The carbon footprint of cataract surgery in Wellington

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ABSTRACT

INTRODUCTION: Efforts to improve the sustainability of ophthalmic care require methods to measure its environmental impact and a baseline measurement to compare against in the future. We aimed to measure the carbon footprint of cataract surgery in Wellington.

METHODS: We used Eyefficiency, an application using established footprinting methods, to estimate the emissions produced by phacoemulsification surgery in two public and two private hospitals. We measured (1) power consumption, (2) procurement of disposable items and pharmaceuticals, (3) waste disposal emissions and (4) travel (other potential sources were excluded). Where possible we used New Zealand emissions coefficients.

RESULTS: We recorded data from 142 cataract surgeries. The average emissions produced by cataract surgery in the region was estimated to be 152kg of carbon dioxide equivalent. This is equivalent to 62L of petrol and would take 45m^2 of forest one year to absorb. The great majority of emissions were from procurement, mostly disposable materials, and the second greatest contribution was from travel (driving).

CONCLUSION: Estimating the carbon footprint of cataract surgery is becoming easier, but improved methods for measuring the footprint of procured supplies are needed. There are significant opportunities for emissions reduction in the most common surgical procedure in New Zealand.

Climate change is the largest global health threat in the 21st century,[1,2] and there is broad support for urgent action to mitigate climate change though emissions reduction, even among ophthalmologists.[3–5] The healthcare sector is a major source of physical waste and greenhouse gas emissions.[6] In New Zealand and Australia, healthcare accounts for around 10% of national economic activity and contributes around 5% of total greenhouse emissions, which is more than aviation.[7,8] The National Health Service of England's target is for their healthcare sector to be carbon neutral by 2040,[9] and recently the New Zealand Government announced its entire public sector will move to achieve carbon neutrality by 2025 (the details for district health boards have not yet been announced).[10]

Due to both high surgical volumes and considerable disposable consumption, cataract surgery is the greatest source of emissions within ophthalmology. Attempts to derive a carbon footprint of cataract surgery have shown widely divergent results in different countries: in Cardiff, United Kingdom (UK), the estimated footprint was 182kgCO_2e,[11] whereas the footprint of the Aravind Eye Care System (AECS) of Southern India was only 6kgCO_2e.[12] This vast difference between the UK's and India's surgery footprints has been attributed to AECS reusing most items (including blades and tips), recycling much of their waste and having high time efficiency and throughput, reduced power consumption and cheaper locally-sourced surgical materials. There are also some differences in how the AECS and UK footprints were calculated.[13]

In this cross-sectional study, we aimed to estimate the carbon footprint of cataract surgery in all hospitals in the Wellington region, New Zealand (two public and two private participated). This was to establish a baseline measure or benchmark for future sustainability auditing, to engage local stakeholders and to consider avenues for improvement. A secondary aim was to compare public and private hospitals and areas of relative strength and weakness.

Methods

Approvals

The study protocol was ethically approved as a Minimal Risk Health Application by the University of Otago Human Ethics Committee (Health): reference HD20/092. Management of all three public hospitals and all three private hospitals in the Wellington region agreed to participate. Wellington Regional Hospital and Kenepuru Community Hospital, both of Capital & Coast District Health Board, and Bowen Hospital and Southern Cross Hospital Wellington all participated. Hutt Hospital of Hutt Valley District Health Board and Boulcott Hospital both agreed to participate but were then excluded because the volume of cataract surgery in the study period was insufficient (fewer than 15 cases). In a memorandum of understanding, the results for each hospital were kept anonymous and were not permitted to be used in marketing.

Study design

The primary researcher (ML) attended as many operating lists containing cataract surgery as possible at all four hospitals between November 2020 and January 2021, collecting up to 40 cases from each hospital from the widest possible range of surgeons.

Broadly speaking, to estimate the greenhouse gas emissions footprint of surgery involves firstly determining the scope of what is included in the estimate; secondly, measuring the included emissions sources; and finally, applying relevant emissions factors to each source to determine the overall emissions. The method used was based on previously published methods,[11,12] which were available through the Eyefficiency application. Eyefficiency can be used to record events in theatre for testing the efficiency of processes, but by entering more details about consumption, travel and waste, it can also estimate carbon footprints. We used Eyefficiency to record case timings and as a guide to understand sources of emissions, but we modified the footprinting inclusions, exclusions and emissions coefficients, as described below.

Carbon footprinting: inclusions and exclusions

We included all elective phacoemulsification with lens implant operations, including complicated cases, as well as the possible additions of suture removal, bleb needling and intravitreal or subtenon injection. We excluded all larger combined surgeries, such as cataract surgery with planned vitrectomy or trabeculectomy or iris suturing. Bilateral cases were performed and measured as two separate cases. The main opportunity for reduced emissions with bilateral surgery was reduced patient travel. There were no manual cataract extractions (without phacoemulsification) during the study. Operations under local or general anaesthetic (<5 in total) were both included, and although the additional time of general anaesthesia was recorded, the additional waste from the anaesthetic could not be measured.

The list of potential sources of greenhouse gas emissions is long. The factors that were included as contributing to the carbon footprint of cataract surgery were: (1) power supply of the hospital, (2) travel for patients and staff in the theatre, (3) procurement of disposable items, pharmaceuticals and solutions and tubing and tips for the phacoemulsification device and (4) waste disposal. This was approximately in line with the similar study from India.[12]

We excluded the construction and provisioning of the hospital. In the UK study, emissions related to information technology, stationery, linen and laundry were calculated to be less than 0.5% of the total, so we excluded them from our analysis.[11] We also excluded capital items, such as instruments, operating microscope and phacoemulsification device, and more peripheral sources of emissions that surround the cataract surgery system, such as food for staff and patients, other human resources around the hospital such as security and reception, scientific activities and background knowledge and training underlying the operation. We also excluded perioperative clinic appointments as there was very little variation between surgeons or hospitals in having one preoperative and two postoperative visits, although this would be a modifiable aspect of travel emissions in cataract surgery.

We measured the emissions from the sterilisation of instruments in one hospital (using British emissions coefficients) and found they were less than 0.25% of total emissions. As the amount was very small and we were uncertain about the accuracy of British coefficients in New Zealand, we decided to exclude this source of emissions.

Carbon footprinting: emission measurement

Electricity consumption

Energy use was calculated by taking the average monthly power consumption of each hospital or surgical unit; and taking a proportion of the power consumption based on the floor space allocated to ophthalmic surgeries; and the proportion of the week scheduled for cataract surgery. In keeping with previous methods, we assumed that $1m^2$ of operating theatre used twice the energy as the average floor space of the hospital, and that all hospitals had equivalent electricity sources from the national grid.[11]

Travel data

Travel methods were collected from all operating theatre staff and the first 10 patients at each hospital: all drove. Private vehicle was then assumed to be the mode of travel for all other participants. Driving distances were calculated to the suburb level to maintain privacy. Emissions from staff travel were divided across the whole operating list. Calculations used the fuel performance of an average New Zealand car (2010 Toyota Corolla 1.6L engine).[14]

Procurement data

The cost of pharmaceuticals and medical equipment per cataract operation were calculated with data collected from theatre managers. As described above, we excluded procurement of other items such as information technology, food and drink, linen and stationery, as they were <0.5% of emissions in the UK study.[11] Procurement costs were converted to emissions using publicly available emissions coefficients ($NZD were converted into £GBP of 2011, when the emission coefficient was calculated).[15] These emissions coefficients are aggregated estimates across broad sectors: the average emissions per £GBP spent on pharmaceuticals or medical supplies. A more detailed product lifecycle analysis for quantifying the footprint of each consumable item was not possible.

Waste data

Some hospitals recycled, and any emissions from recycled waste were not recorded. All other waste went to landfill, and we used New Zealand emissions coefficients to calculate the emissions from transport and degradation of this waste. The weight of waste going to landfill after each case was measured with an electronic spring scale. In hospitals with recycling, landfill waste was predominantly non-recyclable plastics, so we used an emission coefficient for plastic in landfills. For hospitals that did not recycle, where landfill waste was mixed with more paper, we used an emission coefficient for general waste. Wellington landfills perform gas recovery, which mitigates emissions from anaerobic degradation of organic waste (not present in theatre waste), and this reduced the emission coefficient we used for general waste.

Carbon footprinting: emissions coefficients

Each source of emissions was measured in the relevant units: kilowatt hours (kWh) of electricity, kilometres (km) of driving, dollars of procured supplies ($NZD converted to £GBP of 2011), kilograms (kg) of landfill waste and tonne kilometres (tkm) for freight. These measures were converted to greenhouse gas emissions ($kgCO_2e$) using emissions coefficients (Table 1). Where possible, we used New Zealand emissions coefficients sourced from the Ministry for the Environment.[14] Where local information was unavailable, we used the same international and UK coefficients that were used in similar studies.[15]

Results

We collected data on 142 cataract operations from the three months of November 2020 through January 2021: 40 from Southern Cross Hospital Wellington, 41 from Bowen Hospital, 39 from Kenepuru Community Hospital and 22 from Wellington Regional Hospital. Eleven of the 17 consultant surgeons in the region were operating during data collection.

At the two private hospitals, the average number of cataract operations per session was 10.1, whereas the average number of cataract operations per session at the two public hospitals was 3.4. Simple cataract surgery was less common at the public hospitals, particularly Wellington Regional Hospital, as there were many other types of surgery and combined surgery.

Table 2 summarises the emissions results. The average footprint of cataract surgery was 151.9kgCO_2e. The proportions attributed to electricity use, travel, procurement of supplies and pharmaceuticals and waste disposal are also shown in Figure 1.

As shown in Table 2, cataract surgery at public hospitals had a slightly smaller carbon footprint than at private hospitals (145.2 kgCO_2e compared to 158.6 kgCO_2e). Travel emissions per case were lower in private hospitals, primarily due to longer lists of cataract operations (less staff travel per case). Procurement emissions were lower in public hospitals as perhaps they had greater bargaining power or economies of scale for negotiating lower costs per case. Pharmaceutical costs were higher in private hospitals because more surgeons used medication not funded by the national medicines and devices funding agency (PHARMAC), such as ketorolac, and because more surgeons used postoperative antibiotic drops.

The waste produced by each operation had an average mass of 1.32kg. The hospital with the lowest average waste (1.14kg) was a public hospital that did not recycle, and the hospital with the highest average (1.51kg) was the other public hospital, which did recycle. Paradoxically, the public and private hospitals that recycled both had heavier waste bags than their counterparts, despite some waste being diverted to recycling. The majority of the mass was from residual or collected irrigation fluid (balanced salt solution), gloves and gowns and soft plastic packaging for sterile single use items. The cassette and tubing for the phacoemulsification device were not recyclable, partly due to the fluid with biological material within them. At hospitals that recycled, the contents of the waste bags were mostly non-recyclable soft plastics, and in hospitals that didn't recycle, the waste was a more heterogeneous mixture of paper and different plastics

Discussion

We found an average of 151.9kgCO_2e of emissions from cataract surgery in Wellington, not including perioperative clinic visits. This footprint is similar to that of an economy ticket on a one-hour flight, or combustion of 62L of petrol, and would take 45m^2 of forest one year to absorb. By extrapolating this across the approximately 30,000

Table 1: Carbon emissions coefficients.

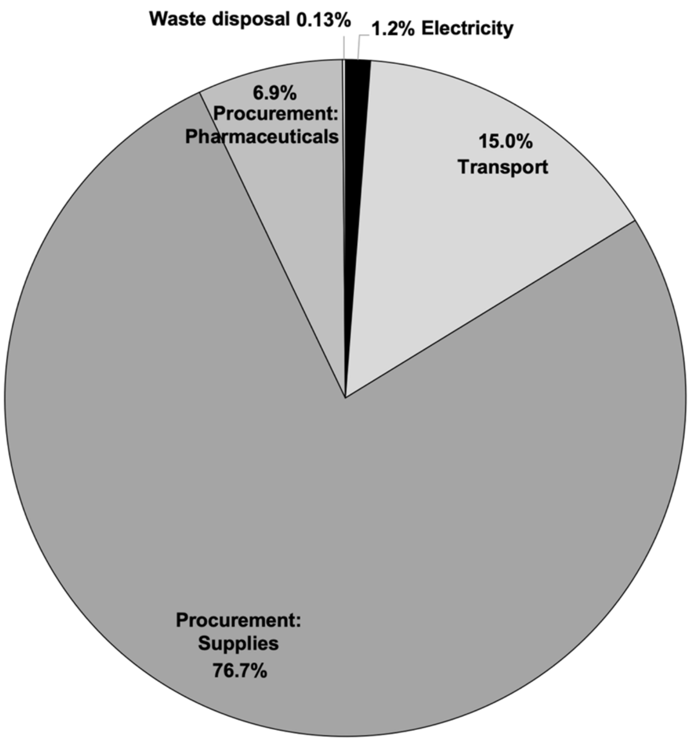
Power	**EC to convert kWh to kgCO_2e**	**EC reference**
Electricity	0.101	NZ
Transport	**EC to convert km to kgCO_2e**	**EC reference**
Car	0.238	NZ
Procurement	**EC to convert 2011 £GBP to kgCO_2e**	**EC reference**
Pharmaceuticals	0.59	UK[11]
Medical equipment	0.54	UK[11]
Landfill	**EC to convert kg waste to kgCO_2e**	**EC reference**
Plastic	0.008934	UK[15]
General waste	0.311	NZ
Waste freight	0.135 kgCO_2e per tkm	NZ

EC: emission coefficient. NZ: New Zealand. UK: United Kingdom. The ECs for plastic in landfill and procurement of medical supplies were sourced from the UK[11,15]. All other ECs are from New Zealand.[14]

Table 2: Carbon emissions (footprint) attributed to one phacoemulsification and lens implantation surgery in Wellington (kgCO_2e).

	Overall (all 4 hospitals)		Public (2 hospitals)		Private (2 hospitals)	
Electricity consumption	**kWh**	**kgCO_2e**	**kWh**	**kgCO_2e**	**kWh**	**kgCO_2e**
	17.8	1.8	17.1	1.7	18.5	1.9
Travel (per case)	**km**	**kgCO_2e**	**km**	**kgCO_2e**	**km**	**kgCO_2e**
Patient	48	11.4	51	12.2	45	10.7
Staff	48	11.4	72	17.2	23	5.5
Total	96	22.8	123	29.4	68	16.2
Procurement	**$NZD**	**kgCO_2e**	**$NZD**	**kgCO_2e**	**$NZD**	**kgCO_2e**
Medical equipment	486	116.5	412	98.8	560	134.2
Pharmaceuticals	40	10.5	57	15.0	23	6.0
Total	526	127.0	470	113.8	583	140.2
Waste disposal		**kgCO_2e**		**kgCO_2e**		**kgCO_2e**
Waste emissions		0.191		0.184		0.198
Waste freight		0.013		0.022		0.004
Total	1.32 kg	0.204	1.33 kg	0.206	1.32 kg	0.203
Total	151.9 kgCO_2e		145.2 kgCO_2e		158.6 kgCO_2e	

Figure 1: The proportion of the average carbon footprint attributed to each source of emissions.



cataract operations performed in New Zealand each year, we estimate this surgery creates 4,500 tonnes of CO_2e a year, which would take 134ha of forest growing for the year to absorb.

This footprint for cataract surgery in Wellington compares well to that found for Cardiff, UK, in 2012, which was 20% greater (182kgCO_2e) when calculated using the same method.[11] However, much of this difference could relate to the UK study including of both preoperative and postoperative clinic visits (ie, increased travel and increased electricity use in clinics). The very low footprint of 6kgCO_2e for phacoemulsification surgery at AECS highlights just how widely the relevant factors can vary.[12] Several reasons contribute to this huge difference: at AECS there is local production of many instruments and intraocular lenses; nearly every item is re-used to some extent; and much of the waste is locally recycled. There are also efficiencies of throughput that contribute to lower transport costs for staff.

Emissions from travel were similar in Wellington (18kgCO_2e) and Cardiff (23kgCO_2e). In our study there were fewer emissions from travel in the private sector (Table 2), due to longer operating lists (ie, staff travel was distributed over more cases). Travel distances for both staff and patients at public and private hospitals were similar. The main reasons for longer operating lists in the private sector were less-complex cases, fewer combined surgeries or non-cataract surgeries, fewer general anaesthetics, the absence of trainee surgeons who take longer to operate and lower turnaround time with less administration required by the operating surgeon. Notably, we did not find any staff or patients using public or active transport across 61 individuals asked.

The majority of emissions were from procurement (83.8%), mostly surgical supplies such as gauze, dressings, gowns and gloves, blades, lens implants, tubing and tips. The emission coefficient converted the costs of procured supplies into emissions, based on international data for the production and supply of medical equipment in general from 2011.[15] Therefore, in our study the emissions from procurement mostly reflect the costs, rather than a careful analysis of product lifecycles. These costs relate to bulk purchasing deals and negotiations with suppliers, and differences in price in different markets probably account for greater emissions from procurement in New Zealand than UK.[11] This is a major source of error in our study: one hospital could demand sustainable supply chains for disposable items, and may pay a greater price for those supplies, and the emission coefficient would incorrectly estimate that the emissions were greater. This decoupling of emissions and price will be a challenge for sustainability auditing in the future. Likewise, when all medical devices, including surgical supplies, become bulk-purchased by PHARMAC, New Zealand's medicines and devices funding agency, their cost will reduce but the level of emissions *per se* that they generate will not change. A more complete method for assessing the footprint of procured supplies is needed.

Emissions from power consumption (1.8kgCO_2e) were very low compared to the UK (66kgCO_2e), due to a few reasons: (1) the UK study included perioperative visits and potentially included power use in the clinics and larger areas of the hospital; (2) British hospitals often use coal boilers for central heating; (3) renewable energy (predominantly hydro) accounts for 82% of New Zealand's electricity supply, compared to just 47% of the UK's.[16] The UK emission coefficient indicates that electricity use in the UK generates nearly six times more carbon dioxide emissions than in New Zealand. New Zealand government policy aims to increase the renewable energy sector to the theoretical maximum by 2030.

Although waste disposal was a minor source of emissions, it was a significant mass and large volume per case (one full rubbish bag that weighed 1.32kg on average). Two hospitals recycled but also had a somewhat greater mass of non-recyclable waste, which could be related to other factors such as larger bottles of irrigation fluid, more assisting surgeons with extra gloves and gowns, or differences in the packaging of supplies. Recycling resulted in a different type of waste going to landfill: more non-recyclable plastic and less paper. And the different emission coefficient for this plastic waste in landfills reduced estimated emissions by 96% in hospitals that recycle. Despite recycling, we estimate the total amount of landfill waste created in New Zealand from cataract surgery to be around 40 tonnes per year. Incineration without energy recovery would produce a great deal more emissions per kilogram of waste.

A major implication of this study is that procurement is the best target for reducing emissions. Reducing procurement emissions starts with partnership with suppliers and understanding the sustainability of supply chains and product lifecycles. A recent survey found that many of the re-use and recycling practises of India would be acceptable to American surgeons if cost and safety were maintained.[13,17] There is a strong appetite for more sustainable, less wasteful surgery, but cataract surgeons, at least in the United States (US), feel a lack of agency.[17] As well as industry, agencies that regulate doctors and hospitals are seen to represent barriers to change and barriers to avenues for effecting change. In New Zealand, PHARMAC's upcoming role in bulk-purchasing surgical supplies represents a major opportunity both to improve measurement of emissions related to procurement and to leverage reductions in emissions during contract negotiations.

Large hospitals, as major employers and the destination for thousands of people every day, could improve the sustainability of transport systems by targeting reductions in their own transport emissions. Innovative approaches include partnerships with local government to further subsidise public transport for patients and employees (eg, the Business EcoPass initiative in Boulder County, Colorado, US). Hospitals could also provide facilities and advocate for better and safer active transport (eg, cycling and walking).[18] Active transport also improves health in the community by increasing physical activity, reducing air pollution and injury and improving mental health.[18,19] Reducing demand for healthcare through better population health is one of the key principles of a low-carbon healthcare system.[5]

In December 2020, the New Zealand Government announced that the public sector will become carbon neutral by 2025.[10] The public hospital systems within district health boards were to be included in principle with further announcements of their dates of inclusion in the year to come. Initially, this will mean a commitment to offsetting carbon emissions, but the longer-term implications will include the budgeting of emissions and procurement of low-emissions services and supplies.

This study had limitations. The most obvious is the calculation of emissions from procured products, which was based on one British emission coefficient that did not incorporate more modern manufacturing or consider the procured materials used in Wellington. Here a product lifecycle analysis of surgical supplies was not possible, but it would form an important part of future research. Likewise, a more granular approach to measuring patient and staff behaviour will help motivate change, such as by capturing variations in the use of consumables or travel and follow-up patterns.

Another weakness is the possibility of selection bias due to the incomplete sample of cataract surgeries performed during the study period. We quickly reached 40 cases from private hospitals without sampling cases from all surgeons, whereas at Wellington Regional Hospital (one of the public hospitals in our sample) we could not reach 40 cases in the time available, despite including nearly every cataract operation. Our methods did not detect any substantial differences between surgeons, and so although the non-random sampling of operations could lead to a non-representative sample, we do not think this led to systematic errors in our estimations of emissions.

To conclude, this study has created a starting point for improving the sustainability of cataract surgery in New Zealand and offers a benchmark for comparison with other hospital systems. Improved methods will be needed to accurately measure how surgical products affect carbon footprints. Our results highlight how working with industry suppliers is perhaps the most effective first step. Central government policy will create high-level and top-down changes, but changes in the behaviour of individual surgeons will also be required. Due to its high volume, cataract surgery is a good early target for meaningfully reducing emissions in New Zealand's healthcare system.

Competing interests:

Nil.

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REFERENCES

1. Costello A, Abbas M, Allen A, Ball S, Bell S, Bellamy R, et al. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. Lancet. 2009;373(9676):1693-733.
2. Watts N, Adger WN, Agnolucci P, Blackstock J, Byass P, Cai W, et al. Health and climate change: policy responses to protect public health. Lancet. 2015;386(10006):1861-914.
3. Chandra P, Gale J, Murray N. New Zealand ophthalmologists' opinions and behaviours on climate, carbon and sustainability. Clin Exp Ophthalmol. 2020; 48(4):427-433.
4. Gale J, Sandhu SS, Loughnan M. Australian ophthalmologists opinions on climate and sustainability. Clin Exp Ophthalmol. 2020;48(8):1118-1121.
5. MacNeill AJ, McGain F, Sherman JD. Planetary health care: a framework for sustainable health systems. Lancet Planet Health. 2021;5(2):e66-e8.
6. Tennison I, Roschnik S, Ashby B, Boyd R, Hamilton I, Oreszczyn T, et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. Lancet Planet Health. 2021;5(2):e84-e92.
7. Malik A, Lenzen M, McAlister S, McGain F. The carbon footprint of Australian health care. Lancet Planet Health. 2018;2(1):e27-e35.
8. Sustainable Development Unit. Carbon footprint update for NHS in England 2015. Cambridge, UK; 2016.
9. Wise J. Climate emergency: new expert panel will set out how NHS can achieve net zero. BMJ. 2020;368:m310.
10. Public sector to be carbon neutral by 2025 [press release]. Wellington: New Zealand Government 2020.
11. Morris DS, Wright T, Somner JE, Connor A. The carbon footprint of cataract surgery. Eye (Lond). 2013;27(4):495-501.
12. Thiel CL, Schehlein E, Ravilla T, Ravindran RD, Robin AL, Saeedi OJ, et al. Cataract surgery and environmental sustainability: Waste and lifecycle assessment of phacoemulsification at a private healthcare facility. J Cataract Refract Surg. 2017;43(11):1391-8.
13. Chang DF. Needless Waste and the Sustainability of Cataract Surgery. Ophthalmology. 2020;127(12):1600-2.
14. Ministry for the Environment. Measuring Emissions: A Guide for Organisations: 2020 Detailed Guide. Wellington, New Zealand: Ministry for the Environment; 2020.
15. Department for Environment Food and Rural Affairs. 2011 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors. London: Department for Environment, Food and Rural Affairs; 2011.
16. Ministry of Business Innovation and Employement. Energy in New Zealand 2020. Wellington: Ministry of Business Innovation and Employment; 2020.
17. Chang DF, Thiel CL,

Ophthalmic Instrument C, Sterilization Task F. Survey of cataract surgeons' and nurses' attitudes toward operating room waste. J Cataract Refract Surg. 2020;46(7):933-40.

18. Petrunoff N, Rissel C, Wen LM, Martin J. Carrots and sticks vs carrots: Comparing approaches to workplace travel plans using disincentives for driving and incentives for active travel. Journal of Transport and Health. 2015;2(4):563-7.
19. Woodcock J, Banister D, Edwards P, Prentice AM, Roberts I. Energy and transport. Lancet. 2007;370(9592):1078-88.