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Chicago expressway system retrospective social benefits minus social costs analysis

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ABSTRACT

The rising demand for transportation and its impact on global warming is a critical societal problem. There is a dearth of ex post facto studies that comprehensively quantify the value of an urban expressway system and its contribution to this dilemma. This article addresses the void with a retrospective social benefits minus social costs analysis of the Chicago city expressway system (project). Monetized values were included for externalities not available to planners when the decision was made to build the highway network. The results of this analysis revealed that net present value (NPV) was clearly positive and substantial. The study also analyzed a hypothetical alternative scenario without the project. This approach assumed internalized regionwide road pricing to account for most known social costs and address the *Theory of the Second Best* issue. The results showed that NPV is about 3 times higher compared to the project. The project had considerable opportunity costs of lost reductions in travel demand, accidents, environmental impacts, and other transport externalities. Estimated total deadweight loss of the project was more than $10,000 million (1960 $) over the period of 1947–1996 at a mid-range 5 percent discount rate. The outcome is highly dependent upon the assumed impact of optimal pricing on travel demand. Follow-up research is recommended to quantify impacts of comparable systemic roadway pricing under proposed scenarios of various highway capacities to assess impacts on welfare and carbon emissions.

1. Introduction

For the period 1990–2017, transportation accounted for 33 percent of carbon dioxide (CO_2) emissions in the United States, the highest amount of any sector. Highway vehicles produced the vast majority of these transport carbon discharges (Tables 12.5 and 12.8, Davis and Boundy, 2020). Carbon emissions are by far the largest component of greenhouse gases contributing to global warming. Planning of the U.S. Interstate Highway System (IHS) was unfolding in the mid-twentieth century after many years of rapidly increasing traffic congestion, accidents and lost productivity due to proliferation of the automobile. Similarly, *A Comprehensive Superhighway Plan for the City of Chicago* was under development (City of Chicago, 1939). There was much debate about the wisdom of penetrating cities with expressways (Karas, 2015; Downs, 1970). Adverse effects were related to aesthetics, destruction of neighborhoods, noise, pollution, segregation, and environmental justice. Debate centered on the extent that reductions in vehicle operating costs, travel time and crashes were worth these effects (Karas, 2015; Downs, 1970).

Net benefits of the IHS including portions within urban areas appeared to be substantial according to research conducted during the early and later stages of construction [e.g., Wilbur Smith and Associates (WSA), 1961; Federal Highway Administration (FHWA), 1970]. However, advancements have since been made in quantifying social costs (Litman, 2016). There is subsequent literature on the economic value of highways in general or on expanding particular road segments (e.g., Cox and Love, 1996; Keane, 1996). Surveys of the extensive research show a wide array of numeric results with most finding that highways have positive and statistically significant associations with productivity and economic benefits (e.g., Bhatta and Drennan, 2003; Shatz et al., 2011). Yet, there has not been a comprehensive retrospective social benefits minus social costs analysis (SBSCA) conducted on an expressway system within a particular U.S. urban region. Would such a study show comparable results?

This paper summarizes methodologies used in SBSCA's to rate the Chicago city expressway system (project) performance against a conjectural option. The study is critical in understanding transportation's contributions to the global warming crisis, negative externalities, and optimal solutions for modernizing the IHS (Unger et al., 2010; National Academies of Sciences, Engineering and Medicine.

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Table 1
Land Square Miles and Population Assumptions by Scenario.

	UA Sq. Miles[2]	Non-City UA Sq. Miles	City/UA Pop Ratio	Chicago City Pop	Non-City UA Pop	Chicago City Pop Density	NE IL Agric. Sq. Miles[2,4]
1947 Actual[1]	600	366	0.826	3.554 M	0.751 M	15,187	2,550
1996 No-build	1,673	1,439	0.417	3.136 M	4.386 M	13,402	1,487
Change from 1947	1,073 (178.8%)	1,073 (293.2%)	0.419 (−49.5%)	−0.148 M (−11.8%)	3.635 M (484.0%)	−1,785 (−11.8%)	−1,063 (−41.7%)
Avg. Yrly. Chg.	21.9	21.9	−0.008	−0.003 M	0.074 M	−36.4	−21.7
1996 Counterfactual	1,807	1,573	0.387	2.908 M	4.614 M	12,428	1,380
Change from 1947	1,207 (201.2%)	1,207 (429.8%)	−0.439 (−45.9%)	−0.646 M (−18.2%)	3.86 M (514.4%)	−2,759 (−18.2%)	−1,170 (−45.9%)
Avg. Yrly. Chg.	24.1	24.1	−0.009	−0.013 M	−0.077 M	−55.2	–23.4
1996 Project[1]	1,840	1,606	0.379	2.851 M	4.671 M	12,184	1,353
Change from 1947	1,240 (206.7%)	1,240 (338.8%)	−0.447 (−54.1%)	−0.703 M (−19.8%)	3.92 M (522.0%)	−3,003 (−19.8%)	−1,197 (−46.9%)
Avg. Yrly. Chg.	25.3	25.3	−0.009	−0.014 M	0.080 M	−61.3	−24.4
1996 HAS[3]	1,372	1,138	0.546	4.332 M	3.190 M	18,512	1,805
Change from 1947	771.8 (129.6%)	771.8 (210.9%)	−0.280 (−33.9%)	0.778 M (21.9%)	2.44 M (324.8%)	3,325 (21.9%)	−745 (−29.2%)
Avg. Yrly. Chg.	13.3	13.3	−0.004	0.024 M	0.042 M	101.2	−12.8

1. Estimated from 1940 and 1950 Census. Land area: Includes Chicago, Aurora, Elgin, Joliet, and Round Lake UA's. 6-county NE Illinois is 4,399 mi^2. City of Chicago is 234 mi^2.
2. This study applied Mothorpe et al. (2013) research to the analysis, which resulted in 122,148 ac (468 ac × 261 miles) of induced lost agricultural land (no-build through project) or 16.1 percent [(122,148 ac/(766,245 ac-8,300 ac expressways footprint (see Table 2, notes 7 & 8))]. To be conservative, the study assumed respective 8% and 10% increases of UA in the counterfactual (exclusion of Chicago city 92-miles expressway & inclusion of counterfactual arterials expansion) and project (inclusion of Chicago city 92-miles expressway & exclusion of counterfactual arterials expansion) scenarios from a no-build plan (exclusion of both 261-miles expressway & counterfactual arterials expansion).
3. The HAS assumed counterfactual expressways without arterial expansions and with expansion of transit. Additionally, the HAS estimated Chicago city population growth rate assumed was based on Tanguay and Gingras (2012)(i.e., 1 percent increase in gas prices relates to a 0.32 percent increase in inner city population over 20 years). With a 30 percent gas price increase, this reflects a 9.6 percent city population increase over 20 years, an annual 0.48% increase in UA population living in Chicago city or a total of 4.332 M by 1996 (assuming 0.48% of actual annual estimates added to cumulative annual increases). In relation, HAS UA size was determined by the change in estimated non-city population change : 3.920 M/2.44 M) = (1,240/X); X = 771.8 mi^2. This could be a generous UA reduction as research showed that, in the late 1980's, a $0.01 gas price increase was associated with a reduction in UA of 4.7 mi^2. Thus, a 30 percent increase in price equated to only a 134 mi^2 (95 cents per gal. × 0.3% x 4.7 mi^2) UA decrease (McGibany, 2004).
4. U.S. Department of Agriculture, Census of Agriculture (1950, 1959, 1964, 1969, 1978, 1987, 1997). In HAS, agricultural land change is calculated based upon non-city urbanization rate per population growth rate [(3.920 M/2.44 M)=(1,197 mi^2/X); X = 745 mi^2]. Thus, 452 mi^2 (1,197 mi^2 – 745 mi^2) of agricultural land was retained in the HAS compared to the project.

Transportation Research Board, 2019). It is difficult to analyze the project without falling prey to being a "Whig historian" by praising or criticizing a past decision based on information available today that was unknown then (Talvitie, 2018). Rather, the study purpose is to identify the most economically efficient alternative and tradeoffs by benefit-cost categories to frame the past, fill a void in the literature, and inform future decision-making.

2. Theory

A problem with conventional benefit-cost analysis (BCA) and SBSCA is they may not facilitate enhanced societal well-being if there are distortions from the optimal allocation of resources elsewhere in the economy not addressed in the analysis (U.S. Government Accountability Office, 2005) (GAO). This is known as the *Theory of the Second Best* whereby, in the case of roadway transportation, demand for travel would be much less if users were required to pay the full costs they impose upon society. A SBSCA/BCA outcome could be much different without this distortion (GAO, 2005). Therefore, the study performed a speculative SBSCA (hypothetical alternative scenario or HAS). The HAS assumed a smaller regional expressway system together with a user pricing feature to internalize most known social costs. The charge was on all roadway vehicles, not just those on expressways. The study conducted these analyses in relation to the counterfactual, which most likely would have occurred in lieu of the project. Cost effectiveness and sensitivity analyses were performed to assess the findings. The resulting urban form associated with inner city expressways is vastly different from the preconstruction period. Therefore, further SBSCA and research is necessary to guide highway decisionmakers regarding potential transport mode and IHS capacity changes.

3. Material and methods

For purposes of this paper, the Chicago region or area was defined based upon U.S. Bureau of the Census (Census) (U.S. Bureau of the Census, 1960, 1970, 1980, 1990, 2000) urbanized areas (UA) and Chicago Area Transportation Study (CATS, 1962) planning area geographic descriptions and data. Northwest Indiana was not included in the analysis as the CATS jurisdiction comprised northeast Illinois. The analysis period covered 1947 to 1996, which was the assumed end of expressway useful life. Generally, the study area expanded over time to encompass the UA's of Aurora, Elgin, Joliet, and Round Lake in accordance with Census geographic descriptions and data. Benefit and cost unit values were used from a number of cited transport economics guidance documents and empirical studies. This included the U.S. Department of Transportation (USDOT) "TIGER Benefit-Cost Analysis Resource Guide," which provided support to applicants for the Transportation Investments Generating Economic Recovery funding (TIGER). The guide recommends using a discount rate of 7 percent, pursuant to the U.S. Office of Management and Budget (USOMB) A-4 and A-94 circulars, and an alternative analysis using 3 percent (USDOT, 2015; USOMB, 2003, 1992).

Assessments in this paper are termed SBSCA, unless otherwise noted, to emphasize the fact that they include both private or direct user

Table 2
Chicago Expressway System Segments (built or committed by 1960)[1].

Expressway	Length (miles)	Lane Miles	Construction Timeframe	Listed Cost[2]	Cost (1960 $)[2]
Lake Shore Dr.[3]	19.0		Late 30′s		
Edens	14.0	84	47′-52′	$22.0	$26.9
Congress	15.5	109	49′-60′	$183.5	$227.2[7]
Calumet	**5.0**	**30**	**50′-53′**	**$8.0**	**$9.2**
Skyway Tollway	7.5	45	56′-58′	$101.0	$107.1
Tri-state Toll.[4]	**83.0**	**498**	**56′-58′**	**$220.0**	**$233.1**
Kennedy	17.0	102	55′-60′	$238.0	$251.5
NW Tollway[4]	**18.0 to Elgin**	**108**	**56′-58′**	**$45.0**	**$47.7**
East-West Toll.[4]	**23.0**	**138**	**56′-58′**	**$83.0**	**$88.1**
Ryan	10.0 (to 99th)	120	57′-62′	$282.7	$285.3
Stevenson	15.0	90	59′-64′	$115.0	$113.0
Calumet (extension)[5]	5.0 (Ryan-130th)	30	53′-56′	$11.4	$12.5
I-80[5]	**30.0 (294–55)**	**180**	**57′-67′**	**$79.5**	**$77.5**
I-290 Extension[6]	**10.0**	**60**	**61′-71′**	**$26.5**	**$23.6**
I-57 (Ryan West Leg)[5]	8.0 (to Tri-state)	48	67′-70′	$20.0	$12.0
Counterfactual/ HAS[7]	**169**	**1,014**		**$462.0**	**$479.2**
Project Total[8]	92	628		$973.6	$1,035.5
Counterfactual Arterial[9]	**314**	**628**			**$157.0**

1. Compiled from Orzeske (1962), Condit (pp. 232–245, 1974), Young (2005), and Christopher and Custodio (1997).
2. Millions.
3. Not included in mileage/cost to keep the SBSCA timeframe manageable as it was constructed well before the other expressways.
4. Monetary estimates based on $415 million in bonds issued for 83-mile Tri-state, 76-mile NW Tollway to Wisconsin, & 28-mile EW Tollway to Aurora (Young, 2005).
5. Estimates based on original Calumet costs.
6. Based on per mile average cost of Tri-state.
7. Only expressways footprint: [262.4 ft (avg. width) × 5,280 (ft per mile) × 169 mi] = 234,144,768 ft^2 or 5,375 acres or 8.4 mi^2. Width based on minimum of 250 ft. ranging up to 375 ft. and more. Based on retention of expressway data in bold., i.e., excluding segments closest to the Chicago city center.
8. Project Footprint: Non-bold data. [262.4 ft (avg. width) × 5,280 (ft per mile) × 92 mi] = 127,463,424 ft^2, 2,926 acres or 4.6mi^2. Width based on minimum of 250 ft. ranging up to 375 ft. and more. Includes $25 million for building West Side Subway, replacing Douglas Park Elevated demolished for Congress (CTA, 1957).
9. $250,000 per lane mile per CATS (p. 13, Table 4, 1962).

impacts and external effects. This is as opposed to a BCA, which focuses only on the direct user effects. Tables summarize benefits and cost estimates calculated for the project and HAS over the 50-year period using discount rates of 3, 5 and 7 percent. All figures are in 1960 dollars using the U.S. Department of Labor, Bureau of Labor Statistics, Consumer Price Index on-line calculator. Measured costs and benefits consisted of the following categories: capital, operating and maintenance (O&M), vehicle operating costs, vehicle hours traveled (VHT), productivity, fatalities, injuries, property damage, residual, and public transportation. Also included are costs and benefits for the following externalities: agricultural, ecological, noise, emissions, resource consumption, parking, health, barrier effects, and residential relocations. There are innate uncertainties in these values despite the supporting research. Excel spreadsheets with complete calculations are available.

There are several overarching assumptions. Construction took place in 1947–1971. The counterfactual consisted of 169 miles (1014 lane miles) of expressway (excluding Lake Shore Drive) only outside of Chicago city, and 628 lane miles added to 314 miles of existing arterials. The project added 92 expressway miles (628 lane miles) in Chicago city and excluded the counterfactual arterial expansions. Overall travel demand and UA size in the project scenario was marginally higher than the counterfactual due to the speed advantages of added expressway capacity. However, public transport service levels in these two scenarios was identical. The HAS consisted of the same counterfactual expressways, exclusion of the arterial expansions, and substantive increases in transit usage. There were no rebuilding costs assumed beyond O&M. A no-build baseline, which excludes the above alternatives, was estimated as part of the analysis. However, the counterfactual is the reference plan of comparison for the project and HAS.

Economically efficient road pricing would require charges up to several times higher than typical costs (Congressional Budget Office, 2011) (CBO). Research shows optimal pricing for all roads could reduce overall vehicle miles traveled (VMT) by 20–40 percent and vehicle ownership by 10 percent (Litman, 2019). The study assumed optimal pricing in the HAS, without any implementation charges, reduced VMT by 20 percent and vehicle ownership by 5 percent from the counterfactual. The pricing covers usage of all roads, both expressways and non-expressways. Table 1 delineates land use and population assumptions for each scenario. Notable 1996 estimates for the HAS compared to the counterfactual were a 24 percent reduction in UA and 49 percent rise in Chicago city population. The following sections in the paper are organized by benefit and cost categories. These include valuation estimates based on cited research, further detailed assumptions, and discussion of major differences between scenarios. Remaining sections consist of the results, cost effectiveness analysis, sensitivity analysis, and discussion/conclusions.

4. Benefits and costs

4.1. Capital

Capital Costs included right-of-way (ROW) acquisition, design, engineering, and construction completed or assumed in the Chicago region during the years of 1947–1971 (Table 2). The project, together with the expressway segments in the counterfactual and HAS, is generally the same as the system built or committed by 1960 as defined by CATS (pp. 51–53, 1962).

4.2. Operating and maintenance

The study calculated per lane mile highway O&M costs from State of Illinois annual reports for 1947–1996 (tables SF-4, SM-1, SM-11, F-2, SF-4A, FM-11, INT-11, HF-2, HM-35 as applicable) ((U.S. Department of Commerce, Bureau of Public Roads, 1964) (USDOC); FHWA, 1965–1996). Lane miles were multiplied by the estimated maintenance cost calculations for each year [$481–$1270 per lane mile range]. The study did not account for operating costs of tollway collection expenses that may be separate from maintenance expenditures.

4.3. Vehicle operating costs

WSA (pp. v, 172, 187, 197, 199; 1961) concluded from research that freeways induce urban trip lengths by 10–15 percent due to travel time savings. Studies show that 1 percent increases in highway capacity (expressways, arterials, collectors) or decreases in travel time or automobile operating costs increase VMT on these roads by up to 0.5 percent in the short term and up to 1 percent and more in the long run (Rodier et al., 2000; Noland, 2001; Hansen and Huang, 1997; Goodwin, 1996). To account for speed differences, the study assumed elasticity for travel in the Chicago region respective to a 1 percent increase in capacity was 0.60 for arterials and 0.90 for expressways.

Requests to the Chicago Metropolitan Agency for Planning (CMAP) and Illinois Department of Transportation (IDOT) for historic Chicago area annual mileage/lanes of these roads and VMT estimates were

Table 3
Major Thoroughfares Lane Miles and Vehicle Miles Traveled Assumptions[1].

	Express Miles	Express Lane Miles	Arterials, Collectors Lane Miles	All Major Thoroughfare Lane Miles	Expressway VMT	Non-Expressway VMT	Total VMT
No-build	133	689	19,649	20,338	53,420.1 M	1,122,027.3 M	1,175,447.3 M
Counterfactual	302	1,562	20,277	21,839	190,303.9 M	1,063,822.3 M	1,254,126.1 M
Project	394	2,190	19,649	21,839	293,397.9 M	972,043.6 M	1,265,441.5 M
HAS	302	1,562	16,114	17,675	152,566.9 M	824,639.8 M	977,206.7 M

1. All road miles are in 1996. VMT is in millions for 50-year period 1947–1996. Numbers may not add exactly due to rounding.

Table 4
Speed Assumptions Based on Non-Expressway Major Thoroughfare Capacity Changes.

Scenario	Express-way MPH	Arterial-Collector Lane Miles/Non-expwy. VMT Ratio	Proportion Higher than Counterfactual[1]	Non-Express MPH Change[2]	Non-Express MPH Proportion Higher than Counterfactual[1]	Overall MPH Increase (expwy. & non-expwy.)[2]
No-Build	50	0.000000622597	–	16–15.00 (15.50)	–	16.00–15.00 (15.50)
Counterfactual	50	0.000000679093	0.09074	16–17.23 (16.91)	0.09098	16.00–18.27 (17.68)
Project	50	0.000000718662	0.05827	16–18.55 (17.89)	0.05776	16.00–20.41 (19.27)
HAS	50	0.000000836829	0.23227	16–22.54 (20.84)	0.23237	16.00–22.85 (21.07)

1. Proportions for counterfactual are against the no-build scenario.
2. The speed increases are incremental through construction completion in 1971. Annual average is bracketed.

unsuccessful. The study calculated annual estimates of this data using known statistics for these roadways in the years 1958 from CATS (1962), 1989–1996 from FHWA, and 1997 from IDOT (1997) in addition to the project construction schedule. FHWA did not report individual UA mileage and VMT data prior to 1989. Table 3 lists the assumptions for major thoroughfare lane miles and VMT in each scenario. The difference in estimated total VMT between the counterfactual and project was nominal. This was due in part to the same amount of total lane miles in these two scenarios. Further, the assumed differences in the aforementioned elasticities affect a relatively small proportion of overall major thoroughfare capacity. The HAS arterial and collector lane miles assumption was based upon a 20 percent reduction from the counterfactual relative to the 25 percent loss in UA. This included deletion of counterfactual arterial expansions. Based upon CATS (p. 118, Table 33, 1959) data, the study assumed that automobiles and light trucks comprise 91.3 percent of VMT.

See Section 4.4 for further details on the assumptions for project-related increases in travel speeds overall, on expressways and other roads. WSA (pp. 282–295; 1961) cites studies regarding the net operating costs of personal and commercial vehicles together on urban expressways. Accordingly, WSA (Table 65, p. 294; 1961) endorses a savings of $0.0097 (through 1974) and $0.0112 (after 1974)(both 1960 $) per VMT on an urban expressway. However, both CATS (1962) (p. 9 & p.126, Table 25, 1962) and Haikalis and Joseph (1961) document research based on modeling of the planned Chicago area traffic network. Their findings are that operating costs decline with increasing speed up to 40 miles per hour (mph) and rise steadily above this level. Thus, there was some uncertainty in estimating VMT costs, and they likely have evolved over time.

This study assumed the above WSA operating cost savings rates per project expressway VMT for all types of vehicles. Based on CATS (p. 126, Table 25, 1962) data and discussion in Section 4.4, by 1971, the study assumed a gradual average project non-expressway speed increase to 18.55 mph and associated maximum operating cost decrease per VMT of $0.00082 (1960 $). For commercial vehicles, the study assumed operating cost values at 3 times that of personal vehicles (Haikalis and Joseph, 1961). Comparably, the HAS value used for non-expressway automobile operating cost decreases per VMT was $0.00277 (1960 $) due to a higher average speed rise to 22.54 mph by 1971. Pre-project peak period travel on Chicago boulevards was faster than on the area's expressway system after it was constructed (Condit, 1974). Traffic analysis of the Chicago area in 2008 shows rush hour travel during the hours of 6:00–9:00 AM and 4:00–7:00 PM comprises about one-half of all vehicle roadway trips (Chicago Metropolitan Agency for Planning, 2016). Thus, the study reduced estimated operating savings for expressway travel by 30 percent due to peak period congestion.

WSA (Table 59, pp. 280–1; 1961) attests that personal vehicle operating costs regardless of roadway type were $0.0976 per VMT, with respective variable and fixed values of $0.053 and $0.045 (1960 $). The study applied these non-speed-related costs for induced and reduced VMT. The study assumed heavy truck travel demand was not impacted by the HAS pricing change. This was due to the mode's general inelastic nature and variance by commodity per Beuthe et al. (2014). Personal vehicle numbers were estimated from CATS (p. 117, Table 40, 1960) and FHWA (1996). Monetary benefits and costs for changes in vehicle operating expenses and transport time specific to induced and reduced VMT were adjusted by one-half pursuant to the "rule of half" (net consumer surplus averages one-half the price change) (p. 7–3, Litman, 2016). The study found the project had a negligible impact on both personal vehicle and truck operating expenses. The reason is that operating cost savings provided by improved speeds were largely offset by costs of induced travel. The HAS outperformed the project in net vehicle operating expense benefits by about $2049.2 million [$2789.4 M (HAS) - $509.8 M (transit cost increases) – 230.4 M (project), 1960 $, 5 percent discount].

4.4. Vehicle hours traveled

CATS respective hourly travel time values are $1.33 for passenger vehicles (or $2.07 at 1.56 persons per vehicle) and $4.00 for trucks ($3.00 driver and $1.00 cargo) (CATS, Table 2, pp. 9–10, 1962). These figures were used in the study. Of note is that USDOT TIGER guidance passenger values are $13.00 (2013 $; $1.65 in 1960 $) (all purposes) and $19.00 (2013 $; $2.42 in 1960 $) for intercity travel (all purposes) while

Table 5
Vehicle Hours Traveled Estimates.

Scenario[1]	Expwy. VHT from Induced VMT (reduced in HAS)	Expwy. VHT Reduction from Retained VMT	Expwy. Net VHT Reduction	Non-expwy. VHT Reduction from Eliminated VMT	Non-expwy. VHT Reduction from Retained VMT	Non-expwy. Net VHT Reduction	Total VHT Reduction	Total VHT
No-Build	–	–	–	–	–	–	–	76,517.1 M
Counterfactual	2,248.0 M	−2,154.1 M	93.9 M	–	−6,778.0 M	−6,778.0 M	−6,684.1 M	69,833.0 M
Project	323.3 M	−2,722.1 M	−2,398.9 M	–	−3,449.3 M	−3,449.3 M	−5,848.2 M	63,984.8 M
HAS[2]	−1,078.2 M	–	−1,078.2 M	−14,021.4 M	−9,880.0 M	−23,901.5 M	−24,979.7 M	44,853.3 M

1. Data for the counterfactual are measured against the no-build scenario. Data for the project & HAS are measured against the counterfactual scenario. Numbers may not add exactly due to rounding.
2. HAS excludes transit data.

the truck driver value is $25.00 (2013 $; $3.28 in 1960 $). This is indicative of travel time value uncertainty and possible increases over time.[1] The study used the TIGER values in sensitivity analysis with a mid-range of $2.03 for passenger vehicles and $3.28 for truck drivers (1960 $). Studies by CATS determined the average Chicago region automobile speed was 11.1 mph (door to door including walking time) (CATS, p.122, Tables 46 & 47, 1960).

Table 4 and Table 5 outline speed and VHT calculations by scenario. These were estimated using a three-step method. First, the study assumed that no-build overall average speed would decline incrementally from 16 to 15 mph during 1947–1996. Second, the study assumed traffic converted to expressways increased to 50 mph. Third, arterial and collector lane miles/non-expressway VMT (50 year totals for both) ratios were calculated by scenario to estimate comparable changes in non-expressway speeds. Pursuant to the "rule of half," induced VMT was netted out in the counterfactual and project scenarios as time savings did not occur for new trips. Similarly, the procedure was applied to the HAS 20 percent reduction in VMT for trips eliminated. The respective estimated travel time savings values for the project and HAS were $2972.8 million and $9016.6 (1960 $, 5 percent discount). However, the HAS amount excluded travel time losses for the increase in transit ridership, which was calculated separately.

Land values in the 6-county northeast Illinois region increased from about $24 to $72 billion (1960 $) from 1947 to 1996 (Arkell, 2020). The USDOT states that any land value increase can only be considered as a one-time stock benefit and cannot include investment by developers. Additionally, other benefits to property value already counted, such as travel time savings, must be netted out. The difficulty in determining the impact of highway investments on overall property values has been analyzed at length (e.g., Chalermpong, 2002; Mohring, 1961; Wheaton, 1977; Martinez and Araya, 2000; Sasaki and Kaiyama, 1990). Specifically, improvement to land values near such roadways are largely countered, or more than offset, by decreased property values in more distant locations. Further, any positive net land values beyond user time savings benefits are likely to be relatively small. Therefore, the study made no attempt to estimate project impacts to property values.

4.5. Safety

CATS provides the annual number of traffic accidents and fatalities for 1962 (including death/crash ratios) (CATS, p. 59, 1962). "2011 Illinois Crash Facts and Statistics" provides comparable data for the 6-county region (IDOT, 2011). Based on the data, the study assumed equal annual incremental changes for each statistic (accidents +0.0019; death/crash ratio −0.000046) as requested year-by-year data was not provided by IDOT and CMAP. The study referenced State of Illinois, Division of Highways documentation of the total number of accidents in Cook and Du Page Counties for 1958, which comprised most of the Chicago UA at that time (State of Illinois, 1958). This was relatively close to the 1958 estimate based on the aforesaid data and assumptions. Accordingly, the study estimated 7,471,424 million crashes in the 6-county region for the 50-year period with the project.

Table 6
Breakdown of VMT and Crash Estimates by Roadway Type[1].

Expressways
Project: 293,397,852,814 VMT × 186/100,000,000 × 1.3203499^2 = 720,541 crashes
HAS: 152,566,883,103 VMT × 186/100,000,000) × 1.3369432^3 = 379,390 crashes
Crash difference: 720,541 – 379,390 = 341,151

Non-expressways
Project: 972,043,602,078 VMT × 526/100,000,000 × 1.3203499^2 = 6,750,882 crashes
HAS: 824,639,839,103 VMT × 526/100,000,000) × 1.3369432^3 = 5,799,132 crashes
Crash difference: 6,750,882–5,799,132 = 951,750

Total crash reduction in HAS from project: 341,151 + 951,750 = 1,292,901

1. Numbers may not add exactly due to rounding.
2. Total prorated ratio based on actual project crash estimates from known data.
3. HAS includes increased transit accidents which raised the prorated ratio.

The study used the USDOT value of a statistical life (VSL) to monetize traffic accident deaths [~$1.2 million (1960 $)]. Severity of injury and property damage only (PDO) estimates were also used from the same source. The study converted data on the number of accidents reduced from the project to the Abbreviated Injury Scale (AIS) to determine estimated level of injury by severity rates (none, minor, moderate, serious, severe, critical) (USDOT, 2015). Values of injuries were deflated further to account for the historic rise in health care costs above inflation, which is an average of about 4.2 percent annually (Fuchs, 2012). The study multiplied the number of non-fatal accidents probability values per the USDOT (column 8, p. 13, 2015) by the guidance AIS unit value levels (p. 3), and then by the number of estimated accidents.

WSA documentation (Figure 116, p. 287; 1961) shows accident rates for roads with controlled and uncontrolled access (186 per 100,000,000 VMT; 526 per 100,000,000 VMT) for urban areas based upon cited empirical research. These rates are generally consistent with more recent research (Papayannoulis et al., 1999; Figure 1–1, Preston et al., 1998). The study applied the WSA empirical rates to the region's VMT by these two road types for each scenario to calculate crash estimates. The project data crash estimate was prorated with the WSA empirical estimate to create annual correction factors. The study used the prorated results to adjust the estimated accidents in each scenario. Accordingly,

[1] The use of changes in travel time to evaluate projects has been a mainstay of transport economic analysis. However, there are uncertainties in travel time value variability and willingness to pay (Talvitie, 2018). Increases in travel time tend to be valued more highly than reductions (Daly and Hess, 2020). The value of changes in access to destinations may be more appropriate, albeit complicated to determine (Metz, 2008). Despite these concerns, analysis used the standard approach which included the aforesaid "rule of half."

crashes were reduced from the counterfactual by 359,305 with the project and 1,652,206 with the HAS (difference of 1,292,901). The disparity was driven by lower VMT in the HAS compared to the project of 48 percent on expressways and 15 percent on non-expressways as shown below (Table 6).

The respective project and HAS estimated deaths reduced from the counterfactual using the calculated death/crash ratio was 1150 and 5523. Fatality, injury and PDO savings from the project were then estimated using the USDOT rates (1960 $). Total safety benefit increases were $616.6 million with the project and $3672.1 million (1960 $, 5 percent discount) in the HAS.

4.6. Agriculture

Per the U.S. Department of Agriculture (USDA), Census of Agriculture (COA) conducted every 5 years from 1945 to 1997, the average per acre value of all agricultural products sold in Cook and the 5 primary Illinois collar counties was $96.53 (1960 $) (USDA, 1950–1997). During the period, these counties lost 1197 mi^2 (766,245 acres) of agricultural land (COA). The assumptions for agricultural land in each of the scenarios are outlined in Table 1. Changes in the estimated amount of farmland lost from project-induced development, less the expressway footprint, were multiplied by the value of agricultural productivity per acre. Similarly, agricultural productivity gains were calculated for the HAS.

4.7. Ecological

The study used an annual ecological cost value per acre for pavement of $526 (1960 $) (Table 4.13, Bein, 1997). Such environmental benefits include bequest, aesthetic, spiritual, recreational, and ecological services (Table 3.12, Bein, 1997). Based on the aforementioned calculations for the expressway footprint and agricultural land, the study assumed that roughly 2454 acres [8300 acres (footprint) × 0.72 (non UA) × (1–0.59) (non UA not farmed) of the 261-mile expressway system was constructed on land in its natural state. Ecological costs for about 839 acres of the project footprint were calculated, which is slightly less than the 92-mile project/261-mile expressway system ratio.[2]

4.8. Noise

Traffic noise due to new roads represents an economic cost. Research has determined that noise causes stress, disrupts sleep, damages hearing and contributes to ill health (World Health Organization, 2011). The FHWA (1997) estimated land use impacts from noise levels based on vehicle type, weight, and speed. FHWA calculated dollar values per VMT based upon lowered land values. These values are $0.00016 (1960 $) for autos on urban highways and $0.002873 (1960 $) as a mid-range for heavy trucks (FHWA, 1997). Delucchi and Hsu (1991) modeled highway marginal noise costs in 377 U.S. UA's by road type using values of housing units and their densities. Their respective calculated values per VMT for autos and heavy trucks on interstates are $0.0006443 and $0.0036331 (1960 $). The study assumed respective mid-range values between these two analyses of $0.0004 and $0.0033 (1960 $) for the light vehicle and heavy truck categories to calculate monetary noise values based on VMT.

[2] The study did not assume any ecological changes due to project-induced or HAS-reduced development. This is because change in the amount of land in its natural state was negligible based on the known urbanization rate and agricultural land losses from 1947 to 1996 (see Table 1). Also, caution dictated that land in an agricultural state may not necessarily have higher ecological value than developed property.

4.9. Emissions

The U.S. Energy Information Administration (2012) (U.S. EIA) identifies fuel economy data in average miles per gallon (mpg) for all vehicles by year (range of 11.9–16.9 mpg). The U.S. Environmental Protection Agency (2014) (USEPA) Clean Energy web site identifies metric tons (MT) of CO_2 emitted per gallon of gasoline burned in vehicles (0.008887 MT). The USDOT quantifies social cost of carbon (SCC) as rising from $3.81–$10.32 (1960 $) per MT over time. These rates may be very conservative (Ricke et al., 2018). Per the TIGER guidance, the study discounted CO_2 values only at the 3 percent rate but also used the results in the 5 and 7 percent benefit columns. The study performed CO_2 fiscal calculations based upon changes in VMT.

The USDOT (2015) provides respective nitrous oxide (NO_X) and particulate matter (PM) values of $1003 and $45,863 (both 1960 $) per MT. An October 2008 EPA Emission Facts Sheet provides the average emissions per mile for passenger cars (USEPA, 2008a). Another October 2008 EPA Emission Facts Sheet identifies the average emissions per mile for heavy trucks (USEPA, 2008b). The California Air Resources Board (CARB), provides the average per mile emission level for medium and heavy-duty vehicles for pre-1987 vehicles for NO_X (0.00001795 MT) and $PM_{2.5}$ (0.00000090 MT) (Table 3, CARB, 2013). The study used these emissions levels for VMT changes instead of the aforesaid 2008 EPA amounts as they more closely replicate the period of 1947–1996. PM_{10} levels were estimated at 7.3 percent higher than $PM_{2.5}$ per the ratio cited in the USEPA documents (2008a, 2008b).

The changes in NO_X and $PM_{2.5}$ by variations in speed are shown in Table 4 of the CARB document. Hence, assuming average speed increases due to the project of 50 percent from 30 to 45 mph would not change average NO_X emissions at all while the $PM_{2.5}$ emission is reduced 33 percent. However, emissions reductions are increasingly evident if starts and stops are reduced resulting in less distance traveled below 30 mph (CARB). Conversely, per FHWA (2017), PM_{10} and $PM_{2.5}$ emissions generally do not vary with speed. Further, NO_X variability is very small and may increase with speed (FHWA, 2017). CO_2 emissions are relatively stable between 30 to 70 mph and rise intensely outside of this range (Barth and Boriboonsomsin, 2009). Due to empirical variations, the study made no further speed-related changes in estimated emissions.

4.10. Resource consumption

As discussed by Litman (2016), resource consumption costs are external costs of transport resource production (primarily petroleum). These include military security costs for foreign oil, environmental damages from oil extraction, oil company tax subsidies, and human health impacts from injuries and pollution during extraction (Litman, 2016). Leiby et al. (1997) studied such externalities in the U.S. and found that the range per barrel of oil is from a negligible amount to $4.60 (1997 $) or a midrange of $2.30. The study assumed this midrange and that a barrel of oil produced 20 gallons of gasoline and 5 gallons of diesel fuel used by light vehicles and heavy trucks, respectively (USEIA, 2018). This equates to $0.092 (1997 $) or $0.0169 (1960 $) per gallon. The study multiplied these rates by the amount of VMT, divided by the aforementioned mileage ratings to estimate resource consumption monetary values.

4.11. Parking

Litman (2016) documents the opportunity costs of land dedicated for free or undercharged parking spaces, which could be used for other purposes. These are paid for directly by users and non-users through increased costs for bundled goods and services. Mackenzie et al. (1992) calculated the annual value of free parking in the U.S. for commuter drivers in 1989 at $85 billion. U.S. total passenger car travel that year was 1495.9 billion VMT, which equates to $0.0568/VMT ($0.0138, 1960 $). The total value of free parking for commuter and other driving trips together has been estimated at $67.8 billion (1991 $) (Lee, 1995). U.S. total passenger car travel that year was 1542.8 billion VMT, which equates to $0.0439/VMT ($0.0096, 1960 $). The study assumed a $0.01 rate to be conservative without differentiating between vehicle fixed and variable costs.

4.12. Health

Litman (2016) analyzed research showing a negative correlation between commuting and other trip-making by personal vehicles with physical activity and health. Gotschi (2011) documented annual per capita health care costs per inactive person, with the average being $544 in 2008 $ ($75 in 1960 $). Gotschi also documented the average annual increase of 4.2 percent in these costs above inflation from 1991 to 2008. The study assumed this finding. Jacobson et al. (2011) studied U.S. licensed driver and obesity rates longitudinal data over the period of 1995–2007. The finding was that an increase of 365 VMT annually per licensed driver is associated with a 2.16 percent increase in the adult obesity rate 6 years later. The Jacobson et al. research outlines the consistency of its findings with other research. Although, collectively, these studies have been unable to establish causality. The study used FHWA (2018) data to estimate the proportion of licensed drivers in the Chicago region. Thus, the study calculated estimated annual costs for changes in inactivity based upon alterations in VMT per the Jacobson et al. research. This did not cover mortality costs from reduced lifespans due to lower cardiovascular activity.

4.13. Barrier effects

Barrier effects are travel delay costs to non-motorized mobility, namely pedestrians and bicyclists, caused by vehicular travel (Litman, 2016). These include wide multi-lane arterials and expressways, which block and/or ban non-motorized pathways or make walking and cycling untenable. Rintoul (1995) studied the transverse effect or the impact on cyclists and pedestrians seeking to cross a highway in a medium size Canadian city. The finding was an average cost of $0.087 Canadian per kilometer or $0.1015 U.S. per mile (1995 $)(0.0198 1960 $). Other research found the barrier effect was about $0.01 (1992 $)($0.0021 in 1960 $) per vehicle mile (Saelensminde, 1992). To be conservative, the study used this latter figure per VMT for all vehicles.

4.14. Uncompensated moving

An estimated 50,000 residents in the city of Chicago were displaced by the expressway construction program (McCarron, 1988). The 2016 estimated cost to move a family in a house or apartment with two or three bedrooms in Chicago was about $900 ($111 in 1960 $)(Upakt, 2019). Per a U.S. Department of Labor Bureau of Labor Statistics (2006) report on consumer spending for 1960–61, the average household in 1960 contained about 3.1 persons. Therefore, the study estimated number of households displaced by the project as about 13,450 [50,000 × (assumed 0.834 proportion of displacements in Chicago city)/3.1]. The study did not assume any change in the HAS as deletion of the counterfactual arterials likely had little impact. Uncompensated moving costs for businesses were not included due to lack of data.

4.15. Productivity

Total real gross output consists of both intermediate sales to other industries and final sales to users for all sectors within the economy (U.S. Bureau of Economic Analysis, 2019) (BEA). CATS (p. 114, Table 38, 1960) tabulated gross output information by business sector for the Chicago consolidated statistical metropolitan area (CSMA) (Cook, DuPage, Kane, Lake, Will, and Lake, IN) for 1947, 1956 and projected for 1980. The study used the 1947–1956 Chicago CSMA and actual 1957–1996 BEA U.S. inflation-adjusted growth output rates to estimate

Table 7
Source of Methodologies, Units and Unit Values.

Criteria	Source	Unit	Per Unit Value (1960 $)	Notes
Capital	See Table 2, note 1	Express Mile Arterial Mile	$5.7 M $500,000	Actual average Expand from 4 to 6 lane
Operating & Maintenance	USDOC (1947-1964), FHWA (1965-1996)	Lane Mile	$481-$1,270 ($913 avg.)	Varies by year
Farm Profits - Induced Dev.	USDA (1945-1997)	Acre	$96.53	
Ecological - ROW	Bein (1997)	Acre	$526	
Uncompensated Moving	McCarron (1988), Upakt, 2019	Family	$111	
VMT – Auto Vehicle Ownership	WSA (1961) WSA (1961) Kockelman (1996)	VMT VMT auto	$0.053 $0.045 −0.068	Variable Fixed Costs (HAS only) Pop. Density elasticity of vehicle ownership
VMT - Heavy Truck	Haikalis and Joseph (1961)	VMT	$0.159	Variable
Noise - Auto	FHWA (1997), Delucchi and Shi-Ling (1991)	VMT	$0.00040215	Average between the two studies
Noise - Heavy Truck/Bus	FHWA (1997), Delucchi and Shi-Ling (1991)	VMT	$0.00325305	Average between the two studies
CO_2	USDOT (2015); USEPA (2014)	MT	$3.81-$10.32	Gradual annual rise
NO_X	USDOT (2015); USEPA (2008a,b); CARB (2013)	MT	$1,003	
PM	USDOT (2015); USEPA (2008,a,b); CARB (2013)	MT	$45,863	
Resource Consumption	Leiby et al. (1997)	Gallon	$0.0169	
Parking	Mackenzie et al. (1992); Lee (1995)	Auto VMT	$0.0100	
Health Care Costs Obesity Rate	Gotschi, 2011; Jacobson et al. (2011)	Per Cap. Cost; Annual Rise	$6.10 to $45.80; 2.16%	4.2% annual rise + inflation; Per capita driver + 365 VMT
Barrier Effect	Saelensminde (1992)	VMT	$0.00210	
VHT – Auto	CATS (1962)	VHT	$1.33	1.56 persons per car
VHT - Heavy Truck	CATS (1962)	VHT	$4.00	Driver and cargo
Productivity-Highway; Highway	Nadiri and Mamuneas (1996); Weisbrod et al. (2001)	$; VHT	0.10–0.35; 0.0038	Return Rate of capital; Elasticity
Productivity-Population Density	Abel et al. (2011)	Pop./mi^2	0.0275	UA Pop. Density Elasticity of Productivity
Fatalities	USDOT (2015)	1	$1.2 M	Value of statistical life
Injuries	USDOT (2015)	1		

(continued on next page)

Table 7 (*continued*)

Criteria	Source	Unit	Per Unit Value (1960 $)	Notes
			AIS 1–5 - varies	See Table 9, note 6, and Table 10, note 9
Property Damage	USDOT (2015)	1 Accident	$500	
Residual	INDOT (2003)	ROW Earth Work Structural Road Base Road Surface	Infinite 100 70 50 30	Years useful life

annual local output through 1996. The study adjusted the BEA estimate further to reflect the 6-county northeast Illinois area, less Lake County Indiana, using CATS CSMA employment data (p. 114, Table 38, 1960) for 1956 and county decennial population proportions. The result was an estimated total of $3822.7 billion (1960 $) in study area productivity or output for 1947–1996.

Consensus is lacking in the literature regarding the relationship between transport investments and economic growth (Melia, 2018). Weisbrod et al. (2001) studied the productivity impacts of travel time reductions brought about by highway investments in the metropolitan areas of Chicago and Philadelphia. These impacts are separate from typical roadway user expense and travel time costs. Productivity benefits correlate to economies of market access, just-in-time production processes, worker time availability, freight inventory and logistics/scheduling, and travel time variability. A primary finding is a uniform Chicago regionwide 10 percent travel time reduction equates to a 0.3798 percent increase in productivity (Weisbrod et al., 2001). The study used this elasticity with the aforementioned estimated VHT reductions to calculate the overall amount of productivity due to the project.

Nadiri and Mamuneas (1996) analyzed disaggregated data from 35 industry sectors of the U.S. economy for 1950–1989. The data includes metrics of gross output, material inputs, private capital, and labor. Nadiri and Mamuneas found the net social rate of return (shown as SRR in tables) on total highway capital was about 0.35 in the 1950's and 1960's while it was 10 percent in the 1980's. The study assumed these rates of return with incremental changes in the 1970's using project capital costs. The HAS productivity impacts consisted of increases from population density benefits (Abel et al., 2011), which were more than offset by reduced highway capital investments, resulting in net costs of $376.8 M (1960 $, 5 percent discount). This estimate was inconsistent with the Weisbrod et al. (2001) method outcome, which showed substantial productivity benefits. The study assumed the negative productivity valuation in the HAS analysis to be conservative. The Nadiri and Mamuneas method used for the project resulted in benefits of $2431.4 million (1960 $, 5 percent discount).

4.16. Residual value

The study used guidelines from the Indiana Department of Transportation (2003) for determining expected useful lives of the different project elements. As a result, the following assumptions were made regarding roadway original undiscounted capital costs expected life based on the 50-year analysis period to determine residual value: ROW, infinite life; earth work, 100 years life; structural, 70 years life; road base, 50 years life; and road surface, 30 years life.

Table 8
Public Transportation Source of Methodologies, Units and Unit Values[1.]

Source	Metric	Value (1960 $) or Number	Notes
Pushkarev & Zupan (p. 174, 1977)	Population Density Elasticity/ Transit Demand	Up to 1.0 or more	22% increase in city population density/ 28% increase in transit ridership assumed.
Iseki & Ali (2014)	Fuel Price Elasticity/ Transit Demand	0.18	@ +$4.00/gal (2014 $)
Noland (Fig. 3, p. 22, 2000)	Hwy. Capacity Elasticity/ Transit Demand	0.06	Assuming high-end highway capacity.
CATS (p. 78, Table 25, 1960)	Avg. Bus Pass. Trip Length Avg. Rail Pass. Trip Length	4 miles 6 miles	Overall avg. increases from 4.26 to 4.71 miles over 50 yr. period similar to CATS.
CTA, RTA[2]	Operating Expenses per Rider	$0.36	Average
CTA (p. 19, 2000)	Bus and Rail Car Purchase Prices	$44,045 $196,291	Assume bus/rail cars useful life @ 12 & 25 years. FTA standard 14 & 31 years (Federal Transit Administration, 2017).
CTA[2]	Revenue Vehicle Miles per Kilowatt Hour	4.35–5.11	Incremental increase over time.
CTA (1965)	Accidents	12.5 – 1.6	Accidents per 100,000 vehicle revenue miles, incremental decrease over time.
Evans et al. (p. 49, Table 6.1, 2014)	Rail Noise	$0.19/621 passenger mile	
Deru and Torcellini (p. 8, Table 3, 2007)	Rail CO_2 Emissions	0.0007 MT/kwh	
Deru and Torcellini (p. 8, Table 3, 2007)	Rail No_X Emissions	0.00000125 MT/kwh	
Deru and Torcellini (p. 8, Table 3, 2007)	Rail PM Emissions	0.0000000416 MT/kwh	
Litman (Table 5.12.3–4, 2016)	Resource Consumption Costs	115 244	Bus/rail passenger miles per 1 gallon fuel.

1. Bus emissions, noise and resource consumption values were treated the same as heavy trucks and included in those calculations. Rail impacts were also included in these categories. Transit accidents were included in the safety calculations. It is assumed that all new transit riders incur travel times twice that of overall road users.
2. CTA (pp.7, 30–31, 1965); CTA (p. 31, 1976); RTA (Table 9, 1983); CTA (pp. 44 & 46, 1991).

4.17. Value summary

Table 7 lists all cost and benefit values and their sources discussed in Section 4.

4.18. Public transportation

From 1950 to 1990, transit ridership dropped more than 50 percent in the Chicago region [CATS, Table 57, 1961; CATS, pp. 18–20, 1998; Young, p. 176, Table A10, 1998; Chicago Transit Authority (CTA), pp. 30–31, 1965; CTA, p. 31, 1976; CTA, 1991; Census, 1960, 1970, 1980, 1990]. Remarkably, commuter rail ridership remained relatively stable throughout this 40-year period (CATS, Table 32, p.129, 1962; CATS, p.

Table 9
Project Social Benefit-Cost Analysis Summary.

COSTS	Equation	Undiscounted	3%	5%	7%
Capital Costs	See Table 2.	($879.6)	($625.9)	($503.4)	($407.6)
Operating & Maintenance	Avg. cost/lane mile × lane miles changes $913 × varies by yr. w/no change after 71′[1]	($1.4)	($0.8)	($0.6)	($0.4)
Noise – Auto	Cost value × increased VMT $0.00040215 × 10,330.9 M	($4.2)	($1.6)	($0.9)	($0.6)
Noise – Truck	Cost value × increased VMT $0.003325305 × 984.4 M	($3.2)	($1.3)	($0.7)	($0.4)
CO_2	3% discount only. See Note 2.	($57.9)	($22.0)	($22.0)	($22.0)
NO_X	Cost value MT × increased NO_X $1,003 × 19,448MT	($19.5)	($7.6)	($4.4)	($2.7)
PM	Cost value MT × (PM_{10} + $PM_{2.5}$ increase) $45,863 × (1,915MT + 1785MT)	($169.7)	($66.2)	($38.2)	($23.5)
Resource Consumption	Cost value gal. × increased VMT/MPG $0.0169 × (11,315.4 M/13.47 MPG avg.)	($13.8)	($5.6)	($3.3)	($2.1)
Parking	Cost value × total auto induced VMT $0.01 × 10,330.9 M	($103.3)	($40.3)	($23.3)	($14.3)
Health Care – Decreased Activity	See Note 3.	($7.9)	($2.4)	($1.2)	($0.6)
Barrier Effect	Cost value × total induced VMT $0.00210 × **10,330.9** M	($23.8)	($9.3)	($5.4)	($3.3)
Uncompensated Moving Costs	Cost value × no. households $111 × 13,450	($1.5)	($1.0)	($0.8)	($0.7)
Farm Revenue - Induced Develop.	Cost value × acres lost (annum amts. total) $96.53 × 300,358	($29.0)	($10.8)	($6.2)	($3.8)
Ecological – Footprint	Cost value × acres lost (annum amts. total) $526 × 32,708	($17.2)	($7.4)	($4.5)	($2.9)
TOTAL COSTS			**($802.2)**	**($614.9)**	**($484.9)**
BENEFITS	**Equation**	**Undiscounted**	**3%**	**5%**	**7%**
VMT Operating – Auto	See Note 4.	$1,121.3	$404.2	$221.0	$128.5
VMT Operating – Truck	See Note 4.	$54.7	$18.2	$9.3	$5.0
VHT Reduction - Auto	See Note 5.	$11,996.7	$4,474.0	$2,511.4	$1,501.1
VHT Reduction – Heavy Truck	See Note 5.	$2,203.9	$821.9	$461.4	$275.8
Productivity	Cap.invest.$879.6 × SRR(0.35–0.10)[1]	$7,362.6	$3,669.4	$2,431.4	$1,666.6
Fatalities Reduced	VSL × (deaths w/o project – deaths with) $1.2 M × (26,459 – 25,309 = 1,150)	$1,375.3	$520.7	$294.7	$177.3
Injuries Reduction	See note 6.	$1,811.0	$575.6	$286.1	$150.4
Property Damage Reduction	Cost value × crashes reduced $500 × 359,305	$179.7	$65.1	$35.8	$21.0
Residual	See note 7.	$211.8	$48.3	$18.5	$7.2
TOTAL DISCOUNTED BENEFITS			**$10,597.4**	**$6,269.5**	**$3,932.9**
NET PRESENT VALUE			**$9,795.1**	**$5,654.7**	**$3,448.2**
BENEFIT/COST RATIO			**13.21**	**10.20**	**8.11**

[1960 $ in millions; nos. may not add exactly due to rounding; compared to the reference plan (counterfactual)]

1. Equation will not exactly equal undiscounted amount due to: year-to-year variations in data; incremental project completion through 1971; and other complexities. SRR is net social rate of return.

2. CO_2: [VMT change / avg. vehicle miles per gallon (mpg)] × metric tons (MT) CO_2 emitted per gallon of gasoline burned × CO_2 cost value; Project: 11,315.4 M VMT / 11.9 – 16.9 mpg range] × 0.008887 MT × $3.81 - $10.32 range = $57.9 M; HAS (Table 9) includes bus & rapid transit increases: [-276,919.40 M VMT / 11.9 – 16.9 mpg range × 0.008887 MT × $3.81 - $10.32 range] + (1,013.0 M Bus VMT / 5 mpg) + (1,079.2 KwH × 0.0007 MT) = -1,363.6 M

3. Yrly. per capita health costs inactivity (includes 4.2% above inflation) × increased PCVMT per cap. × % licensed drivers × annual obesity rate rise (+2.16%/+365 VMT annual) × pop. See spreadsheet.

4. A. Non-speed VMT Operating Costs (all induced VMT): Auto: (var. cost & fixed cost × auto induce VMT × "rule of half"); (-$0.053 × 10,330.9 M VMT × 0.5) + (-$0.045 × 12.1 M VMT × 0.5) = **-$274.0 M auto induced VMT operating cost increases**; Truck: (var. cost × tk. induce VMT); (-$0.159 × 984.4 M VMT × 0.5) = **-$78.3 M truck induced VMT operating cost increases**

B. Speed Operating Savings Expwy. Auto & Truck: (savings per VMT × induced expwy. VMT × peak period congestion reduction (PPCR)) – (savings per VMT × induced overall VMT × PPCR × 0.5 "rule of half."); ($0.0097 or $0.0112 × 103,094.0 M VMT × 0.7) – ($0.0097 or $0.0112 × 11,315.4 M VMT × 0.7 × 0.5) = **$741.0 M auto & truck new expwy. VMT operating savings**)

C. Speed Operating Savings Non-Expwy. (avg. 16.00 up to 22.54 mph): (auto non-expwy. VMT × cost save per VMT) + (truck non-expwy. VMT × cost save per VMT); [($-0.001575 max range × 0.913 × 972,043.6 M VMT) + (-0.004725 max range × 0.087 × 972,043.6 M VMT)] × 0.7 = **$787.3 M retained non-expwy. auto & truck VMT operating savings**

D. Auto Total: **-$274.0 M** + [(**$741.0 M** + **$787.3 M**) × 0.913] = **$1,121.3 M**; Truck Total: **-$78.3 M** + [(**$741.0 M** + **$787.3 M**) × (0.087)] = **$54.7 M**

5. A. Expwy.: [(induced expwy. VMT from new vehicles/expwy. speed)/PPCR)]; [(**11,315.4** VMT/50)/0.7] = **323.3 M VHT added from induced expwy. VMT**; Expwy.: [(induced expwy. VMT from arterials [(((total new expwy. VMT – total overall new VMT)/old speed avg.) – ((total new expwy. VMT – total overall new VMT)/ 50 mph)) × PPCR]; [(((103,094 M VMT – 11,315.4 VMT)/16.91 avg.) – ((103,094 M VMT – 11,315.4 VMT)/50)) × 0.7] = **2,722.1 M VHT reduced from retained VMT**

B. Non-expwy.: [(total proj. non-expwy. VMT/ctfl. avg. non-expwy. speed) – (total proj. non-expwy. VMT/project avg. non-expwy. speed); [(972,043.6 M VMT/16.91 avg.) – (972,043.6 VMT/17.89 avg.) = **3,449.3 M VHT reduced from retained non-expwy. VMT**

C. Auto Total Savings: (auto portions of VHT reduction from retained VMT) × (time value × avg. persons in car) + (auto portion of VHT added from induced VMT) × (time value × avg. persons in car) × ("rule of half")]; [((**2,722.1 M VHT** × 0.913) + (**3,449.3 M VHT** × 0.913))] × ($1.33 × 1.56)] + [(**323.3 M VHT** × 0.913 × $1.33 × 1.56) × 0.5] = **$11,996.7 M**

D. Truck Total Savings: (truck portions of VHT reduction from retained VMT) × (time value driver & cargo) + (truck portion of VHT added from induced VMT) × (time value driver & cargo) × ("rule of half")]; [((**2,722.1 M VHT** × 0.087) + (**3,449.3 M VHT** × 0.087))] × ($3.00 + $1.00)] + [(**323.3 M VHT** × 0.087 × $3.00 + $1.00)

× 0.5] = **$2,203.9 M**
6. (Accidents reduced (AR) × Minor AIS 1) + (AR × Moderate AIS 2) + (AR × Serious AIS 3) + (AR × Severe AIS 4) + (AR × Critical AIS 5) [359,305 × (0.41739 × $237)] × [359,305 × (0.08872 × $3,720)] + [359,305 × (0.04817 × $8,311)] + [359,305 × (0.00617 × $21,054)] + [359,305 × (0.00279 × $46,937)]. Costs rise additionally 4.2 percent above inflation per Fuchs (2012) and Gotschi (2011).
7. Project categories (yrs. useful life): ROW (infinite), earthwork (100), structural (70), road base (50), road surface (30). 261 expressway mile: (93.9 M × 1)+(370.2 M × 0.5) + (308.9 M × 2/7) + (320.9 M × 0) + (420.9 M × 0) =$367.3 M. Sum is reduced to $249.8 M ($367.3 M × 68% cost for 92 miles of full 261 miles of expressways). Sum is further reduced for lost residual value of counterfactual arterial expansions by $38 M ($367.3 M/$1,514.8 × $157 M). Result is $211.8 M ($249.8 M-$38 M).

10, 1971; RTA, Table 9, 1983; RTA, p. 45, 1989; Metra, Table 1b, p. 3, 2018).

Comparable to Chicago city population density changes in Table 1, the study assumed HAS 28 percent CTA ridership gains in line with research by Pushkarev and Zupan (1977). Validation was based on two studies. First, Iseki and Ali (2014) predict about an 18 percent transit ridership increase when fuel prices reach $4.00 per gallon. Second, based on Noland (Figure 3, p. 23, 2000), at least another 10 percent increase may be achieved from highway capacity reduction in the HAS.

A request for CTA capital, operating and ridership data for 1947–1996 was unsuccessful. The study estimated transit capital and operating expenditure increases in the HAS from an array of data outlined in Table 8. Transit noise, emissions, resource consumption, barrier, and accident impacts were included in the roadway calculations for these measures. The study HAS respective costs for transit operating/capital and travel time losses were $509.8 million and $661.8 million (1960 $, 5 percent discount). There is uncertainty in these estimates as overall welfare is also influenced by levels of subsidy and service routing/frequency per Savage and Schupp (1997).

5. Results

Table 9 and Table 10 summarize the respective SBSCAs for the project and HAS. The respective mid-range 5 percent discount rate net present value (NPV) and benefit-cost ratio (BCR) for the project SBSCA was positive at $5654.7 million (1960 $) and 10.20 for the period 1947–1996. Comparative HAS metrics were $16,275.9 million and 14.83. The NPV difference was predominantly VHT, vehicle operating, and safety categories. However, the HAS had a $2342.4 million (1960 $, 5 percent discount) NPV advantage over the project for the sum of externality benefits. All of the project benefits were from, in descending order, VHT (47 percent), productivity (39 percent), safety (10 percent), and vehicle operating (4 percent). Project costs were predominantly from increased capital expenditures. The HAS benefits were from, in descending order, VHT (51 percent), safety (21 percent), vehicle operating (16 percent), and externalities (12 percent). HAS costs were virtually all from transit capital/operating expenditure increases and travel time losses by new riders.

6. Cost effectiveness analysis

Cost effectiveness analysis (5 percent discount) for the project and HAS in relation to the counterfactual is shown below in Table 11 for selected metrics. The HAS was more cost effective for traffic accidents reduced, deaths avoided, and VHT saved. It is difficult to make a conclusion about HAS cost effectiveness regarding productivity. As discussed in Section 4.15, negative productivity shown in Table 10 for the HAS is likely a floor and could be positive and much higher. Factors include travel time savings in the HAS, possible increases to productivity from transit, and policies to offset the pricing program.

7. Sensitivity analysis

Table 12 below shows the NPV's, BCR's and results of sensitivity analyses on benefit-cost categories with tangible influences on predicted outcomes. Substantive changes in costs of travel time, transit, all externalities, accidents and productivity had relatively minor impacts. By far, the most meaningful influence was the assumed change in VMT reduction due to price from 20 to 10 percent in the HAS. This alteration lowered HAS NPV by about 50 percent and reduced project economic efficiency disparity from about $10,621.2 to $2413.2 million (1960 $, 5 percent discount).

8. Discussion and conclusion

Comprehensive retrospective SBSCA found the project performed impressively well. However, there were abundant opportunity costs of not implementing a mechanism to address induced travel and externalities by increasing charges to roadway users. Nearly all of the benefit-cost categories under the HAS had substantive improvements over the project. Trips not worth their full costs were purged. Travel time, vehicle operating, and accident cost savings dominated the HAS advantages due to sizeable reductions in VMT. The sum of HAS externality benefits were considerable and provided insight on the impact of a SBSCA versus a conventional BCA. Ancillary effects of the HAS were reductions in the region's UA and ecological footprint, although the latter could not be substantively quantified. Consistent with the *Theory of the Second Best*, results demonstrated the imprudence of planning to meet travel demand in an imperfect market.

The impacts of transportation decision-making on social benefits and costs in this case study were quite astounding. Estimated social welfare under the HAS would have been 2.7 to 3.1 times higher in lieu of the project. In other words, depending upon discount rate used, economic efficiency over the project 50-year period was reduced by a range of about $7339–$16,863 million (1960 $). For context, this is equivalent to annual deadweight loss of about $1292–$2969 million (2020 $). The total federal-aid highway apportionment to Illinois in 2020 was less than $1600 million (FHWA, 2019). From another perspective, the annualized project welfare loss was $147-$337 million (1960 $). The Chicago, Aurora and Elgin Railroad Company (CA&E) electric interurban line ceased operations in the late 1950's due markedly to the project (pp. 383–405, Plachno, 1989; pp. 13-23, Weller and Stark, 1999). The CA&E annual operating and depreciation cost average from 1926 to 1944 was about $4.4 million (1960 $) (pp. 368–9, Plachno). From another viewpoint, based on CO_2 fossil fuel emissions world data compiled by Adams (2013), HAS CO_2 reductions for the years 1950–1996 could have reduced Chicago UA (IL) region levels by about 13 percent [170.5 M MT Chicago HAS reduction / (45,914.5 M MT U.S. × 0.028 Chicago UA population proportion of U.S.)]. Comparable CO_2 reductions throughout the country may have reduced global discharges by about 3.5 percent [(170.5 M MT / 0.028) / 171,915.2 M MT world].

There are inherent uncertainties in all of the benefits and costs data and values. The findings are highly dependent upon the assumed level of travel demand reduction expected from optimal pricing. It is unfortunate that roadway operating data, particularly VMT and accident-related information, was unavailable for much of the analysis period. While this does cause some trepidation about the findings, known data points served to provide a reasonable basis for the estimates. Predicted changes in crime were not quantified due to the complexity of impacts. Similarly, projected changes in mortality rates were not calculated from altered cardiovascular activity brought about by differences in VMT. Another shortcoming of this research is the limited insight on equity effects. A transportation diversity metric was originally included as part of the SBSCAs but was removed as it could be considered overly

Table 10
HAS Social Benefit-Cost Analysis Summary.

COSTS	Equation	Undiscounted	3%	5%	7%
Noise – Transit Only	(Cost × ind. VMT) + (cost × rail pass. mile) ($0.0033 × 2,255.2 M) +($0.19 × 7,639.5 M /621)	($9.7)	($3.7)	($2.1)	($1.3)
Public Transport – Cap./Oper.	CTA operating + bus + rail cars $1,921.5 M + $234.3 M + $127.8 M	($2,283.5)	($878.2)	($509.8)	($318.7)
Public Transport – Travel Time	Pass. Travel Time Increase × Time Value 1,883.8 M hrs. × $1.33	($2,505.4)	($1,066.3)	($661.8)	($439.2)
Residual	See Note 1	($38.0)	($8.7)	($3.3)	($1.3)
TOTAL COSTS			**($1,957.0)**	**($1,177.1)**	**($760.5)**
BENEFITS	**Equation**	**Undiscounted**	**3%**	**5%**	**7%**
Capital Costs	See Table 1	$157.0	$109.4	$88.5	$73.2
Operating & Maintenance	Avg. cost/lane mile × 50-yr. lane miles $913 × varies by year (see spreadsheet)	$22.6	$10.0	$6.2	$4.1
Farm Revenue – Reduced Develop.	Cost per ac. × ac. (annum amts. total) $96.53 × 8,753,438	$845.0	$343.7	$204.3	$129.0
VMT Operating – Auto	See Note 2.	$11,257.9	$4,543.2	$2,746.5	$1,793.9
VMT Operating – Heavy Truck	See Note 2.	$199.2	$75.6	$42.8	$25.8
VHT – Auto	See Note 3.	$34,380.0	$13,785.4	$8,249.3	$5,310.9
VHT – Heavy Truck	See Note 3.	$3,438.3	$1,331.5	$767.3	$470.6
Noise – Auto	Cost value × reduced VMT $0.00040215 × 276,919.4 M	$111.4	$45.7	$28.0	$18.7
CO_2	3% discount only. See Note 2 in Table 8.	$1,363.6	$528.6	$528.6	$528.6
NO_X	See Note 4.	$5.8	$3.3	$2.6	$2.2
PM	See Note 5.	$2,093.4	$862.8	$532.8	$356.7
Resource Consumption	See Note 6.	$333.4	$142.3	$89.2	$60.3
Parking	Cost value × total reduced auto VMT $0.01 × 276,919.4 M	$2,769.2	$1,135.2	$697.2	$463.9
Health Care – Decreased Activity	See Note 7.	$182.4	$57.9	$28.8	$15.1
Barrier Effect	Cost value × (reduced road VMT + bus VMT) $0.00210 × (-273,363.0 M + 2,255.2 M)	$576.8	$236.6	$145.4	$96.8
Productivity	See Note 8.	($999.3)	($540.8)	($376.8)	($271.6)
Fatalities Reduced	VSL × (deaths w/o HAS – deaths with) $1.2 M × (26,459 – 20,936 = 5,523)	$6,605.9	$3,080.4	$2,057.3	$1,475.1
Injuries Reduction	See Note 9.	$7,115.2	$2,497.5	$1,376.0	$826.6
Property Damage Reduction	Cost value × crashes reduced $500 × 1,652,206	$826.1	$366.5	$238.9	$168.5
TOTAL DISCOUNTED BENEFITS			**$28,614.7**	**$17,453.0**	**$11,548.2**
NET PRESENT VALUE			**$26,657.8**	**$16,275.9**	**$10,787.6**
BENEFIT/COST RATIO			**14.62**	**14.83**	**15.18**

[1960 $ in millions; nos. may not add exactly due to rounding; compared to the reference plan (counterfactual)]

1. Construction categories (yrs. useful life): ROW (infinite), earthwork (100), structural (70), road base (50), road surface (30). 261 expressway miles: (93.9 M × 1)+ (370.2 M × 0.5) + (308.9 M × 2/7) + (320.9 M × 0) + (420.9 M × 0) = $367.3 M. HAS residual is for arterials deletion only at a cost of -$38 M [($367.3 M/$1,514.8) × $157 M].

2. A. Non-speed Operating Benefits Auto Only (all eliminated VMT): [((Auto var. cost × auto reduced VMT) + (vehicles eliminated × AVMT per vehicle)) × "rule of half"]; ($0.053 × 276,919.4 M VMT × 0.5) + ($0.045 × 62,706.3 M VMT × 0.5) = **$8,736.7 M non-speed operating cost savings for eliminated VMT**; No change in truck expwy. VMT & non-speed-related operating costs.
B. Speed Operating Benefits Expwy. Auto Only (all eliminated VMT): (Savings per VMT × expwy. VMT eliminated × peak period congestion reduction (PPCR) × 0.5 "rule of half"); ($0.0097 or $0.0112 × 37,737.0 M VMT × 0.7 × 0.5) = **$143.6 M expwy. eliminated VMT speed savings**
C. Speed Operating Benefits Non-Expwy. (avg. 16.00 up to 22.54 mph): Eliminated VMT: (ctfl. non expwy. VMT – HAS non-expwy. VMT) × operating cost per VMT × "rule of half"); [(1,063,822.3 M VMT – 824,639.8 M VMT) × $-0.0034 max range × 0.5] = **$287.0 M non-expwy. eliminated VMT speed savings** ; Retained VMT: [(ctfl. non-expwy. × auto portion × operating cost per VMT) + (ctfl. non-expwy. × truck portion × operating cost per VMT)]; [(824,639.8 M VMT × 0.913 × -$0.0034 max range) + (824,639.8 M VMT × 0.087 × -$0.0102 max range)] = **$2,289.8 M non-expwy. retained VMT speed savings**
D. Auto Total: (**$2,289.8 M** × 0.913) + **$287.0 M** + **$143.6 M** + **$8,736.7 M** = **$11,257.9 M**; E. Truck Total: (**$2,289.8 M** × 0.087) = **$199.2 M**

3. A. Expwy: [(eliminated VMT/expwy. speed)/PPCR)]; [(37,737.0 M VMT/50)/0.7] = **1,078.2 VHT total expwy. reduction from eliminated VMT**;
B. Non-expwy.: [from eliminated vmt: (ctfl. VMT – HAS VMT)/ctfl. avg. non-expwy. speed)] + [from retained VMT: (HAS VMT/ctfl. avg. non-expwy. speed) – (HAS VMT/HAS avg. non-expressway speed)]; [(1,063,822.3 M VMT – 824,639.8 M VMT/16.91 avg.)] = **14,021.4 M VHT non-expwy. reduction from eliminated VMT**; [(824,639.8 M VMT/16.91 avg.) – (824,639.8 M VMT/20.84 avg.)] = **9,880.0 M VHT non-expwy. reduction from retained VMT**; 14,021.4 M VHT + 9,880.0 M VHT = 23,901.4 M VHT total non-expwy. reduction
C. Auto Total Savings: [**1,078.2 M VHT** + **14,021.4 M VHT** + (**9,880.0 M VHT** × 0.913)] × ($1.33 time value × 1.56 avg. persons per car)] – [(**1,078.2 M VHT** + **14,021.4 M VHT**) × ($1.33 × 1.56) × 0.5 "rule/half"]=**$34,380.0 M**
D. Truck Total Savings (only from retained non-expwy. VMT): [(**9,880.0 M VHT** × 0.087) × ($3.00 time value driver + $1.00 time value cargo) = **$3,438.3 M**

4. NO_X [(chg. VMT × MT value) + (chg. bus VMT × MT value) + (chg. rail kwh × MT value)] × $ value; [(276,919.4 M × 0.000000172) + (2,255.2 M × 0.00001795) + (1,079.2 M × 0.00000125)] × $1,003 = $5.8 M.

5. PM10 & PM2.5: [chg. VMT × MT value) + (chg. bus VMT × MT value) + (chg. Rail kwh × MT value)] × $ value; PM10: [(276,919.4 M × 0.000000087 × 1.073) + (2,255.2 M × 0.0000009 × 1.073) + (1,079.2 M × 0.0000000416)] + PM2.5: [(276,919.4 M × 0.000000087) + (2,255.2 M × 0.0000009) + (1,079.2 × 0.0000000416)]] × $45,863 = $2,093.4 M.

6. Resource consumption: (chg. VMT/MPG × $ value) + (chg. bus pass. miles/pass. per gal. fuel × $ value) + (chg. rail pass. miles/pass. Per gal. fuel) × $ value]; [(276,919.4 M/13.47 × $0.0169) + (13,038.3/115 × $0.0169) + (7,639.5 M/244 × $0.0169)] = $333.4 M.

7. Annual per capita health costs inactivity (includes 4.2% above inflation) × reduced PCVMT per cap. × % licensed drivers × yrly. obesity rate rise (+2.16%/+365 VMT annual) × pop. See spreadsheet.

8. (-Cap. invest. × social return rate (SSR)) + (% UA density chg. × density elasticity of productivity × actual productivity); ((-$157.0 M) × SRR (0.35–0.10)) + (up to

34% x 0.0275% x $3,822,720.7 M). SRR is net social rate of return. Equation will not equal undiscounted amount due to: year-to-year variations in data; incremental expressways completion through 1971; and other complexities. Resulting productivity loss was used and considered a floor based upon reduction in capital investment. VHT savings could boost this to a significant benefit.

9. (Accidents reduced (AR) × Minor AIS 1) + (AR × Moderate AIS 2) + (AR × Serious AIS 3) + (AR × Severe AIS 4) + (AR × Critical AIS 5)
[1,652,206 × (0.41739 × $237)] + [1,652,206 × (0.08872 × $3,720)] + [1,652,206 × (0.04817 × $8,311)] + [1,652,206 × (0.00617 × $21,054)] + [1,652,206 × (0.00279 × 46,937)]. Costs rise additionally 4.2 percent above inflation per Fuchs (2012) and Gotschi (2011).

Table 11
Cost Effectiveness Analysis (1960 $; 5% discount rate; nos. may not add exactly due to rounding).

Metric	Project Capital $503,402,215 Number	Project Capital Cost per Unit or $	HAS Capital $421,315,657[1] Number[2]	HAS Capital Cost per Unit or $
Crashes Reduced	359,305	$1,401	1,652,206	$255
Lives Saved	1,150	$437,741	5,523	$76,283
VHT Saved	5,848,150,005	$0.09	24,979,662,981	$0.02
Productivity	$2,431,399,485	$1.13	-$376,793,532	$1.12

1. Expressway capital of -$88,509,972 + transit investment of $509,825,629.
2. Includes transit.

Table 12
Chicago Expressway System Sensitivity Analysis (1960 $ in millions).

Scenario	3% B/C Ratio	3% NPV	5% B/C Ratio	5% NPV	7% B/C Ratio	7% NPV
Counterfactual (against no-build)	6.40	$9,120.0	5.29	$4,990.7	4.36	$2,860.8
Project	13.21	$9,795.1	10.20	$5,654.7	8.11	$3,448.2
HAS - Building Expressway (non-Chicago city) and Implementing Pricing to Cover all Costs/ Externalities	14.62	$26,657.8	14.83	$16,275.9	15.18	$10,787.6
Assume Increased Real Travel Time Values per TIGER [$2.03 auto passenger (& HAS transit); $3.28 truck driver]						
Project	16.22	$12,207.4	12.40	$7,008.8	9.78	$4,257.6
HAS	14.28	$33,445.2	14.32	$20,323.0	14.50	$13,384.6
Assume 200% Increase in Transit Capital and Operating Costs in HAS						
HAS	7.71	$24,901.3	7.95	$15,256.3	8.26	$10,150.2
Remove all Benefits and Costs for Externalities						
Project	16.91	$9,970.6	12.44	$5,765.6	9.64	$3,524.9
HAS	12.93	$23,305.5	12.93	$14,021.1	13.01	$9,117.8
Assume Productivity Calculated from Travel Time Savings Rather than Capital Expenditures						
Project	14.30	$10,671.7	10.41	$5,786.5	7.85	$3,320.8
Assume HAS Reduction in Accidents is only ½ the Estimate						
HAS	13.10	$23,685.6	13.27	$14,439.8	13.56	$9,552.5
Change Travel Reduction due to Optimal Pricing from 0.2 to 0.1 in HAS						
HAS	7.82	$13,355.9	7.85	$8,067.9	7.98	$5,309.7

controversial. Other metrics may be contentious such as parking, barrier effects and uncompensated moving costs (see Litman, 2016). The increase of public transportation in the HAS within Chicago city likely would have been a boon to disadvantaged populations. This equity benefit assumes it offsets any adverse distributional effects from roadway pricing, which may require additional policy choices. Another HAS equity benefit is the higher population and employment densities. Increased densities improve accessibility or the ability to reach amenities while reducing travel distance and costs. There are additional methods to incorporate distributional impacts into BCA and SBSCA to measure equity (e.g., Martens, 2011; Loomis, 2011).

For the period 1956–1980, CATS forecasted significant increases in economic growth and consumer purchasing power. Expectations were that the number of vehicles and travel demand would almost double during this time with an outward shift of volume densities. In fairness to CATS, these forecasts were based on the fact that the project was either already built or committed (pp. 13–14, 91, CATS, 1960). The study HAS SBSCA results likely could not have been foreseen by society prior to project construction. This is due to changes/progress made in ex ante SBSCA, planning processes, transport technology, sociodemographics, household purchasing power, and mitigation of externalities. In addition, societal awareness and understanding of global warming and environmental sustainability has improved immensely over time. Thus, SBSCA ex ante results of a similar undertaking today could be much different.

Structuring a more efficient transport pricing program would be a complicated endeavor. Perhaps the best option is a combination of fuel/vehicle taxes, VMT charges by time of day and location, and adjustments for equity (see CBO, 2011). Certainly, there are strong political barriers to travel pricing programs. The study findings fill a research void of urban highway system retrospective SBSCAs and demonstrate their value compared to more constrained BCAs. Consequently, practitioners and decision-makers may be prompted to give more consideration to unconventional alternative scenarios in planning highway/transit systems and projects. In particular, pricing as a travel demand technique has untapped potential to mitigate highway negative externalities to human health and the environment. It is recommended that the study be supplemented with more in-depth analysis on equity impacts. Development of additional social cost-benefit categories would improve credibility. Follow-up SBSCAs are advised to support alternatives analysis of the Chicago urban expressway system to address inequities while improving internalization of transport costs and transit. It would be informative to conduct comparable analyses covering other urbanized areas.

CRediT authorship contribution statement

Reginald Arkell: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cstp.2021.01.013.

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