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# Neighbourhood socioeconomic and transport disadvantage: The potential to reduce social inequities in health through transport

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ABSTRACT

Globally, concerns about population growth, urbanisation, traffic congestion, climate change and rising chronic disease are prompting policy-makers and governments to prioritise policies that support local walking and increase access to public transport. These are of particular relevance for those more likely to experience transport disadvantage, such as those in socioeconomically disadvantaged areas, where transport disadvantage tends to be higher. The aim of this study was to examine associations between neighbourhood socioeconomic disadvantage and transport-related spatial measures, identified through a review of transport-related policies. It included 2460 neighbourhoods in Brisbane, Australia as defined by the 2011 Australian national census boundaries. Neighbourhood socioeconomic disadvantage was measured using a census-derived composite index. Policy-relevant spatial measures included: street connectivity, cul-de-sac length, street block length, traffic volume, public transport stops and public transport frequency. Data were analysed using binary and multinomial logistic regression. More disadvantaged neighbourhoods had significantly greater odds of being highly connected, and with cul-de-sac and street block lengths, and public transport stop access and frequencies at levels recommended by Australian urban and transport policies, although they also had higher traffic volumes. Compared with more advantaged neighbourhoods, there was no evidence that disadvantaged neighbourhoods in Brisbane experience transport disadvantage. Although these neighbourhoods have higher levels of traffic, they are more likely to comprise urban and transport design features and levels of public transport access recommended by Australian urban and transport policies. The distribution of transport-related infrastructure in Brisbane has potential to reduce health inequities; and could potentially be enhanced further by reducing exposure to traffic.

## 1. Introduction

Transport access is a social determinant of health, offering the means to reach essential services, facilities, and activities including employment, medical care, education, shops and social networks, all of which affect quality of life (Spinney et al., 2009). To this end, ‘transport disadvantage’ has been defined as the inability to travel when and where one needs to without difficulty (Denmark, 1998).

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Lack of mobility and accessibility to public transport have been shown to be positively associated with socioeconomic disadvantage and social exclusion (Lucas, 2012). Links between transport disadvantage and neighbourhood deprivation have been demonstrated both in the UK (Lucas et al., 2009) and in Australia (Currie et al., 2009; Currie et al., 2010; Dodson et al., 2010; Stanley et al., 2010).

Residents of disadvantaged neighbourhoods have been shown to exhibit poorer health behaviours and outcomes, even after adjusting for their individual-level socioeconomic position (Rachele et al., 2016; Rachele et al., 2015; Rachele and Turrell, 2016; Turrell et al., 2010; Turrell et al., 2012; Brennan and Turrell, 2012; Loh et al., 2016). The need to address such inequalities has been acknowledged internationally (Marmot et al., 2008). Using active and public transport, in lieu of driving is one mechanism for reducing health inequities. First, increases in transport-related physical activity can reduce levels of overweight and obesity (Webb et al., 2012). A systematic review of 30 health impact modelling studies, which quantify benefits from walking or cycling due to increases in physical activity, as well as resulting risks from exposure to air pollution or crashes, demonstrated that health benefits from active travel consistently outweigh risks (Mueller et al., 2015). Even public transport users undertake more incidental physical activity compared with car users, because they walk between origins, transit stops and their destinations (Mees and Groenhart, 2012). Second, health inequities can be reduced through decreases in material deprivation via no longer needing to own and operate one or more motor vehicles because no other transport options are available (‘forced car ownership’) (Gleeson and Randolph, 2002).

Transport and urban design policy can promote healthy and safe behaviours equitably, by prioritising active and public transport (Marmot et al., 2008). For example, transport disadvantage could be ameliorated by investing in walking and public transport infrastructure around socioeconomically disadvantaged neighbourhoods. Addressing transport disadvantage at a policy level will not only assist individuals to access essential services such as employment, education, and recreation, it will also create a healthier, more equitable society, in line with the Australian Government's principles of social inclusion (Rosier and McDonald, 2011). The equitable distribution of transport infrastructure in socioeconomically advantaged and disadvantaged neighbourhoods could therefore help reduce health and social inequities. Government policy shapes the physical makeup of communities and the distribution of services to those most in need. It could therefore play a key role in creating neighbourhoods that support active travel, and enhance equitable access.

The local built environment has the potential to reduce health inequities by providing more equitable access to transport infrastructure; hence, the relationship between neighbourhood-level socioeconomic disadvantage and transport infrastructure is important. This study examined associations between neighbourhood socioeconomic disadvantage and land use and transport measures of urban design features, using the City of Brisbane as a case study. Brisbane has a medium density urban environment, with a population of 1.2 million in 2015 (Australian Bureau of Statistics, 2005), managed by the a single council (Sinnewe et al., 2015). This study builds on our previous work examining policy-derived spatial transport measures, using data obtained from Brisbane City Council (Rachele et al.,). In order to maximise the policy-relevance of this study's findings, the spatial measures used were sourced from state-level government spatial transport policies across selected Australian states. Creating spatial measures that are derived from policy are useful for monitoring the success (or otherwise) of current policy, and inform the development of future neighbourhood land use and transport policies that would help to deliver more walkable, liveable environments that promote active travel (Greenwood, 2008; Badland et al., 2015; Badland et al., 2017). This approach differs from most research to date, which derives spatial built environment measures from the literature (Turrell et al., 2013) or environmental audits (Cerin et al., 2013).

## 2. Methods

### 2.1. *Identification of spatial measures*

To enable development of policy-relevant measures, in 2014, we identified current state-level transport policies in all Australian states participating in the Natonal Liveability Study (i.e.,the Australian Capital Territory (ACT), New South Wales (NSW) Queensland (QLD), Victoria (VIC), and Western Australia (WA)). We sought state policies because, in Australia, each state develops their own transport policies, and these may differ across different jurisdictions. The research team reviewed the policies and excluded those for which spatial measures were unable to be developed. The final list of spatial transport measures (Table 1) was reviewed for completeness by the National Liveability Study's Advisory Group, which consisted of state and federal policy-makers, practitioners, and non-government organisations. Five policy-relevant spatial transport measures relevant to neighbourhood design were identified for inclusion (street connectivity (from NSW), cul-de-sac length (WA and NSW), street block length (VIC) and traffic volume (NSW); and four policy-relevant measures related to public transport access (public transport stops (VIC, WA and NSW) and public transport frequency (NSW))).

**Table 1**
Broad policy areas and number of policies identified for inclusion.

| Broad area | All relevant policies identified | Spatial policies identified |
|---|---|---|
| Neighbourhood design | 17 | 5 |
| Public transport | 22 | 4 |
| Cycling | 10 | 0 |
| Footpaths | 10 | 0 |
| Speed/parking | 14 | 0 |
| Aesthetics | 5 | 0 |
| **Total** | **78** | **9** |

**Table 2**
State-level spatial policy measures, spatial measure development, and modelling approach.

| Quantitative policy measure | Spatial measure | Modelling |
|---|---|---|
| **Neighbourhood design** | | |
| ***Connectivity*** | | |
| High proportion of potential 400 m walking catchment is walkable (New South Wales Government, 2004) | 400 m pedshed ratio around population weighted centroid of SA1 | Divided into quintiles |
| ***Cul-de-sac length*** | | |
| Maximum cul-de-sac length is less than or equal to 120 m (Department for Planning and Infrastructure, 2009) | Maximum cul-de-sac length per SA1 | Dichotomised into > 120 m vs ≤ 120 m |
| Maximum cul-de-sac length is less than or equal to 80 m(Transport Planning Section Sydney Client Services, 2002) | Maximum cul-de-sac length per SA1 | Dichotomised into > 80 m vs ≤ 80 m |
| ***Street block length*** | | |
| Street blocks 120–240 m long and 60–120 m wide (Victoria State Government and ELWa, 2006) | Average Block Length (metres) per SA1 | Dichotomised into > 240 m vs ≤ 240 m |
| ***Traffic volume*** | | |
| 85% of households should be located on a road with a traffic volume less than 1500 vehicles per day (Transport Planning Section Sydney Client Services, 2002) | Traffic volume for SA1 | Divided into quintiles |
| **Public transport** | | |
| ***Public transport stops*** | | |
| 400 m street walking distance around each existing or proposed bus stop (Victoria State Government and ELWa, 2006) | Number of stops within SA1 (greater than 0 aligns with policy) | Dichotomised into > 400 m vs ≤ 400 m |
| ≥ 60% of dwellings should be in a safe 400 m walk from a neighbourhood or town centre, or an existing or potential bus stop (Department for Planning and Infrastructure, 2009) | | |
| Every household should be within 400 m of a bus stop (Department of Urban Affairs and Planning, 2001) | | |
| ***Public transport frequency*** | | |
| Every household should be within 400 m of a bus stop, with at least 1 service every 30 min (Department of Urban Affairs and Planning, 2001) | Mean number of public transport trips per stop that visit this SA1 between 7am and 7 pm | Dichotomised into ≥ 2 services / hour vs < 2 services / hour |

*SA1 = Statistical Area Level 1

## 2.2. Creation of spatial measures

Spatial measures (Table 2) were calculated at the Statistical Area Level 1 (SA1) geography (Australian Bureau of Statistics, 2011) which defined neighbourhoods in this study. These geographic areas generally have a population of 200 to 800 persons, and an average of about 400 persons domiciled. SA1s had spatial measures calculated if their polygon centroid was located within the Brisbane City Council Local Government Area. Spatial measures were developed using ArcGIS 10.2 (Environmental Systems Research Institute, 2011) including the Network Analyst extension for routing and distance calculations and BetterBusBuffers (Environmental Systems Research Institute, 2015) toolset for analysing bus service frequency.

The spatial measures were developed from spatial transport policies where data were readily accessible. Sources of data included Brisbane City Council, Department of Transport and Main Roads (QLD) and Pitney Bowes Australia Pty Ltd. The traffic volume measure was calculated based on a proxy measure of vehicles per day traversing each road segment. The proxy measure was based on the road hierarchy classification of road segments (measured in metres). The equation used was: Σ (Highway, Freeway, Main Road, Connector Road) / Σ (Local Road, Minor Road) with a higher ratio indicating a higher traffic volume. The public transport frequency measure used the General Transit Feed Specification (GTFS) (Queensland Government, 2016), a widely adopted, standardized format for public transportation schedules and associated geographic information.

## 2.3. Neighbourhood disadvantage

Overall, 2572 SA1s existed in Brisbane in 2011, and 2463 (95.8%) were able to be assigned a socioeconomic score using the Australian Bureau of Statistics' (ABS) Index of Relative Socioeconomic Disadvantage (IRSD) (Australian Bureau of Statistics, 2011), relative to the whole of Brisbane. Spatial measures could not be produced by the ABS for three neighbourhoods due to either the type of area, low populations, or poor data quality (Australian Bureau of Statistics, 2011), leaving n = 2460 neighbourhoods in the final analytic sample. The IRSD scores were calculated using 2011 census data and derived by the ABS using principal components analysis. A neighbourhood's IRSD score reflects each area's overall level of disadvantage measure on the basis of 17 variables that capture a wide range of socioeconomic attributes, including: education, occupation, income, unemployment, household structure, and household tenure (among others) (Australia Bureau of Statistics, 2006). For analysis, the 2460 neighbourhoods in Brisbane were grouped into quintiles based on their IRSD scores with Q5 denoting the 20% (n = 492) most disadvantaged areas relative to the whole of Brisbane and Q1 the least disadvantaged 20% (n = 492). The dispersal of advantaged and disadvantaged neighbourhoods in Brisbane is shown in Fig. 1.

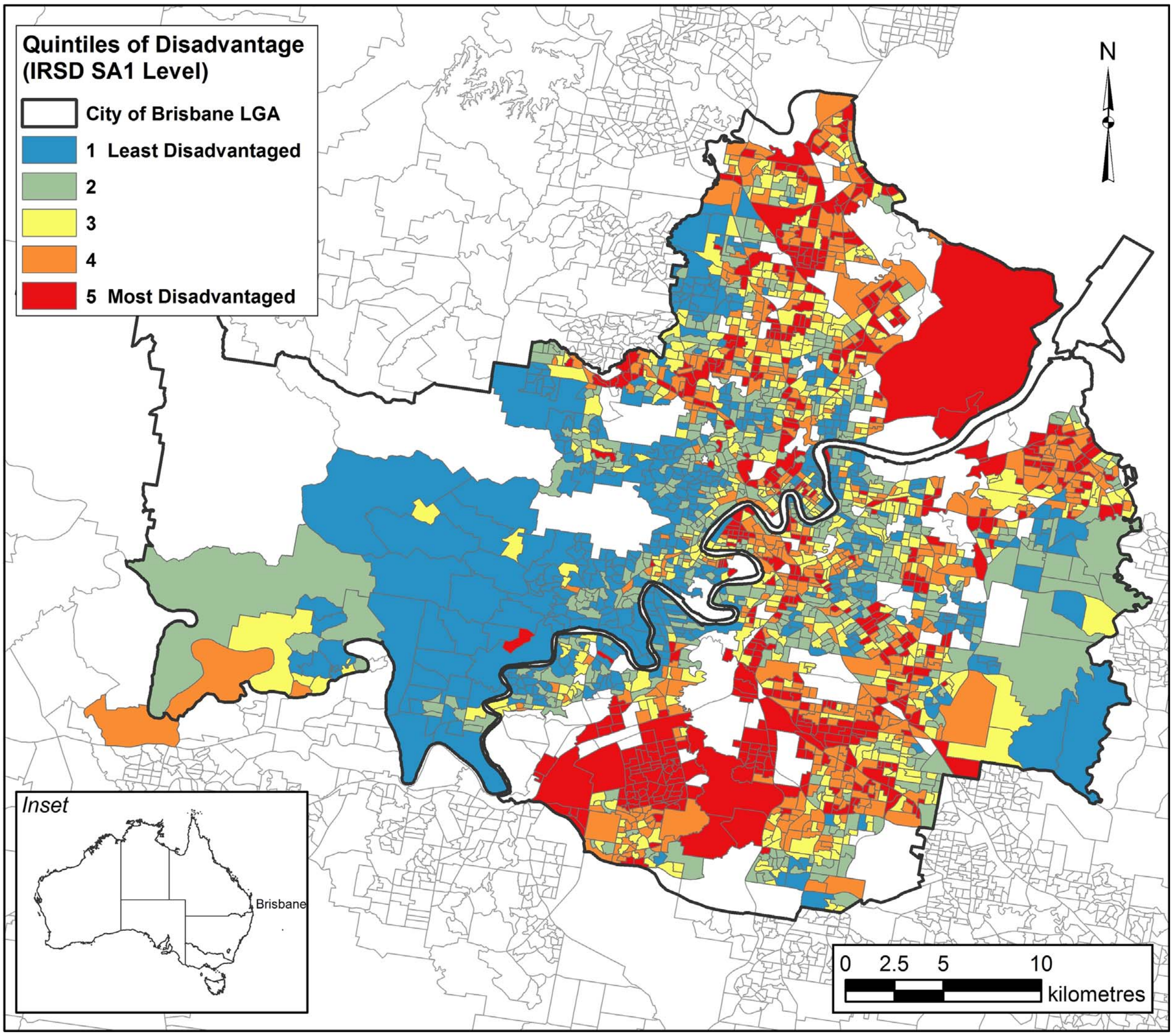


**Fig. 1.** Quintiles of neighbourhood disadvantage in Brisbane, Australia, assigned using the Australian Bureau of Statistics' Index of Relative Socioeconomic Disadvantage from the 2011 census.

### *2.4. Statistical analysis*

Binomial dependent variables were analysed using binary logistic regression, and multinomial dependent variables were analysed using multinomial logistic regression. The lowest walkability and highest traffic volume were used as the reference groups for multinomial outcomes, while not aligning with the transport policy was the reference group for binary outcomes. Neighbourhood disadvantage was the independent variable in all analyses, and the least disadvantaged neighbourhoods (Q1) was the reference group. All analyses were conducted using StataSE version 13 (StataCorp, 2013).

## **3. Results**

The associations between neighbourhood disadvantage and the policy-relevant transport measures are presented in Table 3. Neighbourhood disadvantage was positively associated with the six spatial measures regarding creating walkable communities and increasing access to public transport; and negatively associated with one spatial measure that influenced the desirability of walking.

Disadvantaged neighbourhoods in Brisbane were more likely to have 'highly connected street networks'; for example, neighbourhoods with the highest connectivity were 3.17 (95%CI 2.11, 4.7) times more likely to be the most socioeconomically disadvantaged. Disadvantaged neighbourhoods were also more likely to have shorter cul-de-sac lengths (less than 80 m and 120 m), and street block lengths (i.e., less than 240 m). Shorter cul-de-sac and street blocks increase the connectivity of neighbourhoods. Disadvantaged neighbourhoods were also more likely to have a stop within 400 m, and at least two public transport services per hour.

**Table 3**
Associations between transport liveability policies and neighbourhood disadvantage in Brisbane City, Australia.

| N = 2460 neighbourhoods | Q1 (least disadvantaged) | Q2 | | Q3 | | Q4 | | Q5 (most disadvantaged) | |
|---|---|---|---|---|---|---|---|---|---|
| | | OR | 95%CI | OR | 95%CI | OR | 95%CI | OR | 95%CI |
| **Neighbourhood design** | | | | | | | | | |
| ***Street connectivity***[a] | | | | | | | | | |
| Q5 (lowest, 0.00–0.17) | 1.00 | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Q4 (0.17–0.24) | 1.00 | 1.46 | 0.99, 2.15 | 1.44 | 0.98, 2.12 | 1.89 | 1.30, 2.77 | 1.55 | 1.05, 2.29 |
| Q3 (0.24–0.31) | 1.00 | 1.78 | 1.21, 2.62 | 1.81 | 1.23, 2.65 | 1.92 | 1.30, 2.83 | 1.70 | 1.14, 2.52 |
| Q2 (0.31–0.38) | 1.00 | 1.71 | 1.16, 2.53 | 1.86 | 1.27, 2.74 | 1.69 | 1.14, 2.52 | 2.14 | 1.45, 3.15 |
| Q1 (highest, 0.38–1.00) | 1.00 | 2.91 | 1.94, 4.35 | 2.40 | 1.59, 3.62 | 2.62 | 1.73, 3.96 | 3.17 | 2.11, 4.77 |
| ***Cul-de-sac length*** | | | | | | | | | |
| > 80 m | 1.00 | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| ≤ 80 m | 1.00 | 1.25 | 0.95, 1.65 | 1.49 | 1.13, 1.97 | 1.74 | 1.32, 2.28 | 1.74 | 1.32, 2.28 |
| ***Cul-de-sac length*** | | | | | | | | | |
| > 120 m | 1.00 | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| ≤120 m | 1.00 | 1.43 | 1.11, 1.85 | 1.70 | 1.32, 2.19 | 1.79 | 1.38, 2.30 | 1.91 | 1.48, 2.46 |
| ***Street block length*** | | | | | | | | | |
| > 240 m | 1.00 | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| ≤240 m | 1.00 | 1.90 | 1.13, 3.22 | 2.97 | 1.62, 5.43 | 1.90 | 1.13, 3.22 | 1.39 | 0.86, 2.25 |
| ***Traffic volume***[b] | | | | | | | | | |
| Q5 (highest, 0.70–9.26) | 1.00 | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Q4 (0.41–0.70) | 1.00 | 0.68 | 0.44, 1.05 | 0.94 | 0.60, 1.43 | 0.74 | 0.49, 1.11 | 0.77 | 0.51, 1.15 |
| Q3 (0.25–0.41) | 1.00 | 0.76 | 0.50, 1.16 | 1.02 | 0.67, 1.56 | 0.50 | 0.33, 0.75 | 0.63 | 0.42, 0.94 |
| Q2 (0.12–0.25) | 1.00 | 0.67 | 0.45, 1.03 | 0.95 | 0.63, 1.44 | 0.41 | 0.27, 0.61 | 0.41 | 0.27, 0.62 |
| Q1 (lowest, 0.00–0.12) | 1.00 | 0.72 | 0.48, 1.06 | 0.60 | 0.40, 0.92 | 0.31 | 0.21, 0.46 | 0.27 | 0.18, 0.41 |
| **Public transport** | | | | | | | | | |
| ***Public transport stops*** | | | | | | | | | |
| > 400 m | 1.00 | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| ≤ 400 m | 1.00 | 1.48 | 1.02, 2.14 | 1.58 | 1.09, 2.29 | 1.43 | 0.99, 2.06 | 2.54 | 1.67, 3.86 |
| ***Public transport frequency*** | | | | | | | | | |
| < 2 services / hour | 1.00 | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| ≥ 2 services / hour | 1.00 | 1.61 | 1.13, 2.30 | 1.74 | 1.22, 2.50 | 1.61 | 1.13, 2.30 | 3.02 | 1.98,4.57 |

[a] Pedshed ratio at the SA1 level,
[b] Σ (Highway, Freeway, Main Road, Connector Road) / Σ (Local Road, Minor Road).

However, disadvantaged neighbourhoods were least likely (OR 0.27 95%CI 0.18, 0.41) to have the lowest traffic volumes (i.e., traffic exposure was higher in disadvantaged neighbourhoods).

## 4. Discussion

This study developed spatial transport measures based on current urban design and transport policies from selected Australian states; and examined associations with neighbourhood disadvantage using Brisbane City as a case study. Brisbane's most disadvantaged neighbourhoods were more likely to have incorporated transport and urban design principles found in the review of state-level policies; creating more walkable neighbourhoods and increasing access to public transport. However, more disadvantaged neighbourhoods had higher traffic volumes. This is of concern because exposure to higher traffic volumes have been shown to be associated with increased air pollution causing poorer respiratory health, and increased cardiovascular disease (Gan et al., 2012; Volpino et al., 2004); as well as increasing the risk of road trauma (Giles-Corti et al., 2016).

Previous research from Melbourne, Australia suggests that housing affordability has forced many low-income households out of inner-city areas into outer-suburban locations (Burke and Hayward, 2000). These low density outer-suburban areas foster motor vehicle dependency (Randolph and Holloway, 2005), and are poorly served by public transport (Currie et al., 2009), and shops and local services. Similar findings have been found for South-East Queensland more broadly: Dodson and Sipe (2007) found that disadvantaged neighbourhood in greater Brisbane were more vulnerable to rising fuel costs, and Johnson and Herath (2004) found links between transport access, transport disadvantage, and social disadvantage. On the contrary, previous investigations of the neighbourhood built environment, neighbourhood disadvantage, and health-promoting transport behaviours that have been undertaken within the City of Brisbane have found that residents of more disadvantaged neighbourhoods are more likely to walk for transport (Rachele et al., 2015; Turrell et al., 2014), and that they have built environments that are more conducive to walking (Turrell et al., 2013). Our findings suggest that within the City of Brisbane, there is potential for health inequities and transport disadvantage to be reduced due to the urban design of disadvantaged communities being consistent with a wide-range of contemporary Australian urban design and transport policies that are likely to create more walkable neighbourhoods, and increasing access to public transport. It should be noted however, that there is scope for the transport policies that we identified to be improved. For example, when developing policies designed to increase rates of public transport patronage, factors such as network connectivity and accessibility to meaningful destinations (e.g. employment, education, retail nodes) speed, reliability, ease of transfers and the cost of fares should also be considered (Redman et al., 2013).

One area that the current study found that has potential to reduce inequities further is decreasing traffic exposure in disadvantaged areas. We found that more disadvantaged areas are more likely to have higher traffic volumes in the local area (albeit measured with a road hierarchy as a proxy for traffic volume, rather than actual counts of motor vehicles), compared with less disadvantaged areas. Reducing traffic volumes would also help reduce injury and death from motor vehicle accidents, as well as noise and air pollution, all of which have been found to be higher in disadvantaged areas (Fairburn and Braubach, 2010). Where possible, policy-makers should endeavour to employ strategies that mitigate the harmful effects of increased traffic exposure. For example, roadway designs that facilitate slower vehicle speeds have been shown to reduce the likelihood of a traffic related incident between vehicles and pedestrians from occurring, and reduce the severity of injury to pedestrians if incidents do occur (Stoker et al., 2015). Such strategies should be undertaken in addition to those that reduce overall traffic volumes within residential neighbourhoods. Recent evidence suggests that cities actively pursue compact and mixed-use urban designs that encourage transport mode shift away from private motor vehicles, and towards walking, cycling, and public transport (Sallis et al., 2016). For example, Stevenson et al. (2016) shows that cities of short distances that promote increased residential density, mixed land use, proximate and enhanced public transport, and an urban form that encourages cycling and walking are likely to result in health gains including reductions in rates of diabetes, cardiovascular disease, and respiratory disease, and improvements in disability-adjusted life years.

It should be noted that this study focused on associations between socioeconomic disadvantage and policy-derived land use and transport measures at the neighbourhood level. Extrapolations of these findings to individuals should be made with caveats. For example, previous studies in Brisbane have found that, compared with using a private motor vehicle as a usual form of transport, residents of disadvantaged neighbourhoods were more likely to walk for transport, as were individuals with the lowest levels of education, occupation, and household income (Rachele et al., 2015). However, while Turrell et al. (2014) also found that residents of the most disadvantaged neighbourhoods in Brisbane were more likely to walk for transport, those with the lowest individual-level characteristics were less likely to walk for transport. The two levels of analysis (individual and neighbourhood) are not synonymous, and addressing transport disadvantage among socioeconomically disadvantaged neighbourhoods does not necessarily mean that transport disadvantage is also being addressed among socioeconomically disadvantaged individuals. However, this should not discourage more equitable investment in transport infrastructure: individuals who are more likely to be transport disadvantaged are also more likely to reside in socioeconomically disadvantaged areas (Denmark, 1998; Australia Bureau of Statistics, 2006). Rather, the research agenda moving forward should focus on disentangling the complex relationships between transport disadvantage and socioeconomic disadvantage at both the individual and neighbourhood level; and more broadly, how these interact to influence health. Investigating this issue may require a longitudinal approach that examines the long-term impact of the material deprivation associated with forced-car ownership, as well as physical activity associated with using different modes of transport.

This study has several limitations. First, transport policies administered by local governments were not reviewed, as we focussed on policies administered at the state-level. Second, the generalizability of this study's findings will likely depend on cities with similarities to Brisbane, both in geographical area and population distribution, and specifically the spatial patterning of socioeconomic disadvantage. Further, Brisbane (along with other major Australian cities) has been experiencing gentrification over the past three decades (Randolph and Tice, 2016), and the generalizability of this study's findings are likely to be limited to this period in time. Third, we did not have the resources to gather and apply spatial measures beyond the City of Brisbane. The exclusion of contiguous urban areas such as those within the Shire of Caboolture, Redland Shire, Gold Coast City, and Ipswich (contiguous localities defined in the ABS Social Atlas (Austalian Bureau of Statistics, 2008) for Brisbane) where there is a higher proportion socioeconomic disadvantage than within the City of Brisbane itself, and with a different spatial patterning of socioeconomic disadvantage (Pawson et al., 2015), is therefore a limitation of this study and should be noted when interpreting this study's findings. Fourth, the spatial measures were designed to match the state-level transport policies as closely as possible given the limitations of available data and the detail described in the policy itself. Dividing the spatial measures into categories such as a simple dichotomous variable simplifies the relationship between the spatial measures and neighbourhood disadvantage. Last, it was noteworthy that we were did not identify any policies related to several urban design features considered important for active transport including land use mix and dwelling density (Giles-Corti et al., 2016), and it is possible that these policies only exist at the local government level. Future investigations of land use and transport urban design features with a specific focus on policies should endeavour to review documentation from all levels of government relevant to the jurisdiction of interest.

## 5. Conclusion

This study found that the provision of urban design and transport infrastructure in Brisbane, Australia is favouring disadvantaged communities. It is possible that, at least in Brisbane, there is potential for such urban design features to reduce health inequities and local transport disadvantage by increasing residents' access to health-promoting urban design and public transport. However, a priority for future research is to investigate mobility and accessibility to other underlying social determents of health that create healthy liveable communities: for example, employment, health care services, education, shops and recreation (Badland et al., 2014), and create environments that encourage physical activity (Rachele et al., 2016; Ghani et al., 2016). Further research should also seek to disentangle the complex relationships between transport disadvantage and socioeconomic disadvantage at both the individual and neighbourhood level; and their impacts on travel behaviours, and health inequities. Evidence that health inequities could be reduced through more equitable provision of active transport infrastructure should empower governments seeking to reduce these inequities to adopt comparable strategies to the City of Brisbane.

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## References

Austalian Bureau of Statistics, 2008. Brisbane… A Social Atlas, 2006. ABS, Canberra.
Australian Bureau of Statistics, 2006. Information Paper: an Introduction to Socioeconomic Indexes for Areas (SEIFA). ABS, Canberra.
Australian Bureau of Statistics, 2011. Socio-Economic Indexes for Areas (SEIFA): Technical Paper. In: Australia Bureau of Statistics, ed. Canberra.
Australian Bureau of Statistics, 2011. Australian Statistical Geography Standard: volume 1-Main Structure and Greater Capital Statistical Areas. ABS, Canberra.
Australian Bureau of Statistics, 2011. Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA). Australia Bureau of Statistics, Canberra.
Australian Bureau of Statistics, 2015. Population estimates by local government area (ASGS 2015) to 2015 Data Cubes. 32180 - regional population growth, Australia, 2014-15.
Badland, H., Whitzman, C., Lowe, M., et al., 2014. Urban liveability: emerging lessons from Australia for exploring the potential for indicators to measure the social determinants of health. Soc. Sci. Med. 111, 64–73.
Badland, H., Mavoa, S., Villanueva, K., et al., 2015. The development of policy-relevant transport indicators to monitor health behaviours and outcomes. J. Transp. Health 2, 103–110.
Badland, H.M., Rachele, J.N., Roberts, R., et al., 2017. Creating and applying public transport indicators to test pathways of behaviours and health through an urban transport framework. J. Transp. Health.
Brennan, S., Turrell, G., 2012. Neighborhood disadvantage, individual-level socioeconomic position, and self-reported chronic arthritis: a cross-sectional multilevel study. Arthritis Care Res. 64, 721–728.
Burke, T., Hayward, D., 2000. Housing Past, Housing Futures: Melbourne Metropolitan Strategy Technical Report 4. Department of Infrastructure, Melbourne.
Cerin, E., Lee K-y, Barnett, A., et al., 2013. Walking for transportation in Hong Kong Chinese urban elders: a cross-sectional study on what destinations matter and when. Int. J Behav. Nutr. Phys. Act. 10, 78.
Currie, G., Richardson, T., Smyth, P., et al., 2009. Investigating links between transport disadvantage, social exclusion and well-being in Melbourne—preliminary results. Transp. Policy 16, 97–105.
Currie, G., Richardson, T., Smyth, P., et al., 2010. Investigating links between transport disadvantage, social exclusion and well-being in Melbourne–updated results. Res Transp. Econ. 29, 287–295.
Denmark, D., 1998. The outsiders: planning and transport disadvantage. J Plan. Educ. Res. 17, 231–245.
Department for Planning and Infrastructure, 2009. Liveable Neighourhoods a Western Australian Government sustainable cities iniative. Western Australian Planning Commission, Perth.
Department of Urban Affiars and Planning, 2001. Urban development program accessibility criterion.
Dodson, J., Sipe, N., 2007. Oil vulnerability in the Australian city: assessing socioeconomic risks from higher urban fuel prices. Urban Stud. 44, 37–62.
Dodson, J., Burke, M., Evans, R., et al., 2010. Travel behavior patterns of different socially disadvantaged groups: analysis of household travel survey data for a dispersed metropolitan area. Transp. Res Rec. 24–31.
Environmental Systems Research Institute, 2011. ArcGIS Desktop: Release 10. Environmental Systems Research Institute Redlands, CA.
Environmental Systems Research Institute, 2015. BetterBusBuffers created by Melinda Morang.
Fairburn J., Braubach M., 2010. Social inequalities in environmental risks associated with housing and residential location. In: Environment and Health Risks: a Review of the Influence and Effects of Social Inequalities.
Gan, W.Q., Davies, H.W., Koehoorn, M., et al., 2012. Association of long-term exposure to community noise and traffic-related air pollution with coronary heart disease mortality. Am. J Epidemiol. 175, 898–906.
Ghani, F., Rachele, J.N., Washington, S., et al., 2016. Gender and age differences in walking for transport and recreation: are the relationships the same in all neighborhoods? Prev. Med Rep. 4, 75–80.
Giles-Corti, B., Vernez-Moudon, A., Reis, R., et al., 2016. City planning and population health: a global challenge. Lancet 388, 2912–2924.
Gleeson, B., Randolph, B., 2002. Social disadvantage and planning in the Sydney context. Urban Policy Res. 20, 101–107.
Greenwood, T., 2008. Bridging the divide between community indicators and government performance measurement. Natl. Civ. Rev. 97, 55–59.
Johnson, L., Herath, S., 2004. Big roads, no transport: a report of the Goodna and Gailes community mapping for transport improvements study. Griffith University.
Loh, V.H.Y., Rachele, J.N., Brown, W.J., et al., 2016. Neighborhood disadvantage, individual-level socioeconomic position and physical function: a cross-sectional multilevel analysis. Prev. Med. 89, 112–120.
Lucas, K., 2012. Transport and social exclusion: where are we now? Transp. Policy 20, 105–113.
Lucas, K., Tyler, S., Christodoulou, G., 2009. Assessing the 'value'of new transport initiatives in deprived neighbourhoods in the UK. Transp. Policy 16, 115–122.
Marmot, M., Friel, S., Bell, R., et al., 2008. Closing the gap in a generation: health equity through action on the social determinants of health. Lancet 372, 1661–1669.
Mees P., Groenhart L., 2012. Transport Policy at the Crossroads: Travel to work in Australian capital cities 1976–2011. Melbourne, Australia. Dec.
Mueller, N., Rojas-Rueda, D., Cole-Hunter, T., et al., 2015. Health impact assessment of active transportation: a systematic review. Prev. Med. 76, 103–114.
New South Wales Government, 2004. Planning Guidelines for Walking and Cycling. NSW Government, Sydney.
Pawson H., Hulse K., Cheshire L., 2015. Addressing concentrations of disadvantage in urban Australia.
Queensland Government, 2016. General transit feed specification (GTFS)—South East Queensland.
Rachele, J.N., Ghani, F., Loh, V.H.Y., et al., 2016. Associations between physical activity and the neighbourhood social environment: baseline results from the HABITAT multilevel study. Prev. Med.
Rachele, J.N., Giles-Corti, B., Turrell, G., 2016. Neighbourhood disadvantage and self-reported type 2 diabetes, heart disease and comorbidity: a cross-sectional multilevel study. Ann. Epidemiol. 26, 146–150.
Rachele, J.N., Learnihan, V., Badland, H.M., et al., 2018. Are measures derived from land use and transport policies associated with walking for transport? J. Phys. Activ. Health 15 (1) (in press). https://doi.org/10.1123/jpah.2016-0693.
Rachele, J.N., Kavanagh, A.M., Badland, H., et al., 2015. Associations between individual socioeconomic position, neighbourhood disadvantage and transport mode: baseline results from the HABITAT multilevel study. J. Epidemiol. Community Health 69, 1217–1223.
Rachele, J.N., Wood, L., Nathan, A., et al., 2016. Neighbourhood disadvantage and smoking: examining the role of neighbourhood-level psychosocial characteristics. Health Place 40, 98–105.
Randolph, B., Holloway, D., 2005. Social disadvantage, tenure and location: an analysis of Sydney and Melbourne. Urban Policy Res. 23, 173–201.
Randolph, B., Tice, A., 2016. Relocating disadvantage in five Australian cities: socio-spatial polarisation under neo-liberalism. Urban Policy Res. 1–19.
Redman, L., Friman, M., Gärling, T., et al., 2013. Quality attributes of public transport that attract car users: a research review. Transp. Policy 25, 119–127.
Rosier, K., McDonald, M., 2011. The Relationship Between Transport and Disadvantage in Australia. Australian Institute of Family Studies.
Sallis, J.F., Bull, F., Burdett, R., et al., 2016. Use of science to guide city planning policy and practice: how to achieve healthy and sustainable future cities. Lancet 388,

2936–2947.
Sinnewe, E., Kortt, M.A., Dollery, B., 2015. Is biggest best? A comparative analysis of the financial viability of the Brisbane City Council. Aust. J. Public Admin.
Spinney, J.E., Scott, D.M., Newbold, K.B., 2009. Transport mobility benefits and quality of life: a time-use perspective of elderly Canadians. Transp. Policy **16**, 1–11.
Stanley, J., Stanley, J., Vella-Brodrick, D., et al., 2010. The place of transport in facilitating social inclusion via the mediating influence of social capital. Res. Transp. Econ. 29, 280–286.
StataCorp, 2013. Stata Statistical Software: Release 13. StataCorp, College Station, TX.
Stevenson, M., Thompson, J., de Sá, T.H., et al., 2016. Land use, transport, and population health: estimating the health benefits of compact cities. Lancet **388**, 2925–2935.
Stoker, P., Garfinkel-Castro, A., Khayesi, M., et al., 2015. Pedestrian safety and the built environment: a review of the risk factors. CPL Bibliogr. 30, 377–392.
Transport Planning Section Sydney Client Services, 2002. Road traffic authority guide to traffic generating developments. Blacktown.
Turrell, G., Haynes, M., Burton, N.W., et al., 2010. Neighborhood disadvantage and physical activity: baseline results from the HABITAT multilevel longitudinal study. Ann. Epidemiol. 20, 171–181.
Turrell, G., Hewitt, B.A., Miller, S.A., 2012. The influence of neighbourhood disadvantage on smoking cessation and its contribution to inequalities in smoking status. Drug Alcohol Rev. **31**, 645–652.
Turrell, G., Haynes, M., Wilson, L.-A., et al., 2013. Can the built environment reduce health inequalities? A study of neighbourhood socioeconomic disadvantage and walking for transport. Health Place 19, 89–98.
Turrell, G., Hewitt, B., Haynes, M., et al., 2014. Change in walking for transport: a longitudinal study of the influence of neighbourhood disadvantage and individual-level socioeconomic position in mid-aged adults. Int. J Behav. Nutr. Phys. Act. 11, 0151–0157.
Victoria State Government, 2006. State planning policy framework. In: Planning ELWa, ed.
Volpino, P., Tomei, F., La Valle, C., et al., 2004. Respiratory and cardiovascular function at rest and during exercise testing in a healthy working population: effects of outdoor traffic air pollution. Occup. Med. 54, 475–482.
Webb, E., Netuveli, G., Millett, C., 2012. Free bus passes, use of public transport and obesity among older people in England. J. Epidemiol. Community Health 66, 176–180.