland to Santa Clara. Each day is classified as a good

[2] An example: "In the [TTI] Report San Francisco Bay Area ranked as the third most congested region in hours of delay caused by congestion (Association of Bay Area Governments and Metropolitan Transportation Commission, 2013, p. 8)."

[3] There is a particular irony here. The California Department of Transportation (Caltrans) in its public presentations on Prop 1B emphasized the importance of Intelligent Transportation Systems (ITS) technologies and their reliance on a ubiquitous and reliable traffic measurement system. However, the California Transportation Commission (CTC), which disburses Prop 1B funds, essentially zeroed out the Caltrans request for the measurement system. So Caltrans, CTC and the public continue to be unaware of how effectively Prop 1B funds are spent. This 'no data, no accountability' attitude is repeated across the country.

[4] Excess demand causes congestion as a negative externality. Poor traffic control leads to X-inefficiency (Liebenstein, 1966), which is the failure to achieve technical efficiency and can occur from the lack of competitive pressure. Roadway operators are monopolists with uninformed customer-users.

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