

Cost–benefit analysis of a distracted pedestrian intervention

Md Jillur Rahim ¹, David C Schwebel ², Ragib Hasan,³ Russell Griffin,⁴ Bisakha Sen ¹

► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/ip-2022-044740>).

¹Department of Health Policy & Organization, The University of Alabama, Birmingham, Alabama, USA

²Department of Psychology, The University of Alabama, Birmingham, Alabama, USA

³Department of Computer Science, The University of Alabama, Birmingham, Alabama, USA

⁴Department of Epidemiology, The University of Alabama, Birmingham, Alabama, USA

Correspondence to

Dr Bisakha Sen, Department of Health Policy & Organization, The University of Alabama at Birmingham, Birmingham, Alabama, USA; bsen@uab.edu

Received 22 August 2022
Accepted 27 October 2022

ABSTRACT

Objective Cellphone ubiquity has increased distracted pedestrian behaviour and contributed to growing pedestrian injury rates. A major barrier to large-scale implementation of prevention programmes is unavailable information on potential monetary benefits. We evaluated net economic societal benefits of StreetBit, a programme that reduces distracted pedestrian behaviour by sending warnings from intersection-installed Bluetooth beacons to distracted pedestrians' smartphones.

Methods Three data sources were used as follows: (1) fatal, severe, non-severe pedestrian injury rates from Alabama's electronic crash reporting system; (2) expected costs per fatal, severe, non-severe pedestrian injury—including medical cost, value of statistical life, work-loss cost, quality-of-life cost—from CDC and (3) prevalence of distracted walking from extant literature. We computed and compared estimated monetary costs of distracted walking in Alabama and monetary benefits from implementing StreetBit to reduce pedestrian injuries at intersections.

Results Over 2019–2021, Alabama recorded an annual average of 31 fatal, 83 severe and 115 non-severe pedestrian injuries in intersections. Expected costs/injury were US\$11 million, US\$339 535 and US\$93 877, respectively. The estimated distracted walking prevalence is 25%–40%, and StreetBit demonstrates 19.1% (95% CI 1.6% to 36.0%) reduction. These figures demonstrate potential annual cost savings from using interventions like StreetBit statewide ranging from US\$18.1 to US\$29 million. Potential costs range from US\$3 208 600 (beacons at every-fourth urban intersection) to US\$6 359 200 (every other intersection).

Conclusions Even under the most parsimonious scenario (25% distracted pedestrians; densest beacon placement), StreetBit yields US\$11.8 million estimated net annual benefit to society. Existing data sources can be leveraged to predict net monetary benefits of distracted pedestrian interventions like StreetBit and facilitate large-scale intervention adoption.

INTRODUCTION

Over 6500 Americans died in a pedestrian crash in 2020, according to the most recent data available from the National Center for Statistics and Analysis.¹ This represents a 47% increase from pedestrian fatalities reported in 2011,² in contrast to the 20% increase in total traffic fatalities over the same period. This dramatic increase in pedestrian injury deaths, which remains present after adjusting for population changes, is attributed to various causes.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Smartphone-related distraction is a likely contributing factor to the increasing rate of pedestrian fatalities and injuries in the USA. However, interventions to reduce pedestrian distraction have not been widely adopted.

WHAT THIS STUDY ADDS

⇒ One barrier to widespread adaption is the lack of information on benefits versus costs. This study examines the economic costs and benefits to society of an intervention that reduces distracted walking to increase pedestrian safety and provides a template showing how existing data sources can be leveraged to do similar analyses for other interventions designed to enhance pedestrian safety.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The template developed in this study can facilitate large-scale implementation of any intervention designed to prevent pedestrian fatalities and injuries by providing policy makers information on net benefits of the intervention.

One likely contributing factor is the increasing use of smartphones by pedestrians in and near traffic.^{3–5}

Cognitive-perceptual research repeatedly demonstrates that smartphone use negatively impacts pedestrian safety.^{6,7} Experts cite three components of distraction: (A) visual inattention, which results from the pedestrian's visual attention being diverted to smartphone screens instead of the surrounding traffic environment; (B) auditory inattention, which results from the pedestrian's auditory attention being diverted to smartphone music or conversations instead of the surrounding traffic environment and (C) cognitive inattention, which results from the pedestrian's cognitive attention being diverted to the smartphone and its contents rather than the cognitively complex surrounding traffic environment. One recent meta-analysis offers respective effect sizes of $r=0.17$ (95% CI 0.12 to 0.22; Cohen's $d=0.34$), $r=0.34$ (95% CI 0.23 to 0.46; Cohen's $d=0.73$) and $r=0.18$ (95% CI -0.12 to 0.49; Cohen's $d=0.37$), demonstrating the impact of talking, texting/browsing and music listening on hits or close calls in simulated pedestrian crossings.⁶

Despite evidence that distraction reduces pedestrian safety and that the sharp increase in pedestrian fatalities in the United States over the past decade is attributed partly to distracting



© Author(s) (or their employer(s)) 2022. No commercial re-use. See rights and permissions. Published by BMJ.

To cite: Rahim MJ, Schwebel DC, Hasan R, et al. *Inj Prev* Epub ahead of print: [please include Day Month Year]. doi:10.1136/ip-2022-044740

behaviour by pedestrians, there have been comparatively few attempts to develop and evaluate effective and cost-efficient strategies to reduce distracted pedestrian behaviour and therefore reduce risk of pedestrian injury. Efforts to place warning signs or lights on sidewalks or in crossing areas show initial promise of effectiveness in some trials, but mixed results in other attempts.^{8–11} ‘Distracted walking laws’ have been implemented in just a few jurisdictions around the world, and public health initiatives to reduce distracted walking have not been rigorously evaluated.¹²

One barrier to large-scale implementation by municipalities, cities or states of interventions that show promise in pilot or experimental studies is uncertainty around whether the benefits, when translated to monetary terms, will justify the costs. This creates the proverbial ‘chicken and egg’ problem, whereby large-scale implementation does not occur due to a lack of information on monetary costs versus benefits, and because large-scale implementations do not happen, in turn, no data are generated that will permit evaluation of costs and benefits. What may help break this impasse is a template that enables researchers to estimate monetary costs and benefits primarily using existing data. This manuscript provides such a template—using a recently described strategy, StreetBit—as an example of a smartphone app-based intervention that shows promise of reducing distracted pedestrian behaviour, and thus reducing pedestrian injury rates. Drawing from preliminary empirical findings on the effectiveness of StreetBit to reduce distracted pedestrian behaviour by warning distracted pedestrians via their smartphones to attend to traffic as they approach an intersection and combining that with existing data on the incidence and costs of pedestrian injury, this analysis evaluates whether StreetBit might be a cost-efficient strategy to reduce the monetary fallout from distracted pedestrian behaviour.

StreetBit functions by directly warning distracted pedestrians on their smartphones as they approach a street corner while distracted.^{13–14} Bluetooth beacons are installed on street corners and send unidirectional signals to pedestrians using their smartphones when they come in contact with the beacons. Pedestrians looking at their phones receive a visual warning, and those listening to their phones receive an auditory message. When the warning is received, pedestrians are expected to heed the warning, attend to traffic and cross the street safely.

Preliminary testing of StreetBit was promising.¹⁴ Before large-scale dissemination of programmes like StreetBit, however, a framework for empirically estimating the costs and benefits of implementing the programme that gives local leaders and policy makers information on the return on investment of the large-scale adoption to secure their cooperation.

To accomplish our goal, we gathered data estimating the cost of installing StreetBit at intersections across the state of Alabama and the costs of installing the software on pedestrians’ phones. Together, these data represent the costs of the programme. We also estimated the economic benefits of the programme based on the reduction in costs of pedestrian injuries prevented. The aim was to build a cost–benefit analysis framework whereby the societal benefits of distracted pedestrian prevention programmes like StreetBit can be estimated by leveraging and synthesising existing data from appropriate sources. Beyond informing stakeholders and policymakers about the benefits versus costs of large-scale adaption of StreetBit, this framework has the advantage in that it can be used and adapted by other researchers considering distracted pedestrian interventions and offers guidance on predicting the economic benefit of large-scale dissemination of those interventions.

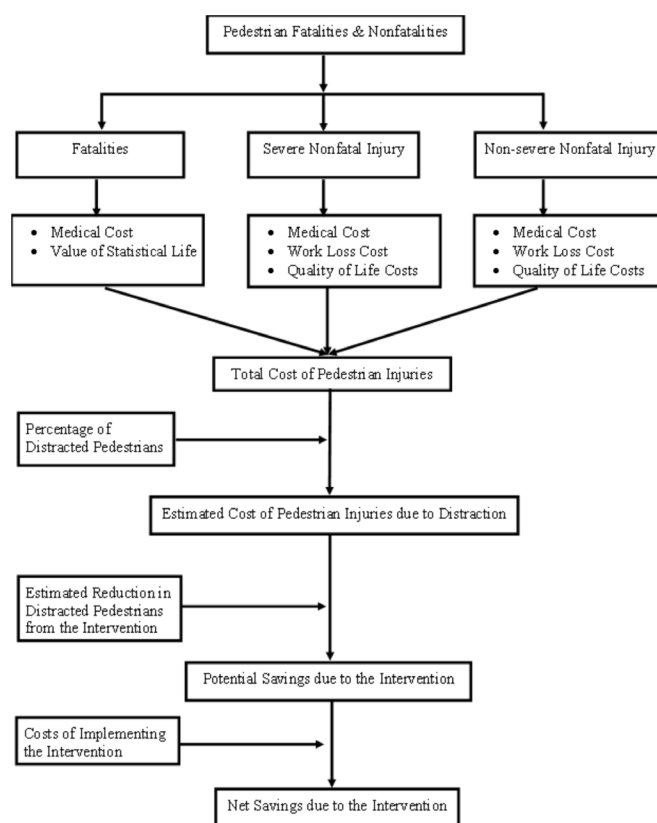


Figure 1 Pedestrian injury cost–benefit analysis framework.

METHODS

Study Location

We focused our analysis on Alabama, the US state ranked as the second most dangerous state for walkers on the streets by Smart Growth America and the National Complete Streets Coalition.¹⁵

Overview of Methods

We estimated costs and benefits to accomplishing our goal of estimating the benefit of StreetBit in terms of monetary savings. To estimate costs, we built a logic model that outlined the key components of costs associated with pedestrian fatality and injury and the baseline prevalence of such fatality and injury (See Figure 1). To populate the costs of pedestrian injury and fatality in the conceptual model, we extracted and utilized data from two sources: (a) eCrash, an electronic traffic crash reporting system for the state of Alabama,¹⁶ which was used to obtain counts of pedestrian injury in the state, including fatal injuries and injuries by the level of severity, and (b) the CDC Web-based Injury Statistics Query and Reporting System (WISQARS) Cost of Injury Reports,¹⁷ which was used to obtain costs associated with pedestrian fatal injuries and injuries of different level of severity. Each dataset was restricted to pedestrian injuries and fatalities occurring in intersections in the state of Alabama.

Next, we considered published reports on the proportion of pedestrians distracted by mobile devices while walking and on the effectiveness of StreetBit in reducing such distractions.^{14–16} These data allowed us to estimate the potential number of fatalities and injuries that would be prevented from the large-scale implementation of StreetBit across Alabama. The monetary savings from these prevented fatalities/injuries constitute the predicted societal benefit of StreetBit.

Data sources

Fatal and non-fatal pedestrian injuries

Fatal and non-fatal pedestrian injury data in Alabama were collected from the state's electronic crash reporting system, developed by the University of Alabama Center for Advanced Public Safety.¹⁷ We conservatively restricted our analysis to injuries occurring at intersections only, as it is unknown what effect programmes like StreetBit might have on injuries occurring at non-intersection locations. We used an average of the three most recently released years of data (2019, 2020 and 2021) for our analysis.

Non-fatal injuries were categorised into two types, severe and non-severe. Severe injuries included those that the eCrash system categorised as 'serious' injuries, and minor injuries were classified as non-severe injuries.

Costs of Injury

For all three categories of injuries (fatal, severe non-fatal, non-severe non-fatal), costs of the injury were obtained from CDC WISQARS.¹⁸ CDC WISQARS provides mean national costs for fatal pedestrian injuries, severe injuries (defined as injuries requiring hospitalisation) and non-severe injuries (defined as injuries where a patient was treated and released at the emergency department). Estimated costs for fatalities include costs for medical care and the statistical value of life, and costs for non-fatalities include medical care costs, work loss costs and quality of life costs. CDC estimated all of these costs based on overall life year and quality-adjusted life year (QALY) losses stemming from potential injuries. The cost per QALY is calculated as [(Value of Statistical Life – discounted lifetime earnings)/discounted life expectancy], and present values were computed by discounting the future using a midyear discounting of 3%.¹⁹ Because the latest data available were from 2020, we inflation-adjusted medical costs to 2021 using the Consumer Price Index (CPI) for medical care, and inflation-adjusted value of statistical life, work loss costs and quality of life cost using the general CPI. WISQARS data were used because corresponding cost data specific to Alabama are unavailable in the eCrash system.

Percentage of distracted pedestrians

No rigorous scientific evidence has been published concerning what percent of pedestrians experiencing an injury were distracted, probably because many injuries occur without reliable witnesses to document whether the pedestrian was distracted or not. Thus, we assumed that the percent of pedestrians experiencing an injury because they were distracted would reflect the overall per cent of pedestrians observed to be distracted. In reality, distracted pedestrians may be more likely to be injured than undistracted pedestrians, so our estimates are conservative.

An observational study conducted at the University of Alabama at Birmingham and Old Dominion University found that 41.2% of pedestrians were distracted by handheld mobile devices while crossing major roadways during the daytime.¹⁶ However, that study was conducted on urban college campuses where distraction rates may be higher than in other settings. Recently collected data from our Alabama laboratory found a distraction rate of 30.4% among pedestrians across multiple locations and at multiple hours, including entertainment districts, a downtown business district, and near middle and high schools and a university campus.²⁰ To accommodate the uncertainty inherent in these figures, we calculated the costs of distracted walking under the assumption of 25%, 30%, 35% or 40% of injured pedestrians being distracted.

Total costs of distracted walking

The total cost of distracted walking is represented by C_Q , calculated as follows:

$$C_Q = [D (M_d + V_d) + S (M_s + W_s + Q_s) + NS (M_{ns} + W_{ns} + Q_{ns})] * P(1)$$

where D represents the total number of pedestrian deaths, S represents the total number of severe pedestrian injuries, and NS represents the total number of non-severe pedestrian injuries; M_d , M_s , and M_{ns} , respectively, represent medical costs associated with pedestrian deaths, severe injuries and non-severe injuries; V_d represents the value of statistical life for pedestrian deaths; W_s , W_{ns} , respectively, represent work loss cost associated with severe injuries and non-severe pedestrian injuries; Q_s , Q_{ns} represents quality-of-life costs for severe and non-severe non-fatal injuries; and P denotes the predicted proportion of pedestrians who were distracted when experiencing an injury.

Benefit of StreetBit

The monetary benefit of StreetBit is defined as the cost savings from the expected reductions in pedestrian injury. We used results from Schwebel *et al* and the standard mathematical formula to derive the 'marginal effect' from ORs in logit models to obtain an estimated percentage of reduction in distracted walking among pedestrians who were deemed to be most distracted at baseline.^{14 21} This calculation used the assumption that concurrent percentage reductions in pedestrian injuries would be distributed proportionately across fatal, severe non-fatal and non-severe non-fatal injuries and corresponding decreases in the associated costs.

Costs of StreetBit

To estimate the costs of StreetBit, we made the following assumptions. First, we calculated the physical costs of beacons at US\$15/beacon, their current market price, and assumed based on existing research that an average of 10 beacons would be placed at each street corner.¹³ The operational lifetime of one StreetBit beacon is 4 years. However, we assumed 10% of beacons would need replacement annually due to theft or vandalism. Further, the batteries need replacing annually, at the cost of US\$1/battery. We also assumed that one employee would dedicate 50% of their annual time towards maintaining the beacons and assumed that, inclusive of benefits, in Alabama would cost US\$40000. In addition, costs for cloud servers to store data would be US\$1500 per month or US\$18000 per year.

Given principles of psychological learning theory suggesting a variable ratio learning schedule creates behaviour change and resistance to extinction,^{22 23} we assumed StreetBit would not need to be placed at every single intersection to achieve the desired outcome of stopping distracted pedestrian behaviour. Without existing empirical evidence to guide us, we computed three scenarios: placing StreetBit beacons at every second, every third, or every fourth intersection in all urban locations across Alabama. We restricted placement to urban locations based on the assumption that they have greater population density and higher frequency of pedestrian activities, and extant evidence that pedestrian injuries involving electronic devices such as head-phones overwhelmingly occur in urban compared with rural counties.²⁴

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting and dissemination plans of this research. We followed the Consolidated Health Economic Evaluation Reporting Standards 2022 checklist for reporting the study.

RESULTS

There were 115, 99 and 126 fatal pedestrian injuries in Alabama in 2019, 2020 and 2021, respectively, averaging 113 deaths annually in the past 3 years. Of these fatalities, 19, 38 and 36 occurred in the intersections in 2019, 2020 and 2021, respectively (average=31 per year). The state recorded 92, 73 and 84 severe non-fatal pedestrian injuries in intersections in 2019, 2020 and 2021, respectively, averaging 83 severe injuries annually. Finally, 130, 108 and 107 non-severe non-fatal pedestrian injuries occurred in the intersections in 2019, 2020 and 2021, respectively, averaging 115 non-severe pedestrian injuries in Alabama annually.

The average medical costs and value of statistical life associated with each fatal pedestrian injury in 2020 dollars were US\$14 169 and US\$10.46 million, respectively, and US\$14 311 and US\$10.98 million after adjusting for inflation. The average medical cost, work loss cost and quality of life cost were US\$99 647, US\$22 406 and US\$205 470 for severe non-fatal pedestrian injuries and US\$9184, US\$2213 and US\$78 360 for non-severe non-fatal injuries. Adjusting these for 2021 figures using CPI medical care, the 2021 medical costs per severe non-fatal injury and non-severe non-fatal injury were US\$100 643 and US\$9276, respectively. Adjusting for 2021 using general CPI, work loss costs associated with severe non-fatal injury and non-severe non-fatal injury were US\$23 148 and US\$23 24, and quality of life costs were US\$215 744 and US\$82278, respectively.

Based on previous findings regarding the proportion of distracted pedestrians,^{16 20} we permitted *P* in Eq 1 to vary between 25% and 40%. Based on published results, we assumed the StreetBit programme would reduce distracted pedestrian behaviour by an average of 19.1% (95% CI 1.6% to 36.0%) across all categories of pedestrian injuries (fatal, non-fatal severe, non-fatal non-severe).¹⁴

As shown in table 1, with the most conservative estimate of 25% of injured pedestrians being distracted, the potential annual savings from implementing StreetBit statewide in Alabama are US\$18 139 937, with a 95% CI ranging from US\$1 519 576 to US\$34 190 457. If the less conservative estimate of 40% of injured pedestrians being distracted is used, the estimate increases to US\$29 023 899 (95% CI US\$2 431 321 to US\$54 704 732).

Alabama has an estimated 168 031 intersections across 461 urban areas, which include cities, large towns and small towns.²⁵ Table 2 represents a cost breakdown for installing Bluetooth Beacons at an individual intersection. Based on the above estimates, placing beacons in one of every four urban intersections in Alabama would cost US\$3 208 600 annually, including the

Table 2 Bluetooth beacons installation cost breakdown per intersection

	Lifetime cost (4 years)	Annual cost
ten beacons at \$20/beacon	\$200	\$50
one beacon replaced each year (four beacons replaced in 4 years)	\$80	\$20
Batteries replaced annually	\$12	\$3
Total cost per intersection	\$300	\$75
The half-time annual employee salary is a fixed cost of the programme. It is not included in the table of per beacon costs but is included in the final cost-benefit analyses.		

fixed costs. Comparable figures to place them in one of every three or one of every two intersections are US\$4 258 825 and US\$6 359 200, respectively.

Even with our most conservative estimate of 25% distracted pedestrians, placing a beacon in every fourth intersection would lead to an annual net benefit of US\$14.9 million for the state of Alabama. Placing beacons in every second or every third intersection would result in net savings of US\$13.8 million and US\$11.78 million, respectively. If the higher estimate of 40% distracted pedestrians is used, then placing beacons at every second, third or fourth intersection yields net benefits of US\$22.7 million, US\$24.8 million and US\$25.8 million, respectively. Net benefits under different scenarios are shown in online supplemental appendix.

Discussion

A rich literature confirms the benefits of policies designed to prevent distracted driving—such as bans on texting while driving—in terms of preventing fatalities and injuries.^{26 27} Such information, in turn, permits calculating the costs and effectiveness of interventions designed to prevent motor vehicle injuries.²⁸ However, despite growing evidence of distracted pedestrian behaviour due to ubiquitous cellphone use, and its causal link to pedestrian injury, there is a lack of information and tools to compute the costs and effectiveness of interventions to reduce distracted pedestrian behaviour. This poses a significant barrier to adopting such interventions by municipalities or states. Our paper offers a roadmap for how existing data and scientific findings can be leveraged to predict the net monetary benefits to society—that is, benefits less the programme costs—of such interventions by implementing the StreetBit programme across Alabama as an example.

Table 1 Costs of distracted walking and potential savings due to StreetBit in Alabama

	Percentage of distracted pedestrians			
	25%	30%	35%	40%
Fatalities	\$85 229 158	\$102 274 989	\$119 320 821	\$136 366 653
Severe injuries	\$7 045 357	\$8 454 428	\$9 863 500	\$11 272 571
Non-severe injuries	\$2 698 978	\$3 238 773	\$3 778 569	\$4 318 365
Cost of distracted pedestrian injuries	\$94 973 493	\$113 968 191	\$132 962 890	\$151 957 588
Decrease in distractions using StreetBit (95% CI)	19.1% (1.6% to 36%)			
Potential savings due to StreetBit (19.1% of total cost of distracted pedestrian injuries)	\$18 139 937	\$21 767 924	\$25 395 912	\$29 023 899
Potential savings (95% CI lower limit)	\$1 519 576	\$1 823 491	\$2 127 406	\$2 431 321
Potential Savings (95% CI upper limit)	\$34 190 457	\$41 028 549	\$47 866 640	\$54 704 732
95% CI lower limit is 1.6% of the total cost of distracted pedestrian injuries occurring in the intersections, and the upper limit is 36% of the total cost of distracted pedestrian injuries. A detailed breakdown of costs can be found in online supplemental table A1.				

Our analysis of the net monetary benefits of implementing a programme like StreetBit to reduce distracted pedestrian behaviour provides strong evidence that the programme is financially beneficial for states or local municipalities to instal. Even in the most conservative of estimated scenarios, the combined financial benefit of reduced medical and work loss costs outweighs the costs of installing and maintaining the programme.

Programmes like StreetBit offer a compelling behaviour change strategy because they disrupt a pedestrian's typical behaviour at the moment they are engaging in a risk.^{13 14} As a pedestrian approaches an intersection while distracted, StreetBit provides a direct and clear reminder to attend to traffic while crossing the street rather than allowing oneself to be distracted by a smartphone. Similar to injury prevention programmes proven to be effective, like smoke detectors and emergency exit signs, the intervention is largely passive; it occurs in the background and provides a reminder to the individual at the moment of risk, encouraging safe behaviour. It can arguably be considered 'intrusive,' but similar interventions, which are designed to prevent dangerous behaviour at the time and location of risk, are successful in other domains, such as the issuance of seat belt reminders in automobiles and the construction of fences around backyard swimming pools.^{29–31}

Our analysis presumes StreetBit functions in a manner that creates some permanency of behaviour change that extends to intersections not arranged with beacons. This assumption was based on behavioural learning theory, which suggests a variable ratio learning schedule creates behaviour change and resistance to extinction.^{22 23} In other words, we assumed that warnings at every few intersections would lead to transferred behaviour at all intersections. The questions of whether behaviour change does transfer, and whether behaviour change is maintained over time, are empirically unknown. One could compare StreetBit to intrusive warnings like alcohol ignition interlock systems that cause behaviour change only when installed.³² In that case, StreetBit would need to be present at all intersections and installed on all pedestrian smartphones. Alternatively, one could conceptualise StreetBit as a system that creates behaviour change through altered individual behaviours over time; as individuals use the system, they recognise better the risks of crossing streets distracted, develop self-efficacy to restrain from phone use on active roadways, and transfer learning from StreetBit-installed intersections elsewhere. They may also initiate broader changes in social norms, such that their behaviour change encourages others to move towards safer behaviour. Future research is needed to evaluate whether StreetBit does in fact alter attitudes, beliefs and behaviours surrounding distracted pedestrian behaviour to create long-term behaviour change or whether it is effective only when installed at particular intersections and on the pedestrian's smartphone, without any transference to other situations or other pedestrians.

Our cost savings analysis was purposely conservative and likely underestimates the total costs associated with distracted walking for at least five reasons. First, we restricted our analysis to injuries occurring in the intersections only. We also excluded 'possible injuries' occurring in the intersections for which severity could not be determined. There were 86, 49 and 68 'possible injuries' occurring in the intersections in 2019, 2020 and 2021, respectively, averaging 68 possible injuries in the past 3 years. Second, our calculations omit costs for police and emergency personnel who attend to crash sites and victims, administrative costs of filing records following pedestrian-vehicle crashes, and possible disruptions and delays for other pedestrians and vehicles around the location where crashes occur. Third, our

calculations omit the more intangible costs of pedestrian injuries, such as emotional trauma or shock. Fourth, the count of pedestrian injuries may be an undercount of collisions involving a pedestrian where injuries were perceived as non-severe or did not have a crash report filed by a law enforcement agency. Fifth, we assumed the rate of injured pedestrians who were distracted would be proportionate to the total number of pedestrians who are observed to be distracted, whereas it seems likely that injured pedestrians are more likely to be distracted than the overall number of pedestrians. Thus, the cost savings and net benefits from the wide adoption of a programme like StreetBit may be higher than what we have estimated here.

Our analysis was liberal in one respect: we presumed 100% uptake of the app among distracted pedestrians. If use of an app like StreetBit were optional or selective, we might assume many users would choose not to instal it. The optimal solution for public health is for the app to be preinstalled on smartphones, such as the current situation with the Driving Focus programme on iPhones, or to make it mandatory for smartphone users, such as the current situation with seat belt reminders in many vehicles.

Our analysis had some limitations. First, we were bound by the data available and therefore made various estimates and assumptions in our calculations. For example, we used national averages for costs associated with fatal, severe and non-severe injuries since there were no available corresponding figures specific to Alabama. Relatedly, publicly available non-fatal pedestrian injury estimates such as those in WISQARS are based on a probability sample that did not allow state-specific estimates. In all instances, when there was a choice, we erred towards the most conservative estimates; hence, the actual net monetary benefits may be higher than those we report. Second, our estimate of the impact of StreetBit on distracted walking was based on research conducted at a large urban university. College students are especially prone to be distracted by their phones,⁷ and younger pedestrians are less cautious when crossing streets than older pedestrians.³³ Larger clinical trials will be needed to test the impact of StreetBit on distracted walking in other settings and among other general populations. Third, we assumed costs of implementing StreetBit and medical and work loss costs would be stable over time. Inflation is likely to impact all costs similarly. However, the costs of technology (eg, beacons and batteries) may decrease or be resistant to inflationary trends, whereas medical and work loss costs may increase more rapidly. Finally, we did not include the costs of promoting and placing StreetBit or a similar programme on pedestrians' smartphones.

In conclusion, we found that StreetBit is cost-effective for local municipalities to improve safety. Equally importantly, this study provided a template that can be used by other researchers and stakeholders to evaluate the cost-effectiveness of large-scale implementation of pilot interventions that reduce distracted walking.

Contributors MJR conceptualised the study, conducted the analysis, drafted the manuscript, and reviewed the final manuscript. DCS and BS conceptualised the study, drafted the manuscript, and reviewed the final manuscript. RH and RG conceptualised the study and reviewed the final manuscript. All authors provided feedback and approved the final manuscript. MJR and BS accepts full responsibility for the work and/or the conduct of the study and had access to the data.

Funding Research reported in this publication was supported by the National Science Foundation under Grant Award Number 1952090 and the Eunice Kennedy Shriver National Institute of Child Health & Human Development of the National Institutes of Health under Award Number R21HD095270.

Disclaimer The content and any opinions, findings, and conclusions or recommendations expressed in this material are solely the responsibility of the

authors and do not necessarily represent the official views of the National Science Foundation or the National Institutes of Health.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. We have used publicly available data for this study. Data generated for this study are available on request.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

ORCID iDs

Md Jillur Rahim <http://orcid.org/0000-0002-8627-0874>

David C Schwebel <http://orcid.org/0000-0002-2141-8970>

Bisakha Sen <http://orcid.org/0000-0002-4209-4418>

REFERENCES

- 1 NCSA [National Center for Statistics and Analysis]. *Pedestrians: 2020 data (traffic safety facts. Report No. dot HS 813 310). National highway traffic safety administration: national highway traffic safety administration*, 2022.
- 2 NCSA [National Center for Statistics and Analysis]. *Pedestrians: 2012 data (traffic safety facts. Report No. dot HS 811 888). National highway traffic safety administration: national highway traffic safety administration*, 2014.
- 3 Fischer P. *Everyone walks. understanding and addressing pedestrian safety*, 2015.
- 4 Ralph K, Girardeau I. Distracted by "distracted pedestrians"? *Transp Res Interdiscip Perspect* 2020;5:100118.
- 5 Retting R, Rothenberg H. *Pedestrian traffic fatalities by state*. Washington, DC, USA: Governors Highway Safety Association, 2015.
- 6 Simmons SM, Caird JK, Ta A, et al. Plight of the distracted pedestrian: a research synthesis and meta-analysis of mobile phone use on crossing behaviour. *Inj Prev* 2020;26:170–6.
- 7 Stavrinou D, Byington KW, Schwebel DC. Distracted walking: cell phones increase injury risk for College pedestrians. *J Safety Res* 2011;42:101–7.
- 8 Barin EN, McLaughlin CM, Farag MW, et al. Heads up, phones down: a pedestrian safety intervention on Distracted Crosswalk behavior. *J Community Health* 2018;43:810–5.
- 9 Kim E, Kim H, Kwon Y, et al. Performance of ground-level signal detection when using a phone while walking. *Accid Anal Prev* 2021;151:105909.
- 10 Violano P, Roney L, Bechtel K. The incidence of pedestrian distraction at urban intersections after implementation of a streets Smarts campaign. *Inj Epidemiol* 2015;2:18.
- 11 Larue GS, Watling CN. Acceptance of visual and audio interventions for distracted pedestrians. *Transp Res Part F Traffic Psychol Behav* 2021;76:369–83.
- 12 Schwebel DC, McClure LA, Porter BE. Experiential exposure to Texting and walking in virtual reality: a randomized trial to reduce distracted pedestrian behavior. *Accid Anal Prev* 2017;102:116–22.
- 13 eds Hasan R, Hoque MA, Karim Y, et al. *Streetbit: a bluetooth beacon-based personal safety application for distracted pedestrians*. 2021 IEEE 18th Annual Consumer Communications & Networking Conference (CCNC), 2021.
- 14 Schwebel DC, Hasan R, Griffin R, et al. Reducing distracted pedestrian behavior using Bluetooth beacon technology: a crossover trial. *Accident Analysis & Prevention* 2021;159:106253.
- 15 Smart Growth America. *Dangerous by design 2021*, 2021.
- 16 Wells HL, McClure LA, Porter BE, et al. Distracted pedestrian behavior on two urban College Campuses. *J Community Health* 2018;43:96–102.
- 17 CAPS [Center for Advanced Public Safety]. *Safety public*, 2022.
- 18 CDC [Centers for Disease Control and Prevention]. Number of injuries and associated costs, 2020. Available: <https://wisqars.cdc.gov/cost/>
- 19 Lawrence BA, Miller T. *Quality of life loss estimation methods for the WISQARS cost of injury module*. Pacific Institute of research and evaluation, 2020.
- 20 Schwebel DC, Canter MF, Hasan R, et al. Distracted pedestrian behavior: an observational study of risk by situational environments. *Traffic Inj Prev* 2022;23:346–51.
- 21 Norton EC, Dowd BE. Log odds and the interpretation of Logit models. *Health Serv Res* 2018;53:859–78.
- 22 Baron RA. *Psychology*. 5th Edition ed. Allyn and Bacon, 2001.
- 23 Herrnstein RJ, Heyman GM. Is matching compatible with reinforcement maximization on concurrent variable interval variable ratio? *J Exp Anal Behav* 1979;31:209–23.
- 24 Lichtenstein R, Smith DC, Ambrose JL, et al. Headphone use and pedestrian injury and death in the United States: 2004–2011. *Injury Prevention* 2012;18:287–90.
- 25 Boeing G. A multi-scale analysis of 27,000 urban street networks: every us City, town, urbanized area, and Zillow neighborhood. *Environ Plan B Urban Anal City Sci* 2020;47:590–608.
- 26 Ferdinand AO, Aftab A, Akinlotan MA. Texting-While-Driving bans and motor vehicle Crash-Related emergency department visits in 16 us states: 2007–2014. *Am J Public Health* 2019;109:748–54.
- 27 Ferdinand AO, Menachemi N, Blackburn JL, et al. The impact of Texting bans on motor vehicle Crash-Related hospitalizations. *Am J Public Health* 2015;105:859–65.
- 28 Ecola L, Ringel JS, Connor K, et al. Costs and effectiveness of interventions to reduce motor Vehicle-Related injuries and deaths: supplement to tool documentation. *Rand Health Q* 2018;8:9.
- 29 Gielen ACE, Sleet DA, DiClemente RJ. *Injury and violence prevention: behavioral science theories, methods, and applications: Jossey-Bass/Wiley*, 2006.
- 30 Krafft M, Kullgren A, Lie A, et al. The use of seat belts in cars with smart seat belt Reminders—Results of an observational study. *Traffic Inj Prev* 2006;7:125–9.
- 31 Lie A, Krafft M, Kullgren A, et al. Intelligent seat belt Reminders—Do they change driver seat belt use in Europe? *Traffic Inj Prev* 2008;9:446–9.
- 32 Coben JH, Larkin GL. Effectiveness of ignition interlock devices in reducing drunk driving recidivism. *Am J Prev Med* 1999;16:81–7.
- 33 Aghabayk K, Esmailpour J, Jafari A, et al. Observational-based study to explore pedestrian crossing behaviors at signalized and unsignalized crosswalks. *Accid Anal Prev* 2021;151:105990.