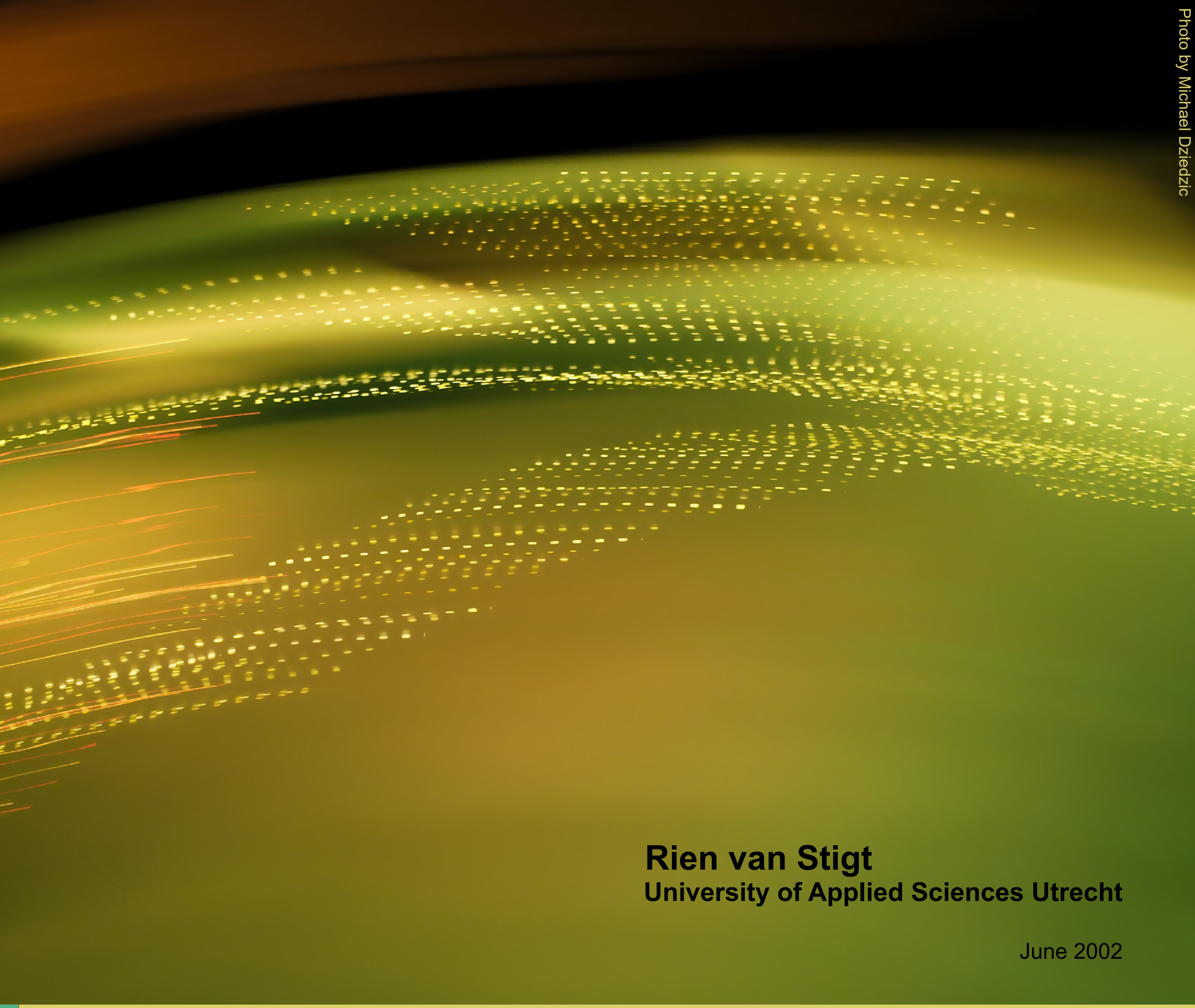

Photo by Michael Dziedzic

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Electric public transport fosters green transit-oriented development

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Densification around nodes of public transport is thought to contribute to healthy and viable cities, provided that the environmental effects of accumulated urban activities are effectively reduced. This approach is known as ‘green transit-oriented development’. By calculating nitrogen dioxide concentrations in three streets in Utrecht, the Netherlands, it is shown that electrification of buses may considerably improve environmental quality, depending on the percentage of bus transit in total street traffic. Accordingly, important benefits for health and annoyance can be expected. Yet, these appear not to result in measurable effects on real estate value. Nevertheless, electrification of city buses is a measure that fits in well with the concept of green transit-oriented development.

Introduction

Individual, fossil fuel-powered transport is known to contribute to both climate change and deterioration of environmental quality in cities (Tsoi and Loo, 2021). This becomes more problematic when a city, as many other cities do, accommodates its population and economic growth largely within existing city limits, to conserve the green and open space surrounding it (De Roo and Miller, 2019; Haaland and Konijnendijk van den Bosch, 2015). The resulting increase in urban density, on the one hand, creates a more viable market for all kinds of urban amenities and services. On the other, however, it causes more noise, higher emissions of pollutants per unit of surface, leaves less room for green spaces within the city and decreases the stormwater permeability of the city’s soil. Cities and their governments, therefore, face so-called compact city dilemmas (Bartelds and De Roo, 1995).

A so-called ‘green transit-oriented’ urban development is advocated as a policy that can deal with this dilemma (Cervero & Sullivan, 2011). High density, mixed function urban development in the direct vicinity of public transport nodes is thought to reduce private car use and stimulate travel by public transport, bicycle and on foot, thus reducing road traffic emissions – this is known as transit-oriented development (TOD). In what is known as ‘green TOD’, additional energy, building, and environmental policies concomitantly counter the negative environmental effects of high urban density.

Electric transit can work both ways: like all transit, it reduces passenger car use, and it further reduces air and, in city conditions, noise pollution from traffic, because it has no exhaust emissions and lower motor noise levels (Jabben et al., 2012; Iversen et al., 2013). In this article, the potential contribution of electric public transport to green transit-oriented development is explored. After a brief introduction of the concept of green TOD, the effects of the replacement of diesel buses with electric ones on air quality are estimated in three representative cases. Then, a discussion is presented on how such a replacement could enhance the attractiveness of green TOD.

What is green transit-oriented development?

Singh et al. (2004) describe transit-oriented development (TOD) as an urban environment with high densities, mixed and diverse land uses, located within an easily walkable area around a transit stop. It is a policy concept that is aimed at both reducing urban sprawl and lowering the dependency on private care use for transportation.

Historically, ‘transit’ has been crucial to urban development. The growth of cities went hand in hand with technical developments of tramways – first horse-powered, later electrical – at the end of the nineteenth century; the fact that cities could reach a metropolitan size thanks to rail transport is still reflected in the name ‘metro’ – from the French ‘métropolitaine’ – for modern rapid urban rail transit systems (Tan et al., 2013). From the 1950s on, the use of automobiles became widespread and the role of public transit diminished. This development led to a phenomenon known as ‘urban sprawl’, where large parts of cities consist of low-density monofunctional residential areas around a central business district, connected to it and to neighbouring industrial areas by direct motorways and highways.

Transit-oriented development entails the integration of land use and transport policies. Instead of developing a residential or business area on the outskirts of the city without considering its accessibility by other than private car transportation, places, where people go to and come from, are carefully planned in relation to existing and new axes and nodes of public transport. Such an integrated development also allows for investments needed to optimally embed public transport, such as high-end terminals or bus stops, tunnels et cetera.

The negative environmental effects of urban densification and mixing of functions can be countered by green policies and therefore it makes sense to not only integrate land use and transport policies, but also environmental policies (Cervero and Sullivan, 2011).

Effects of transit-oriented development

A modal shift from private car to public transport, which is made possible by transit-oriented development, has various environmental effects. The most obvious are energy saving, reduction in greenhouse gas emissions, and improvement of ambient air quality (Tsoy and Loo, 2021). In addition, some improvement in traffic noise level can be expected. Environmental benefits from a modal shift to public transport obviously depend on ridership: the more passengers, the lower the energy use and tail pipe emissions per passenger over a fixed trajectory.

The increasing density of the urban fabric, however, increases the urban heat island effect (Kamruzzaman et al., 2018), leaving less green and open space and less soil permeability to rainwater.

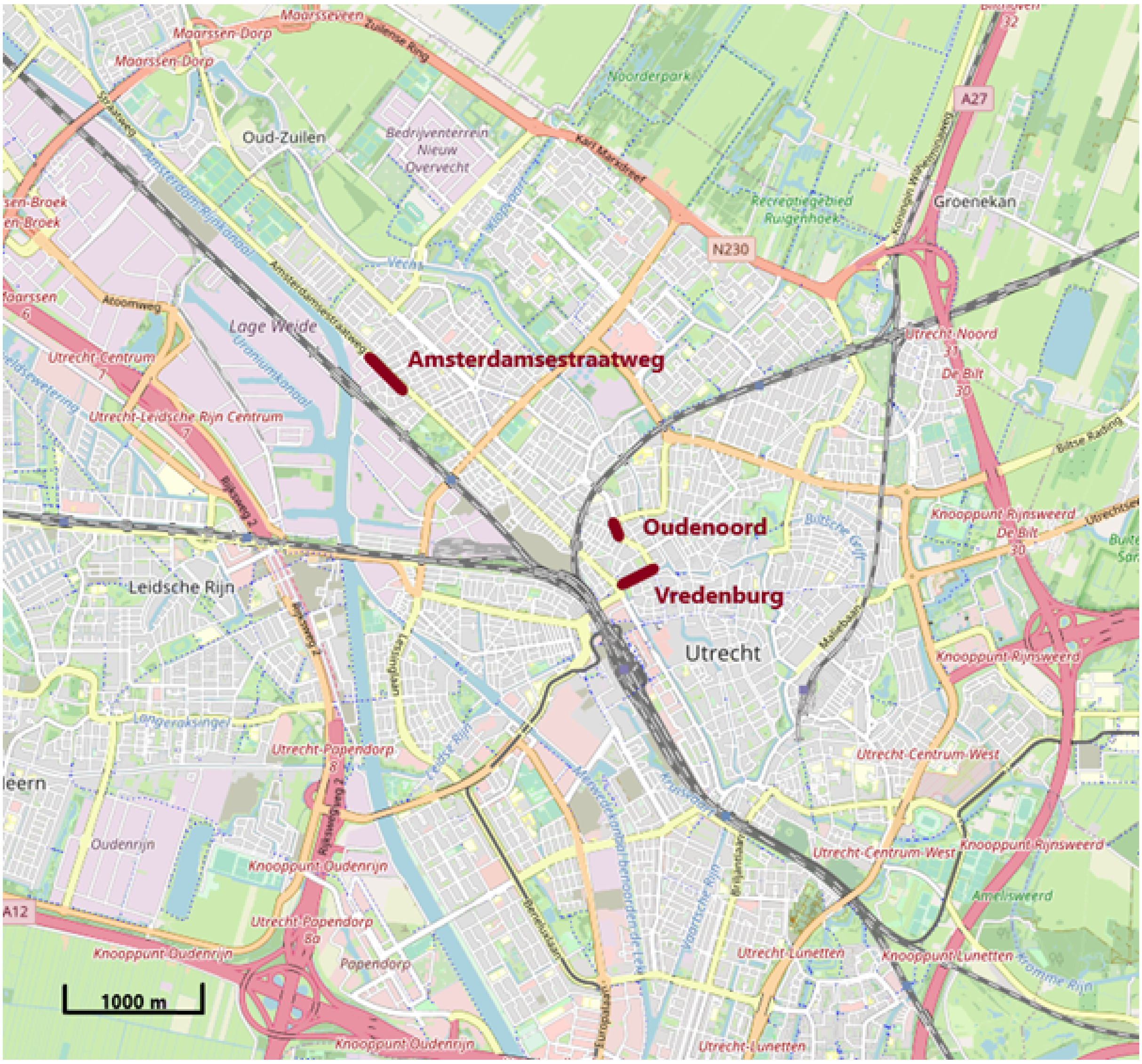
Contribution of electric public transport to green TOD

Electrifying bus transport could benefit green TOD because of its zero tail pipe emissions. Propulsion per se does not cause any emission of pollutants that are known to negatively influence air quality, such as nitrous oxide, carbon monoxide, polycyclic compounds, and particulate matter. Electric buses, however, still do cause particulate emissions from the wear of tires and brakes; for electric vehicles in general, the contribution of wear is about equal to exhaust pipe emissions (Guo et al., 2021).

The extent to which electrification of bus transport would ameliorate air quality will, obviously, depend on the fraction of busses compared to other vehicles using the street as well as on the background concentration resulting from emissions other than traffic in that street. Around nodes of public transport, the fraction of public transport buses can be quite high and the total traffic emissions can be high compared to the city background concentration.

As an exercise to estimate the effect of public bus transport electrification on air quality, we selected three busy streets in Utrecht, the fourth largest city in the Netherlands with around 360,000 inhabitants (Gemeente Utrecht, NL). Of these streets, Vredenburg is in the very commercial centre of the city, and close to the central train station. Apart from taxis, the street is only accessible to bus traffic from local and regional public transport lines. The second street, Oudenoord, is a few blocks away from the centre, and still accommodates a considerable number of buses – according to the city's traffic model around %. The third street, Amsterdamsestraatweg, is located away from the centre and is a busy street connecting the city to its surroundings. The image on the next page shows the location of these three streets within the city.

The effect of replacing diesel-driven buses with electric ones on air quality is expected to be most pronounced in the resulting nitrogen dioxide concentrations, rather than those of particulate matter for two reasons. First, traffic emissions of particulates are caused by propulsion as well as tire and brake wear in about equal proportions; in electric buses, only the former – the so-called tail pipe emission – is reduced to zero. Second, under the circumstances in the Netherlands, the ratio of road traffic contribution to total concentration is much higher for nitrogen dioxide than for particulate matter. A busy suburban street typically shows nitrogen dioxide concentrations up to 20 or 21 µg/m3, with a regional background of around 16 or 17 µg/m3. Street traffic contribution, thus, is about 20%. For particulate matter (PM10), these numbers are 18 µg/m3, 17 µg/m3, and 5%, respectively.



Location of streets for calculation of air pollution.
Source: monitoring site of the Dutch national model for calculation of air pollution, *http://nsl-monitoring.nl*

Table 1. *Traffic intensities in three Utrecht streets*
Numbers are obtained from the traffic model underlying the Dutch national model for the calculation of air pollution

	Traffic intensity (vehicles / 24 h)				
Street	**Passenger cars**	**Middle weight vans**	**Heavy weight lorries**	**Buses**	**Buses (%)**
Vredenburg	0	0	0	3,170	100
Oudenoord	11,237	309	117	1,259	9.7
Amsterdamsestraat-weg	10,004	97	29	237	2.3

Using the national calculation model for air pollution by road traffic, we calculated nitrogen dioxide (NO2) concentrations for each of four scenarios:

1. Current situation
2. 50% replacement of diesel buses by electric buses
3. 100% replacement of diesel buses by electric buses
4. 100% replacement of diesel buses by electric buses and 50% replacement of other fossil fuel-powered vehicles (passenger cars and vans) by electric ones.

In the calculation model, passenger cars, light and heavy trucks, and buses each have their emission factors at the traffic speed allowed in the street. The model is fed with the daily traffic intensity of each category (in vehicles/day). It calculates nitrogen dioxide concentrations by multiplying the number of vehicles in each category with the corresponding emission factor for nitrogen oxides. The results are added up, which amounts to the total traffic emission of nitrogen monoxide and nitrogen dioxide per day. A dilution function, based on wind tunnel experiments, is then used to calculate concentrations at the desired distance from the road axis. The model then calculates nitrogen dioxide concentration resulting from direct tail-pipe emissions of the compound plus the conversion of nitrogen monoxide to nitrogen dioxide (as a result of a chemical reaction with ozone, the concentration of which is known). The resulting traffic contribution of nitrogen dioxide is finally added to the known background concentration.

Nitrogen oxides are emitted by vehicles only in the form of the tail pipe exhaust (unlike particulate matter, which is emitted from wearing brake linings and tyres as well). Since electric vehicles are zero-emission, the above-mentioned replacements of conventional vehicles with electric ones can be simulated in the model by correspondingly lowering the current vehicle intensity by 50 and 100 per cent, respectively.

Table 2. Nitrogen dioxide concentrations in three Utrecht streets in four situations ('n.a.' denotes 'not applicable').

Scenario		**Nitrogen dioxide concentration (μg/m3)**		
		Vredenburg (100% busses)	**Oudenoord** (9.7% buses)	**Amsterdamse-straatweg** (2.3% buses)
1	Current situation	29.4	32.4	23.5
2	50% eBuses	25.4	30.4	23.2
3	100% eBuses	20.7	28.3	23.0
4	100% eBuses & 50% other eTransport	n.a.	24.6	21.2
	Regional background concentration	18.1	19.3	18.1

The results, summarized in Table 2, show that in Vredenburg when half of the buses using the street would be electrified, NO2 concentration drops significantly. Replacing all buses with electric ones almost reduces concentration to the background level (a small contribution, 2.6 µg/m3, from neighbouring roads and highways remains). But even when buses amount to only some 10% of total traffic, like in Oudenoord, the effect of introducing electric public transport is considerable: a 50% replacement knocks off 2 µg/m3, whereas full replacement more than doubles the effect. In terms of actual contribution from road traffic, i.e. subtracting the background concentration, the full replacement of fossil fuel buses with electric ones leads to a reduction of 4.1 µg/m3 on a total of 13.1 or 31%. Obviously, in streets where buses amount to only a small fraction of total traffic, the influence of electrification on air quality is far less, as can be seen in the calculated results for Amsterdamsestraatweg.

Discussion

The most obvious benefits of electrifying bus transit are an improvement in air quality and, thus, human health. Long-term exposure to nitrogen dioxide, even to concentrations around 20 µg m-3, is known to aggravate symptoms of respiratory diseases and is associated with both respiratory disease mortality and all non-accidental mortality, with relative risks ranging from 1.03 to 1.06 (WHO, 2021).

In health studies, nitrogen dioxide also may serve as an indicator for health effects caused by other exhaust-related components, such as carbon monoxide, polycyclic aromatic compounds, benzene and toluene (WHO, 2021). In epidemiologic studies, therefore, observed health effects may be caused by these other components or by the ‘cocktail’ of compounds that people are being exposed to. However, since electric buses have no tail pipe exhaust whatsoever, it is safe to say that lower calculated nitrogen dioxide concentrations represent lower health risks.

Obviously, electric buses also contribute to a reduction in carbon dioxide emissions, provided that the electricity used stems from renewable sources. If this is the case, there is also zero emission of air pollutants by electric power plants. These emissions would, although they do not immediately contribute to concentrations at street level, be included in the background concentration that is used in the calculations presented above.

There is also evidence that lower noise levels benefit health. Borén (2020) calculates a decrease in exposure at the building façade in a representative street of about 6 dB. In a street like Vredenburg, where buses are virtually the sole contributors to traffic noise, this would amount to a decrease from around 65 to 60 dB. Using the relation propose by Miedema et al. (2000), this would lower the percentage of people annoyed by 10% and that of heavily annoyed by 9%.

There is some evidence that air quality influences real estate value. In 70 cities and towns in the Czech Republic, only a weak negative correlation was found between nitrogen dioxide concentrations and housing prices. However, a comparison of strongly and less strongly industrialised cities revealed that such a relation could very well exist (Šilhánkova et al., 2013). Around a steel factory in Italy, only high concentrations of nitrogen dioxide were found to influence residential property prices (Cordera et al., 2019). In Seoul, no effect of nitrogen oxide concentration on housing prices was found using a spatial hedonic approach (Kim et al., 2003). In some districts of Warsaw, a slightly positive but significant effect of nitrogen dioxide concentration on housing prices was found (Ligus and Peternek, 2017). At least two explanations have been suggested for this – a somewhat counter-intuitive relation between real estate value and nitrogen dioxide concentration (Bateman et al., 2001). Firstly, along with nitrogen dioxide, many other traffic-related factors (e.g. particulate matter, noise) may influence the attractiveness of real estate property. This makes it difficult to find a one-to-one relation between the two. Secondly, any variable can only influence real estate value if it is perceived properly – which is doubtful in the case of nitrogen dioxide as it is not directly visible, unlike e.g. soot, and not readily detectible otherwise.

Conclusion

The three Utrecht cases show that the environmental effects, in terms of tail pipe exhaust and noise emissions, of electrifying city bus transport, are considerable, depending on the percentage of bus transport in total street traffic. The exposure-effect relations described in the literature allow the conclusion that also important benefits for health and annoyance can be expected. Yet, health benefits appear not to result in measurable effects on real estate value, which would be expected if an area, because of electrification, becomes more attractive. Nevertheless, these positive health and annoyance effects support healthy urban development, especially in streets with a high percentage of bus transit. Therefore, electrification of city buses is a measure that fits in well with the concept of green TOD.

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