A Bridge Too Big?

New Yorkers' Toll from a 15-Lane Tappan Zee Bridge

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This document is on line at: <http://komanoff.net/cars_II/Bridge_Too_Big.pdf>.
The spreadsheet in which the underlying calculations are performed is available at
<http://komanoff.net/cars_II/TZB_Rebuild.xls>.

This report was prepared by a lifelong New Yorker and veteran policy analyst on issues of transportation, energy and environment. It is motivated by a concern that, as currently envisioned, the replacement Tappan Zee Bridge will be too expensive for its costs to be borne exclusively by bridge users; and that much of the costs will spill over to other state agencies, authorities and/or taxpayers, with adverse consequences to the efficiency and fairness of transportation and governmental administration throughout New York State.

A related concern is that the bridge's excessively high cost could create a perverse incentive for state officials to subsidize or otherwise facilitate driving, and to under-invest in public transit, in the I-87 / I-287 corridor and the lower Hudson Valley, in order to maximize throughput on the bridge and thus restrain the rate of toll hikes on the Tappan Zee. The resulting boost in traffic would last for generations, adversely affecting the quality of life and commerce in the downstate region.

A. Summary

How will the Tappan Zee replacement bridge — a 15-lane structure twice as wide as the current bridge, and with a $5.2 billion price tag — be paid for?

To recover the entire cost through charges on bridge users will require tolls at least twice and perhaps four times as great as the current $4.75 charge for passenger cars (with E-ZPass). Because tolls of these magnitudes — between $10.90 and $20.50 per trip[1] — are unlikely to be politically acceptable, there is a strong likelihood that some of the costs of the new bridge will end up being off-loaded: onto other Thruway users, state taxpayers, or users of MTA or Port Authority bridges, tunnels and mass transit.

Table 1: Tolls Required to Pay for Replacement Tappan Zee Bridge

Scenario	Assumptions	15-Lane TZB Toll	10-Lane TZB Toll
Current		**$4.75**	**$4.75**
Best	High traffic growth ▪ Fed Financing ▪ No Overruns	**$10.90**	**$8.90**
Worst	Low traffic growth ▪ No Fed Financing ▪ 25% Overruns	**$20.50**	**$15.30**
Average	Average of 16 Cases	**$14.90**	**$11.45**

Tolls are $3 (25%) less for 10-lane than 15-lane replacement bridge in best cases, $5.20 (25%) less in worst cases, and $3.45 (23%) less on average. "10-lane" is shorthand for 10- or 11-lane bridge (11th lane being a shared bike-pedestrian path).

Downsizing the project could mitigate the toll increases, as Table 1 shows. Jettisoning 4 of the 6 planned breakdown lanes would shrink the replacement bridge's width by around a quarter, from 183 feet to 135-140 feet. This could trim costs substantially and enable the Thruway Authority to recover the replacement bridge's construction cost with lesser toll rises than those posited in the "15-Lane" column of Table 1. Even with just 8 travel lanes and 2 breakdown lanes, the downsized bridge would still be 3 lanes wider than the current 90-foot Tappan Zee.[2] (The current 7-lane span employs a movable barrier to provide four lanes of travel in the peak direction.) This would ensure that the new structure is safer, easier to drive, and positioned to accommodate travel demand on I-87 for decades.

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[1] As on other Hudson River crossings, tolls on the Tappan Zee Bridge are charged eastbound only.

[2] Wikipedia says the current width is 90 feet: <http://en.wikipedia.org/wiki/Tappan_Zee_Bridge>. The 183-foot configuration of the replacement bridge is diagrammed here: http://bit.ly/y5uB8j.

B. Tolls

The grim conclusions above about the difficulty of paying for the full-size replacement bridge through bridge tolls alone derive from a straightforward comparison of the debt service on its cost to the volume of vehicle trips that would pay off the debt via tolls. The ratio of the two — literally, annual debt service divided by annual trips[3] — yields a first-order approximation of the toll increases that drivers will face to cover the entire cost of the new Tappan Zee Bridge.

These conclusions are arrived at by testing 16 different scenarios of bridge cost and usage, covering a range of assumptions for four key parameters:

- How much, if any, of the bridge replacement project will be eligible for cheap federal financing (modeled as either zero or up to $2 billion).
- Whether construction suffers overruns (modeled as cost increases of zero or 25%).
- Whether bridge traffic volumes are moderately or slightly sensitive to toll levels.
- The underlying rate of traffic growth on the bridge (modeled as 2% a year or zero).

Since each parameter can assume either of two values, the number of possible combinations of assumptions ("scenarios") is 2 x 2 x 2 x 2, or 16. Note that all 16 scenarios pivot off of the current $5.2 billion cost figure; that is, no "bridge diet" is assumed.

For each scenario, I calculated the ratio of annual debt service to annual traffic levels ten years from today (after deducting O&M savings as noted in Footnote #3). The mean of the 16 ratios, $7.70, is the "expected value" of the *immediate increase* in the toll the Thruway Authority would need to impose to recover the entire bridge cost.

The $7.70 figure conceals a wide range: from a low increase of $5.25 in the best case (low-cost financing, no overruns, little sensitivity of travel to tolls, and high traffic growth); to an increase as great as $10.50 in the worst case. But these figures do not reflect the attrition in bridge ridership that higher tolls could trigger, which would require further increases because there would be fewer trips over which to amortize the cost of the bridge. When this "price effect" is taken into account, ***the true range of prospective toll increases to pay for a 15-lane Tappan Zee Bridge becomes $6.15 - $15.75 with an average of $10.15***.

[3] The debt service for the replacement bridge would be partially offset by the Thruway Authority's cessation of expenditures to operate, maintain and repair the existing Tappan Zee span, once it is decommissioned (assuming it is not converted into a bikeway/walkway). After reviewing Internet-available Authority documents, some of which are cited in my spreadsheet cited on the title page, I have chosen to assume that these avoided costs would amount to $75 million a year.

C. Off-Loading Costs: Implications

The idea that the toll to cross the Hudson on the New York State Thruway's Tappan Zee Bridge must more than double and perhaps quadruple to pay for a replacement structure may seem preposterous. It's natural to think that "something will be done." That "something" would probably take one (or more) of the following forms:

1. Off-loading some of the costs onto other Thruway segments and users.
2. Off-loading some of the costs onto the NY State DOT budget or other parts of the state's general fund.
3. Off-loading some of the costs onto the Metropolitan Transportation Authority or the Port Authority.

Each means of off-loading costs would be problematic.

C1: Off-loading costs elsewhere on the Thruway system

From an administrative standpoint, the easiest way to off-load Tappan Zee costs is to raise tolls on the NY State Thruway system. While the amount of the rise would depend on the extent of the off-loading, the economic and political fallout would almost certainly be severe, particularly for the economically challenged region west of Albany.

Although tolls on the Thruway increased substantially in the previous decade,[4] the system still has built up a backlog of deferred maintenance that will necessitate further increases going forward simply to keep the system's *other* 567 miles in a state of good repair. Any attempt to pay for the bridge by levying additional toll increases on the Thruway's non-TZB portions, hundreds of miles away, would likely ignite a firestorm of protests.

My calculations suggest that annual debt service for the full-size (15-lane) replacement bridge will cost between $230 and $329 million, although the Thruway Authority would realize savings by terminating unusual charges involved in operating and maintaining the current bridge (e.g., operating the movable barrier that changes the flow of the seventh lane twice daily; re-decking, inspecting and otherwise safeguarding the 55-year-old structure). By way of comparison, debt service for the entire NY State Thruway System in a recent year (2010) was only $167 million,[5] and only around $500 million in tolls is collected

[4] A toll hike in the first week of 2010 brought the cumulative increase for passenger cars since 2004 to 45%, according to the Syracuse Post-Standard. See A Trip on New York State Thruway Will Cost More on Sunday, Jan. 1, 2010. Note that the original version of this paper stated in error that tolls for the non-TZB Thruway system had not been raised in several decades.

[5] Thruway Authority, statement of General Revenue Bonds and Notes, available at <http://www.thruway.ny.gov/about/financial/grb.html>. Total debt outstanding as of 1/1/12 was $2,158,220,000.

on the entire Thruway other than the Tappan Zee Bridge.[6] In other words, debt service payments for reconstructing the Tappan Zee Bridge as a double-wide span will be large in relation to the Thruway system as a whole.

C2: Off-loading costs to NYS DOT or NYS General Fund

The New York State Department of Transportation spends around $4 billion a year maintaining, upgrading and expanding state roads, bridges and highways.[7] Its budget is at least ten times greater than the estimated debt service for the Tappan Zee replacement project, making it a tempting pocket in which to fold some of the project's cost.

However, a glance at the DOT program statement accompanying the Governor's proposed budget for FY 2013 indicates that the DOT's $4 billion in expenditures are fully spoken for:

> The 2012-13 Executive Budget [includes] $1.16 billion of new funding … under the New York Works program that will accelerate capital investment to maintain, repair and replace critical highway and bridge infrastructure, and to prolong the useful life of these assets. Funded components include over $212 million for bridge repairs on 115 critical bridges throughout the State, $250 million for a pavement preservation program which will treat more than 2,000 lane miles of State roads, and over $700 million to accelerate signature transportation projects throughout the State… The [budget also] builds upon core transportation funding to provide a total DOT capital program of nearly $4.5 billion, including highways, bridges, rail, aviation, non-MTA transit, and DOT facilities.[8]

State DOT expenditures always have multiple claimants, including safety-related work, legislators' pet projects, and the usual basket of state-of-good-repair tasks. Shoehorning even a fraction of the debt service for the Tappan Zee into DOT's oversubscribed finances would set up a collision with these high-priority projects. The same applies to trying to tap the State's general fund to bail out the Tappan Zee project. Education, human resources,

[6] Thruway Authority revenues are posted at <http://www.thruway.ny.gov/about/financial/mf2011/vtm/dec2011vtm.pdf>. Year-2011 revenues for the entire system were $634 million (calculated by prorating E-ZPass revenues of $457.7 million by E-ZPass's revenue share of 72.2%). TZB revenues for 2001 were calculated similarly by prorating $94.6 million by 74.8%, yielding $127 million. The difference between the two underlined revenue figures is $507 million.

[7] See "Transportation" section of the 2012 Executive Budget for 2012-2013, available at <http://publications.budget.ny.gov/eBudget1213/fy1213littlebook/Transportation.pdf>. The table, "IV. Summary of Spending (All Funds)" posted at p. 4 of 6 of that link (and apparently p. 76 of the Executive Budget document) gives State Department of Transportation spending at $3.942 billion for 2011-12 and $4.176 billion for 2012-13. These figures are exclusive of spending by MTA ($4.025 billion and $4.276 billion for the same years), NYS DMV $276 million and $277 million) and the Thruway Authority ($2 million in each year). The latter figure is apparently an appropriation from the General Fund and is aside from the Thruway Authority's own budget of approximately $1 billion.

[8] 2012 Executive Budget, "Transportation" section, p. 74 (link in preceding footnote, p. 2 of 6).

social services, health care, aid to localities, etc., have powerful constituencies; all are likely to be squeezed financially for the foreseeable future, and all would push back hard against any "raid" to shore up financing for the Tappan Zee.

C3: Off-loading costs to the MTA or Port Authority

The Metropolitan Transportation Authority is both a recipient of revenues from taxes enacted by the State Legislature, and, these days, a piggybank that the Legislature and the Governor sometimes tap to fund non-MTA programs and/or to reduce some of those same taxes. The Authority's enormous size — its 2012 operating budget is approximately $13 billion, and as of this writing it has $32 billion in outstanding debt — make it an obvious place for Albany officials to look to service debt that the Thruway Authority will assume to build the replacement Tappan Zee Bridge. The same is true of the Port Authority, though its bi-state nature presumably would make it harder to use it as a source of funds.[9]

While many scenarios can be imagined for having the MTA absorb some of the bridge costs, the most likely would involve dedicating *new* (future) MTA revenue streams to service Tappan Zee Bridge debt. Consider congestion pricing, which is again receiving new attention in the form of two complementary plans, either of which is projected to generate over a billion dollars a year in net revenue for subway, bus, rail and road improvements in New York City and the surrounding region.[10] It is all too easy to imagine a portion of the revenue being siphoned off to support debt service on the Tappan Zee replacement project. This could occur as political horse-trading to gain support from legislators in the Hudson Valley who have an interest in tamping down toll hikes on the bridge, as well as from upstate legislators who wish to preempt the system-wide Thruway toll increases discussed above.

The point here, and indeed the takeway from this discussion, is that the prospect of insupportable toll hikes due to a new 15-lane Tappan Zee Bridge should concern a wider circle than legislators and residents from Westchester, Rockland and other counties directly served by the bridge. The likelihood that costs would spill over from the area immediately surrounding the bridge is all too real. New Yorkers from Brooklyn to Buffalo and from Albany to Montauk have a compelling pocketbook and transportation interest in forestalling a bridge too big.

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[9] Servicing replacement bridge debt with Port Authority funds would add the irony that to ensure that toll revenues did not have to be shared with the Port Authority, the Thruway Authority moved the original Tappan Zee Bridge site northward, to virtually the Hudson River's widest point, ensuring a costly bridge.

[10] See, for example, a March 7 post on Streetsblog, "Details of Sam Schwartz's 'Fair Plan' and Other Orcutt+Komanoff Highlights," available at <http://bit.ly/w39xUd>.

D. A Bridge “Diet”?

The replacement bridge would be two spans, separated by a gap of at least 16 feet. Each span would have four travel lanes, two shoulders and one “emergency access” lane. The westbound span would also have a shared bicycle-pedestrian path separated from the adjacent shoulder by a 2-foot buffer. The westbound (north) structure is 8 lanes totaling 96 feet. The eastbound (south) structure is 7 lanes with a width of 87 feet. The two structures’ combined 15 lanes and 183 feet are double the current bridge’s 7 lanes and 90 feet.

Table 2: Tappan Zee Replacement Bridge, Thruway Configurations

Lane	Westbound (feet)	Eastbound (feet)
Outer Rail	2	2
Bike/Ped ("Shared") Path	12	0
Shared Path Buffer	2	0
Shoulder #1	10	15
Travel Lane #1	12	12
Travel Lane #2	12	12
Travel Lane #3	12	12
Travel Lane #4	12	12
Shoulder #2	8	8
Emergency Access	12	12
Inner Rail	2	2
Subtotal	96	87
Grand Total		183

Doubling the bridge’s width appears to have been a *premise* of the replacement bridge’s design rather than the *outcome* of an open and unbiased planning process, as this excerpt from the Thruway Authority’s “Project Alternatives” report suggests:[11]

> Twin bridge structures would provide superior service redundancy as compared with a single structure. In the event that an incident or extreme event would require the closure of one structure, the second structure could remain open to traffic. At the same time, this redundancy would [give] NYSTA … greater flexibility in planning for the bridge’s inspection, long-term maintenance, and future contract work, and therefore would ensure the structural and operational integrity of this vital link over a longer timeframe. This configuration would also provide for safer work zones for inspection, maintenance, and repair crews.

[11] Available at http://www.tzbsite.com/tzbsite_2/pdf-library_2/02_Project_Alternatives.pdf. Pages 2-4 to 2-5.

The advantages of a double-wide span — redundancy and easier maintenance — are certainly attractive. But these should manifest in clear and robust metrics: reduced delays after serious incidents such as fires, crashes or other disasters; maintenance efficiencies; improved work crew safety; and longer bridge life. Yet the Authority has not attempted to quantify the value of these advantages. For example, no frequencies have been attached to the incidents that would be mitigated by having two spans rather tan one, nor has the Authority offered estimates of the societal savings from each.

A bit of *reduction ad absurdum* may be instructive: Why not mandate that every new home be built with a twinned free-standing structure? Families would occupy the first and hold the second in reserve in case of temporary inhabitability of the primary residence. As a plus, annual inspection and spring cleaning would be more efficient. This mandate would fail any rational cost-benefit test, of course. While upsizing the Tappan Zee replacement bridge might well pass such a test, none has been performed.

Table 3 suggests a number of ways to downsize the replacement bridge while keeping five lanes — four travel lanes and one breakdown lane — in each direction.

Table 3: Alternative Bridge Configurations (lane numbers are for each direction)

Option	Travel Lanes	Shoulders	Emergency Lanes	Bike-Ped?	Width, ft	% Reduxn	$ Savings
Baseline	4	2	1	YES	183	NA	**NA**
ALT #1	4	1	0	NO	124	32%	**27%**
ALT #2	4	0	1	NO	128	30%	**25%**
ALT #3	4	1	0	YES	138	25%	**20%**
ALT #4	4	0	1	YES	142	22%	**18%**

Numbers of lanes are per span, except that Bike-Ped lane is on westbound span only. Percentage reductions in width and cost are vs. baseline. Configurations with one shoulder assume 10-foot widths.

Each of the alternative configurations has 10 or 11 lanes (counting the single bicycle-pedestrian path as one lane). The percentage reductions in width range from 22% to 32%. The associated cost reductions range from 18% to 27%, as discussed in the next section.

E. Cost Savings from A Bridge Diet

A narrower replacement bridge should cost less than the full-size one envisioned and assumed by the Thruway Authority. But how much less?

In lieu of published estimates of the costs of different bridge configurations, I constructed a formula to estimate the extent to which the cost of the replacement bridge would fall as a function of shrinking the bridge's width. It rests on these two assumptions:

- 10% of the project's cost is assumed to be fixed; these costs, for overhead and some engineering, are assumed to be incurred regardless of the bridge's width.
- The remaining 90% of costs obey a 0.9 "scaling factor" such that a 10% shrinkage in width is assumed to reduce those costs by 9%.[12]

The results of this formula are reflected in Table 3: downsizing bridge width by, say, 30%, produces an expected cost saving of 25%. Some of the savings would be realized via reductions in the amounts of steel, concrete and labor. Consolidating the intended two spans into one would also provide savings by reducing the number of caissons, struts, etc. In calculating tolls for a 10-lane bridge, I have assumed that the cost of the full-size bridge is reduced by 22.5% — the mean of the four saving percentages in Table 3.

F. Bridge Volumes

Tappan Zee Bridge traffic volumes on a typical weekday peaked in 2004, at an average of 140,310 vehicles (all figures sum annual eastbound and westbound traffic and divide by 365). The 2011 daily rate of 132,070 vehicles was the lowest since 1998 and was 5.9% less (5.6%, adjusted for leap year) than the 2004 peak.

Table 4, below, uses four-year averages to encapsulate the past two decades; for example, the figure for 2011 is the average of 2008-2011. Even knowing that the 2008 financial crisis and subsequent recession took a toll on bridge use, the extent of the decline is striking, with 4% fewer crossings in 2008-2011 than in 2004-2007. Moreover, even during the peak four-year period of 2004-2007, volume was a mere 2% greater than in 2000-2003, indicating that *growth in bridge volumes had slowed before the housing bubble burst in 2008 and took down the economy with it.*

A detailed treatment of future bridge volumes is beyond the scope of this paper. Current trends militate in favor of slow traffic growth. These include a move away from single-tenant office parks such as those in the "platinum mile" served by I-287 east of White

[12] A scaling exponent is an engineer's rule of thumb for calculating unit cost savings with increasing scale. The closer its value to zero, the greater the savings (an exponent of 1.0 indicates a linear relationship between scale and cost, i.e., zero scale economies). With a 0.9 scaling exponent, the variable cost component of a project must be downsized by a little more than 27% to reduce its cost by 25%. The formula is: **Cost of Bridge with Width W% of Full-Size Design Width = 0.1 x Cost of Full-Size Bridge Cost + 0.9 x (W% * Full-Size Bridge Cost) ^ 0.9**.

Plains[13]; a possible long-term decline in the attractiveness of suburban lifestyles vis-à-vis urban living; more flexible work arrangements such as telecommuting[14]; and a cultural shift away from automobility.[15] None of these trends were forecast 20 years ago, illustrating the difficulty of anticipating societal trends that shape travel.

Table 4: Tappan Zee Bridge Travel Volumes

4-Year Period Ending in Year Shown	Average Daily Volume	Annualized Change from Prior Period
2011	**133,158**	– 1.1%
2007	**138,923**	+ 0.5%
2003	**136,093**	+ 1.7%
1999	**127,049**	+ 2.3%
1995	**116,075**	+ 2.1%
1991	**106,789**	

Source: Volumes for each 4-year period were calculated by author from various Thruway Authority sources. Surprisingly, no single source for this data is available. Year-2011 datum was compiled by author from Thruway Authority document cited in FN 6. Percent figures in text pertain to differences between 4-year periods, whereas percent figures in table are annualized.

To address this uncertainty, I've bounded annual growth by a high rate of 2% and a low rate of zero. This bracket fits nicely around the 1.1% average annual compound growth rate from 1991 to 2011, according slightly greater weight to the 2001-2011 decade in which growth was zero. Note that future traffic volumes will also be affected by travelers'

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[13] See New York Times, "In Westchester County, the Platinum Mile Is Reinvented, Again," Jan. 3, 2012, available at <http://nyti.ms/xHAUIG>. The article reported that one million square feet of commercial office space along the nearly four miles of I-287 in White Plains, Harrison and Rye is now vacant, a rate of 19%, up from 13% in 2002. The article said that the recession "is not the whole story" behind the high vacancy rate, citing competition from "White Plains's newly vibrant downtown" with "upscale shops" and other attractions including the 35-minute Metro-North commute from New York's Grand Central Terminal.

[14] A 2011 report by Jacobs Engineering Group for the Thruway Authority cited a doubling in the number of employees telecommuting at least once a month, from 17 million in 2001 to 34 million in 2008, as a probable contributor to the nationwide decline in automobile use in recent years. The Jacobs report also cited survey data "suggest[ing] that increases in internet usage … may have caused a decrease in discretionary travel" as people spend more time online. See Draft Memorandum, 31 August 2011, attached to Thruway Authority 2012 Budget, pp. 38-39 of 82, available at >http://www.thruway.ny.gov/about/financial/budget-books/2012/2012-budget.pdf>.

[15] See New York Times, "To Draw Reluctant Young Buyers, G.M. Turns to MTV, March 22, 2012, available at <http://nyti.ms/GFy1e0>. According to FHWA data reported there, in 2008 just 46.3% of "potential drivers" 19 and under had drivers' licenses, vs. 64.4% in 1998. A similar falloff mentioned in The Times in "The Go-Nowhere Generation," March 10, 2012, available at <http://nyti.ms/zNBovD>, was attributed in part to the rise in use of social media —an activity that harmonizes poorly with autos.

reactions to the higher tolls that will be required to pay for the replacement bridge, as I now discuss.

G. Toll Shock[16]

"Rate shock" was the term applied to the electricity industry's financial crisis in the 1970s, when utility company finances buckled under the weight of escalating nuclear power costs. Not only were the costs of the reactors spiraling out of control, but the electricity rate hikes required to pay for them caused power use unexpectedly to flatten, as customers reacted to the high rates by conserving. Attempts by some utilities to make up for the revenue shortfalls with "supplemental" rate hikes failed, leading to dividend cuts that cost investors billions.

From this experience, realization grew that energy use is somewhat price-sensitive. Yet it is less widely understood that society's level of *driving* is also subject to changes in *its* cost.

What makes this pertinent to the bridge replacement project is the prospect of a rise in the bridge's toll big enough to drive up the total price of trips that use the bridge. To test for that, I've posited these characteristics for a "typical" round-trip using the TZB:

- Total trip distance (round-trip): 35 miles
- Average fuel economy (mostly highway): 25 mpg
- Gasoline price: $4.00 per gallon
- Current toll: $4.75
- Other trip costs (maintenance, parking where applicable, etc.): $2.80

These assumptions yield a total (round-trip) cost of $13.15. Now consider a ten-dollar hike in the Tappan Zee Bridge toll, raising the cost of the trip to $23.15, or 75% more than with the current toll. How much this increase in trip cost would affect the number of trips (assuming that every traveler faced the same 75% increase) depends on those trips' price-sensitivity, a quantity represented mathematically by their "price-elasticity." A low elasticity assumption of 0.25 implies that the number of trips would fall by 13%; whereas a higher elasticity, say 0.50, would imply a 24% drop in trips.[17] The higher the elasticity —

[16] This section draws on an article I posted on Streetsblog on Jan. 26, "Cost of Tappan Zee Mega-Bridge Could Cause Tolls to Triple" (available at <http://bit.ly/y5uB8j>). That article employed somewhat more draconian assumptions (e.g., higher price-elasticities) and thus had more dire conclusions than the analysis here.

[17] Mathematically, the elasticity — which is actually a negative number — is applied as an exponent (power) to the factor increase in the price of the trip. In this example, the price factor is 1.75, since the toll hike makes the trip 75% more costly. For the low elasticity of negative 0.25, the factor of 1.75 is raised to the negative 0.25 power; the result, shown on any hand calculator, is 0.87, indicating that 87% of trips remain and the other 13% disappear. For the high elasticity, negative 0.5, the result is 1.75 raised to the negative 0.5 power; this yields 0.76, meaning that 76% of trips remain and 24% disappear.

and, of course, the steeper the increase in trips' costs — the more severe the drop-off in the amount of travel.

The $10 toll increase in the cost of trips using the Tappan Zee Bridge in the example above is an illustrative assumption. The actual toll will depend on the cost of the replacement project, whether or not the project obtains cheaper federal financing, and the extent to which costs are off-loaded (as discussed in Section C). A further factor is whether, and by how much, bridge traffic itself increases over time, since more traffic allows the (fixed) cost of the bridge to be distributed over a larger base of trips.

Table 5, below, runs through different combinations of these variables to show how bridge volumes could be affected by the toll needed to recover the replacement project's cost. It assumes the $5.2 billion cost reported in the press, which means no "bridge diet" as discussed in Sections D and E, but no overruns either.

Table 5: Effect of Tappan Zee Replacement Bridge Cost on Travel Volumes

Fed Financing?	Price-Elasticity	Underlying Growth	Trip Cost, % Hike	Volume Loss, %
NO	Low (0.25)	0% / yr	59%	**11%**
YES	Low (0.25)	0% / yr	49%	**9%**
NO	High (0.50)	0% / yr	59%	**21%**
YES	High (0.50)	0% / yr	49%	**18%**
NO	Low (0.25)	2% / yr	49%	**9%**
YES	Low (0.25)	2% / yr	40%	**8%**
NO	High (0.50)	2% / yr	49%	**18%**
YES	High (0.50)	2% / yr	40%	**16%**

Calculations are for 2021. They assume $5.2 billion project cost, 100% of debt service covered by toll, less $75 million a year for maintenance savings. Underlying growth rate in middle column is applied to 2011 average daily volume of 66,000 toll-paying trips. "Trip Cost, % Hike" is increase in total cost of typical trip using the Tappan Zee; increase in *toll component alone* is far greater.

What's most striking about Table 5 is the next-to-last column, showing the increase in the driver's cost for a 35-mile round trip on the replacement Tappan Zee Bridge as a function of different assumptions on bridge financing and volumes. (Thirty-five miles is roughly the distance to travel from Spring Valley in Rockland County to White Plains and back.) The out-of-pocket cost for such a trip, now $13.15, would rise by 40-60 percent — and that is before incorporating the "toll shock" effect on traffic volumes from the direct toll hikes shown. (The toll itself would rise far more steeply, but the relevant figure for predicting future traffic levels is the growth in the trip's *entire cost*, not just its *toll portion*.)

The attrition in volume from such a rise in the trip price could be as high as 21%, in the case with low underlying growth in volume, high trip sensitivity to toll hikes and zero federal financing; or as little as 8%, if each of those assumptions is flipped. But even this low figure is significant, since any attrition in bridge volumes due to "toll shock" would necessitate a further hike in the Tappan Zee toll — barring off-loading of costs. The smallest loss in volume shown in Table 5, 8%, would require a 9% toll rise on top of the increase already shown to make up for the fewer trips over which the fixed costs are spread.

"Losing" 10-20% of trips that would otherwise be made on the Tappan Zee Bridge, due to a steep toll hike, is no small erosion. Where would these "lost" trips go, i.e., how would attrition in bridge volumes actually manifest? The answer is a combination of things: more car-pooling (higher car occupancies); greater use of transit; relocation of trips, particularly to destinations that obviate the need to cross the Hudson; and less travel, period. Some reductions would be fairly immediate; others would evolve over a longer time-horizon.[18]

Higher Tappan Zee Bridge tolls will also cut into TZB trips via "toll-shopping," as some trips divert north to I-84 which crosses the Hudson at Newburgh and Beacon or south to the George Washington Bridge. Needless to say, which trips actually divert will be situation-dependent. It's hard to imagine any toll hike that would cause trips from Nyack to Tarrytown to divert to a bridge other than the Tappan Zee. And even a trip from Albany to Manhattan that now uses the TZB is unlikely to be diverted to the George if the driver expects to lose an hour in heavier traffic. On the other hand, some number of Tappan Zee Bridge trips are marginal enough vis-à-vis other crossings that a modest toll increase should suffice to induce the driver to switch. And since we are talking here about more than modest toll increases, the number of switches could be substantial.

H. A Bridge to Handle Future Traffic Volumes

Lanes on the current Tappan Zee Bridge are 11.2 feet wide. The 12-foot travel lanes for the replacement bridge would be 7.5% wider, and are assumed to have the capacity to move 2,000 autos (passenger vehicles) per hour. With four lanes, each direction of travel would then have a capacity of 8,000 PCE (passenger-car equivalents). This is well in excess of the

[18] Consider a hypothetical Westchester County high school soccer "travel team" that plays a few games a year in Rockland. In the short term, a stiff toll hike should make it more likely that some parents will pool their vehicles for inter-county trips. In the long run, travel leagues on either side of the Hudson might reconfigure to reduce or even eliminate trips across the river. Whether these or analogous changes in commuting, shopping, visiting, recreation, etc. are desirable is beside the point, which is that higher tolls will *cause* them.

average weekday 2011 peak-hour volume of 6,975 PCE, which takes place during the hour between 7 and 8 am.[19]

Table 6: Projected Peak-Hour Traffic Volumes (passenger-car equivalents, eastbound)

	2021	2031
15-Lane TZB, Mean Volume in 16 Scenarios	6,418	7,824
15-Lane TZB, Maximum Volume in 16 Scenarios	7,676	9,357
Bridge Diet TZB, Mean Volume in 16 Scenarios	6,700	8,168
Bridge Diet TZB, Maximum Volume in 16 Scenarios	7,832	9,547

Note that 4 lanes in each direction have combined nominal capacity of 8,000 passenger-car equivalents. "Actual" 2011 peak hourly volume was 6,975 (see FN 18).

Even under the highest-growth scenario of bridge volumes for both the full-size bridge and the slimmed-down design — 2%/year underlying traffic growth from 2011 and federal financing mitigating debt service costs for the replacement bridge — the 8,000 per-hour PCE limit won't be exceeded for at least ten years, i.e., through 2021. That is not the case a decade later, however, as Table 6 shows: peak-hour travel in 2031 is over 9,000 passenger-car equivalents in the maximum-traffic scenarios for both bridge designs, and the mean scenarios involving both the 10-lane and 15-lane bridge are around 8,000 PCE's per hour.

Does this mean that 4 lanes (in each direction) are insufficient to handle peak volumes much beyond 2021? No. This is because the one-hour peak is indeed that: just one hour's worth. During the 8-9 am period following the 7-8 am peak, 14% fewer vehicles pass through the TZB's eastern portal; and the shortfall from the peak in the preceding 6-7 am hour is more than twice as stark, with 29% fewer vehicles than during 7-8 am. *These figures suggest that by applying peak or "differential" pricing, with off-peak discounts offsetting on-peak premium tolls, the Thruway Authority could keep travel demand within the 8,000-per-hour target dictated by a 4-lane (in one direction) bridge design for years to come.*

Consider this exploratory calculation on a datum in the prior paragraph, that 6-7 am eastbound TZB traffic is 29% lighter than during the 7-8 am peak. Posit a flat $15 toll on the replacement bridge — the approximate average toll for the 16 scenarios outlined in Table 1 (all assuming no bridge diet). Now, instead, consider a $20 toll for the peak hour (7-8 am)

[19] At this writing (late March 2012), weekday per-hour TZB traffic volumes were not available from the Thruway Authority's Web site, requiring me to convert available weekday per-hour car and commercial-vehicle volumes from the TZB's peak travel year, 2004 (for which I equated each commercial vehicle to two autos) and prorate them to with 2011 and 2004 annual volumes, adjusting the latter for Leap Year. The result is the eastbound PCE of 6,975 for 2011 noted in the text. Note that the westbound peak volume is less.

and $12 for the pre-peak hour (6-7 am). Based on the time-switching elasticity that the Port Authority observed after it instituted a peak vs. off-peak toll differential on its Hudson River crossings in early 2001, the ratio between consecutive-hour TZB volumes, now 0.71, would be expected to rise to 0.97.[20] That is, instituting a 40% off-peak discount from the premium peak toll should cause enough travel times to change, so that what is now a 29% difference in respective volumes would shrink to just 3%.

Thus, if the 7-8 am peak volume under flat-rate pricing was going to be, say, 9,100 vehicles, then the type of differential pricing sketched above would induce approximately 1,200 trips to "migrate" from the 7-8 am peak hour to 6-7 am. This would reduce the 7-8 am peak to approximately 7,900 vehicles per hour, while lifting the prior 6-7 am volume of around 6,500 vehicles to 7,700. Both figures fall within the 8,000 vehicle capacity.

Would peak (differential) pricing come at a cost? Certainly. Drivers who move their travel time earlier will be inconvenienced, while those who will continue to drive during 7-8 am and pay the premium rate will be disadvantaged monetarily. On the other side of the ledger, however, are toll savings that will be reaped not just by those who will choose to travel off-peak (including "switchers" from the peak), but, more importantly, by *everyone* who will ever drive on the new Tappan Zee Bridge, by virtue of the lower toll enabled by the reduction in the cost of the downsized bridge. As noted in Section C, this benefit may well extend to New Yorkers who use the bridge rarely or never, if downsizing the bridge forestalls higher Thruway tolls, state taxes or transit fares to make up for the shortfall between the bridge's debt service and the tolls that TZB users can be made to bear.

The replacement Tappan Zee Bridge is intended to last at least half-a-century. It appears plausible that travel demand beyond 2031 could be accommodated through a combination of more comprehensive differential pricing, provision of improved public transportation including Bus Rapid Transit, real-time ride-sharing enhanced by digital communications, pay-for parking reforms such as "cashing out free parking" that incentivize drivers to use non-drive-alone means to commute to office parks, and other technologies that will emerge over the next 20 years. This kind of future warrants serious consideration now, before New York State plunges ahead with a project that could saddle future generations with high financial and traffic costs.

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[20] For a look at the mathematics underlying this paragraph, which are based on the Port Authority study, download my "Balanced Transportation Analyzer" spreadsheet via this link <http://www.nnyn.org/kheelplan/BTA_1.1.xls> and navigate to the **Travel-Time Switching** worksheet tab. The spreadsheet is under 4 MB and runs on Excel 2007 or later.

I. Areas for Further Inquiry

The following questions to the New York State Thruway Authority arose in the course of composing this analysis.

- How does the Authority intend to pay for the replacement bridge? Will TBZ users pay the entire cost? If not, who will?
- How does the Authority compute debt service on the financing for the bridge?
- What are the likelihoods of cost overruns? Are issues such as seismic safety, dredging of Hudson River sediment, non-interference with traffic on the existing span, and community impacts fully reflected in the Authority's cost estimate?
- What is the cost to decommission the existing bridge, and is that cost included in the cost estimate for the replacement bridge?
- What is the best estimate of current TZB costs that will be avoided once the old bridge is taken out of service?
- What are weekday, weekend and annual TZB traffic volumes for each of the past 30 years? What are each year's hour-by-hour weekday and weekend volumes over the same period?
- What price-elasticity does the Thruway Authority believe applies to trips that cross the TZB? Has the Authority factored that into its planning for bridge design and financing?
- What does the Authority believe is the applicable price-elasticity for "switching" trip times, as a function of differential (peak vs. non-peak) toll prices?
- What are "distance deciles" for trips that use the Tappan Zee Bridge, i.e., what are the average distances, in miles, of trips that are the shortest 10%, the next shortest 10%, etc., up to the longest 10%?
- How many times in recent years was at least one direction of the Tappan Zee Bridge taken out of service due to an unforeseen event such as a crash, storm, etc.? For how many hours was traffic halted? What were the associated economic losses?
- What, if anything, would be saved in construction cost and time by building the replacement bridge as a single (bi-directional) span rather than as two separate spans?
- What would be saved in construction cost and time by building the replacement bridge to be 25% less wide than the current design (183 feet wide)?

About Charles Komanoff

Komanoff is an activist, economist and policy analyst. He directs the Carbon Tax Center and develops traffic-pricing modeling tools for the Nurture Nature Foundation. A prolific writer, Charles's output includes books, scholarly articles, journalism and landmark reports such as *Power Plant Cost Escalation*, *Killed By Automobile*, and the *Bicycle Blueprint*. A math-and-economics graduate of Harvard, Charles lives with his wife and two teenage sons in lower Manhattan. For links and more, go to www.komanoff.net.