Appendix A - Evidence summary tables

UK direct observation of diversion factors

Aldred, R. and Croft, J., 2019. Evaluating active travel and health economic impacts of small streetscape schemes: an exploratory study in London. Journal of transport & health, 12, pp.86-96.	
Location	England, London (a single street in Hounslow)
Intervention type	Modal filter on a single residential street
Indicators reported	Cycling diversion factor (but 'transfer from mode' is not measured)
How indicators are derived	A small scale road user intercept survey is used to measure mode / route choice if the modal filter were removed. This is accompanied by analysis of secondary multi-modal traffic count data
Bicycle types	Pedal cycle
Survey dates	Spring 2017
Sample size	For the road user intercept survey, 650 leaflets were distributed to all people walking and cycling along the case study street. 124 people responded. • 57% were cycling (71) • 43% were walking (53)

Evidence summary

The before and after multi-modal traffic count data revealed a 31% increase in walking and cycling along the case study street, on which a new modal filter had been installed.

The road user intercept survey revealed that:

- 38% of cyclists on the street - 27 out of 71 cyclists - would not have made the trip or were unsure whether they would have made the trip if the street had been unfiltered
- 26% of pedestrians on the street (13 pedestrians out of 50) would not have made the trip or were unsure whether they would have made the trip if the street had been unfiltered

The 27 new cyclists were asked to report how they would have travelled had the modal filter not been installed and the responses are summarised in Table A below. 16 out of 27 (59%) would continue to cycle, but on another route. 6 out of 27 (22%) would change to an alternative mode.

Hence it can be inferred that 22% of the new cycling trips on the route were diverted from other modes for this scheme.

The study is noted to be exploratory and has limitations. The survey sample is a very small, limited to a single case study street and the mode from which new cyclists have transferred is not specified.

Table A: Reported travel behaviour for cyclists if modal filter removed (source document, table 3)

Behaviour if modal filter removed	Number of cyclists	Percentage of all cyclists	Percentage of new cyclists on the street
Continue to cycle on the case study street	44	62.0%	-
Continue to cycle on an alternative route	16	22.5%	59.3%
Transfer to an alternative mode	6	8.5%	22.2%
Would not travel	1	1.4%	3.7%
Missing data	4	5.6%	14.8%
All cyclists on the street	**71**	**100.0%**	**100.0%**
New cyclists on the street	**27**		

Cycling UK, 2021. Big Bike Revival Evaluation Report	
Location	England (national)
Intervention type	Dr Bike style maintenance sessions delivered in 2020-2021 during the Covid-19 pandemic. Circa 25,000 bicycles were maintained across 77,252 people reached, through 248 schools and 107 workplaces, at 2,849 events. The intervention was delivered through two tranches • Tranche 1 – Maintenance sessions for key workers offered between 1st May 2020 and 31st August 2020 • Tranche 2 – Maintenance sessions offered to community, workplaces and schools (August 2020 to December 2021)
Indicators reported	Car to cycle diversion factors, disaggregated by journey purpose
How indicators are derived	From an online survey of people engaging with the maintenance sessions during 2020-2021. The survey included: • A baseline survey on self-reported cycling behaviour • A follow-up survey on self-reported cycling behaviour after 3 months. The same respondents are asked: "How do you normally travel for the following trips?"
Bicycle types	Pedal cycles
Survey data dates	Surveys were issued during the intervention programme which ran from March 2020 to December 2021
Sample size	**Tranche 1 interventions survey** (key workers only): 613 baseline respondents out of a population of 2,788 bikes fixed and 8463 people reached (it is not clear what reached means, relative to bikes fixed), 10% of baseline sample returned follow-up questionnaires (circa 60 respondents) **Tranche 2 intervention survey** (community, commuters and schools): 3,552 baseline respondents out of a population of 13,468 bikes fixed and 58,640 people reached (it is not clear what reached means, relative to bikes fixed), 41% of baseline sample returned follow-up questionnaires (circa 1,456)

Evidence summary

Tranche 1: Maintenance sessions with key workers (May 2020 to August 2020)

The survey data measured the travel to work mode share for key workers engaging with maintenance sessions before and after as shown in Table A below.

This indicated a 24 percentage point increase in cycle to work mode share following the bicycle maintenance sessions.

It may be approximated from this evidence that 15 percentage points transferred from car, and 9 percentage points transferred from bus. In other words, for every 24 new cycle to work trips, 15 would transfer from car and 9 would transfer from bus.

Normalising to 100% gives cycle to work diversion factors of:

- (100/24 x 15) = 62.5% from car
- (100/24 x 9) = 37.5% from bus

These diversion factors needed to be interpreted as being associated with the combined effect of the bicycle maintenance intervention and the lockdown periods that occurred during the first stage of the Covid-19 pandemic.

Table A - Tranche 1 outcomes. Key worker travel to work mode share before / after bike maintenance (source document table 10)

Commute mode	Mode share before bicycle maintenance sessions	Mode share three months after bicycle maintenance sessions	Change in mode share (percentage points)
Car	45%	30%	-15
Bus	14%	5%	-9
Train	4%	3%	-1
Walk	12%	13%	+1
Cycle	21%	45%	+24
Motorbike, taxi, other	4%	5%	+1
Total	100%	101%	+1
Notes: Sample sizes not quoted in report			

Tranche 2: Maintenance sessions with community, commuters and school children (May 2020 to August 2020)

The baseline and follow-up survey issued to people participating in maintenance events asked the same question on normal travel mode for different journey purposes: How do you normally travel for the following trips? Respondents could choose: car, cycling, walking, public transport or 'other'. The number of respondents that have switched from another mode to using the bike regularly for each journey purposes, after receiving a bicycle maintenance session, are reported in Table B below.

The figures presented under '%age of respondents previously making a journey by car' can be interpreted as marginal diversion factors. In other words, where people switch to commuting by bike after receiving bicycle maintenance support, 27% of those new cycle to work trips have transferred from car.

Table B – Trance 2 outcomes: Modal transfer from car to bike

Journey purpose	New trips now regularly made by bike	%age previously made by car	Number previously made by car
Work	930	27%	251.1
Education	684	42%	287.28
Shopping	2,777	36%	999.72
Other trips	4,976	34%	1691.84
Visit friends and family	3,778	48%	1813.44
Other leisure activities	7,482	36%	2693.52
Total	**20,627**	**38%**	**7736.9**

Nankivell, T., 2021. Local cyclist diversion factors, Active mode appraisal technical note. Manchester: Transport for Greater Manchester.

Panagiotis, P., 2019. What changes in travel behaviour are caused by improved cycle facilitites in Greater Manchester. MSc Dissertation. University of Leeds.

Location	England, Greater Manchester
Intervention type	This is a study of general cycling behaviour in Greater Manchester and is not linked to an intervention.
Indicators reported	Cycling diversion factors
How indicators are derived	A general online survey on cycling behaviour is undertaken in Greater Manchester. A purposive sampling strategy is employed. The survey is open to Greater Manchester residents aged 16 and over (survey distributed via Transport for Greater Manchester social media channels and mailing list) Respondents are asked • What trips do you regularly make by bike? • How did you make that trip before starting cycling?
Bicycle types	Pedal cycles
Survey data dates	August 2019 (survey open for 6 days)
Sample size	603 respondents reporting on 1839 cycle journeys The sample is purposive and not representative of a definable population. Diversion factors may be over-estimates (since the sample may over-represent keen cyclists due to self-selection bias). Diversion factors may be higher than the current TAG values since they are based on uptake of cycling in general rather than new cycle trips associated specifically with cycling interventions.

Evidence summary

Note that the Panagotios (2019) report is a dissertation based on the same data set and the cycling diversion factor evidence is as per the Nankivel (2021) report which is summarised below

The cycle diversion factors revealed by the Greater Manchester survey are summarised in Table A. This reveals, for example, that car as driver was the most suitable alternative mode for 36% of the 1839 journeys captured by the survey.

Table A: Cycle diversion factors, by trip purpose (Nankivel 2021, Table 3)

	Recipient/source modes												
Trip purposes	**Car as driver**	**Car as pass**	**Bus**	**Tram**	**Train**	**Walking**	**Mcycle**	**Taxi**	**Did not make trip**	**Always cycled**	**Row total**	**N**	**% of total trips**
Business	44%	2%	15%	5%	8%	7%	0%	0%	9%	10%	100%	136	7%
Shopping	43%	7%	11%	3%	2%	22%	0%	0%	2%	9%	99%	263	14%
Visiting friends	41%	3%	14%	12%	3%	15%	0%	1%	2%	9%	100%	260	14%
Holidays and leisure trips	41%	7%	2%	2%	15%	6%	0%	0%	15%	12%	100%	239	13%
Commuting	32%	2%	20%	13%	11%	6%	0%	0%	4%	11%	99%	424	23%
Personal business	31%	1%	14%	6%	3%	31%	0%	0%	2%	12%	100%	242	13%
Escort others to school/education	30%	0%	3%	0%	0%	39%	0%	0%	15%	12%	99%	33	2%

Sport and events	28%	4%	21%	14%	9%	7%	0%	6%	2%	8%	99%	134	7%
Education	19%	4%	38%	11%	2%	13%	0%	0%	6%	6%	99%	47	3%
Other	15%	2%	3%	0%	0%	20%	0%	3%	36%	21%	100%	61	3%
Total	36%	3%	14%	8%	7%	14%	0%	1%	6%	11%	100%	1839	100%

The diversion factors reported in Table B have been normalized to sum to 100% across recipient modes, after excluding trips that were always cycled. This reveals a diversion factor from car to cycle of 44%.

Table B Normalised cycle diversion factors, by trip purpose (Nankivel 2021, Table 4)

	Recipient/source modes						
Trip purposes	Car	Taxi	Bus	Train	Tram	Walking	Not going out
Business	51%	0%	17%	9%	6%	7%	10%
Shopping	55%	0%	13%	3%	3%	24%	3%
Visiting friends	49%	1%	16%	4%	13%	16%	2%
Holidays and leisure trips	54%	1%	2%	17%	2%	7%	17%
Commuting	38%	0%	23%	13%	14%	7%	4%
Personal business	36%	0%	16%	4%	7%	35%	3%
Escort others to school/education	35%	0%	3%	0%	0%	45%	17%
Sport and events	35%	7%	23%	10%	15%	8%	2%
Education	25%	0%	41%	2%	11%	14%	7%
Average (of survey population)	44%	1%	16%	8%	9%	16%	7%

It is acknowledged that the survey sample has a different journey purpose distribution when compared against the National Travel Survey (NTS) and the Greater Manchester Travel Diary Survey (TRADS). For example, business trips are over represented in the diversion factors survey: 7.6% of all recorded trips compared to 1.5% in TRADS and 3.0% of trips in NTS.

The authors conduct an analysis to weight and renormalize the survey sample diversion factors to match the TRADS and NTS journey purpose distributions, as shown in the table below. The weighted diversion factors are judged to be ‘relatively similar’ by the report authors.

Comparison of survey sample diversion factors to trip purpose weighted diversion factors. (Nankivel 2021, Table 7)

	Car	Taxi	Bus	Train	Tram	Walking	Not going out	Total
Manchester Survey	44%	1%	16%	8%	9%	16%	7%	101%
Weighted TRADS	38%	1%	23%	9%	12%	11%	5%	99%
Weighted NTS	42%	1%	18%	9%	10%	14%	6%	100%
TAG (full)	11%	8%	19%	14%	12%	19%	17%	100%
TAG (limited)	15%		25%	18%	16%	26%		

TRADS: Greater Manchester Travel Diary Surveys;
NTS: National Travel Survey
TAG: Transport Appraisal Guidance

Sloman L, Dennis S, Hopkinson L, Goodman A, Farla K, Hiblin B and Turner J, 2020. Cycle City Ambition Programme: Final Evaluation Report	
Location	England
Intervention type	Intervention study Post intervention evaluation of investment in cycle infrastructure (lanes and junction treatments) across 7 settlements in England
Indicators reported	Cycling diversion factors
How indicators are derived	Road user intercept surveys (RUIS) are undertaken on new infrastructure. Cyclists using new infrastructure were asked "How would you travel if this scheme was not available?" Face to face surveys were conducted in all locations (some supplemented with online alternatives) with the exception of Oxford, where an online only survey was used, due to the nature of the case study junction.
Bicycle types	Pedal cycles
Survey data dates	2016 to 2019
Sample size	69 to 1138

Evidence summary

The road user intercept survey data is used to estimate cycling diversion factors for the 7 cities as shown in Table A below.

Authors note that the RUIS were undertaken shortly after scheme implementation and modal transfer may be expected to increase over the longer term. Cycle count data shows use of new infrastructure increases over a 3 to 5 year period.

Table A: Cycle city ambition fund diversion factors (Source report, Table E.2)

Route User Intercept Surveys, CCA, response to question "How would you travel if this scheme was not available?" (from Table E.2 in final technical evaluation report)							Proportion of *new* cycle trips that would otherwise have been…		
City	**Year of survey**	**No. cyclist respondents**	**No mode change (would still cycle)**	**Would use car (as driver or passenger)**	**Would use other modes**	**Would not make this journey**	**…made by car**	**…made by other modes**	**..not made (i.e. generated trips)**
Birmingham	2017	352	48%	10%	19%	23%	19%	37%	45%
Grtr Manch.	2019	175	88%	4%	4%	3%	32%	28%	27%
Newcastle	2017	582	90%	1%	6%	3%	12%	55%	33%
Norwich	2017	1032	87%	4%	8%	0%	32%	65%	2%
Norwich	2018-19	1138	82%	7%	10%	1%	40%	55%	5%
Oxford	2016	179	98%	0%	2%	1%	0%	77%	27%
West of England	2016	69	57%	16%	22%	6%	37%	50%	13%
West of England	2017	351	95%	2%	3%	0%	33%	67%	0%
West Yorkshire	2017-18	322	69%	6%	22%	3%	18%	72%	10%
Programme		2920	80%	5%	11%	4%	26%	52%	22%

Woodcock, J., Tainio, M., Cheshire, J., O'Brien, O., Goodman, A. (2014) Health effects of the London bicycle sharing system: health impact modelling study. BMJ (Clinical research ed), 348 (feb13). g425-. ISSN 0959-8138 DOI: https://doi.org/10.1136/bmj.g425	
Location	England, London
Intervention type	Bicycle sharing scheme in London
Indicators reported	Cycling diversion factors
How indicators are derived	An online survey of 2,652 registered cycle hire users is conducted. Respondents "were asked for the main mode that would typically have used to make their most recent cycle hire trip before the scheme was available, with main mode being defined as that covering the longest distance in the trip".
Bicycle types	Pedal cycles (hired)
Survey data dates	July 2011
Sample size	The online survey was emailed to a representative sample of individuals agreeing to take part in surveys. The response rate was 9% of those emailed. A survey sample of 2,652 registered cycle hire users was generated. Sample demographics were shown to be a reasonable match against known characteristics of the population of cycle hire users (77% of sample male compared to 76% in population; 71% of sample lived in London compared to 76% in population)

Evidence summary

The online survey of cycle hire users has been used to derive diversion factors for London cycle hire trips.

2,559 (96.5%) of the 2,652 respondents said that they would have carried out their most recent cycle hire trip by an alternative mode, had the bicycle hire system not been available.

Tables A and B below show the most likely alternative modes suggested by respondents, for their most recent cycle hire trip, disaggregated by cycle hire duration.

Table A: Bicycle hire alternative mode frequencies, by cycle hire duration (source, Appendix 3, table 7)

	Cycle hire trip duration					
Alternative main mode	**<10 mins**	**10-19 mins**	**20-29 mins**	**30-44 mins**	**>45 mins**	**Total**
Own bike	34	69	56	5	2	166
Walking	242	246	70	6	7	571
Bus	80	205	122	14	7	428
Underground	58	312	302	45	18	735
Train or light rail	3	28	21	5	1	58
Taxi or mini cab	11	34	25	4	2	76
Car or van	5	16	13	3	3	40
Motorcycle / moped / scooter	4	5	5	0	0	14
Other	2	6	3	0	1	12
Total	**439**	**921**	**617**	**82**	**41**	**2100**

Mode and / or duration information is missing on 475 of the 2652 registered users.

Table B: Bicycle hire alternative mode percentages, by cycle hire duration (source, Appendix 3, table 7)

	Cycle hire trip duration					
Alternative main mode	**<10 mins**	**10-19 mins**	**20-29 mins**	**30-44 mins**	**>45 mins**	**Total**
Own bike	7.7%	7.5%	9.1%	6.1%	4.9%	7.9%
Walking	55.1%	26.7%	11.3%	7.3%	17.1%	27.2%
Bus	18.2%	22.3%	19.8%	17.1%	17.1%	20.4%
Underground	13.2%	33.9%	48.9%	54.9%	43.9%	35.0%
Train or light rail	0.7%	3.0%	3.4%	6.1%	2.4%	2.8%
Taxi or mini cab	2.5%	3.7%	4.1%	4.9%	4.9%	3.6%
Car or van	1.1%	1.7%	2.1%	3.7%	7.3%	1.9%
Motorcycle / moped / scooter	0.9%	0.5%	0.8%	0.0%	0.0%	0.7%
Other	0.5%	0.7%	0.5%	0.0%	2.4%	0.6%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Diversion factors are then estimated, based on the total number of cycle hire trips recorded from April 2011 to March 2012 (7,392,065 trips). It is assumed that 9% of these cycle hire trips would not have been undertaken if the cycle hire were not available. The 9% is the midpoint of the estimate of 3.5% of trips not being undertaken from the online survey and an estimate of 20% derived from a separate intercept survey of cycle hire users, also undertaken in July 2011.

Table C shows the number of recorded cycle hire trips, by trip duration

Table C: Number of recorded cycle hire trips, by trip duration (April 2011 to March 2012)

	<10 mins	**10-19 mins**	**20-29 mins**	**30-44 mins**	**>45 mins**	**Total**
No. of trips by cycle hire	2,754,341	2,805,403	1,052,427	378,718	401,176	7,392,065
No. of trips that would otherwise have been made by alternative modes	2,506,450	2,552,917	957,709	344,633	365,070	6,726,779

Table D shows the number of trips transferring from alternative modes (applying the modal transfer proportions shown in Table B to the number of trips undertaken shown in Table C). This analysis suggests a diversion factor to cycle hire from car, in London, of about 2%.

Table D: Number of trips transferring from alternative modes

Alternative main mode	**<10 mins**	**10-19 mins**	**20-29 mins**	**30-44 mins**	**>45 mins**	**Total**	**%age modal transfer**
No travel	247,891	252,486	94,718	34,085	36,106	665,286	9.0%
Own bike	194,121	191,261	86,923	21,014	17,808	511,128	6.9%
Walking	1,381,688	681,887	108,654	25,217	62,329	2,259,775	30.6%
Bus	456,756	568,239	189,369	58,840	62,329	1,335,533	18.1%
Underground	331,148	864,832	468,765	189,128	160,275	2,014,148	27.2%
Train or light rail	17,128	77,613	32,596	21,014	8,904	157,256	2.1%
Taxi or mini cab	62,804	94,244	38,805	16,811	17,808	230,473	3.1%
Car or van	28,547	44,350	20,179	12,609	26,712	132,397	1.8%
Motorcycle / moped / scooter	22,838	13,859	7,761	0	0	44,458	0.6%
Other	11,419	16,631	4,657	0	8,904	41,611	0.6%
Total	2,754,341	2,805,403	1,052,427	378,718	401,176	7,392,065	100.0%

Figures derived by multiplying trip numbers from Table C with modal transfer from Table B.

Appendix B - Evidence summary tables

UK modelling using National Travel Survey data

Bearman, N. and Singleton, A., 2014. Modelling the potential impact on CO2 emissions of an increased uptake of active travel for the home to school commute using individual level data. Journal of Transport & Health, 1(4), pp.295-304.	
Location	England, sample of primary and secondary schools in Norfolk
Intervention type	This is not an intervention evaluation
Indicators reported	Car to cycling diversion factors (assumed)
How indicators are derived	This study predicts carbon savings for scenarios in which there is an update in active travel to school. The assumed modal transfer from car to cycling is however based on data and analysis reported in Lovelace et al (2011) (which has also been reviewed).
Bicycle types	Pedal cycles
Survey data dates	See Lovelace et al. (2011) review
Sample size	See Lovelace et al. (2011) review

Evidence summary

This study estimates potential impact on CO^2 emissions of an increased uptake of active travel for the home to school commute, for a sample of schools in Norfolk.

An 'increase Active Travel' scenario is developed, in which potential modal transfer from car to active travel is assumed to follow the distance profile set out in Table A below. The assumed rates of modal transfer are said to be based on a 'proposed car-cycle mode shift from Lovelace et al. (2011)' (see separate review).

Note that these modal transfer proportions are based on assumptions, and are not observed rates of modal transfer from car to bicycle.

Table A: Proportion of journeys previously undertaken by car (based on car-cycle mode shift estimates reported in Lovelace et al. (2011)) – Source, Table 4.

Distance (km)	Walking (%)	Cycling (%)	Walking (%)	Cycling (%)
0-1	50	50	50	50
1-2	40	50	50	50
2-3	10	30	40	50
3-4	-	30	30	30
4-5	-	10	10	30
5-6	-	10	-	20
6-7	-	-	-	20
7-8	-	-	-	10
8-9	-	-	-	10

Lovelace, R., Beck, S.B.M., Watson, M. and Wild, A., 2011. Assessing the energy implications of replacing car trips with bicycle trips in Sheffield, UK. Energy Policy, 39(4), pp.2075-2087	
Location	England, Sheffield
Intervention type	This is not an intervention study
Indicators reported	Bicycle to car replacement ratios (described under evidence summary)
Intervention type	None
How indicators are derived	Modelling assumptions and manipulation of secondary data Bicycle to car replacement ratios are estimated using: National Travel Survey (2008) data - trips by reason and mode Cycling Demonstration Towns project (2009) evaluation evidence on increases in cycling and corresponding decreases in car use for journeys to school
Bicycle types	Pedal cycles
Survey data dates	National Travel Survey 2008 data Cycling Demonstration Towns project – 2009 data.
Sample size	NA

Evidence summary

This paper includes estimates of the bicycle to car replacement ratio (RR) which is defined as:

- RR = change in bicycle trips / change in car trips

It is noted that "the replacement ratio can be interpreted as the number of additional bicycle trips required to replace or prevent a single car trip"

The reciprocal of the replacement ratio can be interpreted as the car to bicycle diversion factor i.e. The number of car trips avoided for every additional cycle trip.

Table A summarises the replacement ratios as estimated from two secondary data sources: The National Travel Survey 2008 data and evidence from the evaluation of the Cycling Demonstration Towns projects (published in 2009 – see review of Sloman et al. (2009)). Further details on how these figures have been estimated and how they can be interpreted is provided below.

Table A: Bicycle to car replacement ratios

Data source	Replacement ratio	Inferred car to cycle diversion factor
National Travel Survey 2008	2.2	1 / 2.2 = 46%
Cycling Demonstration Towns evaluation, 2009	5.2	1 / 5.2 = 19%

The National Travel Survey data method

National Travel Survey data was used to derive replacement ratios and hence diversion factors from all modes, as summarised in Table B. Note this is presented and explained in the paper's 'supplementary information'.

To give an illustrative example of how the figures in Table B have been estimated:

- the National Travel Survey (2008 data) revealed that 34.4% of cycling trips were undertaken for commuting on average (the value showing in the 'Total' column for commuting).
- 57.4% of commuting trips were undertaken as car driver on average.
- Hence the percentage of new cycling commuting trips transferring from driving can be estimated as 34.4% x 57.4 % = 19.7%.
- Applying this approach to all journey purposes and then summing across journey purposes for car driving provides a car to cycling diversion factor of 44%.

Table B: Cycling diversion factors by journey purpose and mode, including existing bike trips

Reason	Walk	Bike	Car Driver	Car Passenger	Other Private	Public	Total
Commuting	3.6%	1.2%	19.7%	3.3%	0.5%	6.1%	34.4%
Business	0.2%	0.0%	1.8%	0.2%	0.0%	0.3%	2.5%
Education	3.9%	0.2%	2.1%	2.2%	0.4%	1.2%	10.0%
Shopping	2.5%	0.1%	4.8%	2.4%	0.1%	1.3%	11.3%
Other	0.2%	0.0%	1.1%	0.6%	0.0%	0.1%	1.9%
Personal	1.6%	0.1%	2.8%	1.7%	0.1%	0.6%	6.9%
Leisure	5.1%	0.7%	12.0%	11.6%	0.4%	3.3%	33.1%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Average diversion factor for all journey purposes	17.1%	2.3%	44.3%	21.9%	1.5%	12.9%	100.0%
Replacement ratio	5.9	44.4	2.3	4.6	66.9	7.7	

Table B includes the percentage of cycle trips that would previously have been cycled (interpreted as being on another route). Excluding these trips and renormalizing to achieve the same journey purpose disaggregation yields the cycling diversion factors for new cycling trips shown in Table C i.e. A car to cycling diversion factor of 45%.

Table C: Cycling diversion factors by journey purpose and mode, for new cycling trips

Reason	Walk	Bike	Car Drive	Car Passenger	Other Private	Public	Total
Commuting	3.7%	-	20.4%	3.4%	0.5%	6.3%	34.4%
Business	0.2%	-	1.8%	0.2%	0.0%	0.3%	2.5%
Education	4.0%	-	2.1%	2.2%	0.4%	1.3%	10.0%
Shopping	2.6%	-	4.9%	2.4%	0.1%	1.3%	11.3%
Other	0.2%	-	1.1%	0.6%	0.0%	0.1%	1.9%
Personal	1.6%	-	2.9%	1.7%	0.1%	0.6%	6.9%
Leisure	5.2%	-	12.3%	11.9%	0.4%	3.4%	33.1%
Other	0.0%	-	0.0%	0.0%	0.0%	0.0%	0.0%
All journey purposes	17.5%		45.3%	22.4%	1.5%	13.2%	100.0%

This method assumes that:

1. The total number of journeys undertaken by people remains constant i.e. new cycling trips would otherwise have been undertaken by other modes of transport
2. New cycling trips accrue in the same journey purpose proportions as past cycling trips (e.g. 34.4% of new cycling trips are for commuting)
3. The new cycling trips transfer from other modes in the same proportions as past modal shares (i.e. 57.4% of the newly cycled commuting trips would otherwise have been undertaken by car).

Cycling Demonstration Towns Data Method

The Lovelace et al. (2011) study draws on evidence from the cycling demonstration towns evaluation (see separate review of Sloman et al. (2009)) which included surveys of how children travelled to school in five of the study towns. This revealed that a 7.3 percentage point increase in the number of cycling trips to school was accompanied by a concurrent 1.4 percentage point decrease in the number of car trips to school i.e.:

- A replacement ratio of 7.3 / 1.4 = 5.2 for cycling to school; or
- A car to cycling diversion factor of 1 / 5.2 = 19.2% for trips to school

It is noted that this car to cycling diversion is subject to uncertainty for a number of reasons: The RR of 5.2 could be:

- over-estimated, since school trips may be resistant to change due to parental safety concerns
- over-estimated, since car travel was relatively low in the demonstration downs (40%) compared to other cities in England (65%). Hence there is less potential for further shift to cycling.
- under-estimated, since the potential for increases in the number of trips undertaken has not been considered.

Sloman, L., Taylor, I., Hopkinson, L. and Cairns, S., 2020. Developing a central scenario for carbon savings from active travel investment: Unpublished report.	
Location	England
Intervention type	This is not an intervention study
Indicators reported	Cycling Diversion Factors
How indicators are derived	Modelling assumptions and manipulation of secondary data Cycle diversion factors have been implied from an analysis of National Travel Survey trip data (Average number of trips by distance and mode for 2019)
Bicycle types	Pedal cycles
Survey data dates	2019 National Travel Survey data is used (NTS Table 0308)
Sample size	250 trips (the number of individuals is not reported in the NTS table)
Population weights applied	Yes

Evidence summary

The argument is made that cycling diversion factors can be implied from data on existing mode share. For example, National Travel Survey data for 2019 indicates that 61% of all trips are undertaken by car (as driver or passenger – see Table A – reproduction of NTS Table 0308 below). It is argued that where new cycling trips are being undertaken as a consequence of investment in cycling, then 61% of these trips would have otherwise been made by car.

Table A – Reproduction of NTS Table 0308 for 2019

Main mode	Under 1 mile	1 to under 2 miles	2 to under 5 miles	5 to under 10 miles	10 to under 25 miles	25 to under 50 miles	50 to under 100 miles	100 miles and over	All lengths
Private:									
Walk	80%	31%	4%	0%	0%	0%	0%	0%	26%
Bicycle	1%	3%	2%	1%	1%	0%	0%	0%	2%
Car / van driver	11%	37%	51%	54%	57%	55%	45%	40%	40%
Car / van passenger	7%	22%	27%	27%	25%	26%	33%	33%	21%
Motorcycle	0%	0%	0%	1%	0%	0%	0%	0%	0%
Other private transport2	0%	0%	1%	1%	1%	2%	2%	4%	1%
Public:	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bus in London	0%	3%	3%	3%	1%	0%	0%	0%	2%
Other local bus	0%	3%	6%	5%	3%	1%	0%	0%	3%
Non-local bus	0%	0%	0%	0%	0%	1%	1%	2%	0%
London Underground	0%	0%	1%	4%	3%	0%	0%	0%	1%
Surface Rail	0%	0%	1%	3%	7%	14%	18%	20%	2%
Taxi / minicab	0%	1%	2%	1%	1%	1%	1%	0%	1%
Other public transport3	0%	0%	0%	1%	1%	0%	0%	1%	0%
All modes	100%	100%	100%	100%	100%	100%	100%	100%	100%

An allowance of 4% for diversion from ‘no travel’ to ‘cycle’ is made based on the following assumptions: “10% of cycle infrastructure investment might be on routes that are attractive for leisure cycling (with a diversion factor of 23%), and 90% of investment on utility cycle routes (with a diversion factor of 2%, based on the average for routes in six CCA cities)” {4% = (0.1 x 23%) + (0.9 x 2%).

The mode shares are normalized for interpretation as cycling diversion factors in Table B below.

Table B - Estimated cycle diversion factors based on NTS 2019 mode shares (source report table 6)

Mode	Diversion factor
no travel	4%
walk	23%
car driver	40%
car passenger	22%
taxi	1%
motorcycle or other private transport	1%
bus	6%
London Underground or surface rail	2%
other public transport	0%

Steer Davis Gleave, 2015. Bikeability Evaluation. London: Steer Davis Gleave	
Location	Hertfordshire, England
Intervention type	Bikeability training (a cycling training scheme for children)
Indicators reported	Cycling diversion factor for secondary school children travelling to school
How diversion factors are derived	Modelling and assumptions (i.e. not through observation). The analysis is based on: A survey of change in number of children cycling to secondary school in Hertfordshire after introduction of Bikeability training (conducted by IPSOS Mori and reported in 2010). National Travel Survey data on travel to secondary school mode share for 2008 to 2013
Bicycle types	Pedal cycles
Survey data dates	Bikeability survey 2010, National Travel Survey 2008 to 2013
Sample size	Not applicable as diversion factors are based on assumptions rather than survey data

Evidence summary

The Bikeability Perceptions and Experiences report, which is based on a survey by IPSOS Mori undertaken in 2010, indicated that the number of children cycling to secondary school in Hertferdshire increased by circa 45% following the introduction of Bikeability training.

The report presents an assessment of the economic benefits of bikeability training, including the benefits of avoided car trips.

- It is assumed that 23.5% of new cycling to school trips would have been made by car, based on the average car mode share for travel to school revealed by NTS data for the period 2008 to 2013 (see table A below).
- It is assumed that half of these car trips would still occur since parents would be dropping children off en-route to other destinations.

Hence this assessment implies a cycling to school car diversion factor, linked to Bikeability training of circa 12% (i.e. 50% of 23.5%).

Table A - NTS Travel to School Mode Shares, 11-16 year olds (source report Table 3-1)

Main mode	2008	2009	2010	2011	2012	2013	Avg
Walk	39%	39%	36%	38%	37%	37%	37.8%
Bicycle	2.7%	3.5%	2.1%	3.5%	2.3%	1.5%	2.6%
Car / van	22%	22%	25%	22%	27%	23%	**23.5%**
Private bus	11%	8%	7%	8%	6%	8%	8.0%
Local bus	22%	24%	26%	24%	23%	26%	24.2%
Surface rail	1%	2%	2%	1%	2%	2%	1.7%
Other transport	1%	2%	3%	2%	3%	3%	2.3%
All modes	100%	100%	100%	100%	100%	100%	100.0%

Appendix C - Evidence summary tables

Modelling using data on relative change in mode share

Bartle, C. and Chatterjee, K. (2017) Local Sustainable Transport Fund Case Study Evaluation. Strategic Employment Sites and Business Parks. West of England Final Report.	
Location	England, Bristol North Fringe and Ports area
Intervention type	Workplace travel planning measures to support non-car commuting, including cycling. These were implemented between 2014/15 and 2015/16 in the Bristol North Fringe and Ports areas
Indicators reported	Travel to work mode share before and after Local Sustainable Transport Fund (LSTF) interventions performed at workplaces
How indicators are derived	Employee travel surveys conducted in March 2014 and March 2016
Survey data dates	March 2014 and March 2016
Sample size	March 2014 travel survey – n = 9,684 March 2016 travel survey – n = 5,823

Evidence summary

LSTF funding was used to deliver various workplace travel planning measures to employers located in the Bristol North Fringe and Ports area

A repeated cross-section travel to work survey was undertaken in March 2014 and again in March 2016 to track how travel to work mode share changed over the LSTF intervention period.

The results are summarised in Table A.

- A 4 percentage point reduction in car commuting occurs in association with a 1.3 percentage point increase in cycling.

Table A: Travel to work mode share (source Table 5-6) for Bristol North Fringe and Ports area combined

	2014		2016		
Travel mode to work on survey day	**Frequency**	**%**	**Frequency**	**%**	**Percentage point change**
Car	6567	67.8%	3716	63.8%	-4.0%
Motorbike	170	1.8%	112	1.9%	0.2%
Cycle	1132	11.7%	755	13.0%	1.3%
Walk	589	6.1%	412	7.1%	1.0%
Bus / coach	547	5.6%	472	8.1%	2.5%
Rail	469	4.8%	254	4.4%	-0.5%
Work from home	117	1.2%	63	1.1%	-0.1%
Other	93	1.0%	39	0.7%	-0.3%
Total	**9,684**	**100.0%**	**5,823**	**100.0%**	**0.0%**

Heinen, E., Panter, J., Mackett, R. and Ogilvie, D., 2015. Changes in mode of travel to work: a natural experimental study of new transport infrastructure. International Journal of Behavioral Nutrition and Physical Activity, 12(1), pp.1-10.	
Location	England, Cambridgeshire
Intervention type	Guided busway, with walking and cycling path, opened in 2011
Indicators reported	Change in commute mode share measured as changes in the share of trips: (i) Involving any active travel (ii) Involving any public transport (iii) Made entirely by car
How indicators are derived	Annual travel behaviour questionnaire surveys were sent to a sample of employees living within 30km of the city centre, between 2009 and 2012 Participants completed a seven day commute diary at each wave. This paper reports on an analysis of the first (pre-intervention) and fourth (post-intervention) survey waves
Bicycle types	Pedal cycles and walking
Survey data dates	First (pre-intervention) wave: 2009 Fourth (post-intervention) wave: 2012
Sample size	First wave: 1164 Fourth wave: 500 470 participants were included in the analysis of change in commute mode share

Evidence summary

It is noted that "of the 470 participants included in analysis:

- 175 reported a change in their active travel mode share for commuting (average change in mode share of −1.3 %)
- 110 reported a change in their public transport mode share (average change in mode share of −1.0 %) and
- 165 reported a change in their car mode share (average change in mode share of +3.4 %)."

i.e. active travel declined overall across the analysis sample.

The study was included to examine the possibility to use the changes in mode use to derive some measure of change in active travel relative to change in car use. This was not found to be possible as is explained in the main report.

Table A, Changes in commuting behaviour (source table 2)

		Number	Percent	Mean	st.d.
Change in proportion of trips involving any active travel	Decrease of 30 % or more	58	12.9		
	Decrease of <30 %	36	8		
	No change	276	61.2		
	Increase of <30 %	34	7.5		
	Increase of 30 % or more	47	10.4		
Change in proportion of trips involving any public transport	Decrease	55	12.2		
	No change	341	75.6		
	Increase	55	12.2		

Change in proportion of trips made entirely by car	Decrease of 30 % or more	31	6.9		
	Decrease of <30 %	39	8.7		
	No change	286	63.4		
	Increase of <30 %	42	9.3		
	Increase of 30 % or more	53	11.8		
Change in number of trips	Decrease of 3 trips or more	87	18.6		
	Decrease of <3 trips	77	16.4		
	No change	194	41.4		
	Increase of <3 trips	62	13.2		
	Increase of 3 trips or more	49	10.5		
Change in commute distance (km)		450		0.2	4.9

The survey data is also used to estimate a multinomial logistic regression on change in mode share. The dependent variable is coded as the 5 mode share change categories noted in table A. It is reported that living closer to the busway was associated with:

- a higher probability of increasing active commuting. The relative risk ratio was found to be 1.80, indicating that commuters living 4km away from the busway were almost twice as likely to report a substantial increase in their active travel mode share compared to those living 9km away.
- a higher probability of reducing car commuting. The relative risk ratio was found to be 2.09, indicating that commuters living 4km from the busway were twice as likely to report a reduction in their car commuting compared to those living 9km away.

Sloman L, Cairns S, Goodman A, Hopkin J, Taylor I, Hopkinson L, Ricketts O, Hiblin B and Dillon M (2018) Impact of the Local Sustainable Transport Fund: Synthesis of Evidence Report to Department for Transport	
Location	England, 12 areas
Intervention type	A wide range of interventions designed to support use of non-car modes in different contexts
Indicators reported	Change in car traffic volume in LSTF intervention areas relative to control areas Self-reported change in car travel and active travel taking part in a Carbon and Congestion case study Change in proportion of adults cycling relative to control areas
How indicators are derived	Indicators of the impact of LSTF interventions at national level are derived from a meta-analysis of a wide range of evidence sources (reported in Sloman et al 2017). Change in car traffic volume is based on DfT road traffic statistics Self-reported change in car travel and active travel is based on a postal survey issued to a sample of residents in the case study area and a control area. Change in proportion of adults cycling is based on data from the Active People Survey
Bicycle types	Pedal cycles
Survey data dates	DfT road traffic statistics – a time trend analysis is performed using data from 2005 – 2015 Postal survey on travel behaviour. A 'before intervention' survey was issued in November 2013. The 'after intervention' survey was issued in November 2014. Active People Survey - a time trend analysis is performed using data from 2010 to 2015.
Sample size	DfT Traffic volume - sample size not reported Postal survey on travel behaviour. 'before intervention' sample: 6,797. 'after intervention' sample: 3,562. Active People Survey – sample size not reported

Evidence summary

Change in traffic volume analysis

The analysis of DfT road traffic volumes indicated that during the LSTF period (2009-11 to 2015), per capita car traffic:

- Reduced by 2.6% in LSTF areas relative to 2005-7 levels
- Reduced by 0.3% in control areas relative to 2005-7 levels
- Hence car traffic (presumably distance) reduced by 2.3 percentage points more in LSTF areas relative to control areas.

Self-reported change in travel behaviour in Carbon and Congestion case study areas

It is explained that:

"The Carbon and Congestion Case Study compared changes in travel patterns in five local authority areas that received LSTF funding ('treatment areas') and three 'control areas' that did not. All treatment areas received a combination of physical measures (such as cycle infrastructure or public transport interchange improvements) and 'softer' measures (such as personal travel planning).

Change was measured by means of a self-completion postal survey and seven-day travel diary administered in November 2013 and repeated in November 20147.

Comparing changes in the treatment areas with those in the control areas:

- *there was a relative reduction in per capita car driving of 8.4 miles per week. This was equivalent to 7% of the levels of car driving in the treatment areas in 2013. This was made up of a fall in per capita car driving distance of 3.1 miles, from 116 to 113 miles, in the treatment areas, and an increase in per capita car driving distance of 5.3 miles, from 149 to 154 miles, in the control areas (pre/post comparison). The difference was not statistically significant.*
- *The fall in car driving was partly due to a relative reduction in overall travel, but there was also a relative increase in travel as a car passenger (+6.1 miles per week), by bus (+1.6 miles per week), and by walking / cycling (+0.4 miles per week)."*

Assessment of the Active People Survey data

During and post the LSTF period (2010-12 to 2013-15), the mean number of days cycled by adults in the past 28 days was found to:

- increase by 2.8% in LSTF Large Project areas
- reduce by 3.8% in control areas
- Hence mean number of days cycled by adults in the past 28 days increased by 6.6 percentage points more in the LSTF Large Project areas compared against the control areas

Sloman L, Cavill N, Cope A, Muller L and Kennedy A (2009) Analysis and synthesis of evidence on the effects of investment in six Cycling Demonstration Towns Report for Department for Transport and Cycling England.	
Location	England: Aylesbury, Brighton and Hove, Darlington, Derby, Exeter, Lancaster, Morecambe
Intervention type	Each town invested $1m per year in cycling (with £500k provided by DfT) from Oct 2005 for four years. This included a 'Bike It' programme of cycling support for mainly primary schools, involving cycle storage, bikeability training and cycling promotion.
Indicators reported	Change in cycle to school mode share and change in car to school mode share
How indicators are derived	Observational surveys Before and after intervention hands-up surveys of school children were conducted measuring mode share on the survey day
Bicycle types	Pedal cycles
Survey data dates	Baseline surveys were undertaken in Sept 2006 or Sept 2007 across 60 schools. Follow-up surveys were undertaken in July 2007 or July 2008 across 22 schools.
Sample size	Baseline survey: n=14,896 Follow-up survey: n=13,200

Evidence summary

Hands-up surveys were undertaken in 60 schools in which 'Bike It' programmes were provided (across all towns with the exception of Darlington). Pupils were asked how they had travelled to school on the day of the survey.

The baseline hands-up surveys were undertaken in September 2006 or September 2007, before the 'Bike It' programme was started.

22 of the schools took part in follow-up 'Hands-up' surveys in July 2007 or July 2008, after Bike-it interventions had been implemented.

The percentage point change in travel to school mode share is illustrated in Figure A below:

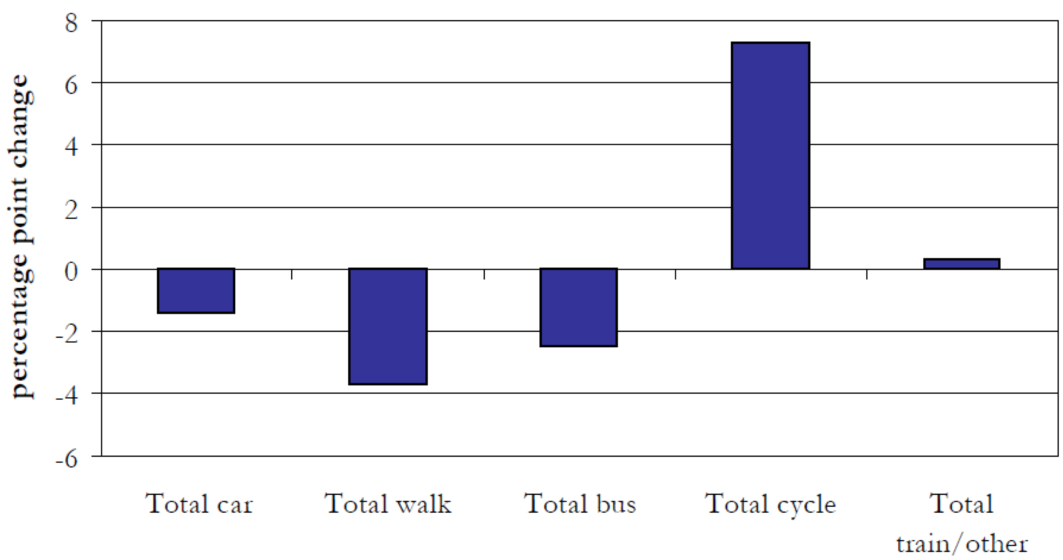


Figure A: Percentage point change in mode share in bike it schools (source document Figure 1)

It is noted that:

- "The proportion of trips to school by car fell by 4% or 1.4 percentage points (from 38.9% to 37.5%)"
- "The proportion of trips to school by cycle increased by 174% or 7.3 percentage points (from 4.2% to 11.5%)
- "Roundly speaking, about half of the increase in cycling appears to have been the result of a reduction in bus and car mode share, with the rest of the increase being the result of modal shift from walking"

This implies a car to cycling diversion factor for journeys to school of approximately 1.4 / 7.3 = 19%. Note that this study is cross referenced by Lovelace et al (2011) in their assessment of the replacement ratio indicator.

The logic for this calculation is as follows:

- To get 1.4 fewer car trips, you need to achieve 7.3 additional cycle trips
- Therefore 1 additional cycle trip will be associated with 1.4 / 7.3 fewer car trips
- Hence 100 additional cycle trips will be associated with 1.4 / 7.3 x 100 fewer car trips (19%)

This method of indirectly inferring diversion factors is examined in the main report and ruled out as due to potential issues with validity.

Note that the report indicates that the hands-up survey data set allows the change in car / cycling to school mode shares to be disaggregated by area, but this disaggregation is not presented in the report.

It is also noted that a full post hoc evaluation of economic benefits such as decongestion benefits is challenging since "we have little indication of the proportion of journeys made by bike that might previously have been made by car".

Song, Y., Preston, J., Ogilvie, D. and iConnect Consortium, 2017. New walking and cycling infrastructure and modal shift in the UK: a quasi-experimental panel study. Transportation research part A: policy and practice, 95, pp.320-333.	
Location	England, Cardiff, Southampton, Kenilworth
Intervention type	Walking and cycling infrastructure implemented in the three case study settlements
Indicators reported	Change in modal share for active travel and car driving
How indicators are derived	A before and two after intervention postal surveys were sent to residents living within 5km by road of each intervention site The questionnaire captured weekly travel and physical activity for each respondent Indicators of time and distance spent using different transport modes were measured This made it possible to calculate the mode share (according to time and distance) and change in mode share before and after interventions were implemented.
Bicycle types	Pedal cycles
Survey data dates	Before intervention survey: April 2010 Follow-up survey 1: April 2011 Follow-up survey 2: April 2012
Sample size	Before intervention survey: April 2010; n= 3516 Follow-up survey 1: April 2011; n=1906 Follow-up survey 2: April 2012; n=1564

Evidence summary

Tables A and B below show the mean changes in modal splits for active travel and car driving by study site for the periods 2010 to 2011 and from 2010 to 2012 respectively.

The percentage changes were calculated for each individual and then averaged across the sample.

Over all three sites and over the longer time period (Table B), it was observed that a 6.3% increase in distance travelled by active modes (walking and cycling) occurred concurrently with a 3.0% reduction in distance travelled by car.

From this we can say that every 1% increase in distance travelled by active modes happened concurrently with a -0.47% reduction in distance travelled by car (taking the ratio 3.0% / 6.3%).

Table A – Mean changes in modal splits for active travel and car driving by study site, 2010-2011 (source table 3)

		Cardiff	Southampton	Kenilworth	All
	n	**592**	**518**	**719**	**1829**
Active travel	Change in time (mins)	-1.18	2.93	0.91	0.81
	%age change in time	-4.20	7.40	3.40	2.40
	Change in distance (miles)	-0.67	3.57	1.00	1.19
	%age change in distance	-4.30	14.70	7.50	6.40
Car driving	Change in time (mins)	2.11	-2.02	-0.88	-0.24

	%age change in time	4.80	-5.50	-1.50	-0.30
	Change in distance (miles)	1.42	-3.12	-1.36	-0.96
	%age change in distance	3.00	-7.00	-2.20	-1.70

Table B – Mean changes in modal splits for active travel and car driving by study site, 2010-2011 (source table 3)

		Cardiff	**Southampton**	**Kenilworth**	**All**
	n	**592**	**518**	**719**	**1829**
Active travel	Change in time (mins)	-2.26	2.97	0.98	0.48
	%age change in time	-7.90	7.80	4.90	1.80
	Change in distance (miles)	0.09	1.78	1.15	0.92
	%age change in distance	-0.50	7.40	13.20	6.30
Car driving	Change in time (mins)	0.29	-2.76	-0.10	-0.71
	%age change in time	0.70	-8.30	-0.10	-1.50
	Change in distance (miles)	-3.12	-2.63	0.32	-1.61
	%age change in distance	-5.50	-6.70	0.60	-3.00

Appendix D - Evidence summary tables

International evidence of cycling diversion factors

Cycle Superhighway, 2019. Cycle superhighway bicycle account 2019. Copenhagen: Cycle Superhighway.	
Location	Denmark – 8 cycle superhighways designed to enable cycling across municipal borders
Intervention type	Protected cycle lanes
Indicators reported	Cycling diversion factors
How indicators are derived	The detailed methodologies are not reported as this is a summary report. The detailed evaluations are published in Danish.
Bicycle types	Pedal cycles
Survey dates	Unknown
Sample size	Unknown

Evidence summary

This document reports car to cyclists diversion factors for 8 cycle superhighways in Denmark, as summarised in Table A below.

The percentage of new cyclists transferring from car ranges from 9% to 26%. The report quotes that, aggregated across all sites, 14% of new cyclists used to travel by car.

Table A: Change in cycling and mode transfer from car for Danish cycle superhighways

Route	%age change in number of cyclists	%age of new cyclists transferring from car
Albertslund Route C99 (18km)	14% from 2010 to 2018	10%
Allerod Route C93 (30 km)	14% from 2010 to 2018	14%
The Farum Route C95 (21 km)	68% from 2010 to 2018	26%
The Frederikssund Route C97 (43 km)	15% from 2010 to 2018	12%
Inner Ring Route C94 (14 km)	21% from 2010 to 2018	21%
The Ishoj Route C77 (14 km)	2% from 2010 to 2018	25%
Ring 4 Route C84 (20km)	12% from 2010 to 2018	12%
The Vaerlose Route C83 (8km)	20% from 2010 to 2018	9%

Flügel, S., Fearnley, N. and Toner, J., 2018. What factors affect cross-modal substitution?– Evidences from the Oslo Area. International Journal of Transport Development and Integration, 2(1), pp.11-29.	
Location	Norway, Oslo
Intervention type	This is not an intervention study
Indicators reported	Cycling diversion factors for various modes
How indicators are derived	Diversion factors are derived from a modelling exercise rather than from observation A mode choice model is estimated on travel diary (revealed preference) data Over 10,000 diversion factors, for various transport modes are simulated by 'systematically changing the underlying transport modes, submarkets and policies' The analysis provides insight into the extent to which Diversion Factors vary by mode, and according to differences in generalised cost between modes. A regression analysis also provides insight into factors explaining variation in diversion factors.
Bicycle types	Pedal cycles
Survey dates	NA
Sample size	The choice model is estimated on a data set of 14,947 trips undertaken in Oslo

Evidence summary

This paper has been included in the review as it provides a very informative overview of methods of estimating diversion factors (including modelling and simulation), and some indicative diversion factor ranges, using data from trip making in Oslo.

Insights on extent of evidence base from literature review

It is noted that 'the literature on Diversion Factors' is limited.

Insights on how diversion factors can be estimated

The paper provides a useful overview of how Diversion Factors (DFs) may be estimated, as follows:

"In several studies, DFs are established based on survey data. They may take the form of direct questions on how respondents would behave if their current mode became unavailable, or of transfer time (and cost) questions on intended behaviour of the form 'How much would your journey cost have to increase before you switch to another mode/don't make this trip?'. DFs are calculated as the proportion who states that they would switch to each mode (or not travel).

Another way to obtain DFs is to observe the change in demand for mode j and the proportion that diverts to mode i. Formally, this would be calculated as (eq 1)

$$\mathrm{DF}_{ji} = (Q_{T1\,i} - Q_{T0\,i})/(Q_{T1\,j} - Q_{T0\,j})$$

where Q is demand (number of passengers); T0 and T1 are time periods or scenarios. In typical scenario analysis (e.g. two model runs), j is the transport mode that is altered in attributes, while i remains unchanged. DFji is then referred to as DF from mode j towards mode i (given a change in mode j). This is the standard procedure for deriving DFs from discrete choice models or transport models. A base scenario (T0) is compared with an intervention scenario (T1) where one (or several) attribute is (are) changed. The resulting Qs are then plotted in the above formula in order to obtain DFs.

DFs can also be calculated 'backwards' from known cross-elasticities, known own-elasticities and known market shares. We have the following relationship, which defines cross elasticities of demand (eq 2):

$$\varepsilon_{ij} = |\varepsilon_{jj}| \frac{Q_j}{Q_i} \mathrm{DF}_{ji}$$

where ij is the cross-elasticity of demand for mode i with respect to an attribute change of mode j; | | jj is the absolute value of mode j's own-elasticity of demand; Qj /Qi is the ratio of market shares or ratio of volumes; and DFji is the proportion of those who leave mode j and switch to mode i. It follows that (eq 3)

$$\mathrm{DF}_{ji} = \frac{\varepsilon_{ji}}{|\varepsilon_{jj}|} \frac{Q_i}{Q_j}$$

When inserting the definition of linear-arc-elasticities in eqn (3), it is straightforward to show that eqn (3) is mathematically equivalent with eqn (1).

Furthermore, when quantities in eqn (1) are predicted on the basis of multinomial logit models we can establish a direct relationship (see the appendix for the derivation) (e1 4):

DFij = Pj /(1−Pi) (4)

where Pj, Pi are (individual) choice probabilities for mode j and i, respectively.

Equation (4) holds true on an individual level, in which case DFji is interpreted by relative probabilities to switch from mode j to mode i. Aggregating over (heterogeneous) individuals (as done in this article by means of sample enumeration), eqn (4) does not necessarily hold on a market level, in which case P represent market shares."

Diversion factor simulation method

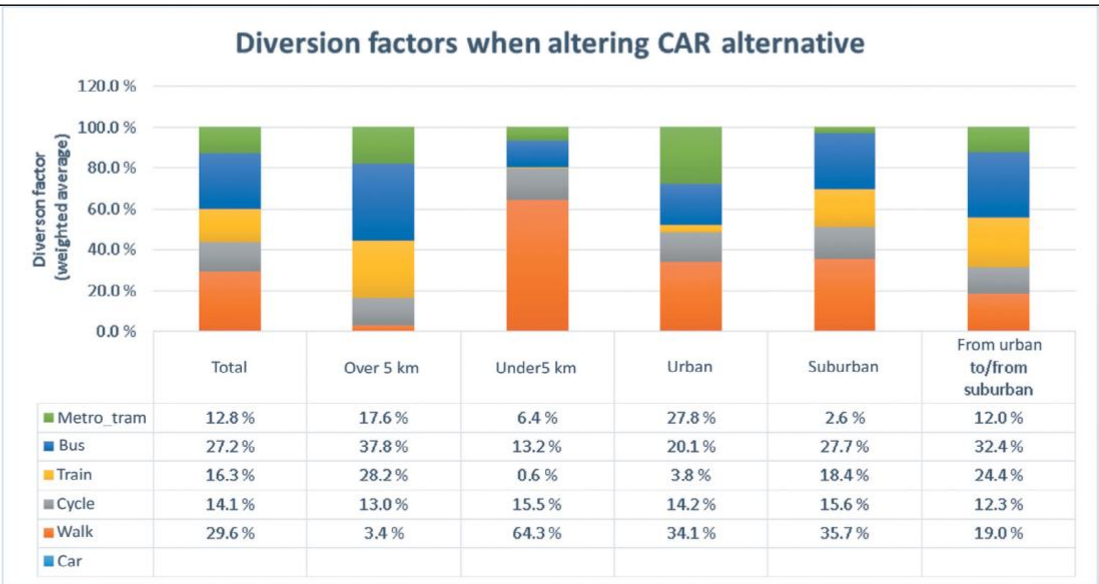
Scenarios are developed to simulate change in modal share if the generalised cost of travel by car, train, bus or metro is altered systematically.

Mode share is disaggregated by mode and journey purpose.

The change in mode share is used to estimate diversion factors.

Simulated diversion factors

The simulated diversion factors, when the generalised cost of travel by car is variously altered are summarised in Figure A. So for example, for journeys under 5km, 15.5% of trips switching away from car would be expected to divert to cycling.



	Total	Over 5 km	Under5 km	Urban	Suburban	From urban to/from suburban
Metro_tram	12.8 %	17.6 %	6.4 %	27.8 %	2.6 %	12.0 %
Bus	27.2 %	37.8 %	13.2 %	20.1 %	27.7 %	32.4 %
Train	16.3 %	28.2 %	0.6 %	3.8 %	18.4 %	24.4 %
Cycle	14.1 %	13.0 %	15.5 %	14.2 %	15.6 %	12.3 %
Walk	29.6 %	3.4 %	64.3 %	34.1 %	35.7 %	19.0 %
Car						

Figure A – Diversion factors, total and by main categories, when car is altered. (source Figure 4)

Diversion factors are not estimated for the situation in which level of service for cycling is improved relative to other modes.

Regression models are estimated with diversion factor as the dependent variable to identify which explanatory variables have ‘a significant effect on diversion factors’.

The regression analysis reveals that: “Diversion Factors to cycling tend to be higher for work-related trips”.

Matute, J., Huff, H., Lederman, J., de la Peza, D. and Johnson, K., 2016. Toward accurate and valid estimates of greenhouse gas reductions from bikeway projects (No. CA 17-2919). California. Department of Transportation.	
Location	USA, Los Angeles
Intervention type	Improvement to cycling infrastructure
Indicators reported	Cycling Diversion Factors
How indicators are derived	Two forms of road user intercept survey were performed at 20 locations where upgraded cycling infrastructure had been implemented in the previous 2 year period and were at least 1.2km long: • A five minute rider dismount survey • A poster survey - a single multiple choice question that could be answered without dismounting Surveys were conducted for time periods 7-11am, 11-3pm, 4-8pm The poster survey asked respondents: If this bike lane did not exist, I would: • Still ride a bike here • Ride bike on another route • Take the bus • Use a car • Not take this trip • Other
Bicycle types	Pedal cycles
Survey dates	January and February 2016
Sample size	Poster survey: 463 responses Dismount survey: 155 responses

Evidence summary

The study develops a method to estimate greenhouse gas reductions from cycleway projects. This includes estimation of avoided vehicle miles travelled, which is dependent on cycling diversion factors.

Avoided Vehicle Miles Travelled is estimated as:

VMT = # of avoided vehicle trips * average length L of avoided trips

Avoided Vehicle and transit trips are estimated as:

Vehicle_Trips_avoided = V_b * m_v
Transit_Trips_Avoided = V_b * m_t

Where V_b is annualized bicycle trips and m_v and m_t are percentage of riders that would have travelled in private vehicles and transit respectively.

V_b is derived from bicycle counts
m_v and m_t are estimated as static parameters – the mean proportion of trips shifted from private vehicles / transit, measured from intercept surveys
L is estimated as a static parameter – the mean average trip length, measured from surveys

The modal transfers, as reported by respondents to the non-dismount and dismount surveys are summarised in Table A. It is notable that a much lower proportion of non-dismount survey respondents reported switching from car 1.9% compared to 11% of dismount survey respondents.

The authors note that: "m_v ranges from a low of 1.9% in the poster responses to 10-25% (depending on trippurpose and facility type) in the dismounted survey responses. m_t is 12.6% in the poster responses and 9-30% (depending on trip purpose and facility type) in the dismounted responses"

Table A: Stated mode shift from oral surveys (source table 4)

Non-dismount poster survey	Non-dismount poster Survey	Dismount survey (all)	Dismount survey (class 2)	Dismount survey (class 4)
N	463	155	86	69
Ride bike on this route	72.40%	29.82%	35.71%	24.79%
Ride bike on other route	13.40%	37.16%	38.78%	35.54%
Take bus	3.50%	6.42%	11.22%	3.31%
Use car	1.90%	11.01%	7.14%	14.05%
Not take this trip	7.30%	11.47%	6.12%	15.70%
Other	1.70%	4.13%	1.02%	6.61%
Total	100.20%	100.01%	99.99%	100.00%

Notes: Class refers to cycle track grade. Higher numbers reflect greater level of service

Table B shows the diversion factors to cycling normalized after removing existing cycling trips. Car to cycle diversion factors for new cycling trips range between 13% and 33%.

Table B: Cycling diversion factors for new cycling trips only (calculated from Table A)

Non-dismount poster survey	Non-dismount Poster Survey	Dismount survey (all)	Dismount survey (class 2)	Dismount survey (class 4)
Take bus	24.3%	19.4%	44.0%	8.3%
Use car	13.2%	33.3%	28.0%	35.4%
Not take this trip	50.7%	34.7%	24.0%	39.6%
Other	11.8%	12.5%	4.0%	16.7%
Total	100.0%	100.0%	100.0%	100.0%

Journey purposes are reported in Table C (extracted from text on page 40 of the source document). It is presumed that these journey purposes relate to the dismount survey respondents only (though this is not stated). It is notable that the majority of journeys (63%) were recreational.

Table C: Respondent journey purposes

Journey purpose	%age trips from dismount survey
Recreational	63.00%
Work	14.00%
Family or personal purposes	8.00%
Shopping	7.00%
Other	8.00%
Total	100.00%

The average trip distance was estimated to be 7 miles (using approximate origin and destination data generated through the dismount survey). This estimate is significantly longer than the mean cycling trip distances revealed by the American Community Survey (3 miles) and National Household Travel Survey and is potentially linked to the high proportion of recreational journeys that are undertaken on LA cycling infrastructure.

Monsere, C., J. Dill, N. Mcneil, K.J. Clifton, N. Foster, T. Goddard, M. Berkow, et al. 2014. Lessons from the Green Lanes: Evaluating Protected Bike Lanes in the U.S. Portland State University, OR: Transportation Research and Education Center.	
Location	USA – Austin TX, Chicago IL, Portland OR, San Francisco CA, Washington D.C.
Intervention type	Protected bicycle lanes
Indicators reported	Cycling Diversion Factors
How indicators are derived	Intercept surveys (bicycle lane users invited to later complete and online survey)
Bicycle types	Pedal cycles
Survey dates	Study conducted between spring 2012 and summer 2013
Sample size	1,111 (33% of those invited to participate)

Evidence summary

Cyclist intercept surveys were conducted along 8 new protected bike lanes across 5 US cities. The new bike lanes were implemented as part of the Green Lanes Project.

Survey intercept times were based on an understanding of the ridership patterns, and typically included AM and PM commuter periods, along with midday and weekend periods.

Riders were stopped and given a postcard which provided a URL to an online survey.

The survey asked respondents:

Consider the trip you were making when you were handed the postcard. Before the facility was built, how would you have made this trip?

The results are summarised in Table A. Aggregating across all sites, 10% of riders switched from other modes, with modal transfer ranging from 6% to 21% (- the "switch from modes" are not specified). 24% of riders had shifted from other bicycle routes.

Table A: Cyclist mode or route without the new facility (source table 6-4)

		Consider the trip you were making when you were handed the postcard. Before the facility was built, how would you have made this trip?				
	Route	By bike using this same route	By Bike using another route	By other mode	Would not have taken trip	Total
Austin	Barton Springs	65%	29%	6%	0%	17
	Rio Grande	55%	38%	7%	0%	42
Chicago	Dearborn	17%	60%	21%	2%	123
	Milwaukee	83%	6%	10%	1%	231
Portland	NE Multnomah	56%	34%	10%	0%	107
San Francisco	Oak Street	75%	18%	6%	1%	247
	Fell Street	80%	11%	7%	1%	247
Washington DC	L Street	56%	32%	10%	2%	300
	Total	**65%**	**24%**	**10%**	**1%**	**1316**

Oak and Fell respondents are counted twice in the total numbers

Murphy, E. and Usher, J., 2015. The role of bicycle-sharing in the city: Analysis of the Irish experience. International journal of sustainable transportation, 9(2), pp.116-125.	
Location	Ireland, Dublin
Intervention type	City Centre Bicycle Sharing System
Indicators reported	Cycling Diversion Factors
How indicators are derived	A survey of users selecting bikes at 6 out of 40 bicycle docking stations is conducted 60 responses were sought from each docking station (30 in each of the morning and afternoon peak periods) Users self-completed the questionnaire (unclear whether this was online or by paper return).
Bicycle types	Pedal cycles
Survey dates	Not known
Sample size	360
Population weights applied	No

Evidence summary

Respondents were asked "whether or not they used a bicycle for their current trip prior to the initiation of the dublinbikes scheme".

68.4% of respondents "claimed not to have cycled for their current trip prior to the launch of the dublin bike scheme".

Respondents were also asked what mode they were using dublinbikes as a substitute for. The results are summarised in Table A (it is not clear whether the proportions apply to the full sample or the 68.4% of users that claimed not to have cycled for the current trip previously). This indicates a car to bike share diversion factor of circa 20%.

Table A: Mode of transport used prior to using the dublinbike scheme (source Figure 4)

Alternate mode	Percentage
Car	19.6%
Bus	25.8%
Rail	8.8%
Walking	45.6%
Total	99.8%

It is also observed that higher income users were more likely to switch from car to bike share than lower income users (Table B). For example Table B shows that 34% of users earning over 50k Euros had switched from car compared to the sample average of 20% switching from car.

Table B. The relationship between income status and modal shift.

	Car		Bus		Rail		Walk		Total
Income	n	%	n	%	n	%	n	%	n
0-20k	1	7.1%	6	42.9%	2	14.3%	5	35.7%	14
21-30k	7	17.5%	11	27.5%	0	0.0%	22	55.0%	40
31-40k	10	12.7%	22	27.8%	5	6.3%	42	53.2%	79
41-50k	20	20.6%	25	25.8%	11	11.3%	41	42.3%	97
50k+	26	33.8%	11	14.3%	9	11.7%	31	40.3%	77
Total	**64**	**20.8%**	**75**	**24.4%**	**27**	**8.8%**	**141**	**45.9%**	**307**

Appendix E – Summary of literature reviews on mode shift to conventional cycles

This appendix presents brief summaries of six international literature reviews on modal transfer to cycling (Panter et al., 2019, Pucher et al., 2010, Scheepers et al. 2014, Wardman et al. 2018, Handy et al. 2014 and Iyer et al. 2019), undertaken as a means of checking the extent of the cycling diversion factors evidence base

Panter et al (2019) present a systematic review addressing the question "Can changing the physical environment promote walking and cycling?" 13 intervention evaluations are examined along with 46 related sources. The review reports no indicators of relevance to understanding proportional transfer to cycling from other modes of transport.

Pucher et al (2010) present an international review of "infrastructure, programmes and policies to increase bicycling". The review examined 139 published articles and secondary data from 14 case study cities. Findings of relevance to understanding the share of new cycling trips that have transferred from other modes included:

- *"One before-after study of new cycletracks in Copenhagen reported a 20% increase in bicycle and moped traffic and a 10% decrease in motor vehicle traffic. However, it was not known how much of the change was due to changes in route choice versus people shifting from driving or other modes to bicycling (Jensen, 2008)."*
- *"Several case studies provide evidence of a shift in mode split for people entering the central business district after conversion to a pedestrian mall, though the impact on bicycling appears limited. In Bologna, Italy, vehicle traffic declined by 50%, and 8% of people arriving at the center came by bicycle after the conversion (Topp and Pharoah, 1994). In Lubeck, Germany, of those who used to drive, 12% switched to transit, walking, or bicycling; bicycling was not separately reported (Topp and Pharoah, 1994)".*
- *"In London, 68% of OYBike trips were for leisure or recreation; 6% of users reported shifting from driving and 34% from transit, while 23% said they would not have travelled (Noland and Ishaque, 2006)".*

Overall then, only one of the reported studies (Noland and Ishaque, 2006) provided direct evidence of diversion factors, relating to the implementation of a bike sharing system in London.

Scheepers et al (2014) set out to "to systematically review the effectiveness of interventions designed to stimulate a shift from car use to cycling or walking and to obtain insight into the intervention tools that have been used to promote and/or implement these interventions". The review identified 19 studies that "focussed on a mode shift from car use towards active transport in a general adult population, which were published in peer reviewed journals and which investigated effectiveness"

Findings of relevance to understanding the share of new cycling trips that have transferred from other modes included:

- An evaluation of a workplace transport plan at Bristol University (Brockman and Fox, 2011) identified that the proportion of staff 'usually' cycling to work increased from 7% to 12%; at the same time the proportion of staff 'usually' commuting by car decreased from 50% to 33%

- A before and after study conducted in New Zealand of a Bike Now programme aimed to stimulate cycling to work revealed that 49% of respondents (n=1587) replaced 'drive a car' trips with cycling trips. (O' Fallon, 2010)
- The introduction of car free areas in Lubeck, Germany found that 12% of those who previously drove into the city centre switched to public transport, walking and cycling. (Topp and Pharoah, 1994)
- A study of 8 bicycle and pedestrian facilities implemented in Chicago revealed that 11% of bicycle path users had transferred from single occupancy vehicles (Thakuriah et al, 2012).
- A study of 18 town-wide cycling initiatives in England (using a natural experiment method, drawing on census data from 1981,1991, 2001, and 2011) identified an intervention effect (compared to control areas) of a 0.69 percentage point increase in cycling to work and a 1.39 percentage point reduction in driving to work (Goodman et al 2013).
- A study of bicycle proficiency training in Columbia, USA indicated that 35% of trips made by car had been replaced with bicycle trips. (Thomas et al, 2009)
- A study of 46 users of the OyBike share system in London revealed that 6% of respondents had shifted from car use; 21% had shifted from walking. (Noland and Ishaque, 2006).
- A study of a bicycle share system in Montreal (n=2,500) revealed that 21% of respondents had transferred from walking; 10.1% of respondents had transferred from motor vehicles; and 21.8% of respondents had transferred from personal bicycle (Fuller et al, 2013).

That is, only four studies are evaluated that directly report diversion factors towards cycling (Topp and Pharoah, 1994, Thakuriah et al, 2012, Noland and Ishaque, 2006 and Fuller et al, 2013). It is also noted that "the quality of the included studies was generally low, since control groups were mostly missing" and "effects on mode shift were sometimes badly reported…it could be questioned if the positive effects on a mode shift really exist'

Wardman et al (2018) perform an international "review and meta-analysis of inter-modal cross-elasticity evidence". Cross elasticities are defined as:

Proportional change in demand for mode A / Proportional change in [attribute of] mode B.

where the attribute altered is commonly journey time, fuel price or generalised cost representing a combination of journey attributes.

The study is contextually relevant because (i) cross elasticities reveal how demand for cycling changes in response to 'stick' interventions (where generalised cost of travel by car is increase) or to 'carrot' interventions (where generalised cost of travel by cycle reduces); (ii) the review provides another yard stick for the quantum of evidence on modal transfer to / from cycling; and (iii) the meta-analysis provides some insight into factors associated with variability in modal.

The review extracts 1096 cross-elasticities for analysis across all modes. There are no cross-elasticities for the case that cycling is the intervention mode, indicating a dearth of evidence on cycling elasticities. However, 33 cross-elasticities are identified for cycling where other modes are altered, as summarised in Table A. This suggests that cycling is more commonly a substitute for car trips when compared against the sensitivity of cycling levels to changes in public transport (which have lower cross-elasticities).

Table A: Cycling cross-elasticities (source Wardman et al, 2018 – Table 5)

Mode Altered	Mean cycling cross elasticity with respect to generalised cost	SE	Number of observations	%age change in cycling in response to 10% increase in gen cost of altered mode
Car	0.34	0.115	8	3.4%
Bus	0.06	0.01	6	0.6%
Rail	0.03	0.018	6	0.3%
LRT	0.05	0.015	5	0.5%
Public Transport	0.12	0.022	8	1.2%
Total			33	

The meta-analysis takes the form of a regression model estimated on cross-elasticities as the dependent variable (n=1096). The regression model was used to examine factors that explain variation in cross-elasticities. It is observed that cross-elasticities vary according to journey purpose and to relative mode share – for example, where bus has a lower mode share relative to car, the cross-elasticity of demand for bus use when car is altered will be higher (as there is more potential for transfer to bus). The regression model is also used to predict various cross-elasticities for different scenarios, but cycling is not included, probably due limitations in the data set.

The review by Handy et al. (2014) includes an overview of 'studies evaluating [cycling strategy] effectiveness' including before and after intervention studies. This review is designed to identify types of approach to evaluating interventions, rather than to describe and evaluate the evidence and indeed no evidence of cycling diversion factors is presented. Nevertheless, with respect to evaluating the extent of the diversion factors evidence base, it is noted that intervention studies 'measure behaviour before and after the implementation of a strategy and test the significance of the behaviour change', by including a control group that has not experienced the intervention. The authors note that Pucher et al (2010) found few studies that meet this criteria, since control groups are difficult to identify and longitudinal studies are expensive to administer.

Iyer et al (2019) review outcomes from 'a portfolio of 19 [cycling and walking] projects that have been implemented in the UK between 2004 and 2019. Table 12 of the Iyer et al (2019) report presents identified cycling outcomes, across multiple indicators, including level of 'mode switch from other modes to bicycle' (linked to the cycle city ambition fund programme), but cycling diversion factors are not reported. Note that the reference list from the Iyer et al (2019) report was interrogated as part of the search conducted for this review.

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