Cost-Effectiveness of Capping Freeways for Use as Parks: The New York Cross-Bronx Expressway Case Study

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Objectives. To examine health benefits and cost-effectiveness of implementing a freeway deck park to increase urban green space.

Methods. Using the Cross-Bronx Expressway in New York City as a case study, we explored the cost-effectiveness of implementing deck parks. We built a microsimulation model that included increased exercise, fewer accidents, and less pollution as well as the cost of implementation and maintenance of the park. We estimated both the quality-adjusted life years gained and the societal costs for 2017.

Results. Implementation of a deck park over sunken parts of Cross-Bronx Expressway appeared to save both lives and money. Savings were realized for 84% of Monte Carlo simulations.

Conclusions. In a rapidly urbanizing world, reclaiming green space through deck parks can bring health benefits alongside economic savings over the long term.

Public Health Implications. Policymakers are seeking ways to create cross-sectorial synergies that might improve both quality of urban life and health. However, such projects are very expensive, and there is little information on their return of investment. Our analysis showed that deck parks produce exceptional value when implemented over below-grade sections of road. (*Am J Public Health.* Published online ahead of print January 18, 2018: e1–e6. doi:10.2105/AJPH.2017.304243)

As the world urbanizes, green space—such as parks in which residents can exercise and enjoy nature—becomes increasingly important for well-being.[1] It also increasingly becomes a scarce commodity. One option for increasing green space is for cities to cover major roadways with parks. Such parks are variously known as "freeway cap parks," "deck parks," or simply "freeway parks."[2–5] This process has been tried in contexts as diverse as Santiago, Chile,[6,7] and Boston, Massachusetts.[4,8,9]

Deck parks can produce multiple health benefits. Most notably, they remove contact between pedestrians and automobiles. In doing so, they not only reduce accidents but they also encourage active, pollution-free transportation such as biking or jogging. Deck parks also place vehicles in a tunnel, thereby reducing noise and air pollution in surrounding neighborhoods. Finally, deck parks provide green space in which people can exercise and relax.[10–13] In doing so, deck parks have the potential to reduce diabetes, heart disease, mental illness, cancer, low birth weight, and death associated with accidents.[14–22] They can also have positive impacts on property values.[23–27]

However, such projects come with huge costs. On one extreme, there was the "Big Dig" in Boston. This project resulted in the creation of 5 urban parks. It also hid a 1.5-mile swath of freeway in the city's urban center. This revitalized the area, producing vibrant and green pedestrian areas with shopping.[8,26] However, the Big Dig was plagued by problems, such as leaking tunnels and ceiling collapses, and the initial investment may run well over $20 billion by the time interest is paid.[8,9,28] The price tag was so high in part because the project involved burying a highway that was elevated.

There are also more feasible projects, in which highways are already below ground or are at ground level. These can more easily be covered with an elevated park. One example of a successful above-grade deck park is Freeway Park in Seattle, Washington, which came at a relatively low cost of $18 million per acre and has become a centerpiece of the city (even as it sits atop 8 lanes of freeway).[29,30] There could be many projects that are easier still to complete because the freeway itself is below grade and can therefore be capped without much disruption to traffic.

Despite the advantages of deck parks, it is rare that such projects are undertaken. This is in part because areas with major roadways tend to have lower property values and in part because green space tends to be a lower-priority investment in cities struggling to provide essential services to their citizens, such as health, welfare, and transportation.[23] Officials often overlook the potential for deck parks to prevent these very problems. Such projects have the potential to serve as powerful public health and transportation investments for low-income communities.

We estimated the cost-effectiveness of such investments with the Cross-Bronx Expressway as a case study for deck park

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implementation. We chose this as a case study because it exemplifies a type of low-cost public works project for a low-income community. We also conducted a 1-way sensitivity analysis on the implementation cost so that our results can be compared with more ambitious projects in other localities.

The Cross-Bronx Expressway is below grade (lower than ground level) and therefore inexpensive to cap. It is a major contributor to both air pollution and noise pollution. The expressway has been implicated in a crime wave that began in the 1970s and from which the South Bronx has still not recovered.[31–34] It wraps through areas with some of the highest prevalence of diabetes, obesity, and asthma in the city.[33] If capping the Cross-Bronx Expressway with a deck park proves to be cost-effective (the health benefits coming at a reasonable cost relative to other health investments), then it could serve as a starting point for examining other projects nationwide.

However, choosing an inexpensive and politically viable example does not guarantee that implementation of a deck park will go as planned. We therefore chose to include the most conservative estimates of health benefits and the highest published estimates of costs for similar projects to ensure that any benefits are likely to be realized in the real world. The resulting analysis is biased against the use of deck parks, thereby ensuring the estimate that we generate is a reasonable starting point from which to evaluate such public works projects.

METHODS

We used a Markov microsimulation model to evaluate the cost-effectiveness of covering portions of the Cross-Bronx Expressway with a deck park. We measured all costs, including direct and indirect costs, and utilities in the form of quality-adjusted life years (QALYs) for both the status quo scenario (no deck park) and the deck park scenario. One QALY (a combined measure of health and longevity) is equal to a year of life lived in perfect health.[35] Future costs and QALYs were discounted at 3% per year following recommendations of the Second Panel on Cost-Effectiveness in Health and Medicine.[36] Our models therefore estimated the net present value of the deck park over the remaining life of the average resident. The net present value is the cumulative future costs of the strategy, discounted to present 2017 dollars.[35] The major simplifying assumption of the study is that gentrification resulting from the deck park will have a neutral impact on the health of members of the impacted communities. Although gentrification can have negative consequences for some at different points in time, the assumption is based on the estimated average impact over the lifetime of current residents and is addressed in more detail in Table A, available as a supplement to the online version of this article at http://www.ajph.org.

Study Population

One previous study evaluating the health effects of an urban green space found that people living within a half-mile distance from a formal green space received the most health benefits.[37] Thus, we limited our study population to only those people living within a half-mile distance from each side of the proposed park decks. We identified 57 census tracts in the Bronx meeting this criterion, encompassing 226 608 residents (average age of 34 years).[38]

Park Area Estimation

We derived the length and width of the whole Cross-Bronx Expressway and sunken sections of it that are eligible for the deck park implementation from Google 3D Maps.[39] The length of the Cross-Bronx Expressway was 6.5 miles, and the width was 0.02 miles. There are 2.4 miles of expressway that can be more easily capped, which corresponds to 36.8% of the road. A corresponding map is provided in Figure A, available as a supplement to the online version of this article at http://www.ajph.org.

Decision Model

In a cost-effectiveness analysis, direct and indirect costs are captured in dollar terms, and intangible costs (e.g., pain or death) are captured in the denominator as the QALY. Our model calculated the cumulative costs and health-related quality-of-life (HRQL) score over the average life span of each community participant. The HRQL score is a multidimensional measure of health that includes physical and mental health states, and it is measured on a scale from 0 to 1, with 0 representing a health state equal in value to death and 1 representing a state of perfect health. Each year of a community member's life is lived in a state measured by his or her HRQL score, such that a person with an HRQL score of 0.7 who lives for 10 years, will have lived 0.7 × 10 or 7 QALYs.[35]

We developed a Markov model by using TreeAge Pro 2016 software (TreeAge, Williamstown, MA). It was based on the standard reference case analysis suggested by the Second Panel on Cost-Effectiveness in Health and Medicine.[36] A Markov model allows us to include an element of time into our analysis such that the initial investment is made now, but recurring maintenance costs and future health benefits are realized over the lifetime of the average community resident. Our model runs year-to-year, allowing participants to live and realize the benefits of the deck park, become temporarily injured, become permanently injured, die from causes related to exposure to automobiles, or die from other causes unrelated to a freeway or deck park.

We tested uncertainty by using broad 1-way sensitivity analyses (i.e., running the analysis over the range of plausible values of a single variable) and Monte Carlo simulations (randomly sampling from distributions of all model variables at the same time).[35] A Monte Carlo simulation allowed us to present a 95% credible interval (CrI), which incorporates all sources of random and nonrandom error together. Model inputs are presented in Table 1, and key assumptions associated with model design and input parameters are presented in Table A.

Probabilities

The base probability of achieving the guideline-recommended physical activity among the Bronx population was reported by the New York City Department of Health and Mental Hygiene.[50] We estimated the impact of the deck park on the increased proportion of people achieving sufficient physical activity by using values from the literature.[37]

We obtained the probability of a pedestrian traffic injury from the Traffic Injury Statistics of the New York State Department

TABLE 1—Parameters Used in a Markov Model Exploring the Cost-Effectiveness of Capping the Cross-Bronx Expressway With a Deck Park: Bronx, New York, 2017

Description	Base Value	Probabilistic Distribution
General parameters		
Average age of target population, y[38]	34	—
Total length of Cross-Bronx Expressway, miles[39]	6.521	—
Total width of Cross-Bronx Expressway, miles[39]	0.0178	—
Length of Cross-Bronx Expressway to be covered with park, miles[39]	2.4	—
Total number of target population[38]	226 608	—
Annual discounting rate[40]	0.03	—
Costs		
Cost of fatal pedestrian injury (medical + productivity loss), $[41,42]	854 123	γ
Cost of funeral, $[43]	7 306	γ
One-time cost of cap park implementation, $[44]	757 101 728	γ
Cost of nonfatal pedestrian injury (medical + productivity loss), $[41,42]	12 191	γ
Annual cost of park maintenance, $/acre[45]	159 167	γ
Property value increase as societal benefit, $/resident[42,46]	4 968	γ
Probabilities		
Probability of pedestrian accident[47]	0.00146	B
Probability of annual pedestrian accident after capping expressway[47,48]	0.00143	B
Probability of nonpermanent injury[49]	0.964	
Probability of permanent injury[49]	0.036	B
Probability of achieving sufficient physical activity[50]	0.22	B
Probability of death from pedestrian accident[48]	0.0117	B
Hazard ratio attributable to living near green space[51]	0.9779	B
Relative risk of achieving sufficient physical activity when living near green space[37]	1.3764	γ
Utilities		
Annual utility gain attributable to living near green space (< 0.5 mile)[52]	0.0031	B
Annual utility of healthy resident in QALY	1	—
Annual utility decrement attributable to nonpermanent injury in QALY[49]	−0.0146	B
Annual utility decrement attributable to permanent injury in QALY[49]	−0.0375	B
Annual utility gain attributable to noise reduction to below recommended level[53–55]	0.000863	B
Annual utility gain attributable to achieving sufficient physical activity[56]	0.023	B

Notes. QALY = quality-adjusted life year.

of Health,[47] and we derived the probability of nonpermanent injury versus permanent injury from the literature.[49] We obtained the probability of death by dividing the total number pedestrian accident–related deaths by the total number of pedestrian accidents along the expressway from Vision Zero View, a New York City Department of Transportation application.[48] We derived the age-specific annual probability of death from all causes from a 2014 US Life Table.[57]

Costs

We derived all direct and indirect costs of injury from the literature.[41] We derived the deck park cost from previous deck park installations in the United States.[44,58] These included filters capable of reducing small particulate matter from diesel exhaust within the deck parks. We used the highest unit cost per acre[44,59] and multiplied this figure by the total area of the proposed Cross-Bronx Expressway cap. We calculated the annual cost of park maintenance by using 2016 New York City data.[45]

We estimated the impact of green space on property values from the literature,[46,60] the median sales value of owner-occupied housing,[42] and the number of households in the target area. We adjusted all costs used in this study to 2017 US dollars by using the Consumer Price Index Inflation calculator[61] and these are presented in Table 1.

Health-Related Quality of Life

A single quasi-experimental study showed that living in proximity of an urban green space improves residents' mental health.[52] We converted these authors' estimates (measured with the General Health Questionnaire) into a QALY-compatible European Quality of Life Five Dimensions Questionnaire (EQ-5D) score with a validated algorithm by Lindkvist and Feldman.[62] This approach measures the mental health benefits associated with exposure to green space but not the physical health benefits.

In addition, we assumed that the covering of the expressway would physically isolate the traffic noise, decreasing the noise level of the target region to recommended level of 55 decibels or below,[54] thereby reducing the incidence of cardiovascular diseases.[63] We mapped this health effect by using a linear dose–response function of noise level and utility reported by Harding et al.[53]

Living close to a park may increase the number of people achieving recommended levels of physical activity by 37%.[37] We mapped this improvement onto the physical domains of the EQ-5D only by using an estimate from the literature.[56] Using only the physical domains of the HRQL score helped ensure that we did not double-count mental health benefits. Nevertheless, because physical activity and mental health both potentially reduce cardiovascular disease, we conservatively reduced the impact of each, measured as a hazard ratio, by 50%. This helped to ensure that we did not overestimate any benefits. Our approach was chosen rather than the prepackaged health economic assessment tool for cycling and walking because the available literature did not map well onto the health economic assessment tool instrument. We did not incorporate willingness-to-pay assessments of living near green space[64,65] because willingness-to-pay estimates may incorporate health benefits. Willingness-to-pay assessments were considerably higher than the costs that we computed. The utility values are presented in Table 1.

RESULTS

Table 2 represents the results of our main analysis. All values represent per-resident means. The total combined direct and indirect net present value of covering the Cross-Bronx Expressway was –$317 (95% CrI = –$3945, $2694). The total net present value for the status quo was $1312 (95% CrI = $922, $1756). The QALYs associated with the freeway park scenario were 32.53 (95% CrI = 32.41, 32.67), and the QALYs associated with the no park scenario were 32.37 (95% CrI = 32.28, 32.48). Therefore, covering the Cross-Bronx Expressway saved both money and lives for the target population in the Bronx.

In the probabilistic Monte Carlo simulation, 84% of the random samples generated both cost- and life-saving results for the deck park implementation compared with the status quo scenario. The acceptability of the intervention arm increased to 100% after the willingness-to-pay value of $30 000 per QALY, a very low standard for cost-effectiveness.[66] Additional results are available in Figures B, C, and D, available as supplements to the online version of this article at http://www.ajph.org.

In a 1-way sensitivity analysis, we found that our model's results were robust with respect to changes in the key parameters of the model. Our model was most sensitive to the change in housing prices. However, a 30% reduction in the amount of societal benefit gained from housing price increases still yielded a net savings in money and lives. We also examined the project cost in a 1-way sensitivity analysis. Even when the cost was doubled, the project remained a very good value, costing just $11 100 per QALY gained.

DISCUSSION

The Cross-Bronx Expressway has a long and storied history of producing social and health problems in the South Bronx.[33] We used this expressway as a case study to estimate the cost-effectiveness of placing a deck park upon below-grade highways and found that it would save money and lives.

Interventions that save money and lives are very rare in cost-effectiveness analyses and are usually confined to other primary prevention interventions, such as vaccines. Cost-effectiveness analyses differ from cost–benefit analyses in that intangible costs associated with morbidity and mortality are not monetized. Rather, they are separated with the goal of estimating how policymakers can maximize health and longevity on any given budget. In the United States, values upward of $150 000 per QALY gained were considered cost-effective under the Obama administration.[35] At this cost per QALY gain, it should be possible to more than triple the projected investment, raising the possibility that more extensive freeway park projects—including those that require burying freeways—would also be highly cost-effective.

TABLE 2—Cost, Quality-Adjusted Life Years Gained, and 95% Credibility Intervals(CrIs) for Cap Park on the Cross-Bronx Expressway, Bronx, New York, Versus No Park, 2017

Strategy	Cost, $ (95% CrI)	Incremental Cost, $	QALYs (95% CrI)	Incremental QALYs
No park	1312 (922, 1756)	—	32.37 (32.28, 32.48)	—
Park	–317 (–3945, 2694)	–1629	32.53 (32.41, 32.67)	0.15

Notes. QALY = quality-adjusted life year.

When one considers the viability of park projects (whether on freeways or not), location and equity are looming concerns. Placing a park deck or even a buried freeway on the West Side of Manhattan would come with considerably more property value gains than would capping the Cross-Bronx Expressway. However, the West Side of Manhattan already has considerable green space, including that within (and upon the roofs of) luxury apartments in the area. There, however, gentrification would be less of a concern than in the Bronx. In the Bronx, the benefits of having access to green space must be weighed against the concerns of local citizens who may fear being displaced. They must also be weighed in favor of the wishes of those who may benefit greatly from higher property values (e.g., homeowners), better schools (parents), and lower crime rates. It must be recognized that social policies create complex "side effects" that are difficult to anticipate, but that must also be mitigated where possible. In the case of the Cross-Bronx Expressway, the adverse impact of gentrification might be mitigated with investments in affordable housing and rent stabilization legislation.

Although the costs of implementation in New York City are somewhat higher than average, so are the potential benefits (because housing prices tend to be higher than average). We chose the higher bounds of costs and the lower bounds of benefits to ensure that the real-world results of any such efforts would be superior to those that we project, that they would be generalizable to other localities, and that they would be robust to cost overruns. In fact, our estimated cost per acre would cover the cost of a freeway-burying project, provided it is not complicated and is well-executed.

We excluded some important benefits from our model. These included (1) the benefits of improved schooling, some of which have been experimentally shown to produce upward of $1 million over the lifetime of each student[3,4]; (2) the effect of the park on crime (although a park can conceivably increase or reduce crime, the percentage of green space in New York City shows an inverse relationship with crime)[67,68]; and (3) the impacts of pollution on asthma (because it was difficult to tease socioeconomic effects from effects on air pollution). However, despite these exclusions, we found that a deck park on the Cross-Bronx Expressway would still save money and lives.

This study may be used as a basis for future applications of deck parks in other cities, and we are happy to share our models and data. These types of projects are particularly well-suited to middle-income settings, where urban property values tend to be higher, governments are desperate for urban land, and implementation costs are considerably lower. However, our study is a case study designed as a thought experiment. Because of the monetary and health–benefit exclusions, our model should not be used as a basis for more complicated or complex projects without further refinements.

Our study therefore also calls attention to the need for more causal and experimental data on the association between noise pollution and health, air pollution and health, freeways and crime, and freeways and school quality. These factors interact, so data need to be collected and published before and after implementation of freeways and parks to help obtain their combined, blunt impacts on health and well-being. In doing so, it will be easier to estimate the net societal benefit associated with such projects.

Deck parks are one tool in an arsenal of potential collaborations between public health researchers and urban planners. Recently, accountable care organizations and the Centers for Medicare and Medicaid Services have made investments in primary prevention of disease.

Our study demonstrates how urban planning can play an important role as a public health intervention, bringing not only quality-of-life benefits but also health benefits. Because our analysis focused only on park space, it did not incorporate the value of the land that was capped. Given that there is space around existing freeways for buildings, developers could conceivably play a role in such projects.

Indeed, collaborative efforts are central to revamping our cities. In addition to private-sector developers, public-sector transportation, education, criminal justice, and other authorities can all be brought into play to ensure that the expertise and resources across sectors are fully realized. With skyrocketing health costs and a strong desire to reduce long-term public-sector expenditures, the time may be right to begin cross-sectorial, bipartisan collaboration efforts to address public health needs. AJPH

CONTRIBUTORS

S. Kim made a substantial contribution to the conceptualization and design of the study, analysis and interpretation of the data, and drafting of the article. Z. Zafari contributed substantially to the design of the study and drafting and revision of the article for the intellectual content. M. Bellanger contributed substantially to the interpretation of the data and made critical revisions for intellectual content. P. A. Muennig made substantial contributions to the conceptualization and design of the study and interpretation of the data and also critically revised the article for intellectual content. All authors approved the submission of the final version.

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HUMAN PARTICIPANT PROTECTION

This study did not involve any human participation; therefore, it does not require any related board approval.

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