Environmental benefits of telecommuting – a hypothetical case study.

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1. INTRODUCTION

Vehicle emissions contribute significantly to the greenhouse gas (GHG) content in the earth's atmosphere, with transportation emissions constituting 24% of the global carbon dioxide (CO_2) emissions (IEA, 2020), contributing to climate change. With the possibility to conduct most business activities by remote, thanks to developments in information communication technology (ICT), this paper considers the environmental impact of telecommuting.

As a party to the United Nations Framework Convention on Climate Change (UNFCC) Paris Agreement, South Africa has committed to climate change mitigation through its Intended Nationally Determined Contribution (INDC). In 2015 South Africa's GHG emissions was reported as 460 Mt CO_2e (McSweeney & Timperley, 2018). The current INDC target is to see GHG emissions peak and plateau at between 398 and 614 Mt CO_2e over the period 2025 to 2030, following a trajectory of a 42% decrease in GHG emissions. Currently, South Africa is set to fall short of this target (WWF, 2018). Cities in South Africa are significant consumers of energy and conversely provide a key opportunity to reduce GHG emissions, especially in the transport sector (Wolpe & Reddy, 2015).

The potential effect of vehicle emission reduction on achieving the INDC target is considered through a hypothetical case study of a large organisation with 2 600 employees commuting to work in the South African commuter context, specifically in the City of Tshwane, a major metropolitan area in Gauteng Province.

1.1. What is the demand for travel and its linkage to land use and ICT to give life to telecommuting?

Gudmundsson, Hall, Marsden & Zietsman (2016) posit that the movement of people, goods, ideas and information is at the heart of a developmental society. The development of the transportation system connecting different activities is therefore fundamental to society. The evolution of modes of travel has significantly influenced the land use -transport interaction system. In 1963 Webber argued that development in transportation and communication technologies would change the urban form as it allows for a more dispersed city (Marcus & Pepper, 1995). Advances in the ICT sector have impacted on the transportation system – sometimes in a complimentary way and sometimes in a substitutional way, where ICT either expands the boundaries of activities or replaces the need to be physically present at activities (Banister & Stead, 2004).

Because travel is seen as a cost (Ortuzar & Willumsen, 2005), ICT has been able to disrupt the land use - transport integration model. The demand for travel is considered to be derived, meaning that what is of interest to the individuals are the activity (destination) and not the travel. As such, in economics, travel is treated as a cost. Any technology that reduces the cost of accessing activities has a potential impact on the transport system. However, the complexity is that the activities are spatially and temporally distributed.

Business policies or norms have been slow to enable an environment that is conducive to maximising the positive impact of the ICT sector on the transport system, particularly in South Africa (Okoli, 2016). That said, certain regions such as the City of Cape Town, have started exploring this through their demand management strategy. Given this, there is a growing need to evaluate telecommuting and the associated environmental impact so as to support decision making in terms of government programs and private sector initiatives. For instance, in the private sector, the impacts of telecommuting might be included when applying for a green-star building certification rating.

Moreover, with the increasing level of road traffic congestion, it is becoming more apparent that it is unsustainable to provide infrastructure to accommodate the growth in travel demand which has been shown to have a significant environmental impact, especially in the long term (Dulac, 2013). It is well recognised that congestion can increase the cost of doing business (Weisbrod, Vary, & Treyz, 2003). Hence, there is a need to explore other strategies that enable or facilitate business activities, such as those underlaid by ICT.

In this exercise, potential emissions saving from telecommuting are investigated focusing on telework.

2. BACKGROUND

2.1. What is telecommuting and why?

A 1995 paper by Marcus discusses the environmental and social impacts of telecommuting and defines telecommuting as “the use of telecommunication and computer technologies to replace or reduce traditional commuting to the workplace” (Marcus & Pepper, 1995). Marcus references statistics by others illustrating the potential saving in vehicle fuel, road maintenance and greenhouse gas emissions.

An increasing number of companies are realising the benefit in offering flexible commute or remote positions (Talty, 2019). The reason most commonly offered for this is that it allows for a better work-life balance as less time is spent in traffic. Studies have shown that working from home increases productivity and job satisfaction while saving on costs and increasing sales (Bloom, Liang, Roberts & Ying, 2015). Benefits include time flexibility, location flexibility, transport cost savings, emissions savings, increased productivity and reduced traffic congestion.

It is to be noted, however, that this is not true for all people and for all types of work. For example, a study involving public sector (municipal) workers showed that working from home resulted in lower organisational commitment and professional isolation (O'Keefe, Caulfield, Brazil & White, 2016; de Vries, Trummers & Bekkers, 2019). Isolation is a common negative aspect and is proportional to the number of days spent working from home and can be decreased by improved access to communication technology and good leadership (de Vries, et al., 2019; Golden, Veiga & Dino, 2008).

By investing in a reliable broadband network, greenhouse gasses can be reduced, not only due to transport emissions but also reduced office construction and operation ((Fuhr & Pociask, 2011). Fuhr and Pociask discuss statistics established in the context of the United States of America (USA) showing that 91% of workers use personal cars to commute; assuming 3 people per car, about 127.5 million personal vehicles are used daily for commute purposes. For an average travel distance of 15 miles (24 km) to work, the travel time when converted to wages equates to 7.2% of USA Gross Domestic Product (GDP). Assuming fuel efficiency of 21 miles/gallon commuting, it can be calculated that if 10% of the workers telecommute, the annual saving in GHG emissions would be 45 million tons. A similar study in Dublin demonstrated that if 20% of the city's population telecommute only once a week (a conservative option), the potential annual emissions saving is 31,172 tonnes CO_2. This increases to 77,931 tonnes CO_2 if 50% of the population in telecommute once a week and 155,863 tonnes CO_2 if 50% telecommute twice a week (O'Keefe, *et al*., 2016).

While telecommuting has the potential to reduce emission due to minimizing the use of vehicles, there is an argument that the emissions saving is off-set by the carbon footprint of technology required to enable work from home, such as computer equipment, networks, data centres and mobile phones. This has been disproven by a study finding that telecommuting, video conferencing and other tele-activities could reduce emissions by 0.5 metric gigatons per year, which is not enough to off-set production of technology (Boccaletti, Loffler, & Oppenheim, 2008). The annual energy consumption of the internet per user in Australia has been modelled to be 75 kWh, which is equivalent to 81 kg of CO_2e. Models based on this have proven that reduced travel through telecommuting and teleconferencing results in overall emission savings (Baliga, Hinton, Ayre, & Tucker, 2009).

2.2. Telecommuting and demand travel

It is argued that the way in which individuals and organisation engage in activities both spatially and temporally continues to evolve (Lyons, 2009; Ortuzar & Willumsen, 2005). The following framework relates how telecommunication interfaces with the transportation system (Lyons, 2009). The interaction framework for travel demand, transportation and ICT is important to understand for purposes of forecasting the anticipated impact.

- **Substitution** – In this instance telecommunications resulting in reduced demand for physical travel. Examples are internet banking and cell phone banking, which have replaced the need for physical access branches.
- **Stimulation** - In certain instances, telecommunication can result in an increased demand for travel. For example, internet advertising entices individuals to physically visit places and internet shopping results in an increased number of light delivery vehicles on the roads.
- **Improved operational efficiency** – ICT has also resulted in improved efficiencies in the transportation system, for instance, the use of intelligent transport systems.
- **Indirect** – There is also a possibility that indirect impacts occur as a result of the implementation ICT, this typically changes activities both temporally and spatially. For instance, implementation ICT may result in a change in land use.

2.3. Environmental Impacts of telecommuting

Developments in ICT have enabled individuals to access specific activities such as work, education and shopping without having to travel. While this reduces individual travel, there are unintended consequences. For instance, a study by the International Energy Agency (IEA) found that there has been an increased demand for travel by light delivery vehicles, which may partly be attributed to online shopping. EIA estimates that this increased demand for travel will result in a 6°C increase in global temperature (Dulac, 2013), which exceeds the threshold of a 2°C increase in average global atmospheric temperatures recommended to avoid irreversible damage to the planet.

Work done by Dulac (2013) found that it is unsustainable to support this type of demand for travel through the provision of infrastructure only and argued that there needs to be a shift to more sustainable modes of accessing activities. Simulations show that a significant impact can be achieved by countries adopting "avoid and shift" policies, whereby travel is avoided and where necessary is replaced by alternative modes of transport (i.e. walking, cycling, electric vehicles, public transport). Telecommuting offers such an opportunity.

2.4. South African perspective

Emissions from the transport sector in South Africa account for 10.8% of the total Greenhouse Gas Emissions (GHG) of which road-transport contributes 91.2%. This is anticipated to grow with the anticipated increase in demand for travel. South Africa's GHG mitigation potential analysis report (Department of Environmental Affairs, 2014) forecast that one of the significant contributors to GHG emissions will be light delivery vehicles. This is theorised to be partly linked with the increased demand in telecommuting or online shopping, although there is little evidence provided.

While the environmental benefits of telecommuting are well-established in the literature, the effect in the context of a South African city has not been established. The commute patterns in South African cities differs from that of other cities in the world, as the public transport systems and the population distribution differ spatially. South African cities are less dense than many other cities in the world, resulting in more dependence on transport ((Wolpe & Reddy, 2015).

TomTom database is used as a yardstick when assessing the congestion levels for different cities. In South Africa, indicators show that the City of Cape Town has the worst traffic congestion in the country (TomTom, 2019). For instance, for the period between 2009 and 2013, the congestion levels in Cape Town rose from 25% to 35%. In this case, congestion was measured as a percentage of free-flow speeds at 3 am against peak period speeds. It is recognised by the city that the provision of infrastructure as the only mechanism to cope with the increasing levels of congestion is unsustainable.

In response, the City of Cape Town has an adopted a travel demand strategy, using flexible working hours as a mechanism. Through this, the city aims to take advantage of the advances in the ICT sector to promote a "Flexible working program", which promotes flexible working hours and enables remote working.

3. METHODOLOGY

The aim of this paper is to present a case for the potential emissions savings that can be achieved when a large employer adopts a telecommuting policy. A number of practical limitations made an actual case study impossible, thus a hypothetical scenario was established as an illustrative model based on several assumptions and available travel data for the City of Tshwane.

The emission savings potential was estimated on the basis of the difference between baseline travel patterns and teleworking travel patterns. For the base case option (business-as-usual), the emissions for travel patterns from 2019, over a 5-year period, through to 2025 were estimated. For the teleworking travel patterns, the emissions were estimated over similar time horizons for three different scenarios. Since telecommuting is not necessarily feasible and applicable for different companies, scenarios were established for 5%, 25% and 50% adoption rates.

Of interest is the potential emission savings. Bus and train services were excluded from the analysis because these function according to a scheduled timetable (running regardless of occupancy), unlike private vehicles and minibus taxis. Thus, for the purpose of this exercise, potential vehicle emissions savings were only estimated as a function of private vehicles and minibus taxis because the difference between the baseline scenario and the telecommuting scenarios will be zero.

3.1. Hypothetical study area and general assumptions

Due to the lack of specific data related to the travel patterns and vehicles, a number of assumptions were necessary. Each assumption represents a limitation to the study, however, it is hoped that the discussion will be useful in stimulating change.

The following set of assumptions were adopted to develop the spreadsheet-based computational model to estimate the potential emissions savings due to the introduction of a telecommuting policy at an institutional level.

- The study location was in the City of Tshwane, Gauteng.
- The institution has 2 600 employees.
- 2% per annum staff growth was assumed.
- One day per week teleworking was assumed (20% of working days).
- The average private vehicle occupancy used was 1.1 persons per vehicle. This is a conservative assumption based on surveys carried out in Gauteng which place the average vehicle occupancy at 1.4 per vehicle.
- The average occupancy per minibus taxi was assumed to be 14 persons.
- Given the complexity of travel pattern, only direct home-work-home based trips were considered.
- Only the peak period travel patterns were considered.
- Based on fuel sales a split of diesel (5%) and petrol (95%) was used for a private vehicle. Derived from eNatis[1] database.
- The annual emissions are calculated based on 228 working days per year, taking weekends and holidays into account.

3.2. Modal split

In general, household travel surveys are reliable in the characterisation of travel patterns that are originating from household and not necessarily reliable for destination-based characterisation of travel patterns (Ortuzar & Willumsen, 2005). For this reason, the modal split for this study was informed by the City of Tshwane's strategic transportation model. The modal split was derived from in the 2014 City of Tshwane household travel survey, which establishes the general mode split for work-related trips in the morning peak was selected, as listed:

- Train (5.2%),
- Bus (9.2%),
- Minibus taxi (28.4%),
- Private vehicle (45.5%)
- Non-Motorised Transport (8.7%)

[1] eNatis is the National administration traffic information system.

3.3. Trip length

Work done by Moselakgomo, Mokonyama & Okonta (2017) has shown that the trip length in Gauteng province is increasing over time, however, on average that it is approximately 25 km.

The total annual distance travelled to work and back by employees using a private vehicle (petrol or diesel) or minibus taxi to commute was calculated by:

$$Distance\ per\ year = \frac{dnumber\ of\ commuters \times daily\ distance \times days\ per\ year}{commuters\ per\ vehicle} \qquad \text{Equation 1}$$

3.4. Emission factors

Table 1 shows the emissions factors for the different modes of travel in Gauteng. The emission factor data used is average data publicly available from Ecometrica (2020), notwithstanding work done by (Forbes & Labuschagne, 2009), which found that for South African emission factors that relate to a petrol vehicle were higher when compared *COPERT IV EURO 3* emissions factors. It was assumed for the purpose of this exercise that all emission factors hold constant throughout the analysis period.

Table 1: Emission factors

Mode	kg CO_2/km	kg CH_4/km	kg N_2O/km	kg CO_2e/km
Private vehicle (Petrol)	0.26481791	0.0000003107	0.0000006214	0.26501085
Private vehicle (Diesel)	0.22772784	0.0000048467	0.0000050953	0.22936749
Minibus Taxi (Diesel)	0.25490142	0.0000107497	0.0000022369	0.25583677

The following equation was used to estimate the potential emissions saving for both the baseline scenario and telecommuting policy scenarios, using the annual distance calculated in Equation 1:

$$Baseline\ emissions_y = \sum[Distance_{a,b,c} * Emission\ factor_{a,b,c}] \qquad \text{Equation 2}$$

Where:

a is fuel type
b is vehicle type
c is emission control technology
y is year

3.5. Scenario analysis

Telecommuting feasibility or applicability depends on the size and function of a company. This was accounted for in this exercise, by assigning low, moderate, and high adoption rate.

The following telecommuting adoption rate options were modelled:

a) Do nothing (business as usual) option presents a case where the base year travel mode mix does not change.
b) Low adoption from base travel patterns to telecommuting:
    - A restrictive work environment that requires employees to be at work on site.
    - 5% of the employees adopt the telecommuting policy.

c) Moderate adoption rate:
   - A moderately restrictive work environment that mostly requires employees to be at work.
   - 25% of the employees adopt the telecommuting policy.

d) High adoption rate:
   - A more flexible work environment that can tolerate employees working from home.
   - 50% of the employees adopt the telecommuting policy.

Furthermore, to avoid professional isolation, a scenario was built assuming tele-commuting is practised for only one day per week (20% of the time). The results can be extrapolated to more days per week.

4. RESULTS AND DISCUSSION

Based on the methodology and the set of assumptions detailed above, the emission savings for different adoption rates options were estimated. The vehicle emissions are directly proportional to vehicle kilometres travelled.

The baseline scenario (shown in Table 2) shows the aggregated emissions based on the travel assumptions discussed above representing the business-as-usual case.

For the year 2019/20, the CO_2e emissions contribution was calculated as 2 987.79 tonnes. The increase in emissions over the years reflects the assumed staff growth, placing the 2025 commute emissions generated by the hypothetical institution considered at 3 298.73 tonnes of CO_2e. This represents an average contribution of 1.15 tonnes of CO_2e per person per year across the entire institution, distributing the emissions contribution across the 2 600 employees, not only those that use private vehicles to commute.

Table 2: Total Baseline scenario

	Total baseline emissions (tonnes)			
Year	**CO_2**	**CH_4**	**N_2O**	**CO_2e**
2019/20	2 967.99	0.06310	0.06107	2 987.76
2020/21	3 027.35	0.06437	0.06229	3 047.52
2021/22	3 087.89	0.06565	0.06354	3 108.47
2022/23	3 149.65	0.06697	0.06481	3 170.64
2023/24	3 212.64	0.06831	0.06611	3 234.05
2024/25	3 276.90	0.06967	0.06743	3 298.73

Based on this, any institution can roughly calculate their baseline employee commute contribution of CO_2e per year assuming the transport modal mix is similar to those assumed here.

Table 3 compares the modelled CO_2e emissions contribution of the institution under the baseline scenario and the three adoption scenarios, while Table 4 shows the CO_2e savings potential for the different adoption scenarios in which 5%, 25% or 50% of the employees telecommute one day per week (20% of the time), relative to the baseline scenario. This works out to a potential saving in CO_2e emissions in the year 2025 of between 0.011 and 0.11 tonnes per employee per year if the saving is distributed across the entire institution.

Table 3: CO_2e emissions contribution per year for each scenario

	CO_2e per annum (tonnes)			
Year	**Baseline**	**5% adoption rate**	**25% adoption rate**	**50% adoption rate**
2019/20	2 987.76	2 957.88	2 838.37	2 688.99
2020/21	3 047.52	3 017.04	2 895.14	2 742.77
2021/22	3 108.47	3 077.38	2 953.04	2 797.62
2022/23	3 170.64	3 138.93	3 012.11	2 853.57
2023/24	3 234.05	3 201.71	3 072.35	2 910.65
2024/25	3 298.73	3 265.74	3 133.79	2 968.86

Table 4: Tonnes of CO_2e saved per year for the 5%, 25% and 50% adoption scenarios employing

	CO_2e savings per annum (tonnes)		
Year	**5% adoption rate**	**25% adoption rate**	**50% adoption rate**
2019/20	29.8776	149.39	298.78
2020/21	30.4752	152.38	304.75
2021/22	31.0847	155.42	310.85
2022/23	31.7064	158.53	317.06
2023/24	32.3405	161.70	323.41
2024/25	32.9873	164.94	329.87

Assuming a high adoption rate of 50%, the model predicts a potential emissions saving of 329.87 tonnes per year CO_2e by 2025 and translates to an institutional emissions saving of 10%, relative to the baseline scenario and accounting for growth in the number of employees. The emissions savings across the institution would be 1% or 5% for the 5% adoption and 25% adoption scenarios respectively.

For the hypothetical institution, a linear increase in CO_2e savings per year is 1% for every 5% of the employee population who telecommute one day per week. From the figures recorded, it is calculated that for every person opting to work from home for one day per week, 0.2 tonnes of CO_2e can be saved per year. This can be extrapolated by multiplying the number of days and number of employees working from home to establish an institutional saving in tonnes of CO_2e. Alternatively, the potential institutional saving can be calculated as a percentage by multiplying the percentage of employees telecommuting by the percentage of days on which they telecommute. This is applicable for companies wishing to reduce their carbon footprint by a target amount.

The value of the emissions saved in the given scenarios is low and negligible compared to the national target to decrease emissions by 42%. However, if these findings are extrapolated the potential impact increases, as demonstrated in the following two examples.

Consider the top employing (by number) state-owned institutions (listed in Table 5). Assume that the travel patterns of employees and modal splits at these companies match the those used in this model, and that these institutions adopted a telecommute policy which sees 50% of their employees telecommuting one day per week in the year 2025. The potential emissions savings would be 13 195 tonnes in a year (for 2019/2020).

Table 5: State-owned companies with the most employees (Business Tech, 2019)

Company name	Segment	Number of employees
Transnet	Transport	56 718
Eskom	Energy	45 982
South African Airways	Airline	5 256
Denel	Defence	3 438
Safcol	Forestry	2 396
SA Express	Airline	711
Alexkor	Mining	331

Alternatively, considering the City of Tshwane's Household Travel Survey found that 493 901 trips are made to work each day. The average distance travelled per trip as well as the mode of transport were inputs in the model used in this study. If the potential savings per person calculated in the model is applied to the number of trips (number of people commuting), the potential impact is a saving of 56 756 tonnes of CO_2e emissions per year. While this is a small fraction of the national emissions, it represents a 10% reduction in commuter emissions in the City of Tshwane.

According to the 2010 GHG inventory (Department of Environmental Affairs, 2014), the total GHG emissions in South Africa in 2010 was 518.239 Mt and the contribution from road transport was 43 Mt. Thus, a reduction of 56 756 tonnes represents a saving of approximately 0.01% of the total and 0.13% of the road transport contribution.

5. CONCLUDING REMARKS

A spreadsheet-based computational model was developed to estimate the potential of emissions savings for telecommuting. The outcomes of the model are important in assisting planners in advocating for travel demand management strategies as part of the mitigation arsenal. It is noted, as a departure point that air quality chemistry is a complex science, therefore, the proposed methodology in this study depends on the correlation that exists between the vehicle kilometres travelled and emission factors.

It is recognised that there is a significant role that shift-avoid policies have to play in terms of addressing vehicle emissions. This is important given internationally adopted agreements that aim to maintain the average global temperatures below 2°C threshold. Telecommuting as a travel-demand management mechanism in South Africa has some potential.

The figures calculated in this study are small compared to the national contribution of road transport to the country's total emissions. The model used in this study is based on assumptions made regarding a hypothetical institution based on the given assumptions. However, the figures are a useful indicator of the potential environmental benefit that can be achieved by adopting a telecommuting policy to reduce the carbon footprint of an institution. The effect can be multiplied by increasing the number of employees telecommuting or the number of days per week spent working from home. Apart from the direct emissions savings, potential indirect savings exist by reducing the need to extend and maintain road infrastructure. This aspect is not accounted for in this model and should be investigated in future models.

Whilst telecommuting has potential in terms of reducing emissions, it remains important to balance this with employee needs and productivity, which will be unique for every institution.

Closing remark: This paper was originally written before the outbreak of the Covid-19 pandemic in 2020, which forced many people to work from home and adopt the technology and mind-set required for telecommuting. The pandemic is likely to be a catalyst for a wider uptake of tele-commuting than the scenario built in this paper.

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