Sustainable Healthy Cities
A National Science Foundation-supported Sustainability Research Network (SRN)

JOURNAL BRIEF: Identifying Thresholds for When Built Environment Variables Affect Transportation CO_2 Emissions

Sustainable Healthy Cities Journal Brief - 2019, No. 19 - Built Environment and CO_2 Emissions

This brief is adapted from the following peer-reviewed journal article: Wu, X., Tao, T., Cao, J., Fan., Y, & A. Ramaswami. (2019). Examining threshold effects of built environment elements on travel-related carbon dioxide emissions. Transportation Research Part D, 75(2019) 1-12.

Study Intent and Research Question

What are the thresholds above or below which built environment characteristics—e.g. land use mix, distance to transit, jobs/population density etc.—affect transportation-related CO_2 emissions? This study uses a new analysis method to focus on the thresholds above and below which certain built environment variables have the most substantial impact on transportation-related CO_2 emissions in the Minneapolis-St. Paul area. Knowing more about thresholds can inform planning decisions by providing a more nuanced view of the point at which investments in certain built environment characteristics can expect to yield substantial effects on CO_2 emissions.

Key Background Information

Studies show that built environment factors—e.g. density and land use—influence travel behavior and CO_2 emissions as a result of influencing vehicle ownership, travel distance, mode choice, trip frequency, and/or travel speeds.

Existing aggregate research at the neighborhood or city level shows that land use and transportation policies could have a large effect on CO_2 emissions. But existing aggregate studies do not show mechanisms of how certain built environment variables affect CO_2 emissions.

Studies of disaggregate variables using household or individual data show that travel-related CO_2 emissions are influenced by the five "Ds" of the built environment: distance to city center, density, diversity of land use, design of streets/their networks, and distance to transit.

Traditional regression analysis of built environment impact on CO_2 emissions assumes a continuous linear relationship between a given variable and emissions, ignoring the possibility of thresholds.

A threshold effect can be important because it means the CO_2 mitigating effect of an intervention can either increase or decrease dramatically after passing a certain threshold (Galster, 2018).

Key Findings

Land use diversity surrounding a residence had the largest contribution to CO_2 mitigation (18.4%), followed by job density (7.5%), distance to downtown Minneapolis (6.9%) and distance to downtown St. Paul (5.9%).

Distance to downtown: As a household is located farther from downtown Minneapolis, its travel-related emissions increase substantially until the ten-mile mark, after which emissions plateau. Reducing distance to downtown from 20 miles to 15 miles will likely not have a large impact, because it falls outside the threshold, whereas a reduction from 10 miles to 5 miles would have a substantial impact.

Distance to transit: As distance to transit grows between zero and one mile, CO_2 emissions increase steadily. Beyond one mile, emissions stabilize. This means that reducing distance to transit for residents already within one mile of a transit stop is likely to reduce their CO_2 emissions. However, reducing distance to transit from 2 miles to 1.5 miles will not substantially reduce emissions.

Population and job density: Between zero and 10 people per acre, CO_2 emissions decrease as population density rises. After 10 people per acre, carbon emissions start to increase again (modestly) as density increases, likely due to increased per capita activity at higher population densities. Between zero and 10 jobs per acre, CO_2 emissions decrease dramatically as job density increases. After the threshold of 10 jobs per acre is reached, the decrease in carbon emissions is much less dramatic per additional job added.

Land use diversity: When land use is relatively homogeneous in an area, increases in land use diversity have little influence on carbon emissions. When there is one relatively dominant land use type and several other land use types present, additional increases in land use

diversity demonstrate significant emissions reductions. Once land use diversity is relatively mixed/evenly distributed in an area, additional increases in diversity show minimal CO_2 reduction.

Intersection density: As intersection density increases, CO_2 emissions increase. While literature suggests intersection density should have a negative impact on emissions due to associations with walkability and transit, an easy-to-navigate grid network could also result in increased car trips.

Policy and Practice Implications

While existing literature shows that investments in the five "Ds" can help reduce carbon emissions, not every investment in every "D" will yield the same level of emissions reduction per unit of intervention.

Knowing the threshold effects of different built environment factors can help planners know what level of investment/degree of intervention might be necessary to achieve certain effects. Certain interventions will not yield substantial carbon mitigation effects until the relevant threshold is met.

Thresholds can also help reveal points at which additional investment/degree of intervention will yield diminishing returns. Beyond certain levels, some interventions stop yielding robust emissions reductions, indicating that once such thresholds are reached, investment might be better directed elsewhere/toward other interventions.

Transportation

Environmental Sustainability

Integrative Scenario Modeling

Further Reading and References

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About the Sustainable Healthy Cities Network

The Sustainable Healthy Cities Network is a U.S. National Science Foundation supported sustainability research network focused on the scientific advancement of integrated urban infrastructure solutions for environmentally sustainable, healthy, and livable cities. We are a network of scientists, industry leaders, and policy partners, committed to building better cities through innovations in infrastructure design, technology and policy. Our network connects across nine research universities, major metropolitan cities in the U.S. and India, as well as infrastructure firms and policy groups to bridge research and education with concrete action in cities.