CAMBRIDGE SYSTEMATICS

The Future of Tolling in Oregon: Understanding How Varied Objectives Relate to Potential Applications

final

report

prepared for

Oregon Department of Transportation

prepared by

Cambridge Systematics, Inc.

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1.0 Background

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Oregon's citizens have become accustomed to funding roads through fuel taxes and vehicle fees. These are tried and true methods; and while citizens may not like paying their fuel taxes and vehicle fees, they generally understand how these mechanisms work, and have built up their traveling behavior on the basis of this system. Since vehicle fees are paid once per year, and fuel taxes are mostly hidden in the price of fuel, drivers tend to treat driving as "free," and it appears as if roads are provided by the government as a public good. By "public good," it is meant that the roads are accessible to any citizen at any time; and that the cost of developing, operating, and maintaining the system is borne by the population as a whole.

In Oregon, tolls have been limited to a few Columbia River bridges. The rationale for tolling bridges has been that they are extraordinarily expensive, vehicles have limited alternatives, and tolls can be collected at one location.

Around the United States and around the world, tolling is seeing a resurgence. There are two main drivers: 1) bridges and highways are increasingly expensive to build, and there is little public appetite for tax increases; and 2) modern electronic tolling technology allows creative new tolling applications that not only raise money, but potentially enhance transportation system performance.

The policy issues surrounding tolling have always been somewhat complicated, with the main question being, "why should my project have to be paid for with tolls when other projects are provided 'for free' by the state?" In the past, this public policy issue has been skirted because tolling has come about through local or regional initiative, with local elected officials taking matters into their own hands when state governments have been unable to develop new highway capacity quickly enough. Traditionally, toll projects have paid for themselves – the capital, operating, and maintenance costs were bonded, and toll proceeds over the period of decades were used to pay off the debt. There are very few toll projects today that can be funded entirely with tolls, which complicates the public policy calculus.

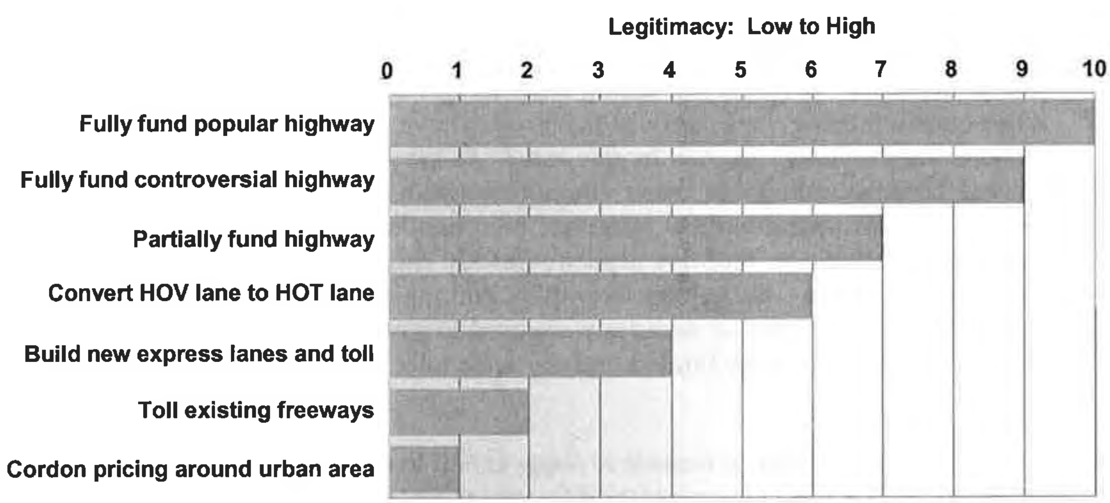
There are now a variety of reasons to support and to carry out tolling. Tolling is hailed by some as the solution to transportation finance woes, as well as a means of solving congestion. Since all but the simplest of tolling applications are as yet untested, most people have little experience with these new approaches. It is not unusual for people engaged in a conversation about tolling eventually to realize that they are not talking about the same thing at all.

Recent state authorizing legislation that allows for an increased use of tolling could result in changes in policy from the current *status quo*. The Oregon Transportation Plan contains numerous references to tolling, yet the specifics of how this tolling would be carried out are unknown and untested. Public debate about tolling quickly degenerates into ideological rhetoric from proponents and knee-jerk responses from opponents (or vice versa), because there is not a common understanding of how tolling would be applied, who would win, and who would lose. The realm of tolling applications is so new that experts disagree on the potential outcomes; policy-makers do not have a good framework for assessing how these different tolling applications work.

For every tolling application, there will be winners and losers. The winners may consider the toll a bargain, or at least feel indifferent between paying the toll and saving time. Those made worse off, either directly or indirectly, are likely to view tolling as expensive or as a less affordable alternative to new capacity funded with new taxes and fees. Even those made better off, however, may question tolling as the most appropriate or legitimate solution.

At the risk of oversimplification, given what the general public knows and understands today, using tolls to fully finance a new highway has a chance of being politically legitimate – at least the public understands it. As a jurisdiction moves into more unknown territory, political legitimacy starts to waver, with less support for a project that may need government support: less for new ideas such as HOT lanes, and even less for extreme ideas such as tolling existing highways.

Figure 1.1 Political Legitimacy of Potential Tolling and Pricing Applications



The public will need to be satisfied that other solutions to congestion and improving access such as, say, ramp metering, land use and parking policies, transit investments, and other forms of funding, including raising the fuel tax or requiring new development to fund its fair share of new capacity, are not superior to tolling or at least included in a portfolio of funding and demand management solutions.

All of these concerns are not intended to prevent the State's consideration of tolling in its funding portfolio, but consideration of new tolling and pricing applications will require attention to perceptions of the current status quo. New tolling projects, therefore, should start with studies that identify those portions of the public directly and indirectly affected by a planned tolling application and a reasonable assessment of the extent of these impacts. They should also consider the extent to which a tolling application is successful at achieving stated policy objectives.

Public opinion research is also an important component; however, studies in other places show that one thing is clear – the public cannot be expected to have an informed opinion if it has little experience with the concept. People's understanding of transportation funding is limited; understanding of what is possible with modern tolling is virtually nonexistent; and people's trust of government to carry out complicated new, controversial projects that will alter one of the lynchpins of their daily lives – commuting and generally getting from here to there – is likely to be very low.

This study provides a conceptual framework which should enable a smoother transition to any new state policy on tolling. The framework should help state officials communicate a coherent rationale and plan for tolling, as well as resolve some confusion among policy-makers and practitioners within the State's transportation community. For example, there are almost a dozen different applications of tolling and it is very likely that few policy-makers are thinking of the same tolling application for any given location. Furthermore, there is a considerable plurality of objectives that policy-makers are hoping to achieve; from funding new capacity to relieving congestion to reducing pollution and fostering economic growth. The lack of agreement among policy-makers on their priority and the potential for some objectives to be in outright conflict would present a confused approach to the public at best.

This document is intended to help Oregon policy-makers understand the basics of different tolling applications and how they relate to the objectives that people expect tolling to accomplish. With this basic understanding, Oregon can then take the next steps, if appropriate, toward a coherent tolling policy that meets its transportation policy objectives.

This framework, therefore, starts with systematic definitions of potential tolling objectives. Next, it describes all of the possible applications of tolling. It then evaluates how well each application addresses each objective. Finally, it presents some examples of how well a given application addresses specific objectives.

Questions addressed by this policy framework:

1. **Does tolling/pricing achieve the desired objective(s)?**
2. **If so, does it cause more severe, possibly unintended consequences?**
3. **Is it the optimal solution to achieve those objectives?**

2.0 Potential Tolling Objectives

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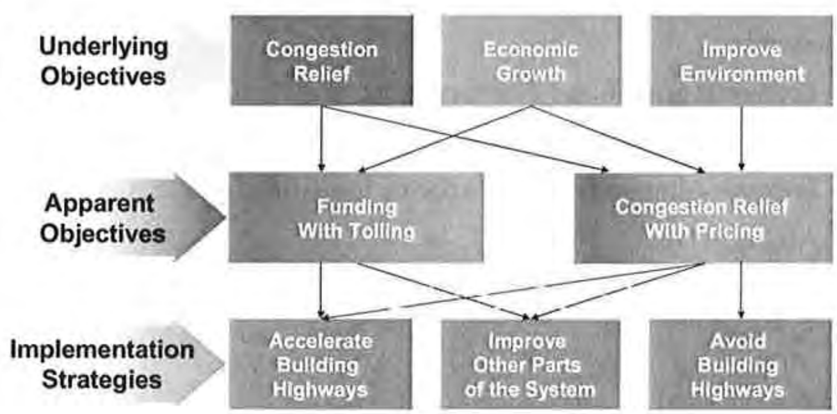
Historically, the only objective for using tolls was to raise money to build a bridge, tunnel, or highway. Over the years, the number of objectives has expanded; and with the advent of open road tolling where tolls can be collected without drivers needing to slow down or stop, the possibilities expand even more. The universe of objectives for tolling is varied, and not everyone involved may have the same objectives (see Figure 2.1). People often confuse the underlying objectives for tolling, such as congestion relief, improving the environment, or stimulating economic growth with the more apparent objectives, which might be summed up as funding through tolling or system management through pricing.

Figure 2.1 Objectives and Strategies of Tolling and Pricing



Ideally, the State might develop evaluation procedures that address only the underlying objectives – these are, ultimately, what it hopes to gain by changing the system with tolling or pricing. The general public and stakeholders, however, will come to the table with their own ideas about what tolling might achieve. Therefore, in developing this overview of the potential effectiveness of tolling and pricing projects, the following four categories of objectives provide a near comprehensive framework for evaluation, where appropriate, for tolling or pricing proposals. Within each of these categories, there are specific objectives which differentiate between ways that people may regard the problems and solutions tolling is intended to address:

1. **Financial:**
   a. Fund project costs,
   b. Maximize revenue generation,

   c. Subsidize multimodal improvements,
   d. Attract private investment, and
   e. Accelerate project delivery;

2. **Congestion relief:**
   a. Demand management,
   b. Improve reliability,
   c. Reduce recurrent delay, and
   d. Mobility enhancement;

3. **Improve environment:**
   a. Air quality,
   b. Growth management,
   c. Increase transit ridership, and
   d. Reduce energy consumption; and

4. **Economic:**
   a. Economic growth and development,
   b. Trade and goods movement,
   c. Improve competitiveness of specific Industries, and
   d. Access to labor.

3.0 Potential Tolling Applications

3.0 Potential Tolling Applications

It used to be that there were simple toll roads, bridges, and tunnels. Now, the universe of applications for toll projects has expanded considerably as advanced technology has allowed tolls to be collected without traditional toll booths. Recent trends in tolling applications are discussed in more detail in the Literature Review (Appendix A), but in general, the following typology represents the types of tolling projects that Oregon might expect to see proposed:

1. **Traditional projects:**
   a. New toll road; and
   b. New toll bridge or tunnel.
2. **Tolled Managed lanes:**
   a. HOT lane:
      i. Convert existing high-occupancy vehicle (HOV) to HOT;
      ii. Build new lanes and make HOT; and
      iii. Convert existing general purpose lane to HOT.
   b. Express toll lane (like HOT, but without HOV priority):
      i. Build new lanes as express toll lanes; and
      ii. Convert existing general purpose lane to express toll.
   c. Truck-only toll (TOT) lane:
      i. Convert existing HOV lane;
      ii. Build new lane(s); and
      iii. Convert existing general purpose (GP) lane.
3. **Toll existing corridors or systems:**
   a. Replacement bridge as toll bridge (potentially with expansion);
   b. Convert existing freeway to tollway;
   c. Cordon or area pricing around or within a defined area (e.g., a CBD); and
   d. Convert system of freeways to tollways within a defined area.

Any of the above applications can work with time of day or dynamic pricing (price varies with actual demand), and the managed lanes concepts require them. Also, any of these applications may involve a project being 100 percent financed from future toll revenue, while others involve small or large contributions from other sources. And in some cases, the project itself is pricing; for example putting tolls on a cordon, where the objective may be to manage traffic demand, generate revenue for a system of improvements, or more likely both.

4.0 Do Tolling Applications Achieve the Objectives?

4.0 Do Tolling Applications Achieve the Objectives?

This section broadly compares the varied objectives of tolling or pricing with potential tolling or pricing applications. The comparison is intended to provide the reader with a sense of which applications are generally useful at fulfilling the different objectives. The broad comparisons are not intended to substitute for more rigorous analysis for particular proposals. The effects can vary widely depending on the specifics of how a project is defined. The matrix illustrates the relationships between applications compared to objectives, and is shown for each of the four categories of objectives in Tables 4.1 to 4.4.

Within this section, each cell of the matrix is examined. This examination provides: 1) a brief explanation of how tolling application would or would not address each objective; 2) an evaluation of how well each potential application fulfills each objective.

4.1 Financial

The capacity of tolls to fund project construction is usually the first overall objective driving the application of tolling. This overall objective consists of a number of more specific financial objectives that address a diversity of financial motivations for tolling. These include funding as much of a project's cost as possible, but also generating cash for other purposes. Specific financial objectives include:

- Fully or partially fund toll project costs;
- Maximize revenue generation;
- Subsidize multimodal improvements (e.g., roadway and transit);[1]
- Attract private investment; and
- Accelerate project delivery.

[1] In Oregon, it is unconstitutional to divert gas tax or toll revenue to transit. However, there are places in the United States where toll revenue is used to subsidize parts of the transit system.

Table 4.1 Evaluation of Tolling Applications Ability to Achieve Funding Objectives

	Fund Project Costs	Maximize Revenue Generation	Subsidize Other Transportation Improvements	Attract Private Investment	Accelerate Project Delivery
1. Traditional					
a. New terrain toll road	Yes	Need to weigh against other objectives	Not likely, but not impossible	Yes, if structured properly	Yes, if structured properly
b. New toll bridge or tunnel	Yes	Need to weigh against other objectives	Not likely, but not impossible	Yes, if structured properly	Yes, if structured properly
2. Tolled Managed Lane					
a. HOV to conversion	Yes, costs likely low	HOT toll policy should maximize flow, not revenue	HOT plus toll revenue to improve operations or add capacity in the corridor can be an effective combination (e.g., incident management, parallel capacity, transit service, etc.)	Not likely, but possible; revenues not likely to be enough in most cases	Does not address – the project IS the tolling
b. New HOT lane	Partial most likely; new urban capacity expensive; free HOV cuts into revenue	HOT toll policy should maximize flow, not revenue	HOT plus toll revenue to improve operations or add capacity in the corridor can be an effective combination (e.g., incident management, parallel capacity, transit service, etc.)	Possible, but government subsidy likely needed	Depends on level of government support; if alternative is GP lane widening, extra revenue from HOT tolls could accelerate the new capacity

Table 4.1 Evaluation of Tolling Applications Ability to Achieve Funding Objectives (continued)

	Fund Project Costs	Maximize Revenue Generation	Subsidize Other Transportation Improvements	Attract Private Investment	Accelerate Project Delivery
2. Tolled Managed Lane (continued)					
c. GP lane to HOT lane conversion	Yes, cost low	HOT toll policy should maximize flow, not revenue	HOT plus toll revenue to subsidize corridor transit can be an effective combination	Does not address – converting a GP to HOT lane would not require new private investment; converting and then long-term leasing would be possible, but policy rationale would be tenuous	Does not address – HOT IS the project.
d. New Express Toll Lane (ETL)	Partial likely; revenue higher than HOT; gov't subsidy still probably needed	Likely public policy decision would be to maximize flow, rather than revenue	Possible, but little chance of "excess revenue" to divert to transit	Possible, assuming gov't subsidy	Possible, additional revenue from tolls could supplement other sources to create the added capacity faster than simple GP expansion
e. Convert GP lane to ETL	Yes, cost likely very low	Likely public policy decision would be to maximize flow, rather than revenue	Given low cost, this is likely to be revenue positive, with opportunity to divert to transit (road financing)	Does not address – converting a GP to HOT lane would not require new private investment; converting and then long-term leasing would be possible, but policy rationale would be tenuous	Does not address – conversion is the project
f. HOV to TOT lane conversion	Possible, costs of TOT conversion likely much higher than HOT conversion due to operational issues	Likely public policy decision would be to maximize flow, rather than revenue	Possible	As above	Does not address

Table 4.1 Evaluation of Tolling Applications Ability to Achieve Funding Objectives (continued)

	Fund Project Costs	Maximize Revenue Generation	Subsidize Other Transportation Improvements	Attract Private Investment	Accelerate Project Delivery
2. Tolled Managed Lane (continued)					
g. New TOT lane	Possible, new TOT lanes likely very expensive; tolls could be much higher than HOT	Possible	Possible	Possible	Possible
h. GP to TOT conversion	Yes, cost likely low, but not as low as HOT conversion	Possible, because conversion would be a "take-away," revenue maximizing policy might be a difficult policy choice	Possible	Does not address – converting a GP to TOT lane would not require new private investment; converting and then long-term leasing would be possible, but policy rationale would be tenuous	Does not address
3. Toll existing corridors or systems					
a. Replacement bridge as toll bridge (potentially with expansion)	Yes, gov't subsidy might be required, depending on circumstances	Possible, but a difficult political choice; revenue maximizing tolls likely very high – public backlash likely	Possible, depends on revenue stream and toll policy	Possible	Likely
b. Convert existing freeway to tollway	Does not address; the project IS tolling	Possible, but a difficult political choice; revenue maximizing tolls likely to create public backlash	Possible, and probably desirable, to justify tolling something that is now free	Does not address – converting a freeway to tollway would not require new private investment; converting and then long-term leasing would be possible, but policy rationale would be tenuous	Does not address; project IS tolling

Table 4.1 Evaluation of Tolling Applications Ability to Achieve Funding Objectives (continued)

	Fund Project Costs	Maximize Revenue Generation	Subsidize Other Transportation Improvements	Attract Private Investment	Accelerate Project Delivery
3. Toll existing corridors or systems (continued)					
c. Cordon or area pricing	Yes	Possible, but a difficult political choice; revenue maximizing tolls likely to create public backlash	Possible, and probably desirable, to justify tolling something that is now free	Does not address – putting tolls on free roads would not require new private investment; converting and then long-term leasing would be possible, but policy rationale would be tenuous	Does not address, but if project delivery is defined as an improved transit/highway system funded by the revenue, then perhaps yes.
d. Convert system of freeways to tollways	Yes	Possible, but a difficult political choice; revenue maximizing tolls likely to create – public backlash	Possible, and probably desirable, to justify tolling something that is now free	Does not address – putting tolls on free roads would not require new private investment; converting and then long-term leasing would be possible, but policy rationale would be tenuous	Does not address, but if project delivery is defined as an improved transit/highway system funded by the revenue, then perhaps yes

Table 4.2 Evaluation of Congestion Relief Objectives

	Demand Management	Reduce Recurrent Delay	Improve Reliability
1. Traditional			
a. New Terrain toll road	Does not address	Likely yes, at least in the short to mid term	Likely yes, at least in the short to mid term
b. New toll bridge or tunnel	Does not address	Likely yes, at least in the short to mid term	Likely yes, at least in the short to mid term
2. Tolled Managed Lane			
a. HOV to HOT conversion	Does not address	Yes	Yes
b. New HOT lane	Does not address	Yes	Yes
c. GP lane to HOT lane conversion	Does not address	Yes	Yes
d. New ETL	Does not address	Yes	Yes
e. Convert GP lane to ETL	Does not address	Possibly yes on ETL, potentially no or worsen on GP	Possibly yes on ETL, potentially no or worsen on GP
f. HOV to TOT lane conversion	Does not address	Potentially for trucks; could worsen for other vehicles	Potentially for trucks; could worsen for other vehicles
g. New TOT lane	Does not address	Yes	Yes
h. GP to TOT conversion	Does not address	Potentially for trucks; could worsen for other vehicles	Potentially for trucks; could worsen for other vehicles

Table 4.2 Evaluation of Congestion Relief Objectives (continued)

	Demand Management	Reduce Recurrent Delay	Improve Reliability
3. Toll existing corridors or systems			
a. Replacement bridge as toll bridge (potentially with expansion)	Potentially yes; price and congestion on bridge could influence regional demand patterns	Likely yes, at least in the short term, due to added capacity	Likely yes, at least in the short term, due to added capacity
b. Convert existing freeway to tollway	Potentially yes; price and congestion on major freeway could influence regional demand patterns	Likely yes, at least in the short term, due to added capacity; need to be careful about unintended consequences	Likely yes, at least in the short term, due to added capacity; need to be careful about unintended consequences
c. Cordon or area pricing	Likely yes	Likely yes; need to be careful about unintended consequences	Likely yes; need to be careful about unintended consequences
d. Convert system of freeways to tollways	Potentially yes; price and congestion on major freeway system could influence regional demand patterns	Likely yes; need to be careful about unintended consequences, with worsening in other locations	Likely yes; need to be careful about unintended consequences with worsening in other locations

Table 4.3 Evaluation of Economic Objectives

	Competitiveness of Specific Industries	Business Attraction	Trade and Goods Movement
1. Traditional			
a. New Terrain toll road	Likely benefit: unless improving exiting roadways more cost-effective	Likely benefit, but only if under or undeveloped land needs new roadway access	Depends, if new road has limited access and bypasses existing bottlenecks
b. New toll bridge or tunnel	Same as above	Same as above	Same as above
2. Tolled Managed Lane			
a. HOV to High Occupancy Toll (HOT) conversion	Possible benefit, if industries need better access to labor	Unlikely benefits: industrial development of raw land usually does not depend on HOT-lane construction	No benefit. HOT lanes are not effective for goods movement
b. New HOT lane	Same as above	Same as above	Same as above
c. GP lane to HOT lane conversion	Uncertain benefits, higher value trip would improve time and reliability, but more congestion in GP lanes and exclusion of trucks in HOT could impose higher costs on business	No benefit; underdeveloped areas would not become more attractive	No benefit, and possible disbenefit if increased congestion in GP lanes impacted trucking throughput, travel time, and reliability
d. New ETL	Possible benefit, if travel times saving remove a congestion penalty on wages	Possible benefit, if underdeveloped area become more accessible	Possible benefit, if trucking has access to ETL or ETL usage reduces congestion in mixed flow lanes
e. Convert GP lane to ETL	Uncertain benefits: higher value trip would improve time and reliability, but more congestion in GP lanes and exclusion of trucks in EFL could impose higher costs on business	No benefit; underdeveloped areas would not become more attractive	No benefit, and possible disbenefit if increased congestion in GP lanes impacted trucking throughput, travel time, and reliability
f. HOV to TOT lane conversion	Uncertain benefits: higher value commodities would benefit, but could increase wages and decrease access to labor	Unlikely benefit: unless TOT makes underdeveloped areas very attractive for truck-related industries	Possible benefit, if trucking benefits exceed disbenefits from potential increased congestion in mixed

Table 4.3 Evaluation of Economic Objectives (continued)

	Competitiveness of Specific Industries	Business Attraction	Trade and Goods Movement
2. Tolled Managed Lane (continued)			
g. New TOT lane	Uncertain benefits: higher value commodities would benefit, but alternative capacity (HOT or GP) may have larger benefit	Possible benefit: if under or undeveloped land needs new roadway access	Possible benefit: if GP lane congestion imposes severe delay and uncertain reliability on goods movement
h. GP to TOT conversion	Unlikely benefits: higher value commodities would benefit, but would increase wages and decrease access to labor	Unlikely benefit: TOT would have to trigger significant industrial development for benefits to exceed disbenefits to mixed flow traffic	Unlikely benefit: TOT would have to generate significant trucking benefits to exceed disbenefits to mixed flow traffic
3. Toll existing corridors or systems			
a. Replacement bridge as toll bridge (potentially with expansion)	Clear benefit, unless bridge tolls do not cover costs and subsidies displace more beneficial projects	Unlikely benefit, unless new bridge triggers industrial development, tolls cover costs, or subsidies do not displace more beneficial projects	Clear benefit, unless bridge tolls do not cover costs and subsidies displace more beneficial projects
b. Convert existing freeway to tollway	Uncertain benefit: depends on the benefits derived for use of tolls, impacts of diversion, and other economic conditions	No benefit; underdeveloped areas would not become more attractive	Uncertain benefit: depends on the benefits derived for use of tolls, impacts of diversion, and other economic conditions
c. Cordon or area pricing	Likely benefit: but depends on the severity of congestion and benefits derived from use of tolls and other economic conditions	Same as above	Same as above
d. Convert system of freeways to tollways	Likely benefit: but depends on the severity of congestion and benefits derived from use of tolls, impacts of diversion, and other economic conditions	Same as above	Same as above

Table 4.4 Evaluation of Environmental Objectives

	Air Quality	Growth Management	Increase Transit Ridership	Reduce Energy Consumption
1. Traditional				
a. New terrain toll road	Countervailing effects needing specific study	Countervailing effects needing study	Unlikely	Countervailing effects needing study
b. New toll bridge or tunnel	Countervailing effects needing specific study	Countervailing effects needing study	Unlikely	Countervailing effects needing study
2. Tolled Managed Lane				
a. HOV to HOT conversion	Countervailing effects needing specific study	Countervailing effects needing specific study	Possible	Countervailing effects needing specific study
b. New HOT lane	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
c. GP lane to HOT lane conversion	Countervailing effects needing specific study	Countervailing effects needing specific study	Possible	Countervailing effects needing specific study
d. New ETL	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
e. Convert GP lane to ETL	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
f. HOV to TOT lane conversion	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
g. New TOT lane	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
h. GP to TOT conversion	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study

Table 4.4 Evaluation of Environmental Objectives (continued)

	Air Quality	Growth Management	Increase Transit Ridership	Reduce Energy Consumption
3. Toll existing corridors or systems				
a. Replacement bridge as toll bridge (potentially with expansion)	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
b. Convert existing freeway to tollway	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
c. Cordon or area pricing	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study
d. Convert system of freeways to tollways	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study	Countervailing effects needing specific study

Each of these is discussed below.

Fully or Partially Fund Toll Project Costs

Historically, the ability of toll receipts to cover construction costs was the primary question asked when a project was considered for tolling. Before trying to answer this question, it is important to understand how the project is defined. For example, a traditional toll road or bridge is fairly straightforward; however, where do the project limits start and stop? In the case of the Tacoma Narrows Bridge in Washington State, the bridge project was about $850 million; however, the entire SR 16 corridor was well over a billion dollars. The bridge project would have been meaningless without the corridor expansion, so is the project properly defined as the bridge only, or the entire corridor?

Other projects may be more difficult. A HOT lane project may be developed to provide choices for commuters, but also to provide congestion-free travel to public transit buses. Should the project cost include the purchase of additional buses, and the operating cost for those buses?

A cordon pricing concept may simply toll existing roads - the only cost being the capital and operating cost of the toll collection equipment. Yet, the underlying objective for the project may be to generate cash to fund an array of transportation improvements. This objective is discussed below.

The simplest approach is to consider the present value of the project cost stream to the revenue stream and compare the two. This will give an indication of the financial picture of the project, but project finance assumptions can have a large impact on the value of the project, such as:

- Public authority or private concession;
- Toll rates, and toll rate increase policy; and
- Responsibility for operations and maintenance.

When these factors are known, a more reliable estimate of how much of the project costs can be covered by toll revenue.

When tolls only partially fund a project, the State (or regional authority) needs to make a policy choice to allocate public funds to that project. This means those funds would not be available for other projects that may be of higher value. It is important to be aware of the potential for toll revenue to change how state or regional priorities are set. Some would say that if tolls can bring some money to the table, then such projects ought to be pushed to the head of the queue. Others would argue that priority setting should not be influenced by funding sources, and projects should stand on their own merits in terms of effectiveness at carrying out transportation, land use, and environmental objectives. This issue becomes more controversial if the potential for toll revenue comes from a private sector proposal that requires a public subsidy. Under these conditions, the private sector proposal can influence project selection and prioritization processes, which may not be in line with community desires.

Maximize Revenue Generation

On a traditional toll project developed and financed through the public sector (or through a quasi-public authority), the usual practice was to set the toll rate high enough to fulfill financial obligations such as debt payments. In some cases, this resulted in a revenue-maximizing toll, but in many other cases, the tolls were set well below this level, and stayed that way for decades.

Toll projects are more expensive to build today, and there are more projects pushing the envelope seeking to maximize toll revenue to enable the project to be built. Whereas historical toll projects never factored in regular toll increases, more recent projects rely on toll increases that track inflation (or consumer buying power, which is higher).

There is a tradeoff between revenue maximization and traffic flow maximization. A purely public project will try to balance these two objectives. A project with private equity will also need to recognize the need for a profit incentive.

When states or regions move beyond the idea of using tolls simply to generate money to build projects, but to manage traffic flow, revenue maximization may be a secondary priority. Indeed, revenue maximization may be the last thing to do. Consider a case where all existing roads in an area are tolled, such as with a cordon or area toll concept. In this case, the revenue maximizing toll is likely to be enormous – far higher than would be politically practical (or rational). Potential rationales for toll setting under these circumstances might be to meet a particular monetary objective to subsidize transit service or to attain a certain level of congestion relief (perhaps measured by average speed in the zone).

Subsidize Improvements to Transportation or Other Public Works[2]

There are older toll systems around the country that spin off extra cash to subsidize transportation improvements, including roadway transit service. Newer traditional toll projects are less likely to be able to do this, at least in the short term, because they are so expensive to build. Nevertheless, tolling existing capacity may generate cash in excess of toll collection costs and provide funding for an array of transportation improvements, such as roadway capacity or intersection improvements, signal timing, incident management, ramp metering, or transit alternatives. The scale of investment may be defined up front or begin with a "wish list" of improvements that is refined and prioritized based on the amount of money and the structure of cash flow over time.

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[2] In Oregon, it is unconstitutional to divert gas tax or toll revenue to transit. However, there are places in the United States where toll revenue is used to subsidize parts of the transit system.

Managed lanes and other forms of congestion-management tolling that have low capital costs may provide the opportunity for subsidized transportation projects or transit service within the corridor or in other parts of a region. For example, the conversion of HOV lanes to HOT lanes in San Diego provides money for improved bus service. The I-394 HOV to HOT lane conversion in Minneapolis has a policy of using "excess" revenue to subsidize transit, but has not yet had excess revenue to offer. The initial private operator of the SR 91 HOT lanes used toll revenues to fund incident management, although this service was considered part of the overall business strategy to keep the lanes performing well and thus attracting patrons.

Cordon and area pricing concepts may be entirely about this cross subsidy, making driving more expensive, but making transit less expensive, more convenient, and more reliable. Presumably, the desire to subsidize transit is tied in to the desire to achieve other objectives related to urban form, air quality, and other environmental considerations. Subsidizing transit with toll revenue is not a policy choice that is readily accepted by the general public, nor is it allowed currently under the Oregon Constitution. Most people expect toll revenue will be used to pay for the road on which they travel, and this is an ingrained, strongly-held opinion.[3] There may be good public policy reasons for this concept, but it will not be accepted easily.

Attract Private Investment

Many governments are highly leveraged already, and cannot afford additional debt. There is a movement in the U.S. towards asking the private sector to finance projects on their own, take some or all of the construction or revenue risk, and thereby provide new transportation infrastructure at "no cost" to the government.

The reality is that the public pays for the project either way – in this case through tolls. There are arguments that the private sector may be able to deliver these projects more efficiently than the public sector, but there are counter arguments to this as well. The issues are complicated and beyond the scope of this project, but bear careful consideration.

In some cases, attracting private investment makes no sense at all. For example, if there was a proposal to toll all existing freeways in a metropolitan area, the rationale for this might be to:

- Generate cash for some combination of highway and transit improvements; and/or

Manage congestion through time-of-day pricing.

These are straight public policy goals, which would be terribly confused by engaging a private entity as an agent. People would (rightly) perceive that their existing toll-free

[3] *Washington State Comprehensive Tolling Study*, prepared by Washington State Transportation Commission, by Cambridge Systematics, Inc., September 20, 2006.

highways are being sold off to the private sector with a tenuous connection to the benefit they are receiving.

Accelerate Project Delivery

Does tolling enable a project to be delivered more quickly than it otherwise would? There are two reasons to accelerate a project. The first is to gain the benefits of the project (improved access, congestion relief) earlier. The second is to beat inflation, since construction costs have tended to increase faster than the overall rate of inflation.

Using tolls to accelerate a project assumes those tolls will create a positive cash flow to contribute towards project construction. In the case of a new highway project, this will often be the case. Looking around the country, project acceleration is probably the primary reason most toll roads were built - people got tired of waiting for projects to be delivered by their state Departments of Transportation (DOT), so they took matters into their own hands, created a toll authority, and delivered the project.

Project acceleration is only applicable where there is a capital project to deliver. In the case of a congestion pricing concept with no new capacity, there is no project to deliver faster, unless you count other capital or operational improvements that might be funded with the dollars collected.

4.2 Congestion Relief

Congestion relief is both an underlying objective and an apparent objective. Traditionally, congestion relief came from providing new capacity in the form of new highway lanes or transit service, or through traffic operations improvements. Current practices now aspire to congestion relief through time-of-day or dynamic pricing. When stating congestion relief as an objective, three more specific objectives may describe the combination of motivations more precisely: 1) demand management, 2) reducing recurrent delay, and 3) improving reliability. For each of these objectives, the following descriptions provide more details to illustrate their relevance in evaluating various tolling applications.

Demand Management

Demand management refers to strategies that reduce the amount of travel, usually by private automobile. The rationale for demand management strategies is generally threefold. One is to reduce congestion. Another is to reduce automotive emissions. The third is to reduce energy consumption (and potentially greenhouse gas emissions). Without these three problems related to auto use, one can argue that *more* traffic is an indicator of a robust economy. Nevertheless, congestion offsets economic development by contributing to noise, delay, visual blight, and barriers between neighborhoods.

The connection between tolling and demand management is that people will alter their travel behavior when the price changes. Pricing can contribute to what is traditionally called demand management when it affects the *overall amount* of travel, particularly by private automobile, or at least the amount of travel during congested peak travel times.

Pricing is best able to influence overall travel demand when applied to the entire transportation system, as in an area pricing concept, or a concept where all roads are priced by time of day. Pricing on individual roadways such as HOT lanes or a single highway are unlikely to change overall travel demand - rather they are likely to move traffic from one road to another, from one mode to another, or from one origin-destination pair to another.

The most effective measures of travel demand are vehicle miles traveled (VMT) or person miles traveled (PMT). These can be estimated through on-the-ground spot measurements, and forecast through travel demand models. Ultimately, however, overall levels of travel demand may not be the most effective comparator - rather, given changing technology, it may make more sense to measure auto emissions, energy consumption, and noise, rather than travel demand itself.

Reduce Recurrent Delay

Recurrent delay is that which is predictable, and is driven primarily by too much traffic volume trying to squeeze through insufficient roadway capacity (i.e., bottlenecks). This condition is distinct from nonrecurrent delay, which is caused by episodic events (e.g., accidents, inclement weather, roadway construction, etc.) that temporarily reduce capacity or degrade operations. There are two ways to look at recurrent delay:

1. Travel time (or speed) on a particular road or entire corridor; and
2. Travel time (or speed) on the entire regional transportation system.

With a traditional new highway or highway widening project, travel times and speeds should improve in the corridor of interest. While there may be some spot bottlenecks caused by the rearrangement of traffic patterns, typically these would be overwhelmed by the travel time savings afforded by the new capacity.

With pricing projects, the effects on congestion can be more complicated and difficult to predict. Pricing existing facilities can affect trip origins and destinations, intermediate stops (i.e., trip chaining activity), mode of travel, time of departure, or whether the trip is made at all. It is possible that congestion relief in one corridor might be offset by additional congestion in other corridors. And the models used to estimate these effects may not necessarily be up to the task of doing so reliably. The evaluation of a tolling project would measure the effect on recurring delay for the entire transportation network; major origin-destination pairs; income groups; and different times of day and trip purpose (e.g., commuters, school, tourists, personal, and business). Some of these may be more easily measured and forecast than others.

How is recurrent delay measured and forecast? Recurrent delay is relatively easy to measure in a particular corridor if that corridor is equipped with permanent measuring stations that can evaluate traffic volume and speed by location and time of day. Since such systems are expensive to install and operate, it is less likely that the equipment will be available to measure delay at enough locations throughout the region to evaluate system travel time and speed by time of day, and hence congestion levels.

Forecasting is more difficult, since it relies on models that simplify very complicated behavior. The most common models decision-makers are familiar with are regional travel demand models. These are good at forecasting aggregate behavior, but have less reliable predictions when the complications of specific traffic conditions affect behavior in a specific corridor. For some corridors with limited alternative routes and modes, this may not be an issue. Corridors with multiple routes and modes and significant goods movement may challenge the regional models to deliver results that allow decision-makers to have a good understanding of the results of their choices.

The ideal measures for evaluating recurrent delay are:

1. Mainline travel time (or speed);
2. System travel time (vehicle hours of travel or person hours of travel);
3. System speed (VMT or PMT/hour) compared to free flow; and

In all three measures, the analysis should study particular origin-destination pairs and demographic groups, to the extent the data and analysis tools allow it.

Improve Reliability

The Federal Highway Administration (FHWA) defines reliability as "the consistency or dependability in travel times, as measured from day to day and/or across different times of the day."[4] It is best understood by considering two examples. In one, a highway is normally uncongested, yet there is a curve that causes frequent crashes. Although traffic normally flows unmolested, when there is a crash, travel through that corridor can be severely disrupted, so travelers need to plan for extra time, since crashes happen frequently. The second highway is always congested. Normal speeds during peaks may be 20 miles per hour, but they are consistently so, and travelers can reliably expect it to take them three times longer on this route – even though it is very congested.

Travel time reliability is very data intensive to measure, but several types of measures have been developed. When planning new projects, travel time reliability is much more difficult to forecast, although some techniques are under development.

[4] The FHWA, Travel Time Reliability, Making There On Time, All The Time, accessed at: http://ops.fhwa.dot.gov/publications/tt_reliability/TTR_Report.htm on June 13, 2007.

When thinking about travel time reliability in the context of tolling and pricing projects, it is reasonable to conclude that measures that reduce recurring congestion also will be effective at improving reliability. So, new capacity, such as added lanes or new highways, can be expected to decrease recurring congestion, as well as improve reliability – at least in the short term. Over the long term, it is possible that additional traffic growth may overwhelm the system again, returning it to the prior levels of congestion.

Travel time reliability benefits are often cited in connection with all types of express toll lane projects (HOT, TOT, ETL). These special lanes can be priced to keep traffic at the level at which flow and speed are optimized. Therefore, if a traveler has a special need to be somewhere on time (i.e., they value reliability very highly for that trip), then they can pay a toll and ensure a reliable trip.

When considering reliability in the express lane context, it is important to distinguish those choosing to pay the toll (and gaining a reliability benefit) from those who choose not to pay the toll. In the case of converting existing HOV lanes or building new HOT lanes, there are no "take aways," and the nonpayers should be no worse off than they were beforehand. Nevertheless, in situations where an existing general purpose lane is converted to any form of express toll lane, nontoll payers are squeezed onto fewer lanes, potentially resulting in higher congestion levels, and therefore worse reliability. The same concern would hold true for proposals to toll existing freeway or roadway capacity. The reliability gains of the winners may be overwhelmed by the reliability losses of the losers. Only through careful analysis can the expectation in each circumstance be forecast.

4.3 Economic Growth

The direct user benefits from tolling applications presented in the previous section (4.2 – Congestion Relief) may foster three specific economic growth objectives: 1) competitiveness of specific industries; 2) business attraction; and 3) trade and goods movement. These three objectives of economic growth are more or less separate from one another; although they share the same quantitative and qualitative performance measures to evaluate various tolling applications. These measures will allow policy-makers to determine the scale of economic benefits and disbenefits of alternative tolling applications.

Before describing how well each tolling application generates benefits for the three economic growth objectives, it is necessary to convey a critical yet somewhat confusing attribute of tolling with respect to economic growth. The measurement of economic benefits is based on the concept of consumer surplus. This method of measurement assigns no benefit to a user of a toll facility who decides the price of the toll is just equal to the benefits (e.g., time savings or more certain reliability). In fact, this toll-payer is demonstrating that he or she is at least indifferent to the toll versus the benefit (i.e., values these benefits at least as much as the toll). Thus, there is no net benefit to such a user. Benefits are generated when the value to a motorist using a tolled facility exceeds the price of the toll. This is called consumer surplus, and reflects the fact that many users regard the toll price as a bargain and would pay more if the price were increased. Since this willingness to pay more is not being captured by the toll, it is valued as the aggregate benefit to users. In addition, nonusers may benefit because the diversion of users to the tolled facility may free up capacity in the nontolled facilities and reduce congestion.

The remainder of this section describes the relevant performance measures and answers a few critical questions about how well the various tolling applications address each of the objectives: 1) competitiveness of specific industries; 2) business attraction; and 3) trade and goods movement.

Competitiveness of Specific Industries

Tolling applications generate benefits for some industries but may have either no effect for others or impose disadvantages. Understanding how a tolling project could produce these varied outcomes is explored below by answering three questions shown below.

Does A Tolling Application Make Specific Industries More Competitive?

Only some industries or industry clusters will become more competitive if their transportation costs are reduced by tolled improvements. This happens where congested corridors impede the movement of goods, other on-the-clock travel or force workers to endure longer commutes, or travel longer distances to access jobs. In these cases, tolling applications may either expand roadway capacity or manage demand, thus improving the efficiency of existing roadway capacity. New tolled facilities, for example, may improve accessibility to major markets (customers), suppliers, or labor force.

These improvements lead to direct benefits for truckers, commuters, or other on-the-clock users of the transportation system. These direct user benefits then lower business costs for firms or give them access to a larger *and more diverse* pool of labor (see below). These direct benefits to existing business help them become more competitive compared to their rivals in other regions, thus expanding their market share. This expansion in turn generates indirect and induced economic growth for the region and communities connected to the region. These final benefits are measured as an increase in employment and higher gross regional output. This latter benefit is added to the monetized direct benefits (described in Section 4.2) to provide the total benefit used in a benefit-cost analysis.

Some industries will not become more competitive because they face other critical constraints to their growth that lower transportation costs will not affect. Aluminum smelters, for example, compete on the price of electrical power; and some manufacturers face high trucking costs because carriers charge them for empty backhauls, rather than the cost of increased congestion. Careful industry-specific analysis will allow for isolation of specific industries that benefit from a tolling application's direct benefits.

These final economic benefits must be compared to the next best alternatives, which usually include building nontolled facilities or not building any additional capacity. They must also account for the disbenefits of changes in travel patterns and volumes that may impact consumer or visitor spending at businesses, or reduce property values in neighborhoods traversed by diverted traffic.

Does A Tolling Application Benefit Industries of Particular Importance to the Region?

Even when the tolling applications generate increase competitiveness for specific industries, some industries generate more economic growth than others. These differences depend on a number of conditions. One of the most critical is how much a specific industry purchases its inputs from the local economy versus importing these from other regions. Local purchasing creates more indirect economic activity (i.e., multiplier effects). Another qualification of the total potential economic benefits involves which specific industries dominate a region's economy. Some industries are more transportation intensive than others, such as freight and manufacturing versus service and high-tech.

Finally, it may be more important to help specific occupations or socioeconomic strata (e.g., poor, blue collar workers, out-of-work timber workers, minorities, etc.). Thus tolling applications may be targeted for certain corridors where there are industries that will benefit these workers.

How Well Does a Tolling Application Improve Labor Market Accessibility and Reduce Commuting Costs?

Research suggests that the access to labor markets is an important factor that can improve productivity across industries. Population concentrations and transportation improvements provide businesses with access to skilled workers who are in demand across all industries. By effectively sharing this labor pool, employers create a more stable labor demand function than if every firm was on its own. This reduces the cost of doing business and provides productivity improvements for all firms having access to this labor pool.[5] This effect is described in greater detail in the Task 1 Technical Memorandum for the ODOT/CSI study, *The Economics of the RTP Update*.

Business Attraction

A tolling application may attract new business to a region or play a critical role in recruiting new industry. This second objective of economic growth involves attracting new business to the region that would not have otherwise come without additional roadway improvements. This growth comes from improving access to underdeveloped land or to industrial land where firms have less than optimal access to their customers and/or suppliers, because the exiting roads are too congested, or there are no existing roads or interchanges. Even if the existing roads and interchanges have capacity, they may be too narrow, steep,

[5] Chatterjee, S., *Agglomeration Economies: The Spark that ignites a City*, Business Review, Fourth Quarter 2003, p. 6-13.

curved, or in poor condition. A tolling application could help fund a new or wider road (from two to four lanes) or a new interchange that would not otherwise be built. Tolling revenues could improve the condition of a substandard existing road or interchange.

Under the right conditions, such new or better access would attract new business to these underdeveloped parcels and generate new jobs and output. This outcome, however, depends on the scarcity of industrial land in a region and the specific attributes of the target parcels. For example, are they close enough to major freeways; do they have adequate nonhighway infrastructure (water, drainage, etc.); do they have access to skilled labor; or can they get expedited approval of their development?

Trade and Goods Movement

Tolling applications could lead to increased trade and the movement of goods that will benefit the region. Some regions are located along major trade corridors and may have key trade facilities, such as intermodal rail terminals, air cargo airport, seaport, and border crossings. The capacity and efficiency of the roadway networks can determine how well trade moves through the region to destinations or from origins outside the region. Often these through shipments may become involved in some sort of economic activity in the region, such as transloading, handling in a distribution center, or even unloaded and involved in some sort of value-added activity. These activities will generate economic growth (i.e., increase employment, generate income, and produce regional output).

Nevertheless, some portion of this truck traffic may roll on through the region with little or no interaction with the region's economy. Thus, its impact on regional economic growth is negative because through-trucks take up roadway capacity that would otherwise be used for on-the-clock traffic directly related to the region's economic activity. Tolling applications that divert this through traffic from the existing roadway capacity would – in effect – provide more capacity for the region's local value-added activity and could foster economic growth, but only under the right conditions. A tolled truck lane, for example, could divert through trips off roadways that serve regional traffic, but the net economic benefit of this investment would depend on comparing the benefits to the region's economy to any subsidy to cover the cost of the project that could not be funded with tolls.

Finally, benefits of through travel foster economic growth in those regions where these trips begin and end, but they may not generate economic growth in the local region and may even give businesses in competing regions an advantage over local firms. These exogenous benefits would be worth demonstrating in order for the region to demand Federal funding for these multiregional or national goods movement corridors. Nevertheless, some empirical evidence suggests that some corridor improvements (including toll-funded projects) may allow industries to relocate to adjacent regions with lower labor costs, lower land costs, better access to suppliers or customers, etc.

4.4 Improve the Environment

Typically, new toll roads or bridges have the same type of environmental consequences as nontolled facilities - positive or negative. New terrain highways may open up new areas for development, potentially encouraging longer distance travel, but they may also relieve congestion, reducing the amount of stop and go traffic that wastes energy and has higher levels of emissions into the air. The specifics of these effects vary widely from case to case.

The new types of tolling products such as HOT lanes and congestion pricing of existing facilities are very different. These are pursued because they may be able to alter travel behavior to alleviate congestion or encourage use of mass transit. So there is interest in seeing whether these new products help achieve four specific environmental objectives: improve air quality, address growth management concerns, increase transit ridership, or reduce energy consumption.

Air Quality, Energy Consumption, and Greenhouse Gas Emissions

Tolling applications that reduce stop-and-go traffic will tend to improve air quality, but these gains may be offset by increased amounts of travel if additional capacity is involved. Applications that take existing capacity and make more effective use of them are also likely to improve air quality, especially if there is a component that tends to improve transit service. Without project specifics, it is difficult to make a blanket statement about particular types of projects.

Air quality effects can be measured through tried and true models that work with travel demand models. One caution is that these models may not be able to adequately capture the dynamics of stop-and-go traffic and the relief from stop-and-go traffic that are the desired outcome of many pricing projects, so additional model development and testing may be necessary.

The comments related to air quality also apply to energy consumption. Effects will vary significantly depending on the circumstances. And the same caution regarding the reliability of models to accurately estimate the effects is relevant as well.

Increase Transit Ridership

Increasing transit ridership is probably not an end unto itself, but a strategy to achieve other underlying objectives, such as improved air quality, lower energy consumption, and an urban form that is not auto dependent. Nonetheless, increasing transit ridership may be a stated objective of some policy-makers.

Capacity enhancement projects that make it easier to drive are probably not conducive to increasing transit ridership, but new express toll lane projects of all sorts could provide increased reliability for transit, leading to increased ridership. Pricing applied to existing highways could increase the cost of auto travel, such that transit becomes more attractive. Without the countervailing benefit of subsidizing transit service, prohibited by the Oregon constitution, transit ridership benefits are likely to be minimal from most tolling applications in the State.

Growth Management

Tolling can support or impede growth management objectives, depending on a rather complex set of market conditions. If all other market conditions are neutral, then tolls would motivate some residents that need to access locations reached by using the tolled roadway to locate closer in to avoid the tolls or save time. This adjustment would occur until the value of time savings equaled the price of the toll. However, this adjustment is highly hypothetical and would depend on the cost of land at either end of the tolled corridor, the permanence of the toll, the level of congestion on the general purpose lanes, and other conditions. The likelihood of unintended consequences is very high.

Given this complexity, new terrain toll highways are unlikely to advance growth management objectives. Congestion pricing of new toll lane capacity in the urban areas will have the effect of making it easier to travelers to live further from their jobs, because they will be able to reliably get to work and back for a price. Congestion pricing of existing systems may have the effect of pushing new growth, both housing and employment outside of the urban core, putting strain on the urban growth boundary. On the other hand, if the congestion reduction benefits of congestion pricing outweigh the actual toll cost, the urban region may become more attractive, thereby, making it easier to attain growth management. These are complicated issues needing careful study, and there is no certainty that the study results will be able to forecast all the unknown and unintended consequences from such actions.

5.0 Concerns and Unintended Consequences of Tolling

5.0 Concerns and Unintended Consequences of Tolling

The discussion above focuses on how well different tolling applications meet some of the objectives that people have when they consider tolling. It is important, however, to also consider other concerns and consequences of tolling. Some of the major concerns that are not discussed under one of the objectives are presented below.

■ 5.1 Uses of Toll Money?

Use of revenue raised by tolling can go a long way to enhancing or diminishing the political legitimacy of a tolling or pricing project. While there is no one right answer to how the money should be spent, one or more of the following philosophies may apply. They are listed from most restrictive to least restrictive:

1. Use the money only for the construction, operations, and maintenance of the facility on which it is being collected, and remove the tolls once bonds are paid off;
2. As above, but allow tolls to continue to pay for continuing operations, maintenance, and rehabilitation needs;
3. As above, but also allow for related expenses in the corridor, such as to access roads and parallel facilities;
4. As above, but also allow for transit service subsidies in the corridor;
5. As above, but also allow for other highway or transit subsidies in the general region; and
6. As above, but allow for other transportation projects anywhere in the State.

Public opinion nationally seems to default to the first of these as the only politically legitimate approach. Nevertheless, all of these approaches are in evidence somewhere in the United States, and there are good reasons why some of these other approaches may be appropriate. For example, HOT lane projects tend to try to cross subsidize transit in the corridor to counteract concerns of being unfair to people of modest means. In New York City and San Francisco, toll revenues from bridges provide a big portion of transit revenues. Whichever approach is chosen, it helps to have a rational basis for choosing one or the other.

5.2 Unintended Consequences

The descriptions in the previous sections described likely intended consequences for each tolling application. In addition, some unintended consequences were described under the financial, congestion relief economic, and environmental objectives. Nevertheless, additional unintended consequences of tolling are almost certain, but their particular manifestations and scale are difficult to predict and their appearance may vary from case to case. Some of the most common concerns include the following:

1. Diversion of traffic to nontolled routes and impacts on neighborhoods;
2. Toll increases that are not offset by benefits, resulting in reduced travel to business establishments (thereby impacting the economy);
3. Congestion from use of traditional toll plazas;
4. Toll evasion;
5. Inadequate transit service or other modal alternatives create hardships for low-income households;
6. Private-sector ownership or effective control of key corridors and accessibility; and
7. Inadequate consideration of alternatives to tolling, including funding from existing sources or increased taxes, ramp metering, incident management, parking management strategies, etc.

This list could be expanded. Many unintended consequences will not be known until tolling projects are fully implemented, and even then these may emerge only in the long term. Those that do appear early and seem severe may diminish over time. Given all this uncertainty, the following descriptions of significant unintended consequences are organized into four topics and provide summaries of major public concerns that were not identified in the previous sections.

Operational Issues

Toll collection itself and the need to segregate toll traffic from nontoll traffic can cause significant operational concerns. Some issues are well tested, such as with traditional toll plazas, but others are still in experimental stages, such as ways to delineate express toll lane traffic from general purpose traffic. Some specific considerations include:

1. **Methods.** Standardized methods, technology, and system architecture;
2. **Costs.** Procedures for controlling the cost of toll collection;
3. **Toll evasion.** Adequate enforcement so that there are not real or perceived weaknesses in the revenue collection system;

4. **Traffic operations.** Sufficient attention to merging, diverging, and weaving associated with special purpose lanes (if applicable); and

5. **Education and implementation.** Marketing of transponders and technologies designed to make tolling more efficient.

Equity

Previous sections described specific winners and losers for each of the tolling applications. This section tries to address equity at a larger scale by answering the question: would including tolling in the current funding portfolio increase overall *equity*? The answer depends on how one defines *equity*. Equity has two different and almost opposite meanings in this context:

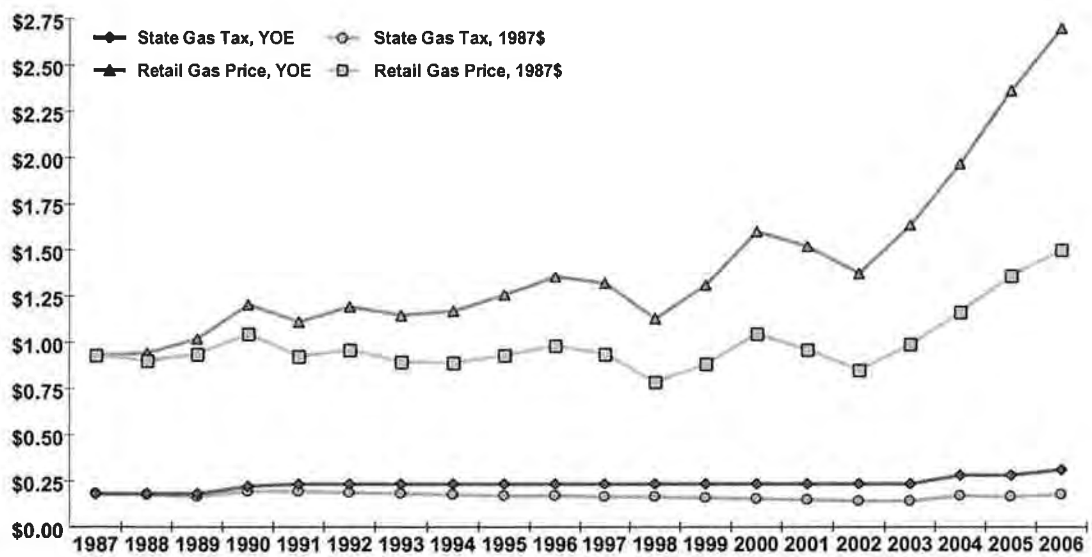
1. In the first definition, *equity* could mean that a user of a roadway should pay a price that is proportional to the benefit they receive or to the cost of providing the roadway capacity to serve them. According to this definition, tolling (especially peak period or dynamic tolling) is the most equitable type of funding. This definition applies if transportation is regarded as a semi-private good and should be funded with user charges similar to a utility like water or power.

2. In the second definition, *equity* measures a user's ability to pay, which would mean that their financial contribution to the cost of providing transportation should correspond to their income. This equates equity with burden and would apply if transportation is regarded as a public good that should be funded from taxes that are proportional – if not progressive – relative to a citizen's income.

While policy-makers may decide which definition of equity should be used to evaluate the addition of tolling to the State's funding portfolio, there appears to be widespread public perception that any increased use of tolling would impose hardships on low-income households, and this unintended consequence gives rise to the most persistent public challenge to tolling: Asking poor people to pay the same toll as rich people seems inequitable. But this begs the question: Compared to what alternative funding source? The answer depends on the most likely alternative sources of funding that the State would use instead of toll revenues.

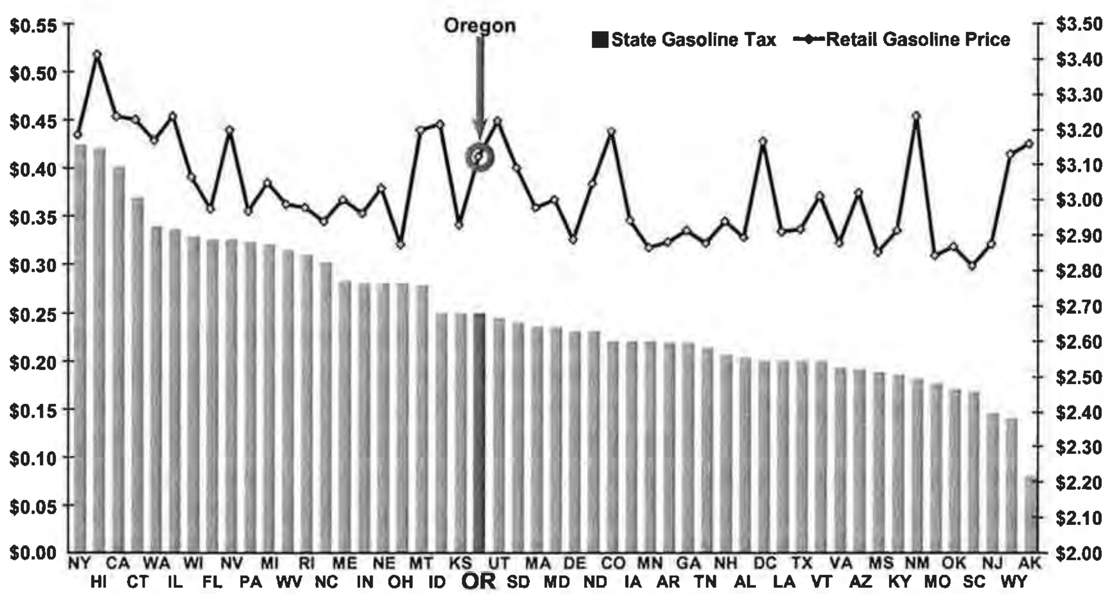
The most likely alternative would be an increase in the State's fuel tax, which provides the majority of current funding. Conventional wisdom posits that increasing fuel taxes increases fuel prices by roughly the same amount (i.e., inelastic). While a full exploration of this logic is beyond the scope of this study, the authors are compelled to suggest that some evidence suggests the contrary: that the relationship between fuel taxes and fuel prices is elastic. For example, in Figure 5.1 there appears to be very little if any correspondence between fuel prices and fuel tax rates over time for Washington State. In addition, Figure 5.2 shows a graph of current average fuel prices for each state and the corresponding current fuel tax rates.

Figure 5.1 Gas Tax vs. Retail Gas Price for Washington State
1987 to 2006



Source: Washington State Department of Transportation, U.S. Energy Information Administration.

Figure 5.2 Gasoline Tax vs. Retail Gas Price
State by State Comparison for 2007



Source: American Petroleum Institute (gas tax rates); American Automobile Association (retail gas prices).

There appears to be little or no relationship between fuel taxes and fuel prices. If increasing fuel taxes would not result in an equal increase in fuel prices, then this alternative funding source would be less regressive than tolling.

Even if society as a whole benefits from a toll project, tolling may impose a more regressive or burdensome funding regime on particular groups. The public is typically interested in who the winners and losers are by geography and income class, and in understanding how much they win and lose. Finally, the unintended consequences involving equity may go beyond cost burden to include inequitably burdened for travel time, convenience, environmental considerations, and consistency of policy application from project to project. For example, if one project is tolled while another is not, there should be a rational policy basis for this difference.

Privacy

Modern electronic toll collection methods involve some level of tracking of behavior. There are concerns that this information could fall into the wrong hands or be used by law enforcement officials in ways that are not intended. Methods to address these concerns need to be well thought out. However, even with adequate "safeguards" built into the tolling methods, pervasive public skepticism may defeat government assurances.

Adequacy of Analytical Methods

Many of the analytical methods used to evaluate tolling projects rely on sophisticated models. Some effects are difficult to accurately forecast with regional travel demand models, and the tools needed to get better information can be expensive. It is important that analysts using these models and the audience of their results understand any limitations before using the results to make decisions.

6.0 Adequacy of Analytical Methods and Consequences

6.0 Adequacy of Analytical Methods and Consequences

Many of the analytical methods used to evaluate tolling projects rely on sophisticated models. Some effects are difficult to accurately forecast with regional travel demand models or economic models, and the data needed to get better information can be expensive. It is important that the analysts using these models and the audience of their results understand these limitations before using the results to make decisions.

The following evaluations of analytical methods provide a cursory review of major limitations with the state-of-the-practice methods. These are organized according to the typology of tolling applications presented in Section 1.0 of this report. This typology has three categories of toll applications: 1) traditional projects, 2) new tolled managed lanes, and 3) toll existing corridors or systems. Each category is broken out into more specific applications and variations on those applications. For each application, the limitations in available analytical methods to measure likely benefits and disbenefits are discussed.

■ 6.1 Traditional Projects

These applications include new toll roads, bridges, or tunnels. All require an analysis of traffic demand for the proposed facility under conditions of tolling. The fact that a number of new toll projects fail to achieve projected usage illustrates the potential difficulty of performing this analysis accurately, particularly in undeveloped areas that require concurrent estimations of local growth rates. To mitigate the risk of financial failure, the bond market insists upon an "investment grade" analysis applying conservative assumptions with extensive risk analysis. The recent trend towards equity participation by the private sector in toll road development mitigates this risk for the public sector, but the issue of forecast risk for toll projects still remains for the project developer.

The primary risk for any new road, bridge, or tunnel emanates from the source of future demand. If the traffic volumes forecasted to use the new facility are currently using parallel (and very congested) routes, the risks are lower. If, however, the future demand for the new facility depends on new development within the corridor or at either end, then investors regard the forecast volumes as much more speculative. Current analytical methods depend on forecasts from land use models that are often unavailable, expensive, data-intensive, and/or held in low regard outside of the planning community.

Should the project be unable to generate sufficient revenue, likely financial remedies could include increasing tolls, limiting access to alternative routes (e.g., with weight restrictions, metering, signal timing, speed restrictions). These responses call into question the public purpose of the project. For instance, if the project is intended to relieve congestion on existing routes, a toll regime that optimizes revenue could reduce the value of the congestion reduction objective. Conversely, a toll regime intended to optimize use of the new facility could increase the size of the public subsidy and alter the geographic incidence of who pays for the facility. It may be wise to anticipate such issues by considering the *Purpose and Need* statement for the project when developing policies related to toll amounts and public subsidies.

A second issue is the source of the public subsidy. Since particular areas or jurisdictions are likely to benefit more from the project than the State as a whole, it may be appropriate to consider how to generate some portion of the required subsidy from local government or private sector beneficiaries. Evaluation of these options can also benefit from carefully developed policy guidance.

6.2 New Tolled Managed Lanes

These facilities are usually constructed along side existing GP lanes. The three types of toll managed lanes are HOT, express toll, and truck only. The analytical methods most commonly used to evaluate all three applications are similar, but each has different challenges.

High-Occupancy Toll (HOT) Lane and Express Toll Lanes

HOT lanes may be created by either converting existing HOV to HOT, building new lanes and make them HOT, or converting an existing GP lane to HOT. Or, special toll lanes may be provided without HOV preference.

The primary policy challenge involves making sure that allowing low-occupancy vehicles to use HOV lanes does not degrade service levels for HOV and transit. If service is degraded, the potential policy options are to suspend the HOT operation, or increasing the occupancy requirements for HOV. The first option could lead to revenue shortfalls if those revenues are being counted upon to pay back project costs or subsidize transit service. The second option could engender some public outcry, if a significant share of the project cost was funded with public money. The reality is that if HOV traffic was at such a level that redefinition of HOV was needed, such a policy decision would be needed even if there were no HOT lane. However, when HOT lanes are under discussion, it is unlikely that the two issues could be disentangled, and the public may perceive that the HOV definition is being change to accommodate toll payers.

HOT lanes and express toll lanes present some interesting analytical challenges. The value of these lanes is based on minute by minute variations in congestion and travel time (or perceived travel time). Such variations are not handled well by traditional four-step travel demand models. Rather, more expensive and sensitive microsimulation models are needed to represent the operational characteristics of particular highways. Since the amount of traffic choosing to pay to use the special lanes changes the congestion levels in the nontolled lanes, the analysis procedures become particularly sensitive and challenging.

A particular analytical issue is quantifying the value of reliability and forecasting that reliability. Whereas recurrent delay is mostly predictable based on traffic levels, nonrecurrent delay is less predictable, but avoiding nonrecurrent delay can be even more valuable to travelers that need to be on time for appointments. The accuracy of analytical methods can have a critical role in determining the overall benefits of express toll lanes and the price sensitivity to tolls. The latter has direct consequences on the financial feasibility of funding an express toll lane.

The preferred analytical method for measuring the value of reliability is Buffer Index. The Buffer Index quantifies the extra time that travelers needs to build into their schedule to be very confident (e.g., 95 percent confident) that they are on time. An index number of 1.25 means that a traveler needs an additional 25 percent added on to the travel time in order to meet this on-time target.

One analytical challenge arises because the Buffer Index is calculated using average travel times from a travel demand model. Forecasting average travel times may be difficult for some highly congested corridors, and is subject to significant external market forces that often change future levels of traffic, including but not limited to the effects of business cycles on commuting and trucking and changes in land use.

Another issue is anticipating the needed design features for the safe and efficient operation managed toll lanes. Safe operation and, perhaps, high utilization of the lanes may require special drop-in ramps, wide shoulders, added enforcement, or other features that may add considerable expense over other alternatives, such as GP lanes.

Another challenge is developing an evaluation methodology for comparing special toll lanes to other available alternatives. Traditional usage of level-of-service or volume/ capacity ratios is no longer appropriate, given that the purpose of the special toll lane is to provide reliable performance to those willing to pay for it rather than overall facility capacity or throughput. Consequentially, it is necessary to compare the performance of alternatives in an economic sense rather than in terms of traffic performance. This implies the use of a benefit/cost analysis that incorporates the consumer surplus enjoyed by those using the special toll lanes, as well as the travel time savings of other users of the facility. Particular attention will have to be paid to the performance of the alternatives throughout the day and not just in the peak hour.

Truck-Only Toll (TOT) Lane

Most of the proposed TOT toll lanes involve constructing new lanes on an existing freeway that has heavy use by commercial vehicles. In addition to the analytical challenges noted for HOT express toll lanes, TOT lane evaluation must take into account the potentially significant economic benefits and disbenefits that come into play with goods movement. These benefits are driven by changes in the business costs of specific industries shipping goods through the corridor, changes in the attractiveness of the area served by the corridor to new business, and the potential for second-order effects to logistics of industries. The analytic tools available for evaluating these effects are very data intensive. The commodity flow data required, for example, is expensive and often inaccurate. The accuracy of the analytical methods themselves remains inadequate for measuring the full consequences of these economic and logistic effects. Last, attention must be paid to the higher construction and maintenance costs inherent in TOT lanes.

6.3 Toll Existing Corridors or Systems

Replacement Bridge as Toll Bridge

The evaluation of replacing an existing bridge with a tolled bridge is reasonably straight forward if the existing structure must be either replaced or shut down; although the same challenges described for more traditional projects also will come into play here. A more complex analysis would be necessary if the replacement structure expands capacity. As discussed for the analytical methods used for new toll roads bridges, and tunnels (Traditional Projects), the need for such additional capacity is straight forward if the demand exists today, but becomes much more uncertain if the increase in demand is dependent of future growth in the corridor.

When analyzing a brand new bridge as a toll bridge, all the traffic on the bridge will be new. The traffic may not as high as it would be if it were toll free, but it is all new. When converting an existing bridge to a toll bridge, the calculations are very different. People have built up their home-work-shopping lives around the fact of a toll-free bridge. When that equation changes, people will have to modify their travel behavior and make new choices – they can either continue to use the bridge and pay the toll, or avoid the toll. In some cases, they may be able to drive further and still make the crossing. In others, there may not be other crossing alternatives, in which case their choice may be to change their origin or destination so that they do not have to cross the bridge, or to eliminate the trip entirely. Both of these choices have important social and economic consequences that are difficult to forecast and to quantify. If the new toll rates are extreme enough, it could impact the home and work location choices of some of the population.

Convert Existing General Purpose (GP) Lane to HOT or Express Toll lane

The conversion of an existing GP lane to an ETL has the potential to create winners and losers. Drivers in lanes that were previously toll free will now be squeezed into the remaining nontolled lanes if they do not want to pay the toll. Flow in the priced lane will be faster and more reliable, and potentially even higher than before (since stop-and-go conditions pass fewer cars per hour than freely flowing traffic). People willing to pay will benefit. Those that are not willing may not. The overall benefit/cost may be positive, but one group may benefit at the disbenefit of another.

Another issue warranting policy attention is the use of revenues generated by the special toll lanes in excess of conversion and operating costs. If the toll receipts are used to fund new transit service in the corridor (currently not allowed in the State Constitution) in order to relive congestion and provide an alternative to paying a toll, then a forecast of mode shift to transit becomes critical to the project's evaluation. The forecast of transit mode shift would use a travel demand model that are more reliable when applied to a systemwide analysis of travel volumes but often less reliable when applied to multi-modal analysis within a specific corridor.

Convert Existing Freeway to Toll Way

Tolling existing freeways constitutes more of a fundamental change in governance than an individual project financing option. Policy rationales may include generating dollars, managing congested flow, or both. Either way, conversion from toll-free to toll is a significant departure from the status quo, and will have significant effects.

The key analytical questions will relate to: 1) the elasticity of demand – how will the public react to the tolls, which represent an increase in cash outlays; 2) the expected traffic diversion or other change in travel behavior resulting from the applications of tolls to a single facility; and 3) the resultant operational efficiency of the newly tolled facility and those that remain nontolled. A regional travel demand model will be the most likely tool used to evaluate the change in travel volumes and diversion to alternative routes, but such models have severe limitations.

These models make use of simplified models of traffic flow that assume standard relationships of speed, volume and capacity, but ignore some interesting departures from those relationships when flow is optimized. For example, a lane of freeway can typically handle about 2,000 vehicles per hour. However, when the demand exceeds capacity, the actual volume handled drops considerably, and is impossible to forecast accurately. The actual flow in super saturated conditions might vary from 800 to 1,400 vehicles per hour, meaning that a lane of traffic delivers fewer vehicles, not more. Regional travel demand models cannot account for this seemingly counter intuitive phenomenon. It is difficult enough for transportation professionals to understand this phenomenon, and even more difficult for the general public.[6]

Aside from the impact on travel time on a particular highway, it is not inconceivable that the application of tolls to a single facility results in an increase, not decrease, in either overall systemwide hours of delay or VMT as motorists divert to longer and similarly congested routes to avoid paying the toll. This diversion may result in even broader economic consequences as certain locales become less attractive due to higher access costs. Such ambiguous consequences point out not just the need for careful economic analysis of the tolling proposal but that similar attention is paid to the policy objectives behind it. As discussed above, proposals with large unintended consequences will mandate consideration of alternate approaches to tolling, if not the importance of the policy objective itself.

The public perception of such proposals can be expected to hinge heavily on the use of the revenues generated. If more people can be expected to be made worse off from the tolls, public acceptance will have to be based upon the belief that society in general is improved, which in turn can only be demonstrated through a highly regarded use of the toll receipts. Achieving such a threshold of political legitimacy becomes even more critical given that the likely traffic diversion from tolling a single freeway effectively precludes significant environmental benefits.

Cordon or Area Pricing Around or Within a Defined Area

Unlike tolling on specific corridors, this application has not been widely analyzed and pushes the boundaries of even the state-of-the-practice travel demand forecasting tools. Foreign experiments in cordon pricing have been analyzed using a variety of tools with mixed results. Even if the direct effects of cordon pricing on travel behavior could be forecast accurately, the first and second order effects of this behavior on retail sales economic growth, land values, development patterns and induced residential growth, to name only a few of the possible effects, remain well out of reach of current analytical methods.

The second-order economic effects on property values, tourism, retail sales, and job creation exceed the analytical capabilities of all but the most sophisticated economic modeling tools. But many stakeholders would insist on some analysis of how cordon pricing would change shopping patterns and affect retailers. The methodology used to quantify the effects on a central business district (CBD), for example, may need to measure effects on business attraction, property values, wages, occupations, output, employment, personal income, and other economic metrics. Furthermore, these stakeholders would push for mitigation of potential disbenefits such as adapting time-of-day pricing to shopping patterns (e.g., charge-free window during off-peak periods, adjusting the end of the tolling

[6] See "The $1,000 MacDonald Challenge" at: http://www.wsdot.wa.gov/Traffic/Congestion/Rice/Default.htm.

period). Other strategies would include discounts or suspensions of tolling on target weekends or certain seasons that correspond with periods of relatively low congestion and relatively high retail activity. Finally, some merchants may demand that tolls could be redeemed or pro-rated against purchases at stores, restaurants, entertainment venues, etc. All of these would affect toll revenues and travel patterns and would need to be evaluated.

Convert a System of Freeways to Tollways within a Defined Area

Most of the analytical challenges likely to be encountered in an area-wide conversion of freeways to tollways have been discussed in the previous applications. Nevertheless, the analytical challenge of forecasting long-term land use adjustments would become even more important for this application. A system of tolled freeways within an urban growth boundary may generate a variety of unintended consequences. These could include urban sprawl beyond the boundary, increased density in some neighborhoods, significant increases in land values within the boundary, relocation of some businesses from inside to outside the boundary and visa versa. In other words, tolling's expected effect on travel patterns throughout the urban area will generate broader, and analytically more challenging, second order effects as those discussed under cordon pricing. The enormous sunk cost investment in commercial and residential real estate in an urban area is likely to dictate the need for a high level of understanding of these second order effects.

7.0 Lessons and Conclusions

7.0 Lessons and Conclusions

This report is intended to help planners and policy-makers be clear about the objectives that tolling is trying to achieve. As demonstrated, there are numerous potential objectives – tolling is no longer just about raising money to build a road. Once the objectives are clear, it is important to understand the potential stakeholders (winners and losers), and then craft an evaluation to show how these stakeholders might be affected. The report demonstrates that these relationships are not always obvious and take some thought.

The report also considered each potential generic tolling application and considered how this application might help carry out one of the potential objectives. In some cases, the potential benefits are clear. In others, there is a tenuous connection between the application and the objective, meaning that further evaluation is warranted. In all cases, the specifics of an individual application could change the calculations, so the evaluation of generic applications should be used with caution.

The evaluation of winners and losers is important, because individuals, communities, and interest groups will make evaluations on their own. Since tolling is new to Oregon, they may not have good information. This means that while technical analysis is important, the communication of that analysis is just as important.

Gaining a useful understanding of the public's perceptions of tolling as a solution is an interesting challenge. As has been illustrated above, people are likely to make quick judgments about tolling before having the time or patience to understand a specific proposal. This dynamic plays against honest efforts to move projects along quickly, because if people do not understand something, or understand it incorrectly, they are more likely to reject it. These considerations will be important as Oregon advances its understanding of how tolling might fit into the future of transportation in the State.

Appendix A

Glossary

Appendix A. Glossary

Congestion pricing	A type of road pricing where the specific objective is to manage congestion.
Elasticity	The price elasticity of demand (PED) measures the nature and degree of the relationship between changes in quantity demanded of a good and changes in its price. When the price of a toll falls, the quantity drivers demand of the access typically rises – if it costs less, drivers will use the toll facility more, all other conditions being equal. Most higher income drivers will be price inelastic (i.e., they will not be deterred from paying a higher toll) and low-income drivers will be price elastic.
Express Toll Lane (ETL)	A type of managed lane where all vehicles must pay a toll.
High-Occupancy Toll Lane (HOT)	A type of managed lane where vehicles may use high-occupancy vehicle (HOV) lanes even if they do not conform to the HOV definition, for a price.
High-Occupancy Vehicle (HOV) Lane	A type of managed lane restricted to vehicles with multiple occupants. The requirement for number of occupants might vary from location to location.
Managed lane	A lane or lanes designed and operated to achieve stated goals by managing access via user group, pricing, or other criteria. A managed lane facility typically provides improved travel conditions to eligible users.
Nonrecurrent delay	A type of highway delay that occurs because of incidents, and is therefore not as predictable as recurrent delay.
Pricing	A specific kind of tolling where the level of toll (or price) is used to change travel behavior. In the context of this report, "road pricing".
Public good	A good or service provided by government for use by everyone.
Recurrent delay	A type of highway delay that occurs regularly, due to too much traffic and/or geometric constraints

Road Pricing	See "Pricing".
Tolling	Charging a price to use a road, bridge, or tunnel.
Travel time reliability	A measure of variation in travel time from day to day.
Truck Only Toll Lane (TOT)	A type of managed lane that is open only to trucks, where trucks pay a toll.

See http://mutcd.fhwa.dot.gov/rpt/tcstoll/glossary.htm for definitions of other terms regarding tolling not used in this report.

Appendix B

Literature Review

Appendix B. Literature Review

■ Introduction

This literature review summarizes the recent advances in the economic impacts of tolling. We have organized the literature review according to six topics of interest within the broader subject of the economic effects of tolling. Within these six topics, we investigated specific subtopics that were most relevant to this study's broader subject. These six overall topics and their subtopics are:

Trends in Tolling

- Tolling Background and History;
- Definition of Key Terms;
- Current Trends in Tolling Applications;
- Recent Innovations in Tolled Managed Lanes;
- Cordon or Area Pricing; and
- Conclusions: Tolling Opportunities and Constraints.

Analysis of Economic Effects of Tolling

- Impacts of Tolling Options; and
- Evaluation Procedures for Toll and Nontoll Projects.

Toll Elasticity

- Factors Affecting Price Sensitivity; and
- Pricing Strategies and Responses.

Environmental Effects of Tolling

- Potential Impacts of Tolling; and
- Evidence from Studies.

Value of Time

- The Basis for Valuing Time;
- Values Commonly Used in Transportation Studies;
- Variations by Trip Purpose and Other Factors;

- The Value of Travel Time Reliability; and
- The Value of Time for Commercial Traffic and Goods Movement.

Trends in Tolling

Tolling Background and History

Tolling has been used for centuries to finance highways. For example, early road building in the United States relied heavily on private, profit-seeking entities, and the historical remnants of these early turnpikes can be seen in the numerous roads with the "turnpike" moniker. The earliest turnpike in the United States was the Philadelphia and Lancaster Turnpike Road, built in 1795. These early turnpikes ultimately failed, as more efficient canals and then railroads were developed in the mid-1800s.

It was not until the popularization of automobiles in the early to mid-20th century that toll-backed financing gained renewed popularity. Starting with the Pennsylvania Turnpike in the 1930s, state after state embarked on building intercity highways using toll revenue bonds. For the most part, these new highways were developed by special purpose authorities and were financed with bonds backed by the anticipated toll collections. This era of turnpike building extended into the 1950s and early 1960s, but was mostly extinguished by the advent of the Interstate Highway System begun in 1956. Though some of these early turnpikes paid off their debt and removed their tolls, most still operate as tolled facilities, since the need to upgrade, expand, and extend could be funded through continuing toll collection on the original facilities.

The late 1970s and 1980s saw another revival of the toll financing concept, this time focusing on urban expressways in a few fast-growing areas, where traditional revenue sources were inadequate to meet growing traffic demands.

In the 1990s and continuing into the early part of the 21st century, toll facility development continued, this time enhanced by the promise of electronic toll collection to reduce or eliminate the delays commonly associated with traditional toll roads. Electronic toll collection also opened the opportunity for new concepts in tolling, such as high-occupancy toll (HOT) lanes, express toll lanes, truck only lanes, cordon tolling, and mileage-based pricing. Innovations are proceeding at a pace, whereby, it soon may be technically feasible to toll a broad spectrum of other roads, using global positioning satellites (GPS) or roadside short-range radio methods. Though the more recent activity has been more widespread than that in the 1970s and 1980s, tolling continues to be a solution primarily being done by a few states with intense traffic needs.

The advent of electronic toll collection has broadened the potential policy rationale for tolling. Whereas, the historical use of tolling has been to fund high-cost projects, it can now be used to manage congestion on a network with limited capacity. Economists have long argued that using flat user charges (the gas tax) does not reflect the true value of highway travel under congested conditions. Using price to manage demand is used in the airline, hotel, and telecommunications industries, to name a few. With electronic tolling, it can now be used in the highway industry, and many regions are starting to move in that direction.

Among the general population, tolling continues to be seen strictly as a means of raising revenue. Among practitioners, there is growing awareness of the opportunities to use pricing to manage demand or system effectiveness. Since pricing for system management is still in its infancy, there are still many uncertainties surrounding how price might impact different population groups, congestion levels on priced and nonpriced facilities, land development patterns, and economic competitiveness.

Definition of Key Terms

There are a variety of terms used to describe the different types of tolling projects in use around the country, and everyone using them does not necessarily use the same terminology. As such, we have provided these definitions as they will be used in this report:

- **Tolling –** This involves charging a direct fee to use a highway, bridge, or tunnel (generically referred to as a "highway" or "toll road" for this report).
- **Pricing –** A subset of tolling, pricing focuses on the use of tolls to manage traffic demand, with revenue generation being a secondary objective. Various adjectives are sometimes used to modify the term pricing: variable, congestion, and value. They all essentially mean the same thing: varying the toll charged based upon the time-of-day, day-of-week, and/or real-time traffic conditions in order to appropriately manage traffic. Pricing can be applied to traditional toll roads, bridges, tunnels, or designated highway lanes (i.e., managed lanes as defined below).
- **Traditional Toll Road (or Bridge/Tunnel) –** A highway that requires toll collections from all drivers (usually with the exception of emergency vehicles). Typically, those tolls are used to support operations and maintenance, as well as to pay debt service on the bonds issued to finance the toll facility. The toll rate does not vary by time of day or day of week. Tolls may be collected at a flat rate at toll plazas, or based on distance traveled using tickets, electronic transponders, or video recording of license plates. Many existing traditional toll roads are converting to some form of electronic toll collection, and most new toll projects incorporate the option to pay electronically.
- **Managed Lanes –** Any type of highway lane that is set aside for special use. A managed lane could be a traditional high-occupancy vehicle (HOV) lane (i.e., a lane restricted to vehicles that carry 2+ or 3+ passengers), a truck-only lane, or a bus-only lane. More recently, managed lanes also may refer to highway facilities for which tolled lanes are adjacent to free lanes. Drivers have the option to either pay the toll and use the toll lanes (to take advantage of travel time savings), or use the toll-free lanes instead. HOVs, transit buses, and motorcycles often are allowed to use the toll

lanes at no charge. The appropriate toll amount may be determined according to actual real-time traffic volumes.

Current Trends in Tolling Applications

There are several current trends in the planning and development of new tolling projects, as discussed below.

Existing Systems Leveraging New Capacity

Regions with successful and mature toll roads have a significant advantage when trying to develop new toll projects. Historically, many of the nation's toll roads were developed using revenue bonds, which meant that projects needed to generate enough revenue to cover debt service in the early years. However, once they got through these early years (sometimes with the help of general obligation guarantees), they quickly became money makers, and had excess revenue. Depending on the enabling legislation or relevant bond documents, this excess revenue from the existing system often could be used to subsidize extensions or entirely new toll projects. A few recent examples of new toll projects being developed using system financing or guarantees are highlighted below.

In Texas, toll road authorities in both Houston and Dallas have continued to build new facilities backed by revenue streams from existing systems. In Dallas, the Metroplex Toll Financing System (MTFS) allows the Texas Department of Transportation (TxDOT) and/or the North Texas Tollway Authority (NTTA) to make toll projects available for investment by other entities that would then receive returns on their investments, as well as benefit through accelerated project development and completion. Candidate MTFS projects would be those toll projects that can reasonably be expected to generate toll revenues beyond the level necessary to pay debt and expenses. These candidates could be designated MTFS projects and represent an opportunity for local entities to partner in the investment, thereby, sharing in any surplus revenues generated by the toll project. For example, if City A were to contribute 10 percent of the funding for Project X, then that city would receive 10 percent of the surplus revenues from Project X. This surplus revenue could provide an ongoing funding source for the city to use in other transportation projects. In keeping with the premise of regional project support, first choice to invest in a MTFS toll project would belong to those cities and counties directly affected by a project. Contributions are not limited to cash, but include donated right-of-way, design, or other contributions to the value of the total project.

Also in Texas, the **Texas Mobility Fund** is a revolving fund that is designed to back bonds that are pledged towards the construction of highway projects. The proceeds from the sale of these bonds could be used to finance construction on state-maintained highways, publicly owned toll roads, and any other project that is eligible for the State's Highway Fund.

Other examples of using leverage from mature systems include:

- Florida's Turnpike and other agencies in Florida have built extensive systems of toll projects by using established revenue streams from earlier projects;
- In Massachusetts, excess revenues from the Massachusetts Turnpike Authority, obtained from toll increases, have been used to help close the funding gap in the Central Artery/Tunnel project, most of which is untolled; and
- In New York City, the MTA uses toll revenues from its bridge and tunnel crossings to subsidize its transit operations.

Leveraging the revenue of an existing system can create concerns about interregional and intraregional equity. People may not always be willing to have the tolls collected on "their" part of the system used to support projects on a part of the system that they do not use.

Startup Traditional Toll Facilities

Many regions are turning to tolling to enable construction of limited access highway projects (or bridges/tunnels) that are not being funded through general funding mechanisms. When funding highway projects on a pay-as-you-go basis, it can often take years or decades for enough dollars to be available to pay for a project. With tolling, the dedicated future revenue stream can be bonded, enabling the project development to be accelerated. Recent projects are being developed through the public sector, as well as through public-private partnerships.

Public Sector

Historically, toll roads were developed by special purpose public authorities that raised capital, either through the sale of nonrecourse revenue bonds backed by toll collections. With nonrecourse bonds, shortfalls in toll revenue could result in default. These bonds were used in most of the major eastern toll roads, such as the Massachusetts, Pennsylvania, and New Jersey turnpikes. In some cases, projects mitigated some of the default risk with backup pledges from government, either through general obligation bonds (where state or local governments pledged tax revenues to make up for any revenue shortfalls from tolls), or limited obligations of specific revenue sources (such as gas taxes).

In the mid-1980s, the toll road system in Harris County (Houston), Texas, was financed with bonds backed by both toll revenues and a general obligation pledge of the County. Likewise, in the mid-1990s, the E-470 Public Highway Authority developed a startup toll facility in the Denver region with partial support from a regional vehicle registration fee.

In contrast, the Foothill/Eastern and San Joaquin toll roads in Orange County, California, were developed by two public authorities (one for each corridor), largely through the use of nonrecourse toll-backed debt.

For some projects, a combination of factors led to toll revenue in the early years to be considerably lower than forecast. Both Houston and Orange County toll road systems opened in the midst of severe economic recessions. This resulted in both financial and public relations difficulties. The E-470 project, in some ways, was the most speculative, as it was heavily dependent upon future traffic growth that would result from development spurred by the road itself. However, the risks inherent in the project were mitigated somewhat by both the pledge of the vehicle registration fees and the funding of deeply subordinated loans by the state DOT and local governments.

It is becoming increasingly difficult for new standalone projects to be self-supporting without revenue pledges from other sources (either nontoll or existing, mature toll facilities). This is probably due to the higher cost of road development. The rates on the Harris County system are about $0.08 to $0.14 per mile, while those on the Orange County projects are $0.13 to $0.23 per mile and the Denver project is $0.18 per mile. By comparison, the toll rate on older, established facilities is much lower: the Illinois Tollway charge has been $0.03 per mile until recently, and the toll rate on the New Jersey Turnpike is $0.04 per mile. Rates on these older facilities have not had to keep pace with inflation.

Public-Private Partnerships

The mid-1990s brought greatly increased interest in the role of public-private partnerships (PPP) in the development of toll facilities. The interest in PPPs for this study is limited to situations where the private sector is responsible for contributing some or all of the capital needed to build a project. This may be contrasted with the *governmentally funded* design-build projects. In design-build projects, the private sector takes responsibility for delivering a project for a fixed price and a fixed date, but the funding ultimately comes from public sources such as taxes (Federal, state, or local grants or tax-supported bonds). For PPPs, where the private sector contributes capital, the level of private involvement varies considerably from project to project. For example, the Dulles Greenway project in Virginia and the Camino Colombia project in Texas were actually owned by private investors. Other PPPs have made use of 63-20 corporations, where ownership of the project resides in a publicly appointed nonprofit corporation, such as the Greenville Southern Connector in South Carolina and Pocahontas Parkway in Virginia.

All of these toll PPPs have struggled in their early years, with the Greenway project requiring restructuring of its debt, and the Camino Colombia project recently going bankrupt and closing. The Camino Colombia project was recently bought by TxDOT for less than one-quarter of its construction cost and has been reopened.

Many other attempts at developing toll roads as PPPs have failed or been derailed, due to adverse public reaction or the changing needs of the public sector. In recent years, potential public-private toll road projects in Minnesota and Arizona were canceled. The Tacoma Narrows Bridge project in Washington started out as a PPP, but was converted to a traditional, publicly financed toll bridge after public protest over the private sector profiting from a public project. In Chesapeake, Virginia, the Chesapeake Expressway went through its development process with the intent of being financed and operated through a 63-20 corporation, but ultimately, the project ended up being developed and owned by the

City of Chesapeake, since much of the risk that was to have been transferred to the private sector had been reduced through the project development process.

Developing toll projects as PPPs is still in its infancy in the United States, with techniques and legislation evolving.

Recent Innovations in Tolled Managed Lanes

The advent and rapid advancement of electronic toll collection technology allows for tolling to be applied in ways that were not possible a decade ago, making tolling faster and more convenient for both the drivers and the operating agency. In addition to the increased convenience to toll-paying customers, electronic toll collection allows for pricing to be used for traffic management purposes in addition to, or even instead of, revenue generation.

Some of these new concepts have been implemented, while others are the subject of proposed legislation or policy discussion. The focus of this working paper is on these recent innovations in tolling, which have primarily been new or enhanced tolled managed lane applications. There are several types of such applications described below.

HOT (High-Occupancy Toll) Lanes

HOT (High-Occupancy Toll) lanes grew out of the recognition that some traditional HOV lanes were underutilized. HOT lanes allow a single-occupancy vehicle (SOV) to pay a toll to use HOV lanes that have excess capacity. Three HOT lane projects were developed in the mid-1990s: SR 91 Express Lanes, I-15 HOT Lanes, and Katy Freeway QuickRide. In May 2005, the first MnPASS lanes on I-394 in Minneapolis opened to traffic, and the I-25 HOT lane is due to open in Denver this fall. Each of these is described below.

SR 91 Express Lanes

This was the first PPP to emerge in California, and involved the construction of four new express lanes (two in each direction) in the median of the heavily congested SR 91 freeway that connected homes in Riverside County to jobs in Orange County. The express lanes were about 10 miles long, and provided only one entry and exit point at each end. Toll rates were set based on historical traffic information to ensure free flow of traffic, and were intended to maximize revenue for the owner/operator, while maintaining a high level of traffic flow. The project combined innovations in PPPs (design-build development, private operations) with innovations in tolling (variable pricing and all-electronic collection).

The California Private Transportation Company operated the project as a business, focusing on customer satisfaction. They provided such a high level of emergency/safety surveillance that some drivers chose to pay to use the toll lanes even during periods when there was no congestion on the adjacent free lanes. The company also frequently surveyed customers to enhance the customer experience.

The project was an unqualified success. The typical customer used the facility once or twice a week (rather than everyday), but felt as if they received value for the money they paid when they needed to avoid congestion on the adjacent free lanes.

Over time, however, the project came under increasing criticism, especially from commuters residing in Riverside County. A clause in the franchise agreement entered into between the company and the California DOT (Caltrans) limited Caltrans' ability to provide capacity enhancements that competed with the HOT lane project (a so-called "noncompete" clause). Ultimately, the project was sold by the private developer to the Orange County Transportation Authority (OCTA) for a profit. OCTA is moving forward with the capacity enhancements, and has modified the tolling policy to increase traffic flow at lower toll prices.

I-15 HOT Lanes

Around the same time, the San Diego Association of Governments (SANDAG) moved forward with a demonstration project funded in part from the Federal Highway Administration's (FHWA) congestion pricing pilot program (now called value pricing). The project involved conversion of the existing reversible HOV lanes to about eight miles of HOT lanes. Toll prices are set dynamically, meaning that the traffic volume on the HOT lane dictates the toll price, changing every six minutes to keep traffic at free flow in the HOT lane. This project is not a private venture, and the upfront capital costs were not extensive since the lanes already existed. The only costs were for toll collection and enforcement. Excess revenue from the project is used to support improved transit service in the corridor.

Katy Freeway QuickRide

Another variety of HOT lane project was built in Houston, where an existing reversible single-lane HOV lane was modified to increase the number of drivers using the lane. On the Katy Freeway, HOVs were defined as cars with three or more people during certain peak hours. With the QuickRide program, HOVs with two or more could pay to use the HOV lane during those hours. Use of the lane is by subscription only, and the lane has a few hundred paying customers a day. The program was extended to the U.S. 290 reversible HOV lane in 2000 (for the a.m. period only).

I-394 HOT Lane (MnPASS)

The first HOT lane to open for quite awhile just opened recently in Minneapolis, where the existing HOV lane on I-394 was converted to a HOT lane. The project extends for 9 miles in one direction (11 in the other), with part of the project a single lane in each direction, and the remainder two lanes reversible. I-394 is different from previous HOT lane projects in these ways:

- Most of it is a single lane in each direction, with only a double-white stripe separating the HOV/Toll traffic from the general purpose traffic.
- There are zones where there are breaks in the striping to allow drivers to enter or exit the facility. This is in contrast to the single on- and off-points on previous projects.
- There are two tolling zones, and prices change dynamically every three minutes, based on traffic density in the HOT lanes. Drivers are shown the price to use either one or both tolling zones at the beginning of their trip, with the price at entry guaranteed, regardless of any price changes by the time they get to the new section.
- Enforcement of the HOV and tolling is done by roving patrol vehicles. Some patrol cars are equipped with enforcement transponders that allow them to query the transponders of vehicles in the toll lane that do not have more than one occupant.

The project is still new, but early indications have found that about 4,000 people per day use the facility, and that the buffer-separated design is generally being heeded by the public. The algorithms that modify the tolls have been found to be very sensitive to short-term variations in traffic density that result from the "platooning" or grouping of vehicles behind slower vehicles (particularly buses); alternative approaches are being studied. A recent study by a television news team found that the HOT lane saved about an hour of time over the course of a week's worth of commuting at a cost of about $12.00.

The HOT lanes originally ran for 24 hours a day; whereas, the HOV lanes they replaced only operated during peak hours in the peak direction. However, this has now changed, such that the traffic in the nonpeak direction is allowed free access to the HOT lanes. This is because traffic conditions in the general purpose lanes were found to worsen with the take away of the previously nonrestricted HOV lanes.

Early findings also are that the lanes are not generating enough revenue to cover operations expenses. This may be due to the change in hours of operation described above.

I-25 HOT Lane

The I-25 HOT Lane Project in Colorado opened in spring 2006. This project was a conversion of the existing I-25 HOV facility. State law currently maintains free access for HOV2+, motorcycles, Inherently Low-Emission Vehicles (ILEV), and hybrids. Colorado DOT currently is seeking a change in state statutes for the hybrids to become tolled. The important constraints on this project are as follows:

- The full funding grant agreement between the Federal Transit Administration (FTA) and the Regional Transportation District (RTD) specifies that net revenues must go to transit;

- Bus travel times take precedence over all others using the facility, meaning that the addition of SOV traffic should not impact bus operations; and
- Entering and exiting loading constraints for the facility into the downtown Denver grid network mean that the pricing for this facility will be on a published toll schedule to be updated periodically, rather than with dynamic pricing.

The revenue priorities for this project are to cover operations, maintenance, enforcement, and rehabilitation. The project is not anticipated to generate additional net revenue within the first 10 years of operation.

Summary of HOT Lane Experience to Date

HOT lanes are not one-size-fits-all. Each of the five HOT lane projects developed to date has had different policy motives. The SR 91 project grew out of a desire to increase capacity in a heavily congested corridor, and provided a way for a private partner to develop the project motivated by profit. The I-15, I-394, and I-25 projects grew out of a desire to utilize spare capacity on the HOV lanes; I-15 and I-394 HOT lanes were also implemented out of a desire to cross-subsidize transit service in the corridor. The Katy Freeway QuickRide program was a way to obtain more productivity out of underutilized HOV lanes during the hours when HOV2s were not permitted to use them.

Express Toll Lanes

As with HOT lanes, express toll lanes are situated next to regular highway lanes. The difference from the HOT lane concept is that with an express toll lane, all personal automobiles using them pay a toll – there are no exceptions made for HOV vehicles. However, transit vehicles and/or registered vanpools would usually be allowed to operate for free. While these lanes typically represent added highway capacity, existing toll-free lanes also could be converted to toll lanes. Express toll lanes also could be located adjacent to traditional toll roads, but employ variable pricing (based on time of day and/or congestion levels) to maintain free-flowing traffic.

The Tampa-Hillsborough County Expressway Authority recently opened three express toll lanes elevated over the existing Lee Roy Selmon Crosstown Expressway (a toll road), although tolls are the same as for the original toll road. The Miami-Dade Expressway Authority also has been studying a similar project on its SR 836 toll road. Express toll lanes also are being actively studied in Maryland, Georgia, and Minnesota.

Truck-Only Toll (TOT) Lanes

Truck-Only Toll (TOT) lanes have the potential to improve safety and increase productivity in the trucking industry. One concept is dedicated toll truckways for long-haul truck movements. The toll truckways would be built next to existing roadways, but would be barrier-separated from general traffic to improve safety. The toll truckways could potentially be built to withstand greater vehicle weights, thus, enabling a single truck driver to carry several times the payload than currently is permitted in most states. In theory, truckers would, therefore, be attracted to use the TOT lanes, because the toll cost would be offset by the additional safety and productivity. With the TOT lane concept, a single truckway lane would be provided in each freeway direction of travel, with frequent passing lanes and staging yards near cities or major highway junctions. The concept also could involve a rebate of fuel taxes for mileage spent on the toll truckways. Separating truck traffic from auto traffic also has potential safety benefits by separating vehicles with different operating characteristics into separate traffic streams.

TOT lanes have been studied in the Los Angeles region on SR 60 and I-710, both of which are heavily utilized by trucks accessing the Ports of Los Angeles and Long Beach. The preliminary Los Angeles region studies found that urban TOT lane facilities would need to overcome challenges that include truck trips of short lengths, limited travel time savings during off-peak periods, and significant construction costs and geometric constraints related to adding lanes in an urban environment. In 2002, the Virginia DOT solicited proposals from private entities for improvements on the I-81 corridor. The selected bidder, STAR Solutions, proposed the construction of TOT lanes on this corridor, but this proposal found significant opposition from the trucking industry. The final environmental impact statement (FEIS) was released in April 2007, and TOT lanes have been eliminated from the proposed improvements.

Another TOT lane concept involves urban corridors, which do not necessarily allow longer or heavier vehicles. Such a system of TOT lanes has been recently studied in the Atlanta metropolitan areas, with the findings that TOT lanes had a high potential for relieving congestion, potentially even more than HOV or HOT lanes. Some of the scenarios studied involved the conversion of existing and planned HOV lanes to TOT lanes. Such a policy would be unprecedented and be politically very difficult to implement. However, the study does point the way towards the potential for TOT lanes in dense urban regions with heavy truck demands.

Tolled Managed Lane Issues

Tolled managed lane facilities in their various forms are an exciting and promising mechanism to generate revenue, manage traffic congestion, and improve operational efficiency. Some members of the public continue to be skeptical with respect to paying tolls, particularly when toll-free alternatives are available. One of the biggest challenges with tolling involves creating a common understanding of what is being proposed, and the policy or strategic basis for the particular proposal. Some of the key issues surrounding tolled managed lane concepts are discussed below.

All Express Toll Lanes Depend on Congestion

Express toll lanes, whether HOV are allowed in for free or not, depend on congestion to be successful. It is congestion that creates the value offered by a lane managed through pricing. If there is no congestion, there is no need for such a facility. This means that express toll lane solutions are best suited in corridors where there is little opportunity to expand capacity, and where the traffic management potential of toll lanes provides a benefit to all travelers at some time when their personal value of time is high enough to warrant paying extra to be somewhere on time.

Traffic Management Benefits of Toll Lanes Depend on Tolls Forever

Traditionally, people expect tolls to be removed once the debt to finance a facility has been paid off. In the case of express toll lanes, the value of the project depends on the tolls staying on. It is the tolls that create the traffic management benefit, and that benefit will be lost if tolls are removed. This leaves the question of what should be done with the money collected by tolls on a managed lanes system.

Revenue Productivity

How much of the capital cost of a highway improvement can a toll lane project generate? Can it produce excess revenue to subsidize other highway or transit projects? There is a tendency to think that tolling projects can be big revenue generators, but in fact there are likely to be very few applications for which tolling could be fully self-supporting, except for projects that simply involve a conversion of existing general purpose lanes to tolling lanes. The success of express toll lanes depends largely on congestion levels in adjacent lanes. In most metropolitan areas, such congestion only lasts for an hour or two during morning and evening rush hours – typically not enough to pay for an expensive infrastructure project. In addition, the sections of highway with the greatest need for capacity expansion are often the ones with the most geometric constraints – meaning that the upfront design and construction costs will be high. Increasingly, pricing projects are being considered for their potential traffic management capabilities, regardless of their ability to fund new infrastructure construction.

Policy Justification

It is important to clearly articulate the policy rationale for considering a tolling project. One rationale might be to simply provide a supplemental revenue source to enable a project to be built sooner than it would otherwise. Another might be to provide a congestion-free alternative in places where "building your way out of congestion" with conventional freeway lanes is not possible. Whatever the policy objective is for a particular project, it must be clearly articulated and justified for both decision-makers and the public in order for a new tolling project to be approved.

Equity

Equity considerations may emerge in public discussions, including "Lexus Lane" concerns (i.e., providing a highway lane that is only affordable to the wealthy) and geographic concerns (i.e., why travelers must pay a toll for certain parts of the transportation network, while other parts have no tolls). In some cases, the public also has expressed concerns about the private sector being in the business of collecting and setting tolls for a profit. They may not understand why, if the private sector is able to make a profit on such projects, the public sector does not simply develop the project on its own.

Implementation

Implementing new tolled managed lane projects often have particular challenges. For example, how would cars get in and out of the lanes - any time they want, via special ramps, or with merge/weave zones? Would tolling just happen during peak periods or all day? How would safety be affected? What happens if an accident blocks one or more tolled managed general purpose lane(s) for some period of time?

■ Cordon or Area Pricing

Cordon or area pricing is a relatively new concept; whereby, vehicles are charged a toll to enter a highly congested area, or to travel within that area. The concept has been in use in Singapore since 1975, and recently enacted in the central business district portion of London. The concept in London originally involved a flat toll of £5 (later increased to £8) to drive within the priced area during normal business hours. The toll has resulted in a significant reduction in congestion, with the revenue being used to subsidize additional transit services. Generally considered a success, the London cordon charge was recently expanded to a larger area.

In 2006, Stockholm, Sweden entered into a seven-month trial of a cordon tolling; whereby, a toll of less than $3.00 was charged to cross the cordon line (in or out), with a maximum daily charge of about $8.00. Money from the toll went to pay for enhanced transit service. After the seven-month trial, the concept was halted, and a nonbinding referendum was held on whether to continue. The cordon toll was quite popular with residents in the City of Stockholm itself, and less popular with those from the suburbs. The government in Sweden has decided to make the cordon toll permanent in July 2007.

One of the key drivers of success in both of these pricing implementations was that transit availability and use were extremely high even before the tolls were enacted. Therefore, improvements to transit service were not difficult to accomplish, and it was relatively easy for drivers to switch to transit when faced with increased driving costs. With the exception possibly of New York City, such conditions do not exist anywhere in the United States.

Conclusions: Tolling Opportunities and Constraints

The use of tolling in numerous forms is under intense consideration in many regions of the country. Some states and regions have been successful at advancing the idea that tolls can be used to finance desired highway improvements, while others have struggled to advance proposals beyond the discussion phase. This section explores some of the lessons learned from recent toll project development activities, and the opportunities and constraints for such activities in the future.

Underlying Conditions

Leveraging Existing Toll Facilities Provides a Head Start

Regions that have existing toll assets have an advantage over those just starting out, because they have the ability to leverage the revenue stream from the current facilities. The ability to provide system financing (i.e., apply excess revenues from other parts of the toll enterprise) or to provide loans or seed money provides new projects in such communities a "head start" over other areas. Areas with existing toll facilities also have a head start on the public relations and political battles regarding the use of tolls in the first place.

Heavy Traffic Congestion Breeds a "Last Resort" Mentality

Places with intense traffic congestion have a greater incentive to move to tolling than those that do not. Especially in areas with rapid growth, traditional public funding is often inadequate to keep up with traffic needs. Often tolling is a way to advance a project that cannot be afforded for 10 or 20 years. Where congestion is not as pressing an issue, communities may make the choice to wait the extra time for the desired highway projects.

Political Champions Needed

It usually takes an elected official to champion a particular toll project. Without the benefit of an elected champion, projects are less likely to advance.

Electronic Toll Collection Removes One Big Objection

Many people still equate toll roads with congestion at toll booths. With electronic toll collection, most new toll projects are able to offer highway-speed toll collection facilities, which eliminate this objection.

Expectations vs. Reality

It is rare for a startup toll project to be able to be fully self supporting without some kind of credit enhancement or financial contribution. The difficulty of startup toll projects has been demonstrated repeatedly around the country. Various factors contribute to this reality:

- Development costs are high, especially in congested urban areas.
- Projects being built in anticipation of (or to accommodate/encourage) future development are inherently risky. Although development costs in these areas may be lower, potential revenue from traffic also is likely to be more speculative. High population and employment growth rates over extended periods of time are no guarantee of future continuation of such trends. Indeed normal trends in the business cycle might lead to a situation where the high growth that leads to the pent up demand for a startup toll road stalls by the time the road opens, thereby, impacting early year revenues from a project.
- The full and timely payment requirements of traditional municipal bonds set a high bar for feasibility. Credit enhancements that give projects time to mature are likely to be critical for most projects to be acceptable to investors.
- Administration and efficiency of toll collection are relatively easy, especially with the implementation of electronic toll collection.

Attempts to mitigate these factors also may exacerbate the toll facility's financial problems in later years. For example, the San Joaquin Hills toll road was built in anticipation of a continuation of intense traffic growth in Orange County. The debt service was structured so that early year payments were lower, but later year payments were higher. The financing also assumed toll rate escalation over time. When growth stalled in Orange County at the opening of the toll road in 1997, the agency struggled to make debt service payments. In traditional financings, this early year pressure ultimately would ease, as traffic grew sufficiently to meet a level debt service payment schedule. However, in the case of the San Joaquin Hills toll road, since debt service increases over time and toll rates increase over time, traffic never really had a chance to catch up.

The growing acknowledgment of traffic uncertainty in the ramp-up period is being reflected in recent initiatives in the various states. The Florida and Texas case studies show that the states are willing to contribute to the development and early year support of new toll projects. Colorado allows state and local support for toll projects up to 10 percent of the cost (and is exploring how it might incorporate Federal assistance).

Recent activities with FAST lanes projects are recognizing that such projects are unlikely to be self supporting. In Minnesota, a PPP program designed to attract private partners initially anticipated 100 percent private funding; however, over time, the financial realities of such lanes have migrated that thinking toward "how much" the public subsidy will need to be.

Outlook

Whether, where, and how to use tolling to fill gaps in funding for expansion of highway infrastructure comes down to how different regions treat the financial, philosophical, and political questions that toll financing entails.

Questions

1. Should funding for building or expanding corridors be paid from general fuel tax revenues (general user fees), or from user fees generated in the corridor (tolls)?

Texas has all but made the policy decision to fund new limited-access highway capacity at least partially through tolls. A number of states may be creeping towards that idea, and yet others are not ready to embrace such policies. An important consideration in this question has to do with equity between corridors or regions. Should one corridor be expected to pay its own way, while others benefit from traditional DOT revenue streams? When DOTs do provide backstop financing or seed money, how can they ensure equity around their states?

Such issues are not new and are not limited to toll finance. When projects are funded with general user fees, the same issue of social equity must be dealt within the intrastate distributions of public funds. With projects that are partially funded by tolls, another equity issue that arises is related to double taxation – if drivers are paying gas taxes, why should they have to pay again with tolls? If they pay tolls, are they entitled to a rebate on gas taxes? The Massachusetts Turnpike, for example, offers rebates on fuel taxes for drivers that provide documentation of using the Turnpike. Ultimately, the answers to these questions are political, but there are potential answers to why tolls may not be double taxation. For instance, most new toll facilities will not be self-supporting from tolls for many years, and the fuel taxes cover the costs not paid for through tolls – thereby allowing the project to be built and provide mobility benefits earlier than with tax-only projects.

One key difference between discussions of toll finance today and a decade or two ago revolves around government involvement. Federal policy still prohibits tolling the Interstates (with the exception of a few pilot projects). States are beginning to realize that they need to play an important role in project finance if new projects are to succeed, and are more open to supporting projects financially through a combination of toll and other tax-based revenues. For example, the Chesapeake Expressway in Virginia is a tolled facility, but state policy-makers recognized early on during project development that it could never be self-sustaining. The State contributed public funds to cover 75 percent of the total capital costs.

2. To what extent should projects have to be self-sustaining?

It is much easier to finance a new toll project if there is an existing stream of revenue from a mature project to provide a source of funds for pooled financing. Such cross-subsidies, while financially desirable, can bring out interregional and intraregional concerns regarding the allocation of scarce dollars. Geographic equity concerns increase based on the size of the funding transfers from one part of the system to another. As noted above in the Dallas/Fort Worth region with the Metroplex Toll Financing System, carefully crafted agreements are possible.

3. What role should the private sector play in developing projects?

Public-private partnerships typically bring innovation, risk transfer, and accelerated completion to the project development process. If the project is financed with toll revenue bonds, PPPs can help structure the debt financing so that it avoids state borrowing limitations. They allow states to avoid debt cap limitations. However, the price of private involvement can include a real or perceived loss of public control. The successful SR 91 project in Southern California is an example where the public gave up control over toll setting and improvements to competing routes, with the ultimate result being a perceived need to buy out the private involvement. Washington and Virginia also have backed out of potential PPP deals to some extent motivated by issues of control. Though not a U.S. project, the current lawsuit in the Province of Ontario between the private owners of the Highway 407 ETR in Toronto and the government over who has the right to set toll rates is a telling example of privatization issues.

4. Are toll lanes an appropriate response to traffic congestion in urban areas?

Toll lanes provide an interesting response to a difficult problem. The conventional wisdom is that "you can't build your way out of congestion," and indeed the increase in new lane miles has not come close to the increase in vehicle miles of travel over the last few decades in the United States. Toll lanes serve a dual purpose – they bring a funding source (tolls and possibly up-front capital from private partners), and the ability to manage demand through variable pricing.

The use of variable pricing to offer improved reliability to those willing to pay is a new concept in congested urban highways, but not new in other arenas, such as air travel and hotel pricing. It also has a long history in other public utilities, such as telecommunications and electricity. While the telecommunications industry has moved away from "congestion pricing" in recent years, and has embraced more of a flat-pricing model, this is because of intense competition among providers, and the fact that the telecommunications system now has lots of excess capacity – certainly not the case for highways.

In the constrained capacity environment of urban highways, using tolls to provide a measure of reliability to the public could be a creative compromise. Most people acknowledge that enough capacity cannot be built to ward off congestion problems. However using prices to keep lanes flowing, when people really need them, is a concept that might gain favor over time. The policy rationale for providing partial public subsidies for such toll lanes is fairly solid as well – when people pay to use the express lanes, they free up capacity in the "free" lanes, thereby, benefiting everyone. And when a particular traveler really needs the uncongested capacity in those cases where their own value of time is high enough to warrant paying the toll, they will be happy the lanes are available.

Express toll lanes are being advanced in several places right now, and time will tell the extent to which they can achieve political acceptance and achieve the objectives intended.

At current and anticipated future levels, the motor fuel tax will be inadequate to satisfy all the highway construction demands in areas where new highways are still needed. In most of the country, toll-revenue financed projects can be expected to be successful at closing some of this revenue gap in a limited number of locations where conditions are most favorable.

This is an April 2007 update of material prepared for the Washington State Comprehensive Tolling Study in October 2005.

Economic Effects of Tolling

This section summarizes the state of the practice in economic analysis of tolling. The sophistication and experience applying the various methods, however, has not advanced as far as it has for other types of transportation investments (e.g., capacity expansion, transit, Intelligent Transportation Systems (ITS), etc.). Furthermore, the full final report presents some of the deficiencies in current techniques and itemizes some of what is not being measured.

Impacts of Tolling Options

This section of the literature is focused on the impacts of various tolling options on local and regional economies. In particular, the key questions are:

1. How does tolling of transportation facilities impact the economy? This can be measured in terms of business-related transportation costs, spending by visitors and other consumers on nearby businesses, and ultimately business attraction, retention, and expansion.

2. How do different tolling and congestion pricing alternatives impact the economy? Are some tolling options more beneficial to private-sector businesses and the broader economy?

3. What is the geographic scale of economic impacts? Local, regional, state, national?

Generally speaking, there is a fairly minimal amount of available research studies and reports on this topic. One exception is the London Congestion Pricing initiative that has actually measured before and after effects of implementing a cordon pricing strategy, thereby, reducing auto trips to and within downtown areas of the city.[7] Despite a significant drop in auto trips, which some feared would lead to a decrease in consumer spending in certain areas, analyses and surveys could not find a significant change in total central London retail sales.

[7] Leape, Jonathan, *The London Congestion Charge*, Journal of Economic Perspectives, Vol. 20, No. 4, Fall 2006, pp. 169. Another survey found that 72 percent of businesses felt road charging was successful, and a plurality (32 percent) felt neutral regarding the economic impact.

Most other tolling research studies have focused attention on other economic concepts:

- **Revenue generation provided by tolled facilities and comparing revenues to costs (broadly defined) –** This is an important *financial feasibility* issue for both public and private agencies considering tolling.
- **Benefit/cost analysis from a social accounting and economic efficiency perspective –** A very important concept explored within the project evaluation component of the literature review.
- **Economic impacts of constructing or implementing a tolling facility –** These evaluations examine the economic contribution of short-term spending effects on transportation (tolling or nontolling). This type of analysis is typically not considered when making transportation investment decisions as would be expected in a similar impact for similarly sized projects (even if that project produced zero travel performance benefits). Nevertheless, to the extent that tolling or public-private partnership options help fund transportation projects and thereby accelerate their implementation (or facilitate a project that otherwise would not be constructed), it is possible that this type of impact could have both positive near-term and long-term economic effects. This concept will be further explored below.

The remainder of this section attempts to answer the core questions presented above.

How Does Tolling Impact the Economy?

Absent tolling strategies on transportation facilities, the impacts of transportation on the economy generally fall into the following two categories:

1. **Changes in transportation costs –** Typically, reductions in travel time; fuel and non-fuel operating costs; safety (e.g., fewer accidents); and reliability (e.g., reduction in nonrecurrent delay). Reductions in business-related travel costs (shipping and receiving goods, other on-the-clock travel) are a direct input to the production process, varying by industry, just like land, capital, and labor. Thus, businesses can capitalize upon reduced travel costs by lowering overall costs and prices, expanding market share and profits, and even substituting production towards a lower priced input – all in the name of economic competitiveness. Recent research by the Federal Highway Administration (FHWA) and U.S. DOT, among others, finds that there is a multiplier effect by which businesses can convert direct travel savings into even greater production effects.[8]
2. **Changes in transportation access –** A related but different effect is the manner by which transportation improvements can improve accessibility to what matters to

[8] The FHWA Freight Benefit/Cost Study suggests that traditional user benefit measures underestimate the full benefit to businesses by about 15 percent.

business. In other words, transportation investments can improve access and connectivity between businesses and customers; visitors; skilled labor force; multimodal transportation facilities (airports, marine ports, intermodal rail); suppliers; and buyers (e.g., downstream manufacturers and wholesalers).[9] These transportation impacts can have very direct impacts (e.g., elimination of a highway exit providing consumers access to local businesses) and more indirect impacts (e.g., improved access to high-skilled labor and a commercial airport could help attract/expand professional services industries with heavy reliance on those amenities). These impacts can most readily be measured in terms of business output or jobs by industry.

Given this background, the next question is how does tolling impact either transportation costs or accessibility? The answer would seem to be: it depends. Many tolling projects, whether a new toll road or congestion pricing schemes on existing facilities, are intended to improve travel times, travel reliability, and reduce congestion. The improved travel performance does come at a cost – the price of tolling is an offset to travelers receiving benefits from a tolled facility. In fact, people and businesses will only choose to use tolled facilities if the benefit they receive in terms of travel performance is greater than or equal to the cost (price of the toll). This choice, however, is not available to the communities adjacent to a tolled road. Their roadways may become more congested by traffic diverting from the tolled road onto adjacent roadways. Net travel times for those using these free alternative routes may increase.

In social benefit/cost accounting, the toll is simply a transfer from individuals to the public sector, with the common assumption that the public sector can do similarly welfare-enhancing activities as the private sector (in aggregate terms). For individuals, however, the benefits in travel times, reliability, and accessibility are partially offset by the size of the toll. For businesses, where transportation costs are an input of the cost of doing business, it has long been held that the value of time for various freight and on-the-clock travel is typically greater than that for nonbusiness trips. This implies, therefore, that the transportation travel performance benefits of tolling projects (across a broad spectrum of tolling schemes) will generally provide larger benefits to business-related travel. In other words, business travel will have a higher willingness-to-pay for fast, reliable transportation service, and consequently receive a larger monetary benefit per trip. In the London congestion charging system, nonbusiness car trips decreased at a much higher rate (34 percent) than commercial truck trips (7 percent), consistent with a higher value of time for the truck trips.[10]

Similar to nontolled projects, the expected economic effects to industries of tolled projects can be best measured through travel performance measures that take into account speed,

[9] Weisbrod, Glen, *Evolution of Methods for Assessing Economic Development Impacts of Proposed Transportation Projects*, March 2006. Transportation accessibility impacts on the economy are explored in depth in a recent paper presented at the International Transportation and Economic Development Conference.

[10] Leape (2006).

reliability, and cost. Another implication is that the value of time can vary by industry and commodity as discussed in the value of time section. Thus, careful estimates of the commodity trips impacted (e.g., high-value electronics or highly perishable food products versus low-value gravel or other raw materials) and the industries served by the relevant transportation facilities will be a key determinant to the economic benefit to industries and the broader economy.[11] Finally, a primary goal of urban congestion charging systems is to improve reliability through pricing/operations techniques. Reliability (as described in the value of time section) is particularly important for business-related travel as it impacts shipment delivery windows, hours of operations, and numerous other business activities.

What is the geographic scale of tolling impacts on the economy?

Just like nontolled transportation facilities, the geographic scale of impacts from toll facilities can vary greatly. A common rule in evaluating the economic impacts of transportation improvements is to assign benefits from travel performance based on the location of origins and destinations of affected trips (e.g., for commodities based on shippers and receivers). Affected trips can include not only those on new/improved facilities, but also broader network effects as the improvement draws additional trips freeing up capacity on other routes. Thus, the geographic scale of tolling projects can largely be assessed based on the origins and destinations of trips impacted. For example:

Urban area congestion pricing (including cordon pricing schemes) – The primary intent of these congestion pricing schemes is often to reduce congestion during peak periods of travel (i.e., morning and afternoon commutes). Accordingly, it is likely that a majority of the affected trips will be of a regional nature. For an area like Portland, Oregon, with major roadway trade routes (I-5 corridor) and large volumes of freight moving into and out of the Port, it also is likely that congestion pricing scenarios that reduce the number of discretionary auto trips will benefit longer-distance goods movement trips with origins and destinations far from the local/regional area. About one-half of these longer-trip benefits, however, will accrue to businesses outside the region or the state, and thus having no benefit to the region.

Cordon pricing strategies have the potential to create very localized impacts in terms of increasing the costs to access parts of a city (potentially affecting visitors and spending), as well as making alternative roadways around the cordon a more attractive route option. The actual impacts will vary greatly, though, based on the magnitude of the charge for entering/exiting the cordon zone, alternative options to access the city (e.g., public transportation), and the capacity of nearby roadways to absorb additional traffic.

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[11] One exception to this discussion is the number of anecdotal stories about long-haul truckers deliberately avoiding tolled facilities even when they provide faster travel times. A more detailed discussion would account for the incentives provided to truckers in terms of how they get paid, costs they incur, etc.

The use of the toll revenue also has an effect on the economy. The economic benefits depend directly on how these additional revenues (or transfers) are spent. As an extreme (and hypothetical) example, suppose all the revenue were spent on a transit mode with very low ridership. Then the tolling scheme is largely a tax levied on toll-paying drivers and time penalty on those drivers diverting to slower alternative routes. Even if the toll revenues are used to subsidize efficient local transit, some businesses and parts of the region are likely to benefit at the expense of others. The most common and logical use of toll revenues, however, would be effective investments in the corridor's transportation infrastructure, such as incident management, additional capacity, and improved operations and maintenance.

New tolled facilities – Longer-distance toll facilities, such as the proposed I-69 section in Indiana from Evansville to Indianapolis, or possible statewide toll corridors in Texas, will generate economic impacts across a broad geographic area, similar to nontolled facilities, based on facilitating long-distance business and personal travel. Potential economic impacts of note include: 1) is the new facility helping to connect major markets not otherwise accessible? 2) what is the freight share of traffic? and 3) the number and locations of exits/interchanges and the ease of entering the tolled facility along the corridor route.

Project Acceleration

A final economic effect of tolling worth considering is project acceleration. This applies, in particular, to new transportation facilities, or high-cost capacity expansions of existing ones. Simply put, the use of tolling to at least partially cover the costs of transportation capacity expansions can help accelerate the construction and use of facilities. Given the relative scarcity of funds compared to identified needs from most transportation agencies, the potential to move forward with larger, more costly projects is greatly amplified by a funding stream. If a project is needed and will produce significant travel performance benefits to large volumes of traffic, accelerating project implementation such that a region and its citizens and businesses can enjoy those benefits sooner is a good thing.[12]

In economic terms, the present value of benefits will be larger as benefits start accruing sooner, so it is better to complete needed projects sooner. This also can reduce the risk of various cost overruns, such as the recent high escalation of construction cost inflation.

Completing projects more quickly can also help a regional economy accommodate expected growth, and mitigate any potential for businesses to leave due to increasing levels of congestion. A recent study for the Oregon Business Council and Portland Business Alliance is based on that exact premise – future economic vitality and growth are

[12]For further discussion of the economic benefits of project acceleration, see *Performance Review of U.S. DOT Innovative Finance Initiatives*, for the FHWA by Cambridge Systematics, July 2002.

jeopardized by rising levels of congestion on the transportation system.[13] Thus, failure to invest in capacity-expanding transportation initiatives to reduce bottlenecks, improve reliability, and ensure efficient movement of goods will result in economic losses. The bottom line, therefore, is to expedite meaningful transportation investments and to the extent that various tolling schemes can help facilitate project implementation, it can be argued that tolling is, in fact, good for business.

Evaluation Procedures for Toll and Nontoll Projects

Transportation projects are typically evaluated or prioritized based on multiple evaluation criteria. These can range from engineering-related measures (pavement condition, useful life, structural condition) to safety (accident rate); travel efficiency (reduced delay); environmental (emissions, wetlands impacted); and impacts to the economy. Tolling projects are no different – they too should be evaluated based on multiple measures, whether they be quantitative or qualitative assessments. Nevertheless, the facility-specific revenue collection element of tolling alternatives does create a different set of impacts to be considered. This section of the literature review, therefore, is focused on understanding the differences in impacts and how the impacts should be considered within the most commonly applied evaluation context – benefit/cost (B-C) analysis.

Nevertheless, benefit-cost analysis does not evaluate the feasibility of tolling based on its social acceptability, or what may be called a political economy approach. This approach may be far more critical to the desirability of a tolling alternative than B-C analysis. The political economics of tolling would examine the distributional implications of tolling on specific user and nonuser constituencies. In more simple terms, the political economic analysis would focus on winners and losers, who would be affected by the use of the money, and how would they be affected. Traditional B-C designates the use of toll receipts as a "transfer," which is not sufficient for a political economic approach.

The transportation benefit/cost literature on tolling alternatives is relatively thin, and thus analysts at all levels are using different techniques and making different assumptions about what should and should not be considered a benefit or cost. Key evaluation assessment questions to consider include the following:

- Should the revenue collected through tolling and congestion pricing alternative be considered a benefit, a cost, neither, or both?
- What are the core set of benefits and costs that should be estimated when evaluating a tolling project?

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[13] *The Cost of Highway Limitations and Traffic Delay to Oregon's Economy*, for the Oregon Business Council and Portland Business Alliance by Economic Development Research Group, March 2007.

- Should the travel benefits stemming from tolling revenues used to add capacity or improve service on the transit system be counted as benefits?
- What are the differences between a "before and after" benefit/cost evaluation compared to projected estimates of benefits and costs?
- If using a travel demand model to estimate future toll traffic and revenue that accounts for both travel time and cost, how should travel benefits be estimated?

How to Treat Toll Revenue Within Benefit/Cost Analysis

From the perspective of a transportation agency, toll revenue is a benefit. It provides a revenue stream that the agency can use to offset capital or operating costs on tolled or even nontolled facilities. From the perspective of a traveler who pays the toll, it is a cost. Travel choices are dependent on a variety of travel time, cost, and reliability factors; and adding a toll to an existing roadway or using a toll on a new facility is a cost to the traveler. So, which is it – a cost or a benefit? Actually, from a benefit/cost analysis perspective, which is focused on economic efficiency, it is neither. Instead, it is a *transfer*, as the toll revenue is transferred from private travelers to transportation agencies (presumably with the public good in mind).

Two recent cordon pricing benefit/cost evaluations in London and Stockholm make this point succinctly:

1. "The charge payments made by drivers are not included [in the benefit/cost analysis], as they represent a transfer rather than a resource cost."[14]
2. "In principle, and contrary to what some commentators believe, the money raised as toll payment…should be ignored. This amount is neither a gain nor a cost. It is a transfer."[15]

It should be noted, however, that the public may not take such a benign view of the transfer. Public reception to a tolling proposal may reflect in part attitudes towards the government entity advancing it or on the selected use of generated revenue.

Benefit and Cost Concepts to Include

There are a set of benefits and costs that should be considered and, to the extent possible, quantified in most tolling or congestion pricing benefit/cost evaluations. A key point to keep in mind is that any B-C analysis should use a reasonable time period to evaluate the

[14] Leape (2006), pp. 171.

[15] Prud'homme, Remy, and Pierre Kopp, *The Stockholm Toll: An Economic Evaluation*, 2006.

range of benefits and costs as some impacts (e.g., implementation) will be near term, while some of the benefits (e.g., travel time savings) will occur over a number of years once a facility is constructed or reconfigured with pricing.

Benefits

- **Travel time savings –** In many cases, the largest direct benefit of tolling or congestion pricing projects is reflected in terms of reduced travel time. Either by introducing new facilities to reduce travel time and distance to key destinations or pricing existing facilities to reduce peak-period demand (and therefore congestion), tolling typically will reduce travel times. This benefit needs to consider the value of time by different trip purposes and vehicles.

- **Reliability –** As discussed in other sections of the literature review, reliability and the reduction in travel time variability are another key benefit of tolling, especially in urban congestion pricing examples. Methods to evaluate and estimate reliability are still under development, but examples of methods capturing the standard deviation of travel using Buffer Index concepts are quickly gaining acceptance.

- **Improved safety –** To the extent that tolling policies reduce traffic volumes on specific highway segments or more importantly reduce overall highway trips (e.g., urban cordon pricing strategies), safety benefits in the form of reduced accidents should be counted as a social benefit.

- **Air and noise emissions –** Similarly, reduced highway trips will typically reduce air and noise emissions, and standard parameters are available to quantify these impacts.

Costs

- **Implementation and/or investment costs –** Whether it be the construction of a new tolled facility or implementing a tolling scheme on existing facilities, there inevitably will be an up-front capital cost to implementation.

- **Tolling scheme operating costs –** There are typically annual costs associated with operating any tolling scheme, even one that does not require toll both collectors. This can be in the form of maintenance and purchases of new equipment, compliance and monitoring costs, etc.

- **Traffic management –** Tolling schemes, especially in urban areas, may also require increased bus service or other traffic management to accommodate the changes in trip behavior caused by tolling.

- **Deterred drivers –** For those travelers who change mode and decide not to drive due to a toll or congestion pricing policy, there is a cost even if they can substitute transit or other modes to continue making their trip. From an economics perspective, the toll increases the cost of highway travel; and using a demand curve representing the range of travelers and willingness to pay, those that switch to another mode are using a second-best option. In essence, there is a consumer surplus loss (valued high at the value of the avoided cost).[16]

Specific tolling projects are likely to produce an even more complex set of impacts that needs to be carefully evaluated in terms of potential inclusion as a benefit or cost. A simple rule is that the financing components of toll projects tend to be transfers to/from individuals and transportation agencies, and thus should not be included. Other impacts on travelers, the economy, and costs to transportation agencies may be valid. Some studies also tackle the issue of distortionary taxes and the marginal cost of taxation. This is a level of analysis likely beyond most evaluations, but worth considering. For example, on the one hand, a reduction in motor fuel taxes due to tolling (stemming from reduced vehicle miles traveled (VMT)) would appear to simply be a transfer (from transportation agencies to individuals). As pointed out by Prud'homme and Kopp (2006), if those lost revenues need to be gained through taxing mechanisms, using nonuser taxation (e.g., personal income) tends to be more distortionary on the economy in terms of incentives and efficiency, and could have secondary negative effects.

Perhaps more important in evaluating cordon pricing or congestion pricing of selected highways will be the secondary effects on business and residential location. Many commercial land uses (e.g., retail, office space) compete in part on the basis of geographic advantages, such as proximity to customers or related businesses. Changes in the relative cost of accessibility through the application of tolls could affect the relative location advantages of a variety of firms. Similarly, residential locations may become more or less attractive due to changes in the cost of accessing employment. The added out-of-pocket cost would need to be weighed against the cost savings and improvements to accessibility that might be achieved by significant congestion reduction, if it occurs as a result of the pricing program.

Benefits from Future Use of Toll Revenues?

For traditionally financed highway tolled facilities, the revenue stream earned through ridership is typically used to help pay back bonds or other financing mechanisms directly related to that transportation facility. Thus, the financing and impacts are more concentrated on that individual facility.

For urban congestion pricing schemes, however, the revenue earned may be used to increase funding on other parts of the transportation system. For example, in the London congestion charge scenario, the program was marketed and sold to the public, not just in terms of reduced congestion but also based on a promise to use toll revenues to improve transit (primarily bus) service. As noted by Leape (2006): "it is worth noting that, given the UK government requirement that all charge revenues be spent on transport improve-

[16] Leape (2006), pp. 171 and Eliasson, Jonas, *Cost-Benefit Analysis of the Stockholm Congestion Charging System*, Transek AB, 2006.

ments, the charge payments are likely to be generating significant additional benefits in reduced travel times and accidents and other savings…" Consequently, in some cases, especially when toll revenue is large and the additional transit service required to handle the "evicted" drivers who switch mode to transit is modest, there can be additional benefits as the charge payments produce a virtuous cycle of funding to improve other parts of the system and mitigate any negative network effects.

It should be noted, however, that both cited evaluators of Stockholm pricing scheme find that in that case, the tolling revenue was modest compared to the increase in public transport required to handle the evicted drivers (new transit riders). Thus, the key factors seem to be: 1) amount of toll revenue, 2) new transit service required, and 3) capacity and service levels of existing transport system.

Before and After Evaluations Compared to Prospective Analyses

Many of the congestion pricing evaluations cited in this section are empirical evaluations that compare traffic data both before and after the implementation of a congestion pricing scheme. Meanwhile, project decisions on whether or not to attempt tolling strategies are unavoidably based on projected impacts. In either case, the list of benefit and cost concepts to include should be the same. The main differences are:

- The data and tools used to capture effects are often different. Before and after evaluations ideally will use very detailed traffic effects that simulate consistent travel conditions to derive with and without effects. Of course, other factors can contribute to changes, but most analyses can fairly easily isolate changes to a tolled facility or pricing scheme based on historical trends. Prospective analyses typically require careful travel demand simulation models to estimate travel behavior changes due to tolling. While travel demand models are far from perfect, they do provide a consistent set of data and relationships to compare scenarios.
- Before and after evaluations are often based on a small sample of observed data and thus extrapolating results to a longer time period should be done carefully. For example, the Stockholm analyses are based on a six-month trial program, and since the users of the system knew that it would be temporary, it is possible that their behavior was different had they known (or thought) that the congestion pricing scheme was permanent.

Travel Demand Models, Tolling, and Travel Benefits

For prospective analyses that employ travel demand models to forecast traffic patterns and volumes with and without tolling schemes, it is critical that the models account for both travel time and cost (including the toll). This may seem like an obvious point, but is worth noting since many of the urban area travel demand models assign traffic to the highway system solely based on travel time (shortest path). Thus, using "generalized cost" equations and some sort of distribution of values of time is appropriate when assigning traffic and estimating ridership on tolled facilities.[17] This is no simple matter as it directly relates to assumptions in the modeling about value of time, trip purposes, and avoiding "all or nothing" traffic assignments. In other words, two people with exactly the same income, trip purpose, and travel destinations may choose different mixes of tolled and nontolled travel. Developing reasonable and realistic travel distribution patterns based on observed data from current tolled facilities would seem to be an important consideration for future travel modeling of tolling.

Finally, while it is completely appropriate to use a generalized cost approach to assign traffic within a travel model estimating toll-related volumes, it is not appropriate to use the same generalized cost approach to estimate benefits. As documented above, the primary benefit will be in the form of travel time savings (a by-product from the traffic assignment decisions), and the tolls paid represent a transfer. In other words, even though modeling traffic behavior needs to take into account the cost of tolling, benefit calculations should simply be made from the resulting vehicle hours of travel (VHT) reductions, applying appropriate values of time by trip purpose.

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Toll Elasticity

Introduction

The demand response due to changes in toll rates is referred to as toll elasticity. This elasticity is calculated by dividing the percent change in demand by the corresponding percent change in toll rate. For example, if a toll increase of 50 percent results in a 15 percent reduction in traffic on the toll facility, then the elasticity would be -0.30; meaning that a 1 percent toll increase resulted in a 0.30 percent reduction in traffic. There are several methods for computing elasticities, but this paper is directed at the factors affecting toll elasticity – not the methods of computation.[18]

Factors Affecting Price Sensitivity

Toll sensitivity can vary widely across toll facilities due to a number of factors, including the following:[19]

- **Alternate routes –** The existence of alternate routes and their condition is the biggest factor influencing toll sensitivity. A toll route is usually chosen to save time and possibly distance over another nontolled route. Other reasons for choosing the toll road may relate to a sense of reliability and safety. The relative location and operating conditions (congestion) of the competing facility will greatly impact the decision of a trip-maker when faced with a toll or toll increase.

- **Trip Purpose –** It has been widely documented that value of time varies across trip purpose. Business-related and work trips have higher values of time than a discretionary trip, such as one involving recreation or shopping. A facility that has more discretionary trips in the vehicle mix will likely show more sensitivity to toll increases than a facility that has a higher percentage of commuters or business travelers. This means that the same toll increase in both facilities will lead to a higher traffic impact on the facility with more discretionary trips.

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[18] Common elasticity measures are discussed in Pratt (2003), Appendix A, *Elasticity Discussion and Formulae.*

[19] Adopted and updated from material presented by Wuestefeld and Regan, 1981 International Bridge Tunnel and Turnpike Association Workshop.

- **Trip length –** The total cost of a trip is a function of vehicle operating costs, travel time costs, and toll rates. Therefore, the longer a trip, particularly if some portion of the trip is on a nontolled facility, will lead to the toll cost becoming a smaller percentage of the overall trip cost.

- **Vehicle Mix –** The mix of cars and trucks on a toll facility can influence the sensitivity to a toll increase. Theoretically, truck trips are less likely to divert due to them being nondiscretionary in nature, and because the additional toll cost can be passed along to the shipper and consumer. Trucks also have higher operating costs than cars, making the toll a lower percentage of the overall total trip cost. In practice, however, trucks are often very sensitive to toll rates. Truckers often say that they cannot pass the extra cost along to shippers because of the competitive nature of their business. Also, truckers that drive for fleets will have different values of time than those that are sole proprietors.

- **User characteristics –** A facility that has higher income users also will be less sensitive to toll increases as compared to a facility with lower income users. Other characteristics such as age and gender of the users can affect the reaction to toll increases.

- **Destination choice and long-term land use –** Cordon schemes and, to certain extent congestion pricing, can have the effect of diverting trips to or through particular areas regardless of potential improvement to travel times if people value more the money paid on tolls. This issue is especially sensitive in central business areas, where traffic reductions may be desirable to improve level of service, but these diversions are threatening to downtown businesses and landlords.

■ Pricing Strategies and Responses

Theory of travel behavior over the years has evolved through the adaptation of concepts from economics and psychology, as well as from practical efforts to forecast travel demand. The key elements of this theory are time and cost and the compensatory relationship between them (Harvey, 1994). A hierarchy of behaviors takes place ranging from route choice decisions during a particular trip to weekly activity choices that determine trip-making patterns, to more long-term choices regarding the location of a residence.

Understanding the demand responses within this hierarchy of travel behavior under a toll choice environment and how they correspond to the various types of toll and pricing projects is critical in evaluating the market response from the implementation of a toll project or toll increase. Toll pricing can affect many levels of the behavioral hierarchy, including the following:

- **Route choice –** The trip-maker decides whether the toll cost path offsets the additional time and distance cost that would be incurred by choosing an alternate nontolled path.

This decision is influenced by changes in congestion, trip purpose, and the magnitude of the toll.

- **Time of travel –** The use of time-of-day pricing can cause users with flexibility to shift their start times to lower priced periods. It also can cause those trip purposes with high values of time and individuals with higher incomes to shift into the previously congested time periods.

- **Mode choice –** The use of pricing can cause shifts to other modes of transportation if available and competitive, as well as increase the number of carpools if tolls are discounted or waived for higher occupant vehicles. Even if there are no discounts for carpoolers, carpoolers can share the cost of driving, thereby, reducing the cost per person.

- **Destination choice –** A toll can lead to changes in destination choice, whether it is for a specific trip or a longer-term shift, such as changing the location of a residence or job.

- **Trip-making itself –** If a toll is instituted for a facility or corridor that was previously free, and there are no (or much less attractive) toll-free alternatives, drivers may choose to forego certain trips, or combine them with other trips.

Table B.1 illustrates the various tolling strategies and corresponding market responses that are likely to occur. For example, a traditional toll facility will generally affect all trips in the corridor. The primary market response to this type of tolling is usually in the form of choosing an alternate route. In the case of tolling a bridge where alternate routes are less likely or nonexistent, there can be a reduction in overall trip generation and/or changes in route destination to avoid crossing the bridge.

The use of congestion pricing, where toll rates vary by time of day in order to manage demand of a facility, will cause drivers to make shifts in their route choice, time of day, and mode. Time-of-day pricing is most appropriate for facilities with significant peak-period congestion.

In the case of tolled managed lanes (i.e., HOT lanes and express toll lanes), the impacts they have on the travel market are similar to those of a congestion pricing strategy; in that their goal is to better utilize the existing capacity of the corridor by managing the demand through either operational requirements (HOV lanes) or pricing structures. Price elasticity is used to change behavior, such that the tolled lanes are always free flowing.

Table B.1 Travel Impacts of Pricing Strategies

Pricing Strategy	Description	Market Segments/ Travel Impact
Toll roads	Highways, bridges, and tunnels that require all drivers to pay fixed tolls. Typically, the tolls are used to support operations and maintenance of the facilities, and to pay debt service on the bonds issued to finance the toll facility. Can have time-of-day pricing, but mostly for revenue generating purposes.	Generally, all vehicle trips within the toll road corridor are impacted by the toll road. The primary market response to this situation is usually a shift in vehicle routing to alternate route(s). In the case of tolling bridges with limited or no alternate route, trip reductions and destination changes can occur.
Congestion pricing/ value pricing	Toll facilities that are designed to manage traffic demand by varying toll rates based on the time-of-day, day-of-week, or real-time traffic conditions.	Variable pricing by time-of-day allows traffic managers to affect peak period travel the most. The primary market response to this strategy is a combination of shifts in vehicle routing and time-of-day shifting. Value pricing is only effective if there are significant peak period congestion levels.
Tolled managed lanes	Examples include: • HOT lanes; • Express Toll Lanes (all vehicles pay); and • TOT lanes.	The market response to this strategy is a combination of shifts in travel frequency, vehicle routing (typically between "free" lanes and tolled lanes), mode shifting, and time-of-day shifting.
Cordon and area pricing	All vehicles entering a congested area (or driving with the area) during specified times, such as a CBD, are charged a toll.	The strategy would be feasible only in the largest U.S. cities where alternative travel options are available. The strategy can be implemented on a time-of-day basis, so that travel during the most congested time periods can be targeted. The primary market response would be mode shifting and trip reduction and destination changes.
VMT user fees	All users of the highway system would be charged a fee based on the amount of miles they travel. This base fee would then be augmented with additional fees for travel during the peak period on congested highway facilities.	Unlike the facility-based road pricing strategies, VMT user fees are designed to impact all travel within the covered jurisdiction. Market response would be changes in mode choice, time of day, trip frequency, and destination changes. Longer-term responses might be to home and work location decisions.

Cordon or area pricing has recently been tried in London and Stockholm. In these cases, all trips traveling within the tolling zone (London) or entering or leaving the cordon (Stockholm) were charged tolls during the business day, resulting in significant reductions in congestion. In both cases, there were attractive travel options. Only about 12 percent (Litman, January 2006) of peak-period trips were made by automobile before the implementation of cordon pricing in London. During the first few months of operation, peak-period auto trips dropped to 10 percent of the total. Most of the shift was to public transport, particularly bus. Other market reactions were to shift travel time (Toll is in effect between 7:00 a.m. and 6:30 p.m.), or change destination to avoid driving into central London.

There are discussions underway in the U.S. regarding tolling all travel, potentially as a replacement to the gas tax. Such a system is now being tested in Oregon. The use of a VMT user fee is different than a facility-based toll; in that it affects all the travel within the area it is imposed upon. This would likely have market responses in trip frequency, destination choice, mode choice, and time of day (if time of day pricing is used).

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Environmental Effects of Tolling

Potential Impacts of Tolling

The potential environmental effects of tolling, including emissions of criteria pollutants and greenhouse gas (GHG) emissions, are complex. Whether a tolling project will have positive, negative, or neutral environmental effects depends upon the specific context of the project and how it is implemented. Furthermore, there are only a few cases in which the environmental impacts of tolling projects have been quantified.

Before examining the results of specific studies, a number of generalizations can be made about different types of toll projects:

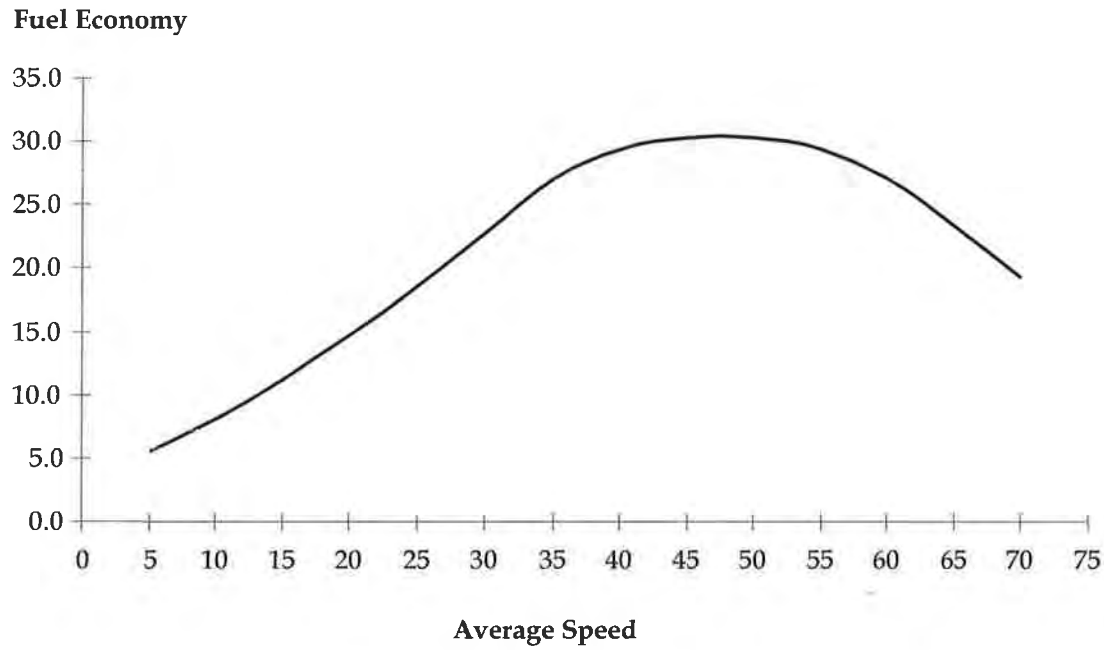
- Toll projects that involve the construction of new highways or new lane capacity financed by tolls without reducing capacity on existing facilities are likely to increase emissions. The reason is that by adding capacity, they are likely to increase vehicle travel over time due to the phenomenon of "induced demand." The effects will be most significant in locations that are experiencing high existing levels of traffic congestion, and for which the toll facilities provide significant congestion relief.

- The conversion of a network of free roads into toll roads, such as an areawide cordon pricing system, is likely to reduce emissions to the extent that travel demand is reduced because travel is now more expensive. The extent to which emissions are reduced will depend upon the level of toll that is charged; the pricing system (e.g., fixed vs. variable); and the alternatives available to drivers (untolled roads, public transit, alternative destinations, etc.).

- Conversion of only a limited set of free roads (e.g., one or more metropolitan freeways) into tolled facilities could either reduce or increase emissions, depending upon its effect on overall travel demand. To the extent that trips are simply diverted to arterials or to off-peak time periods rather than foregone completely, such a scheme could be more or less emissions-neutral, or could actually increase emissions if travel on the arterials produces greater emissions as a result of increased stop-and-go driving conditions.

- Tolling systems that primarily serve to shift demand rather than reduce it (e.g., HOT lanes adjacent to free lanes), as well as congestion pricing or time-of-day pricing systems, may have negative or positive impacts on emissions, depending upon the specific traffic operations characteristics (speed, acceleration rates, etc.) on the various facilities affected. Vehicle emissions tend to be greatest under congested conditions characterized by stop-and-go-traffic or considerable acceleration and deceleration. As a result, the use of tolls to reduce congestion and smooth traffic flow could reduce emissions. On the other hand, emissions also increase at higher speeds, so free-flow traffic at over 65 mph on freeways could potentially lead to higher emissions than would occur under moderately congested freeway conditions, or on a smoothly-flowing arterial network. To demonstrate this, a relationship between average travel speed and fuel economy is demonstrated in Figure B.1. This relationship was taken from the ITS Deployment Analysis System (IDAS) software developed by the FHWA. As shown, an improvement in average travel speed up to 40 mph will decrease fuel consumption. An improvement beyond 40 mph will either lead to no change in fuel economy, or an actual increase in fuel consumption as average speeds move beyond 55 mph.

Figure B.1 Relationship of Average Travel Speed and Fuel Economy
(in Miles Per Gallon)



Source: IDAS

- Toll projects, in which the revenues are invested in alternative modes especially public transportation, could have the effect of reducing emissions by shifting travel demand to less-polluting modes. Projects that directly improve transit performance (e.g., allowing buses to use managed lanes) also could have a similar effect. The specific impacts and benefits will depend upon the extent to which public transportation is made competitive with driving, as well as the emissions characteristics of the public transportation vehicles themselves. However, if surplus revenues are used to build more roads, air quality may worsen due to added capacity and additional sprawl. The latter may be the case in state and regions where highway user fees are required by statute to be used for highway capacity and restricts using these revenues on other modes.

In addition to these regional and systemwide effects, tolling may also lead to localized increases in emissions as a result of stop-and-go or slow-and-go traffic operations at toll plazas. A number of studies have been conducted to quantify the emissions impacts of queuing at toll plazas. With the new generation of tolling technology that utilizes automatic pass readers, however, this impact is being reduced and even eliminated through systems that rely primarily or entirely on in-motion readers.

Evidence from Studies

Replogle (2006) notes some evidence of reductions in traffic volumes from congestion pricing and cordon pricing. A study of congestion pricing on Hudson River crossings into Manhattan documented reductions in peak-period traffic volumes of seven percent in the first year of operation as a result of offering differential peak and off-peak toll rates. Congestion pricing systems in highways in San Diego and Texas also have helped spread peak-period traffic to other times of the day. While these results likely corresponded to a reduction in peak-period emissions, the extent to which traffic increased in the off-peak periods (i.e., trips were shifted rather than eliminated) was not noted, nor were any changes in emissions as a result of changes in traffic speed and congestion levels.

A study of the SR 91 Corridor in California evaluated the emissions impacts of express toll lanes built in this corridor in the late 1990s. Emission models applied to PM peak period showed generally higher emissions than a comparable nonexpress toll lane freeway widening because of vehicles operating at higher speeds. Express lanes showed the highest impacts – an 8 percent increase in corridor volatile organic compound (VOC) emissions and a 24 percent increase in Nitrogen Oxide (NO_x) emissions. The study assumed that corridor VMT was constant under each alternative and did not evaluate impacts of mode or route shifting (Sullivan, undated).

A study by Cambridge Systematics (2006) took travel demand model results from tolling studies in Minnesota and Washington State, and applied speed-based fuel consumption factors to network model output to estimate the impacts of HOT/express tolling systems on energy consumption. The Minnesota study evaluated a system of express toll lanes (new capacity) and HOT toll lanes (conversion of existing HOV facilities) on existing freeways in the Minneapolis-St. Paul region. Traffic was modeled for 24 one-hour periods for an average weekday. The study found a reduction in overall VMT of 0.1 percent in 2010 and 0.4 percent in 2030, and increases in average speed ranging from 2.6 percent in 2010 to 4.9 percent in 2030. Link-level traffic volumes and speeds led to reductions in energy use of 41,000 gallons per day (0.9 percent) in 2010 to 147,000 gallons per day (2.5 percent) in 2030.

In Washington State, a system of HOT lanes in and around Seattle was analyzed under two scenarios: 1) conversion of all existing and planned HOV lanes to HOT lanes; and 2) adding one lane along existing and planned HOV corridors to form two HOT lanes in these corridors. Four time periods were modeled representing an average weekday. In 2030 under Scenario 1, VMT increased by 1.4 percent, average speed increased by 2.0 percent, and fuel use decreased by 7,000 gallons per day (0.1 percent) compared to the base case. Under Scenario 2, VMT decreased by 0.2 percent, average speed increased by 1.3 percent, and fuel use decreased by 66,000 gallons per day (1.4 percent) compared to the base case.

Both studies showed relatively small impacts on a daily basis. These particular pricing strategies are focused on congestion during the peak periods, and therefore may have little or no effect on fuel usage during the rest of the day. During certain times of the day, these strategies could actually increase fuel usage, depending on where operating conditions fall along the speed/fuel usage curve. For example, the Minneapolis-St. Paul study showed fuel reduction impacts of around five percent during the congested peak periods, with practically zero impact estimated to occur during the off peak and night time periods since congestion is not a problem during these time periods.

Nevertheless, the results are interesting because they showed that fuel use (and therefore GHG emissions) held roughly constant even when VMT increased, or declined more than VMT decreased, since increases in average speeds led to vehicles operating more efficiently. (It is difficult to say whether similar results would hold true if criteria pollutants were analyzed, since the speed-emission relationships are not necessarily the same as speed-fuel consumption relationships.) Both studies accounted, in varying degrees, for factors including trip distribution, mode choice, and time-of-day shifting. On the other hand, the studies did not account for any potential second-order effects, such as longer-term redistribution of population and jobs resulting from the tolling policies and traffic impacts, or mode shift impacts.

Relationships between speed and fuel consumption also vary by vehicle type and technology, as well as change over time. For example, improvements in aerodynamics and transmissions have led to improvements in fuel economy at higher speeds over the past three decades. On the other hand, the new crop of hybrid vehicles shows much greater fuel efficiency gains at lower speeds and much flatter speed-fuel economy curves; meaning that as use of this technology increases, the impacts of speed changes on emissions could largely disappear.

Rodier and Johnston (1999) used a regional travel demand model in conjunction with an emissions model to evaluate the impacts of regionwide systems of new HOV, HOT, truck-only, and high-occupancy toll/truck (HOTT) lanes on total organic gas (TOG), Carbon Monoxide (CO), NO_x, and Particulate Matter (PM) emissions in Sacramento. These four alternative scenarios increased VMT by 1.5 to 2.2 percent compared to the base scenario, while decreasing vehicle delay by 5 to 15 percent. In contrast to the findings of the Minnesota and Washington State studies, all four scenarios increased emissions, with the lowest increase for the HOV scenario (1.1 to 3.2 percent depending upon the pollutant) and the highest increases for the truck-only and HOTT scenarios (up to 4.4 percent for

NO_x), because of an increase in commercial vehicle travel VMT. This study included basic time-of-day impacts (peak vs. off-peak period), as well as trip generation, trip distribution, and mode choice impacts.

A study by Deakin, Harvey, and Skabardonis (California Air Resources Board, 1998) examined the potential emissions impacts of pricing strategies in four California cities. Congestion pricing of 0.8 to 19 cents per mile resulted in VMT reductions of 1.5 to 3.0 percent and emission reductions of 3 to 6 percent. Emission reductions were greater than VMT reductions because of the benefits of reduced stop-and-go traffic. A VMT fee of 0.2 cents per mile reduced VMT and emissions by about 4 percent.

Cordon pricing systems in London and Trondheim, Norway, have reduced traffic in peak and off-peak periods, as well as corresponding emissions levels. In London, cordon pricing has reduced traffic congestion by 30 percent, while the volume of traffic entering the priced zone has decreased by 18 percent, and congestion outside of the priced zone has not increased (Transport London, 2005). The improvements in travel times, increased transit use, and reduced congestion are estimated to have reduced Carbon Dioxide (CO_2) by 20 percent and NO_x and fine particulate emissions from road traffic in the priced zone by 12 percent (Transport London, 2004). In Trondheim, cordon pricing around the central business district has reduced peak-period traffic by 10 percent and off-peak traffic by 8 percent (Replogle, 2006). These findings suggest that cordon pricing has had an overall environmental benefit in London. It should be noted that in both situations, revenues were reinvested in public transit, which helped to explain some of the traffic reduction.

A 7-month congestion pricing experiment in the inner city of Stockholm, Sweden, in 2006 reduced traffic volumes by 22 percent. This reduction led to CO_2 emissions reductions of 14 percent in the inner city, and 2 to 3 percent overall in Stockholm County. It also reduced emissions of particles and Nitrogen Dioxide (NO_2) by 8 to 12 percent in the inner city, and 3 to 5 percent for the region as a whole (City of Stockholm, 2006). As with London and Trondheim, toll revenue was reinvested in transit service.

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Value of Time

The Basis for Valuing Time

From the perspective of economic theory, avoidable time spent traveling is a nonproductive activity against which there is an opportunity cost (Cohen and Southworth). For example, time spent traveling is time that could be spent working, shopping, or undertaking household activities. Travel time savings is generally one of the most significant categories of benefits quantified in studies of the economic benefits of transportation projects.

A common approach to determining the value of travel time savings to individuals, commonly referred to as the "value of time" (VOT), is to base this value on some fraction of the hourly wage rate. Valuing time equivalent to an individual's hourly rate assumes that the time spent traveling could be spent working. Valuing it at some fraction of this rate assumes that whether the travel is supplanting paid or nonpaid activities, individuals' willingness to pay to save time is generally in proportion to their income (ability to pay).

By observing choices that people make when traveling (e.g., a quicker, higher-cost route or mode vs. a slower, lower-cost route or mode), economists can make inferences about how much people actually value their time. Hundreds of studies have been done since the 1960s using data on observed travel behavior in conjunction with consumer choice models (such as logit models) to estimate values of time.[20] These are known as "revealed-preference" studies. Other studies using "stated-preference" surveys have asked people to make choices among hypothetical alternatives. Many of these studies have examined not only the average value of time across the traveling population, but also how values vary by trip purpose, mode of travel, income level, and other factors. Reviews of VOT studies have found that many relationships (e.g., with respect to income or other personal factors) tend to remain stable over time and across regions (Gunn, 2001).

Values Commonly Used in Transportation Studies

The average VOT for commute travel is commonly placed at about one-half the average wage rate (Cambridge Systematics, 1994), with the VOT for personal noncommute travel at somewhat less than this level. One review concluded that the VOT for the journey to

[20] Wardman (2001) found 143 studies alone conducted in Britain between 1980 and 1996.

work averages about 50 percent of the before-tax wage rate, with a range from roughly 20 to 100 percent (Small, 1992; cited in Small 1998).

The Highway Economic Requirements System (HERS) model is a model used by the U.S. DOT for economic analysis of nationwide transportation investment programs and also provided in a version for use by states (U.S. DOT, 2002a). HERS incorporates values of time assumptions for vehicle occupants from the U.S. DOT Departmental Guidance (1997). For on-the-clock travel for occupants of four-tire vehicles, HERS uses the recommended value for "business travel" ($18.80 per person-hour), while the value used for occupants of larger vehicles is the slightly lower recommended value for truck drivers ($16.50 per person-hour). For personal travel, HERS uses the recommended value for personal local travel ($8.50 per person-hour). The Departmental Guidance recommends using a higher value ($11.90 per person-hour) for personal intercity travel. HERS also includes assumptions regarding average vehicle occupancy (1.43 for autos and four-tire trucks, and 1.0 to 1.12 for larger trucks), and hourly cost per vehicle ($1.09 to $1.90 for automobiles and four-tire trucks) to arrive at average values of time saved per vehicle for various classes of vehicles, ranging from small automobiles to large trucks. Values for years subsequent to 1995 are indexed using the Bureau of Labor Statistics Employment Cost Index for total compensation of civilian workers.

■ Variations Among Individuals

VOT varies widely among population subgroups. As expected, it varies with income, since people with higher incomes have a higher willingness (or ability) to pay to save time, as well as a higher opportunity cost of lost wages from work time. For example, a stated-preference survey of residents of the SR 91 corridor in Southern California found that the value of travel time varied from $2.64 per hour for an annual household income of $15,000 to $8.05 per hour for a household income of $95,000 (Small et al., 1999). VOT at the median income level was $5.30 per hour.

The variation of VOT with respect to income is not necessarily linear. Research from Britain and The Netherlands suggests that the value of time as a proportion of income is a decreasing function of income, with income elasticities as low as 0.5 (Hague Consulting Group et al., 1999), meaning that doubling income would increase the VTTS by 50 percent. The UK Department for Transport recommends the assumption of a linear value of time with respect to income for business travel, and a somewhat lower value (income elasticity of 0.8) for nonwork travel (Mackie et al., 2003).

Variations by Trip Purpose and Other Factors

The value of time for a particular traveler and trip also can vary widely, based on factors such as the trip purpose, trip conditions, and degree of comfort (Small, 1998). For example, for transit analysis, it has been observed that the value people place on time spent walking to a transit stop or waiting for a vehicle is two to three times higher than the value of time riding on the vehicle (i.e., people find walking or waiting more onerous than riding, and would pay more to avoid it). Similarly, people may place a higher value on time spent driving in congested conditions than in uncongested conditions, as a result of greater stress, frustration, and perhaps arrival time uncertainty. Wardman (2001), reviewing studies from Britain, found that travel under congested conditions is valued 48 percent higher on the average than under uncongested conditions, and also cites reviews by Miller (1989) placing this value at 67 percent higher and by Train (1976) in the American context placing the value at 30 percent higher.

Business trips ("on-the-clock" travel) are invariably valued at a higher level than nonbusiness trips, and a somewhat higher value is placed on commuting trips than leisure trips (Wardman, 2001). Since business travel is typically compensated through wages, it is typically valued in economic studies using the prevailing wage rate. It should be noted, however, that the average business traveler has been found to have a higher-than-average wage rate, since administrative, professional, and sales staff typically travel more than lower-paid laborers and clerical employees (Cambridge Systematics, 1994).

Under unusual circumstances (e.g., late to an appointment), people may find themselves willing to pay much more to save time than they normally would. In the context of tolling, variations in the value of time imply that some people are likely to use an uncongested toll vs. congested free alternative under almost any circumstances, even if the time saved is worth less than the average value of time to the traveling public, or even to specific groups of travelers.

Value of time also has been found to vary with trip distance (Wardman, 2001; and Small, 1998), although findings on the nature of this relationship have differed. Economists also have debated whether small increments of time savings are valued less than larger increments (measured per unit of time saved). Common practice in transportation impact studies is not to make this assumption, however, in part because the resulting estimate of benefits would depend upon whether the project was evaluated as a single long project vs. accumulation of many smaller projects.

The Value of Travel Time Reliability

Most time valuation studies have examined responses to changes in average or representative daily travel times. However, there is growing evidence that the reliability (variation) in travel times is an important factor in valuing time, and that the value of saving *unexpected* travel time can be significantly greater than the value of saving expected travel time. In part this is because of the high opportunity cost of being late for certain events, such as a business meeting or daycare pick-up. It also has been found that people intrinsically value certainty and find it more onerous to wait in traffic if they were not expecting to do so.

The previously-referenced SR 91 corridor study found that on the average, travelers place a value of $0.21 per minute ($12.60 per hour) of time shifted from uncongested to congested conditions. The implication is that travelers value unexpected travel time at over twice the value of expected travel time ($5.30 at the median income level). The study also found that the value of reliability is significantly higher for shorter trips ($0.79 per minute for a 10-minute trip vs. $0.13 per minute for a 60-minute trip). It also is valued somewhat more highly (about 20 to 25 percent) for work trips than nonwork trips, and for higher-income vs. lower-income travelers.

The FHWA's IDAS incorporates default values for travel time reliability (in dollars per person-hour), as well as travel time. Travel time values are consistent with HERS and U.S. DOT guidance. Travel time reliability values in 1995 dollars are $28.90 for automobile travelers, $50.88 for commercial trucks, and $26.70 for transit and other travelers. These values are three times the value of expected travel time for each user group (Cambridge Systematics, undated).

The Value of Time for Commercial Traffic and Goods Movement

As a starting point, the value of time for commercial traffic (bus drivers, truck operators, etc.) is often assumed to be the average compensation rate (wages plus fringe benefits) for the vehicle operator, since the wages and benefits are a direct expense to the business. HERS incorporates a default value of $16.50 per person-hour in 1995 dollars for trucks (with an average occupancy of 1.0 to 1.12), plus an additional cost per vehicle-hour ranging from $6.16 to $7.16 for trucks with three or more axles. Some have suggested, however, that the value of commercial vehicle operator time used in HERS is low and should be updated.

There are a number of other factors that cause the value of time for any particular truck shipment to vary. Prevailing wage rates may vary by industry and in many cases, truckers are not paid on an hourly basis, but instead are paid per mile or per delivery. Urban deliveries, typically using smaller trucks, frequently require two people, and some studies have therefore assumed higher vehicle occupancies for small truck classes. Delays can lead to overtime payments that are higher than standard wage rates.

Furthermore, operator wages and benefits are just one component of the total cost of moving goods, and some other costs can be time dependent as well. These include, for example, inventory costs (money tied up in inventory is not earning interest); stockout costs (lost sales due to unavailable product); and spoilage costs (depreciation in the value of perishable goods, such as fresh produce or newspapers, over time). Shorter and more predictable travel times also can lead to "reorganization effects," or adjustments in logistical arrangements that shippers make in response to lower costs of freight movement (ICF et al., 2001). These other time-dependent costs can vary widely, not only by commodity but by the specific circumstances of the shipment, and are difficult to quantify even for the specific businesses making the decisions. In some cases, responding to increasing travel times or unreliability, shippers have been able to take advantage of new technology to revise their delivery processes and actually *reduce* their logistics costs – further complicating the valuation of commodity travel time.

A National Cooperative Highway Research Program (NCHRP) study (Small et al., 1999) quantified the value of travel time savings and reliability based on a stated-preference survey of 20 shippers. The study found that carriers on average value freight travel time savings at $144 to $192 per hour, depending on model specification. This study also valued the savings in schedule delay late at $371 per hour, and recommended applying a mark-up factor of 2.5 to the value of time when the time savings are under highly congested conditions. The study notes that the midpoint of the value of time estimate is about 30 percent of the overall average hourly trucking expense. The authors provide the caveat, however, that there were a number of methodological limitations with the survey and considerable uncertainty in the results. Based on this study and other research, the FHWA has concluded that shippers and carriers value transit time in the range of $25 to $200 per hour, depending on the product being carried; and that the value of reliability for trucks is another 50 to 250 percent higher (U.S. DOT, 2002b).

Economic Development Research Group (2006) provides estimates of how the value of travel time reliability varies by commodity type. These estimates reflect the additional user productivity benefit of truck pickup and delivery time savings for production processes and export shipments that depend on timely deliveries. For Montana's economic cost structure, product mix, and export structure, the hourly cost of delay ranges from approximately $40 for service deliveries, agriculture, mining, and wood services, and drayage and warehousing to values of $53 for nondurables manufacturing goods and $66 for durables manufacturing goods.

An additional complicating factor from the perspective of toll analysis is that drivers may not recognize the true value of time of their shipment. For example, Weisbrod (2003) note that drivers making short-distance urban deliveries are often paid by the hour, and therefore have nothing to gain by paying tolls out of pocket to save time. Even if tolls are reimbursed by the company or drivers are paid by the shipment, they are unlikely to recognize the full costs of delay resulting from nonwage costs, such as overhead, vehicle operating costs, and inventory costs.

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