

1 **Bridge Prioritization by Benefit Cost Ratio in New York City**

2 by

3 **Edward N. Hernandez**

4 *New York City Department of Transportation*

5

6 *Word Length: 6604*

7 *Figures and Tables: 2*

8

9 Contact Information:

10 Ed Hernandez, JD/MUP

11 Deputy Director of Economic Analysis, NYC DOT

12 55 Water Street, 6th Floor, (04A)

13 New York, NY 10041

14 e-mail: ehernandez@dot.nyc.gov

15 Office: 212-839-6925

16

17 Submission date: 3/8/17

18

1 **ABSTRACT**

2 The New York City Department of Transportation (DOT) maintains a portfolio of 789 bridges within the
3 five boroughs of the City of New York. Because funding from all levels of government is limited, the
4 DOT anticipates the need to make difficult decisions regarding the allocation of its resources. In an effort
5 to inform this decision making process, the DOT has begun a study to rank its bridges by benefit cost
6 ratio (BCR). The DOT's emphasis is not on whether the projects show a benefit cost ratio of above or
7 below 1.0 in an absolute sense, but on developing a consistent benefit cost methodology based on readily
8 available data that can produce dependable and replicable rankings across hundreds of projects. This
9 effort has required that the DOT think creatively with regards to travel time savings, safety, and social
10 benefits. It is the DOT's hope that by developing a proper BCR metric for our bridges, the DOT can
11 better inform decision makers regarding the relative importance and cost effectiveness of each of our
12 infrastructure investments. The DOT feels that the lessons learned in producing this analysis would be of
13 great interest to other municipalities facing similarly difficult decisions regarding their aging
14 infrastructure.

15

16

1 The New York City Department of Transportation (DOT) maintains a portfolio of 789 bridges within the
2 five boroughs of the City of New York. The majority of the DOT's capital budget is spent on the repair
3 and reconstruction of bridges – approximately \$10 billion in the current Ten Year Plan. Yet the DOT
4 may require up to twice this amount to meet the need for bridge reconstruction in the next ten years.
5 Because funding from all levels of government is limited the DOT will need to make difficult decisions
6 regarding the allocation of its resources. In an effort to inform this decision making process, the DOT has
7 begun a study to rank all of its bridges by benefit cost ratio - an ambitious goal that has triggered an
8 intense data gathering effort with regards to bridge usage, user mode, alternate routes and costs of
9 construction. This effort has also required the DOT to think creatively with regards to assumptions
10 regarding travel time savings, safety, and social benefits. While still in its early stages, the investigation
11 has already yielded valuable information beyond its initial goals. As of this writing, the DOT has
12 developed rankings for approximately 153 bridges. It is the DOT's hope that by developing a proper BCR
13 metric for its bridges, it can better inform decision makers at the highest levels regarding the relative
14 importance and cost effectiveness of each of our infrastructure investments and make the best decisions
15 possible with the taxpayer dollars available. The DOT feels that the lessons learned in producing this
16 analysis would be of great interest to other municipalities facing similarly difficult decisions regarding
17 their aging infrastructure.

18 **BACKGROUND AND HISTORY**

19 In 2014, under the leadership of DOT Commissioner Polly Trottenberg and (now) Executive Deputy
20 Commissioner Joseph Jarrin, the DOT embarked on an ambitious attempt to perform economic analysis
21 on its entire capital project portfolio. The seeds of this initiative were born from the agency's success in
22 using benefit cost analysis of capital projects to support its federal grant applications for those projects.
23 Due in part to those efforts, the agency was awarded \$25 million by the federal government under the
24 TIGER VI grant to support capital investments in Vision Zero - the City's ambitious initiative to reduce
25 annual traffic deaths to zero. By working on this grant application key city personnel gained experience in
26 the methods and best practices required for successful economic analysis of transportation projects.
27 Agency leadership then made a decision to build upon this capacity and develop a program of economic
28 analysis that would assist the agency in making difficult, yet necessary, future funding decisions. The
29 city's bridge portfolio was chosen as the first focus of economic analysis because it accounted for the
30 largest share of the DOT's capital budget and the largest shortfall in funding. The DOT hopes that an
31 objective economic analysis will help rank projects with the greatest benefits and the lowest costs, and
32 will thereby maximize the benefits of each dollar spent.

33 **Goal of the Study**

34 The DOT's goal was to develop a method to rank its bridge projects using benefits and costs. This is
35 slightly different than the typical objective of a benefit cost analysis. In a typical benefit/cost analysis the
36 benefits and costs of a "Build" scenario are compared to the benefits and costs of a "No Build" scenario
37 and a project whose benefits outweigh its costs is generally considered a good investment worthy of
38 construction. Its benefit to cost ratio is above 1.0. However, the goal of this study is to prioritize and rank
39 re-building projects for funding purposes using benefits and costs as our criteria – not to determine
40 whether these projects should be rebuilt at all. As such, the DOT's emphasis is not on whether the
41 projects show a benefit cost ratio of above or below 1.0 in an absolute sense, but on developing a
42 consistent benefit cost methodology based on readily available data that can produce dependable and
43 replicable rankings across hundreds of projects.

44 **The Study Generally**

45 This study asks whether a bridge should be rebuilt or demolished given its estimated cost, its current
46 usage, and the added distance of the alternate routes available. It monetizes the current usage and the time

1 inconvenience that would be caused by permanent demolition of the bridge. Because it evaluates bridges
 2 that have already been built, it allows the DOT to take measurements of how much each bridge is being
 3 used and by whom. This allows the DOT to gauge benefits with a greater degree of accuracy than
 4 economic studies of future construction or future expansion that are often based on assumptions of future
 5 usage and users.

6 In addition to providing greater accuracy in the prediction of benefits (since they are not
 7 predictions but actual measurements of current use), this approach to analyzing already-built
 8 infrastructure allows the DOT to think creatively about infrastructure renewal projects in already-built
 9 environments like New York City. For example, if an existing four lane bridge receives a relatively low
 10 ranking because it does not have enough users to justify its high reconstruction cost, perhaps the DOT can
 11 explore reconstructing it as a two lane bridge (reducing costs) and thereby improve its benefit/cost ratio.
 12 If the majority of a bridge's monetized benefits are due to pedestrians and cyclists, perhaps more space
 13 can be devoted to those users in the next incarnation of the bridge and less to motorized vehicles.

14 It is important to note, however, that this is intended to be a broad analysis to create preliminary
 15 rankings for further investigation, and in no case should this analysis by itself be used to justify the
 16 demolition or closure of a bridge simply based on its benefit cost ratio without additional study or
 17 analysis. As will be explained herein, this study is based on an analysis of a limited (but important)
 18 category of benefits, and it in no way captures all of the benefits and costs that should be taken into
 19 consideration before making a decision to close a bridge.

20 **Benefits Generally**

21 A bridge provides many different benefits to society. Some of these benefits are easier to measure and
 22 monetize than others. For example, the amount of time saved by using a bridge to cross a river is easier to
 23 measure than the value of the scenic view of the river from the middle of the bridge. The following is a
 24 list of some of the benefits that bridges provide, and the ones that the DOT has measured for this analysis:

25 **Table 1:**

Benefit	Description	Included in DOT Analysis		
		Monetized	Quantified	Qualitative
Faster Travel (Travel Time Savings)	Faster time to reach destination when bridge is open	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	No
Lower Vehicle Operating Costs	Lower vehicle operating costs when extra distance is avoided	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	No
Emissions Reductions	Lower GHG emissions when additional distance is avoided	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	No
Pavement Maintenance Savings	Lower cost of maintaining roads when vehicles travel less distance	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	No
Safety	Difference between the number and severity of injuries on the alternate route and the build route	<input checked="" type="checkbox"/>	No	<input checked="" type="checkbox"/>
Utilities	Carrying utilities infrastructure over less	No	No	No

	distance			
Resilience	Faster evacuations during emergencies	No	No	No
First Responder Access	Faster emergency response time	No	No	No
Recreation	Enjoyment of crossing bridge, or view of bridge, or view from bridge, etc	No	No	No
Property Values	Change in nearby property values depending on presence of bridge	No	No	No

1

2 As Table 1 shows, the DOT has monetized five types of benefits for this study. Four of these
3 benefits are quantified and included in the primary BCR metric discussed herein. We have also created a
4 secondary BCR metric called the “Safety BCR” which is a combination of the quantitative data included
5 in the primary BCR metric and qualitative data regarding safety.

6 It is important to note that certain benefits, with potentially large monetary impacts, were not
7 included in this study - chief among these are utilities benefits. Some New York City bridges carry (1)
8 high voltage power lines that provide electricity, (2) telecommunications infrastructure that provides
9 television, internet and phone access, as well as (3) water mains that provide fresh potable water to entire
10 neighborhoods. In addition, each bridge carries a different mix of utilities. While the DOT is aware of the
11 types of utilities on each of its bridges, it does not have information regarding the magnitude and effects
12 of the impacts or the industry specific expertise to monetize these impacts. Therefore, due to the
13 complexity of including this category of benefits in such a broad study, the DOT has decided to not
14 include them in this phase of the analysis but to revisit them once this study has flagged a smaller number
15 of bridges for more rigorous analysis.

16 Utilities notwithstanding, travel time savings are the primary benefit produced by a bridge. It is
17 the reason why most bridges are built. In our sample of 153 bridges, monetized benefits from vehicle
18 operating costs, emissions reductions and pavement maintenance savings were less than 5% of total
19 monetized benefits – travel time savings accounted for the rest. Travel time savings were not calculated
20 using a traffic model. This could take several days of computer time per bridge due to the complexity of
21 our local roadways – even if complete data was available. A different, more practical approach was
22 required due to the large number of bridges requiring analysis. Instead, an approximation was developed
23 based on alternate distance travelled (in the No Build scenario) and average speed per user, such that
24 travel time savings could be computed by spreadsheet. This method will be described below.

25 **Choice of Candidate Bridges**

26 Despite the fact that the benefits analysis was limited to five categories of benefits, data collection
27 (pedestrian/bicycle counts and measurements of alternate route distance) for nearly 800 bridges would
28 have been unrealistic. The data requirements of this analysis are discussed in further detail in the
29 “Number of Users” section and the “Alternate Route” section below. Therefore, the DOT narrowed the
30 list of candidates by first focusing on those bridges which were unfunded or underfunded in its 10 Year
31 Plan. The DOT narrowed this further by removing critical bridges such as the East River bridges, bridges
32 supporting arterial roadways, and bridges on emergency escape routes since it was thought that these
33 bridges, because of their critical nature, would most likely find funding at some point in the future. Due to
34 available funding and time constraints during the DOT’s initial data gathering phase, this number was

1 further reduced to 194. Intensive data gathering on these bridges began in early May of 2015 and was
2 completed in late June 2015.

3 **METHODOLOGY**

4 As previously stated, this study's emphasis is not on whether projects are truly above or below 1.0 in an
5 absolute sense, but on developing a consistent benefit cost methodology based on readily available data
6 that can produce dependable and replicable rankings across hundreds of projects. This distinction heavily
7 influences our BCR methodology and so it is important to understand its impact. Because of this
8 distinction, it is far more important that the methodology used herein prioritize uniform standards for
9 measuring costs and benefits for each bridge over methods that may potentially be more accurate for
10 some bridges but cannot be applied consistently to all bridges. For example, if the DOT was in possession
11 of detailed traffic studies which would allow it to calculate traffic delays for some bridges but not for
12 others, they would not be used because they would violate the need for uniformity of measurement.
13 Instead, the DOT tried to develop a travel time savings methodology that would approximate these results
14 and could be applied to all of the bridges uniformly. In this manner it could guarantee that all of the
15 bridges had been rated according to the same standards and that it was comparing apples to apples. **As a**
16 **result, what the DOT has developed can be more accurately described as a benefit cost ranking**
17 **rather than a benefit cost ratio.** This metric is an excellent tool for prioritizing hundreds of projects
18 quickly with easily obtainable data, but should not be used to decide whether a project's costs outweigh
19 its benefits in an absolute sense. As discussed earlier, many benefits, such as utility benefits, were left out
20 of the calculation due to the difficulty in gathering such a large amount of data on so many projects
21 simultaneously. Nevertheless, despite the omission of these important benefits, over 85% of the 153
22 projects analyzed produced a benefit-to-cost ratio of greater than 1.0.

23 This analysis follows a standard Benefit Cost methodology with the present value of the benefits
24 being divided by the present value of the costs. As with all benefit cost analyses, the BC ratio is derived
25 by comparing the costs and benefits of the build condition to the costs and benefits of the no-build
26 condition. In the DOT's case, all of the bridges studied were already built, therefore the "no-build"
27 condition had to account for the demolition of the existing bridge since a deteriorating bridge cannot be
28 allowed to collapse of its own accord. For this reason the "No Build" condition is also referred to as the
29 "Demolition" scenario. More detail on the No Build Condition can be found below. The formula for this
30 benefit cost analysis is set forth below (Equation 1). The assumptions used in the formula will be
31 discussed first, followed by a brief discussion of the data gathering process. The formula will then be
32 applied, and its components explained, using a real world example.

33 ***Equation 1:***

$$34 \text{ Benefit Cost Ratio} = \frac{\text{Present Value (Benefits of Reconstruction) - Benefits of Demolition}}{\text{Present Value (Cost of Reconstruction - Cost of Demolition)}}$$

38 **The No Build Condition**

39
40 In most benefit cost analyses the "No Build" condition indicates no action was performed to
41 improve or change the existing condition. The benefits and costs of no action are measured so that they
42 can be compared with the benefits and costs of the Build Condition which by definition involves an action
43 of building or changing the existing condition. A typical example of this is where a highway project is
44 being considered. The No Build assumes no highway is built and cars have to travel on the local road.
45 The benefits of the local road are compared to the benefits of the highway, and the costs of the highway
46 are compared with the costs of the local road. The costs of the No Build are typically low, since nothing
47 was built, however, depending on the No Build condition, maintenance might be high over the applicable

1 life cycle. The No Build scenario used in this study is unusual in that it starts with an already built asset
2 that is nearing the end of its useful life and must be closed in the near future for safety reasons if nothing
3 is done to rehabilitate it. Moreover, this No Build scenario includes the cost of the demolition of the asset,
4 since it was thought that a scenario where the bridge is merely allowed to collapse of its own accord was
5 unrealistic. Whereas the Build Scenario (Reconstruction Scenario) assumes construction of the new
6 bridge two years in the future (two years for design before construction occurs). The demolition scenario
7 assumes closure and demolition 6 years in the future, since it is assumed that demolition will be more
8 politically contentious than rebuilding. Yearly maintenance costs are included in both scenarios, except
9 that in the demolition scenario maintenance ends on the demolition year, as do benefits that accrued while
10 the bridge was still in operation. It is because of this demolition No Build scenario that this analysis also
11 includes an alternate route measurement which is used to determine the time value lost by the users of the
12 bridge over the course of the No Build scenario.

13

14 **Present Value.**

15 The present value is the current worth of a future sum of money. That future sum of money is discounted
16 by the discount rate. The discount rate can be understood to be the cost of capital or the minimum return
17 on the investment (over the long run) to meet expectations. For New York City, the cost of capital is the
18 coupon on New York City Capital Bonds. That coupon in 2015, when the first batch of bridges was
19 analyzed, was 3.6%. While this number is rather low when compared to the discount rate required for
20 federal grant applications (7%), the value of the discount rate matters very little when the goal is to
21 provide a relative BCR ranking. The discount rate is extremely important where being above or below 1.0
22 can make or break a project, but when the goal is to rank projects amongst each other the discount rate
23 isn't as critical since it won't change the ranking of the projects relative to each other. For the purpose of
24 this study the DOT applied a discount rate of 3.6% to all projects.

25 **Expected Useful Life**

26 This model assumes an expected useful life of 40 years for a vehicular bridge, and 70 years for a
27 pedestrian bridge. The DOT's bond commitments require a 40 year minimum useful life for its bridges
28 before they can be substantially rehabilitated. However, its bridges are built to withstand 50 years of use
29 before they require substantial rehabilitation. This study opted for the more conservative measure of 40
30 years. Pedestrian bridges are expected to last longer without the need for substantial rehabilitation. The
31 DOT's Bridges Division expects the typical pedestrian bridge to perform safely for at least 75 years
32 without major rehabilitation. The model conservatively assumes 70 years for pedestrian bridges.

33 **Benefits of Reconstruction.**

34 The primary benefit derived from any bridge is the travel time savings enjoyed by the users of the bridge
35 over the life of the bridge. In order to calculate this value the DOT needed to determine (1) the average
36 dollar value of time for New York City residents, (2) the number of vehicles, bicycles and pedestrians
37 crossing each bridge, (3) the average velocity of each mode type, (4) the bridge length, and (5) the
38 alternate route length. By identifying the alternate route and calculating the time saved by using the
39 bridge, the DOT can place a monetary value on the travel time savings created by the bridge.

40 **Value of Time**

41 On June 29, 2016 the United States Bureau of Labor Statistics released a New York City Economic
42 Summary Report. It states that the average wage for all occupations for New York City was \$28.84/hr as
43 of May 2015. According to Federal Government BCA guidance this number should be halved for non-
44 business travel. Inflating this number from May 2015 to June 2016 by the Consumer Price Index resulted
45 in an hourly wage of \$14.56/hr. It should be noted that when calculating the value of time for trucks, the

1 hourly value of time does not need to be halved since it is assumed that truck travel is business travel.
2 During the data gathering portion of this study motor vehicle classifications were not obtained, therefore
3 truck travel was valued at the same hourly rate as private motor vehicle travel.

4 **Number of Users**

5 It was important that the benefit analysis reflect not just motor vehicle data, but data for all users
6 including pedestrians and cyclists. Since there was no recent pedestrian or cyclist information on the 194
7 bridges in the first round of the study, the DOT used a consultant to obtain the data. Miovision video
8 processing was used to count vehicles, cyclists and pedestrians at each bridge. Counts were conducted
9 from 7 am to 7 pm on a weekday (Tuesday, Wednesday or Thursday) and on a weekend day (Saturday or
10 Sunday) on each bridge for a total of 24 hrs of video footage. Some wider bridges required multiple
11 cameras to capture all of the lanes and they produced more video footage. Video collection was not
12 conducted on rainy days as this would obviously distort the data.

13 The results were converted into annual average daily traffic (AADT) by assuming that overnight
14 usage (which was not recorded) was approximately 25% of daytime usage. Some highlights of these
15 results: the highest pedestrian count was at East 167th Street and Grand Concourse in the Bronx with an
16 AADT of 37,102; the highest bicycle count was at the Grand Army Plaza entrance to Prospect Park in
17 Brooklyn with 10,062; the lowest pedestrian count was at a small pedestrian bridge in Inwood Park in
18 Upper Manhattan with an AADT of 9; the highest vehicular count was on Northern Boulevard over Alley
19 Pond Creek in Queens with 47,453; the lowest vehicular count was on 44th Avenue over the CSX train
20 tracks in Queens with 601.

21 **Average Speed per Mode**

22 New York City DOT designs its roadways, crossings and signal timings based on an average pedestrian
23 walking speed of 3 feet per second or 2 m.p.h. In order to remain consistent with the DOT's policy this
24 speed was used. For the purpose of this study motor vehicle and bicycle speed was assumed to be 9.5
25 mph. This is slightly faster than speeds measured for both bicycles and motorized vehicles in the
26 Manhattan Central Business District, but since most of the bridges were located outside of the CBD the
27 DOT assumed a slight improvement in speed (*I*).

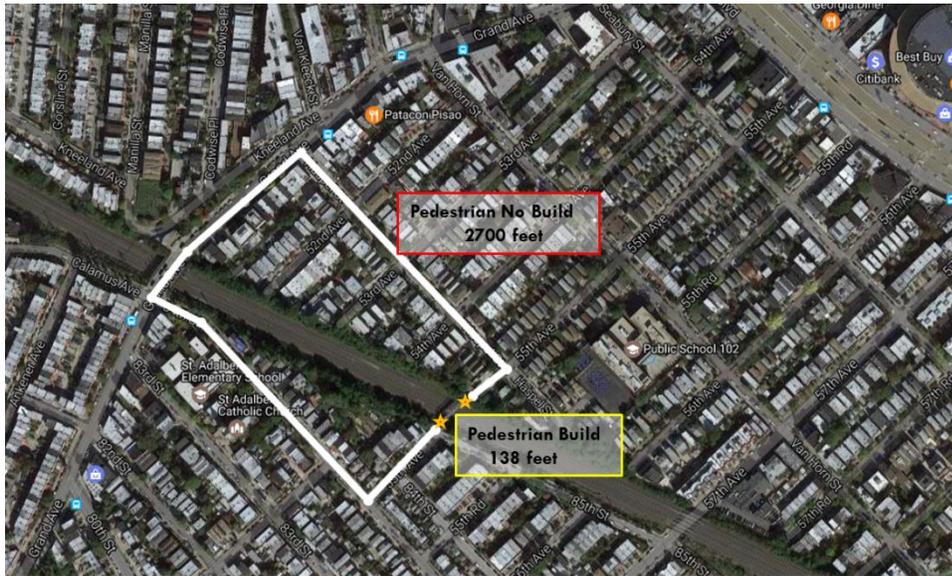
28 **Bridge Length**

29 Here the DOT used the length of the deck area which is a record kept by our Bridges Division.

30 **Alternate Route Length**

31 The alternate route used for each bridge is the shortest route available between the two ends of the bridge
32 using any roadway (other than the bridge itself) regardless of street directionality. See Diagram A below.
33 This methodology sets a consistent and replicable standard for determining alternate routes for vehicles,
34 bicycles and pedestrians. In the absence of a rigorous traffic analysis for each bridge, such as an
35 origin/destination study (which would be conducted as part of a rigorous benefit cost analysis conducted
36 by an urban planner or an economist if the demolition of any one bridge was seriously being considered),
37 any other start and end points would appear arbitrary and more importantly would reduce the consistency
38 of comparison that is necessary for this study. It also provides a practical alternative to computer traffic
39 models which can take several days to run (for just one bridge) given currently available technology.
40 Running a model on 153 bridges would be impractical. Finally, computerized traffic models typically
41 measure motor vehicle impacts and fail to address impacts to other users such as pedestrians and cyclists.
42 These can be substantial oversights, especially in an urban environment. The methodology described
43 herein allows DOT to take into account not only the motor vehicle travel time benefits, but also the
44 pedestrian and cycling benefits so that impacts to all users can be taken into account.

1 Diagram A: Alternate Route Measurement



2 3 Measurement of the Alternate Route on the 55th Avenue Pedestrian Bridge

4 Despite the benefits listed above, there are some shortcomings to be aware of when using this
 5 methodology instead of a traffic model. For one, it does not measure delays to motor vehicle users caused
 6 by traffic congestion on the alternate route. This may be particularly pronounced in areas with already
 7 high traffic volumes along the alternate route, but less so in areas where alternate routes are not at
 8 capacity. In order to compensate for this, the DOT used an average vehicular speed only slightly faster
 9 than that of the typically congested CBD (9.5 mph vs 8.7 mph). While this may adequately adjust for
 10 delays to existing users of the bridge, it does not take into account delays to existing users of the alternate
 11 route. This may result in undercounted motor vehicle delays. However, the methodology counteracts this
 12 undercounting, by overestimating the length of the alternate route and resulting motor vehicle delays by
 13 assuming that all former bridge users will double back to the other side of the bridge as shown in Diagram
 14 A. It is believed that along all but the most congested alternate routes these competing impacts all but
 15 cancel each other out. However, this has yet to be rigorously proven.

16 In sum, the author believes that this method is the most consistent, objective, accurate, and
 17 efficient method of measuring travel time savings short of performing a time consuming
 18 origin/destination study for all users.

19 APPLICATION OF METHODOLOGY TO SAMPLE BRIDGE

20 Diagram A above shows a pedestrian bridge in Elmhurst, Queens. This is one of the 153 bridges the DOT
 21 analyzed using the methodology described above. This bridge will serve as an example of how to utilize
 22 this methodology. It is a simple example as there is only one type of user: pedestrians. The amount of the
 23 time needed to cross this bridge will be calculated first. The amount of time for one crossing will be
 24 monetized. We will then use this to determine the value of all of the crossings performed in a day (using
 25 AADT), then a year, then over the expected life of the bridge. The results will be discounted to their
 26 present value. This will then be compared to the No Build or Demolition Scenario where the distance to
 27 be crossed (the alternate route) is much greater, takes longer, and therefore has a greater monetized value
 28 per crossing.

29 Benefits of Reconstruction

1 The bridge length, as indicated by the DOT's records and verified by Google Maps, is 138 feet.
 2 At 2 mph or 3 feet/sec it will take a pedestrian 46 seconds to cross this bridge. At a value of \$14.56/hour
 3 this crossing has a time value of \$0.186 per person. The pedestrian bridge pictured above has an AADT of
 4 853 which when multiplied by \$0.186 equals \$158.66 in crossing time per day. This number in turn
 5 multiplied by 365 days equals \$57,910. The present value of \$57,910 over 70 years (this is a pedestrian
 6 bridge) is \$1,473,325. See calculations below:

7 *Calculation 1:*

8 Present Value of Travel Time Over Bridge = $PV (L_y D_y A((D_B/V_P)T_v))$
 9

10 Where:

11 PV=Present Value

12 L_y = Assumed Bridge Life in Years

13 D_y = Number of Days in a Year

14 A = Annual Average Daily Traffic

15 D_B = Distance to cross bridge in feet

16 V_P = Velocity at which pedestrians walk

17 T_v = Value of Time

Example:

PV = Present Value uses discount rate of 3.6%

L_y = 70 years

D_y = 365 days

A = 853 pedestrians

D_B = 138 feet

V_P = 3 feet/sec

T_v = \$14.56/hour

20 When this value is inserted into Equation 2 (below) it should be stated as a *negative* because this
 21 is not a gain in time, but time *lost* by pedestrians in crossing the bridge. If the time lost crossing the bridge
 22 is less than time lost on the alternate route, then there is a *positive* benefit. See below:

23 *Equation 2:*

24 Benefit Cost Ratio = $\frac{(-\$1,473,325) - (PV \text{ of Benefits of Demolition})}{\text{Present Value (Cost of Reconstruction - Cost of Demolition)}}$
 25
 26

27 **Benefits of Demolition**

28 The benefits of demolition in Equation 3 were calculated exactly the same as benefits of reconstruction,
 29 except that pedestrians must now walk 2,700 feet (15 minutes) rather than 138 feet (43 seconds) to reach
 30 the other side of the bridge. All other values remain the same. The present value of the benefits of
 31 demolition is \$28,832,805. Again, this should be stated as a negative or a *disbenefit*, see Equation 3
 32 below.

33 *Equation 3:*

34 Benefit Cost Ratio = $\frac{(-\$1,473,325) - (-\$28,832,805)}{\text{Present Value (Cost of Reconstruction - Cost of Demolition)}}$
 35
 36

37

38 Solving for this:

39 *Equation 4:*

40 Benefit Cost Ratio = \$27,359,480

1 Present Value (Cost of Reconstruction – Cost of Demolition)
2

3 The present value of the travel time savings benefits of this pedestrian bridge is \$27,356,559. This
4 method was also followed for vehicular bridges. The travel time savings from vehicles and bicycles were
5 also added to the pedestrian totals. Finally, motorized vehicles were assumed to have an occupancy of 1.4
6 persons (the New York City average), therefore the AADT was multiplied by that amount in order to
7 determine the number of actual users being impacted.

8 **Cost of Reconstruction**

9 *Equation 5:*

10 Cost of Reconstruction = PV (Bridge Replacement Cost) + PV (Annual Maintenance Cost)
11

12 The cost of the reconstruction scenario is the sum of both the one-time cost to replace the bridge and the
13 recurring annual cost to maintain the bridge throughout its useful life. The cost of replacement is based on
14 a standard cost-per-square-foot of deck area developed by the Bridges Division. This per-square-foot-cost
15 includes both hard and soft costs, and is an average based on 15 years of bid price data adjusted for time.
16 It is based on average bid prices prior to 2014. The same per-square-foot-cost of construction is applied to
17 both pedestrian and vehicular bridges. Deck area data for all bridges was provided by the Bridges
18 Division. In addition, a cost equivalent to 2,000 square feet of deck area is added to all non-Americans
19 with Disabilities Act (ADA) compliant bridges in order to account for the cost of ADA accessible ramps.
20 This cost does not apply to all pedestrian bridges since some of these bridges cross at grade over sunken
21 railroad and expressway trenches. The pedestrian bridge in Diagram A is estimated to cost \$5,200,000 to
22 replace.

23 The DOT estimated yearly maintenance costs since actuals were not available on a per bridge
24 basis. The annual cost of maintenance was assumed to be 1% of the cost of replacement. This includes but
25 is not limited to: sweeping, clearing storm drains, snow plowing, painting, and minor repairs such as
26 replacing joints and bearings. For the pedestrian bridge in Diagram A, this would result in a yearly
27 maintenance cost of \$52,000. For the present value calculation, it was assumed that all of the bridges
28 would be built 2 years in the future; therefore, the present value of the bridge replacement is \$4,676,534.
29 The present value of the maintenance costs over the 70 year life of the bridge is \$1,322,961. See Equation
30 5A below.

31 *Equation 5A:*

32 Cost of Reconstruction = \$4,676,534 + \$1,322,961
33

34 The present value of the maintenance cost and the replacement cost was summed (\$5,999,495)
35 and entered into Equation 6 below:

36 *Equation 6:*

37 Benefit Cost Ratio = $\frac{\$27,359,480}{\$5,999,495 - \text{PV Cost of Demolition}}$
38
39

40 **Cost of Demolition**

1 The cost of the demolition scenario is the sum of the present value of demolition and the present value of
 2 maintenance through the year of demolition. Based on previous bridge demolitions in New York City, the
 3 cost to demolish a bridge was assumed to be 4% of the cost to replace the bridge, with a minimum cost of
 4 \$500,000. An increase in this percentage would have the effect of increasing the BCR of reconstruction.
 5 Intuitively, this makes sense: if the cost to demolish increases and the cost to rebuild remains the same,
 6 then the rebuild scenario becomes more appealing. The DOT assumed demolition would occur 6 years
 7 from the date of the study; therefore the present value of this bridge demolition was \$404,400.
 8 Maintenance was calculated to accrue for the next 6 years until demolition: \$52,000 per year for 6 years.
 9 The present value of the demolition cost and maintenance through the demolition date was \$680,577. See
 10 Equation 7 below.

11 *Equation 7:*

$$12 \text{ Benefit Cost Ratio} = \frac{\$27,359,480}{\$5,999,495 - \$680,577}$$

15 Solving for the above:

16 *Equation 8:*

$$17 \text{ Benefit Cost Ratio} = \frac{\$27,359,480}{\$5,318,918} = 5.14$$

20 This pedestrian bridge has a benefit cost ratio of 5.14. This places it in the 60th percentile of the rankings.

21 **Additional Benefits**

22 Given the AADT and alternate route data that was compiled for the analysis above, it was also easy to
 23 calculate Vehicle Operating Costs Savings, Emissions Reductions Benefits, and Pavement Maintenance
 24 Savings using TIGER grant methodology and valuations (2, 3). These benefits were included in the BCRs
 25 for vehicular bridges. However, their impact is miniscule compared with travel time benefits. For
 26 example, on average they amounted to no more than 5% of total benefits – combined. For this reason we
 27 will sidestep a discussion of these benefits and refer those who are interested in further detail to the
 28 TIGER guidance documentation (2, 3).

29 **Safety Benefits**

30 The DOT has a deep commitment to safety, starting with our commitment to Vision Zero – Mayor de
 31 Blasio’s ambitious goal to eliminate all pedestrian and traffic deaths in New York City. The DOT felt it
 32 was necessary to attempt to measure the relative safety implications of closing a bridge and find a way to
 33 include it in the rankings. For example, if a pedestrian bridge were to be closed, would this put
 34 pedestrians on a particularly dangerous alternate route? Would closing a vehicular bridge divert cars to
 35 areas with a heavy pedestrian presence? Would the injury rate increase or would the added traffic bring
 36 vehicles to a crawl and thereby reduce injuries to all users? Answering these questions would require a
 37 level of analysis that would take months to undertake for one bridge – let alone for 200. Therefore, the
 38 DOT looked for a way to approximate the potential safety impacts with data that could be readily
 39 attained.

40 The DOT maintains a computerized database of traffic related injuries and fatalities called Traffic
 41 Safety Data Viewer. The data is mapped and joined via GIS to the intersection nearest where the crash
 42 occurred. The data contains severity and mode of travel. Using Traffic Safety Data Viewer, the DOT was

1 able to calculate the number and severity of injuries along the alternate routes and the existing bridge
2 routes. Using 5 year averages, the DOT then monetized the yearly cost of these injuries using TIGER
3 methodology for the monetization of safety benefits. For each bridge, the present value of injuries on the
4 build route was subtracted from the present value of injuries on the no-build route. This calculation
5 provides a relative measure of the safety benefit of the build condition.

6 *Equation 9:*

7
$$\text{Safety Benefit} = \text{Present Value of Injuries on No Build Route} - \text{Present Value of Injuries on Build Route}$$

8 When the safety benefits were being calculated for pedestrian bridges, only pedestrian and bike
9 injuries on the alternate route were counted. If the alternate route for pedestrians was a continuous
10 sidewalk without exposing the pedestrians to a street crossing, the safety benefit was set equal to zero.

11 As one would expect, once these benefits were added most bridge BCRs increased. The DOT
12 called this BCR the “Safety Benefit BCR” and it was tracked separately from the “Plain BCR” (the travel
13 time savings based BCR). The Safety BCR boosts the rank of those bridges which have particularly
14 dangerous alternate routes. It emphasizes that a bridge not only has travel time impacts, but its existence
15 also has a safety impact to its users. While most bridges remained within 3 or 4 places of their former
16 ranking, some bridges jumped significantly in the rankings once safety was included. One bridge in
17 Brooklyn, where the alternate route included a particularly crash prone intersection, moved 48 spots
18 higher in the rankings, and another in Manhattan moved 30 spots higher for similar reasons. This
19 indicates a particularly dangerous condition along the alternate route, and is a red flag alerting us that if
20 the bridge is demolished, remedial safety measures should be considered along the alternate route so as to
21 lessen safety impacts. This is an important finding and it is the DOT’s hope that the Safety BCR will be
22 used in conjunction with the “Plain BCR” to determine prioritization and its impacts.

23 **HOW THE RANKINGS ARE BEING USED**

24 As discussed earlier, the ranking methodology used herein should not be used to determine whether to
25 eliminate a project but only to rank them; however, it may be used to flag those projects where a thorough
26 benefit cost analysis should be considered. The DOT is now conducting an in-depth benefit cost analysis
27 of the bridges in the bottom ten percent of the “Plain BCR” rankings. Traffic modelling will be used in
28 these in-depth analyses, and a greater range of economic benefits will be explored - such as benefits to
29 property values, utilities, economic benefits to the local economy, etc. The presence of certain bridges in
30 this category has reinforced the opinions of some of the DOT’s senior engineers regarding the need (or
31 lack thereof) for some smaller bridges. For example, the metric supports the DOT’s recent decision to
32 close the 216th Street Pedestrian Bridge (ranked 148 out of 153 bridges). The fact that the BCR ranking is
33 accurately predicting the conclusions of the DOT’s senior engineers is an encouraging sign. It shows that
34 the BCR ranking method is producing a credible and useful metric. The rankings are also forcing us to
35 ask hard questions about the cost of the bridges in the bottom tenth percentile. Perhaps the answer is not
36 to find new benefits or demolish a bridge, but to reconstruct at a scale that reflects their actual usage. By
37 reducing their size and cost these low performing bridges may be saved.

38 **CHALLENGES**

39 The travel time savings methodology on which this model relies cannot be applied to bridges whose sole
40 function is recreational, not utilitarian. Of the 193 bridges the DOT originally set out to rank, 57 were
41 small bridges, many of them foot bridges, located within parks. The alternate routes were often
42 meandering and several orders of magnitude longer than the build routes because paths within parks are
43 not designed in a grid with efficiency of mobility in mind, rather they are purposely designed to lengthen
44 ones enjoyment of the park experience and to channel visitors through certain limited paths. Blind

1 application of the BCR ranking methodology results in astronomical benefit cost ratios. A different
2 methodology, yet to be devised, is required. An accurate valuation of recreational time is also necessary.
3 During recreational time, a longer route is not necessarily a less desirable route. The value of one's time is
4 different. The proper cost of a footbridge overlooking a lake is more than just the time saved by crossing
5 the bridge. But how much is it worth? Such questions might never be resolved by resorting to economics
6 and may properly lie in the policy making or political sphere. There are limits to what can or should be
7 measured, and perhaps that is a positive result.

8 **CONCLUSION**

9 The DOT's benefit cost ranking metric is a reliable measure based on readily available data that can
10 produce dependable and replicable rankings across hundreds of projects with minimal data inputs. It is a
11 powerful tool that can help decision makers with difficult choices regarding the allocation of scarce
12 resources.

13

1

2 Acknowledgements

3 The author of the study is grateful to Commissioner Polly Trottenberg and Executive Deputy
4 Commissioner Joseph H. Jarrin for their support of this effort, and to the members of the Bridges Division
5 Executive Committee for their feedback and assistance.

6

7 References

8

- 9 1. New York City Department of Transportation. *New York City Mobility Report 2016*.
10 <http://www.nyc.gov/html/dot/downloads/pdf/mobility-report-2016-screen-optimized.pdf>.
11 Accessed March 8, 2017.
- 12 2. U.S. Department of Transportation. *TIGER Benefit Cost Analysis Resource Guide*, March 27,
13 2015. [https://www.transportation.gov/policy-initiatives/tiger/tiger-benefit-cost-analysis-bca-](https://www.transportation.gov/policy-initiatives/tiger/tiger-benefit-cost-analysis-bca-resource-guide)
14 [resource-guide](https://www.transportation.gov/policy-initiatives/tiger/tiger-benefit-cost-analysis-bca-resource-guide). Accessed March 8, 2017
- 15 3. U.S. Department of Transportation. *TIGER Benefit Cost Analysis Guidance*,
16 https://www.transportation.gov/sites/dot.gov/files/docs/TIGER_BCA_Guidance.pdf. Accessed
17 March 8, 2017.

18