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Private opportunities, public benefits? The scope for private finance to deliver low-carbon transport systems in Kigali, Rwanda

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ABSTRACT

A significant portion of finance for a low-carbon transition is expected to come from private sources. This may be particularly the case in the transport sector, where there is a large private sector presence and substantial investment needs, and in low-income countries, where climate action is unlikely to be the first priority for public finances. However, it is unclear whether private finance can deliver the full range of actions that are needed for a low carbon transition, or what role the public sector can and should play to mobilise these resources. Kigali, the capital of Rwanda, is one of many cities in lower and middle income countries seeking to break away from business-as-usual trajectories and pursue more sustainable forms of urban development. In this paper, the economic case for a large set of low carbon transport investments in Kigali, Rwanda, is analysed from the perspective of a private investor and from the perspective of the city as an economic unit drawing on a data and methods used in a city-wide review of low carbon study of Kigali conducted in 2015 by the Climate Smart Cities team at the University of Leeds. Comparing the public and private perspectives provides the opportunity to explore the financing mechanisms and policy frameworks appropriate for different kinds of low-carbon investment, and to consider how governments in developing countries can lay the foundations for compact, connected low-carbon cities.

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1. Introduction

The transport sector accounted for 23% of global energy-related GHG emissions in 2010 and some projections indicate that emissions from this sector could rise by >70% by 2050 (Sims et al., 2014). Transport therefore needs to be central to global climate change mitigation efforts, and the question of how best to transition to lower carbon transport networks has received substantial attention (IEA, 2013; UN-HABITAT, 2009; Creutzig and He, 2009; Voukas and Palmer, 2012). At the same time, the sector's importance extends far beyond carbon emissions. Transport networks link people with employment opportunities, healthcare and education, shape communities and provide means of bringing goods and services to market. Efficient and accessible transport is therefore not just important for economic growth, but more fundamentally for human wellbeing.

In the urban centres of East Africa, and in many low and middle income countries more generally, low per capita incomes and historical underinvestment in public transport infrastructure have led to a dependence on walking, bicycle and motorbike (Oyesiku, 2001; Abuhamoud et al., 2011; Voukas and Palmer, 2012). However, with rising incomes urban residents are increasingly turning to private vehicles, fuelling investment in car-based transport networks (UN-HABITAT, 2009, 2010a; Sietchiping et al., 2012). This trend is evident across the Global South. Marcotullio et al. (2005), for example, find that transport emissions and energy use in developing countries are rising to meet U.S. (per capita) levels at much lower levels of income.

This trend has a number of negative consequences. Car-centred transport networks require more land, promote urban sprawl, raise congestion, increase expenditure on energy and generate air pollution that causes respiratory illness, particularly among vulnerable groups such as infants, the elderly and physical labourers (UN-HABITAT, 2009, 2010a; Goodwin, 2004; Litman, 2009). Dependence on private vehicles can also contribute to the development of two-tiered transport systems, where those without access to vehicles are forced to depend on non-motorised and informal public transport networks, often leading to greater exposure to air pollution and risk of traffic accidents. This compounds social and environmental inequalities (UN-HABITAT, 2009, 2010b). Critically, transport networks are costly and complex to change in the future as physical infrastructure—as well as social and political institutions—become 'locked-in' (IEA, 2013; Whitelegg, 2015; Driscoll, 2014; Rode et al., 2014).

By comparison, multi-modal transport networks that include well-connected mass transit infrastructure (buses, trams and trains) and non-motorised options (pedestrian walkways and cycling lanes) are less energy and emission-intensive, promote more compact forms of urban growth and are more socially inclusive (Kenworthy, 2006; Rode et al., 2014). However, these transport networks require substantial upfront capital investment, strategic urban planning and sophisticated technical and management capabilities, which can often be beyond the capacity of governments in low- and lower-middle income countries.

Recent research finds that substantial opportunity for private investment in low carbon transport exists in many cities. Gouldson et al. (2015a), for example, identify large-scale opportunities to invest in low-carbon transport in exemplar cities across a range of middle-income countries; the World Resource Institute finds that a low carbon pathway for urban transport could save $300 billion in annual infrastructure investment (Lefevre et al., 2016); and the New Climate Economy programme reports that investments in low-carbon urban transport across the world could have a net present value of >10 trillion USD (Sudmant et al., 2016).

What has not been sufficiently explored are the consequences of low carbon transport investments being led by private, rather than public, investors. This question is particularly significant in low-income countries where the state faces severe resource constraints. Yet private sector investors are likely to have narrower objectives than the state, focusing on investment returns over shorter timeframes and ignoring wider social and environmental benefits (EU, 2003; Grimsey and Lewis, 2002). The source of investment funding, in addition to its scale, is therefore likely to influence which investments are made, and by extension, the pathway to decarbonisation. However, discussions on this subject rarely evaluate, let alone disentangle, the economic opportunities for private and public actors, nor does the literature sufficiently engage with what for climate change is the most important question: the extent that private finance can bring about a shift to a low-carbon climate resilient society.

In this paper we explore the economic case for low-carbon investment in urban transport from the perspective of private and public investors. For private investors, we assess a traditional business case for investment in specific measures and develop a 'private scenario' that includes all those measure that would generate net economic returns to the investor at market interest rates. We compare this to the 'public case' for investments, where the cost of low carbon investments is compared against the city-wide economic savings from

those investments, including avoided fuel expenditure and revenue from fares. The 'public scenario' does not include wider impacts, such as reduced congestion, improved public health, and other areas: although these are crucial and could be monetised, they do not necessarily contribute to the business case for prospective investors.

We hypothesise that the 'public scenario' will show a case for investment in a larger number of measures as a result of city-wide energy savings, and a slightly lower discount rate applied to public sector investments. In practical terms, findings from this work can inform the selection of transport infrastructure options and the choice of policy and financing instruments used by local and national governments to direct private investment. These findings also have conceptual significance in important debates about the role that public and private finance can and should play in urban development in low-income countries and in tackling climate change more broadly.

Section 2 of this paper introduces the case study city, Kigali in Rwanda. Section 3 outlines the methods we use to evaluate the economic feasibility of a large set of low-carbon measures in the transport sector in Kigali. Section 4 describes the results, particularly identifying which measures could be attractive for private investors compared with public investors. Section 5 draws on these results to inform a discussion about the role of public and private actors in financing a low-carbon transport system, while Section 6 provides key conclusions and policy recommendations.

2. Context: Kigali

With an urban growth rate of 5.4% per year, Eastern Africa is projected to have the fastest growing cities in the world in the period through to 2050 (UNPD, 2015). Between 2000 and 2015, Kigali grew at an annual rate of 5.3%, from a city of 580,000 to a city of 1.3 million, and over the coming 15 years the city is projected to grow 4.0% annually to a population of 2.4 m in 2030 (UNPD, 2015). If these forecasts are correct, the city will quadruple in size in the first 30 years of this century.

By the standards of the region, the City of Kigali has been extremely successful in managing urban growth and improving liveability. Environmental initiatives, including a plastic bag ban and improvements to public waste disposal, earned the city the UN Habitat Scroll of Honour Award in 2008 (UN-HABITAT, 2008). Rwanda is also a leader on climate change in East Africa. Rwanda's Fund for the Environment and Climate Change, FONERWA, was the continent's first dedicated national climate change fund and is among the largest such funds, despite Rwanda's relatively small size and very low carbon emissions (UNCSD, 2012). These examples illustrate the country's strong political and institutional commitment to green growth.

Continued economic and population growth, however, pose an on-going challenge to sustainable urban development. As of 2011, 80% of the population of Kigali lived in informal neighbourhoods and 60% of the population was employed in the informal sector (NISR, 2014). Although economic growth has been rapid over the last decade, averaging >5% p.a., per capita income across the nation is still low at approximately 640 USD in 2013 (World Bank, 2016a, 2016b). While average incomes in urban areas are higher, most poverty reduction has been achieved in rural areas: nation-wide, Rwanda saw the proportion of the population living in poverty fall from 58.9% in 2000/01 to 39.1% in 2013/14, while Kigali saw a fall from 22.7% to 20.7% over the same period (NISR, 2016). More than 87% of Kigali residents are below 40. This potentially offers a 'demographic dividend' in the long-term, but meeting the healthcare, sanitation, housing, and employment needs of this young, low-income population represents a significant challenge in the short-term.

As recently as 2008, only 12% of roads in Kigali were paved (Kumar and Barrett, 2008). However, between 2005 and 2011 the stock of private cars more than doubled, leading to rising congestion and contributing to high levels of particulate air pollution in the city (NISR, 2014; Henninger, 2013). Although motorisation rates remain low—in 2013 45% of trips were made by walking or cycling SSI (2011a, 2011b)—these trends have important implications for mobility, air pollution, emissions and energy use. Rising congestion and air pollution will make the city centre less attractive for living and working, with particularly severe impacts on the mobility and health of the urban poor. Expenditure on imported fuel will continue to drain foreign currency reserves, a consideration made especially important by the fact that Rwanda spent 55% of its export revenues on oil in 2014 (RURA, 2015). Business-as-usual development will not only raise the level of emissions from the city today, but will create path dependencies that ensure that emissions from the city stay high for decades to come.

However, both municipal and national governments in Rwanda have demonstrated their capacities for innovation and implementation in the transport sector, notably constructing wide pedestrian walkways alongside paved roads (unusual among African cities) and pioneering car-free zones throughout the city centre. In this paper, we explore other measures available to the City of Kigali to engage private finance and deliver against its environmental and social goals.

3. Methodology

The structured approach to analysing the economic case and impact on emissions from implementing low carbon measures is described below. The first stage involves the development of a business as usual scenario for the transport, mapping the levels and costs of energy consumption in Kigali between 2000 and 2032. The second stage involves the assessment of the private and public case for low-carbon transport, measured against energy use and expenditure in the business as usual scenario.

3.1. Development of a business as usual scenario for transport

A baseline scenario, describing the number of trips, energy use and emissions from transport in Kigali, is developed using data drawn from the Rwandan Ministry of Infrastructure (MINIFRA) and SSI (2011a, 2011b). This hierarchical multimodal transport model includes data on the number of trips per day, average vehicle speed, occupancy rates, travel time and walking distances by travel mode in Kigali for 2010.

To forecast travel demand in 2032, an estimate of total trip demand between 261 city zones is drawn from SSI (2011b). To this data are added an estimate of total intra-zonal trips made in the city. This estimate is based on a comparison of the number of inter-zonal trips per person per day from the SSI (2011b) model with the total number of trips per person per day (inter- and intra-zonal) in other East Africa cities (Kumar and Barrett, 2008). It is assumed that all intra-zonal trips are made by non-motorised transport, i.e. by walking and cycling.

The total number of trips is then distributed across transport types by mode share, with data obtained from SSI (2011a, 2011b)). The number of non-motorised trips per person per day is held constant between 2015 and 2032. The number of trips by private transport is assumed to grow proportionately to the rate of growth of vehicle ownership at 5.8% p.a., which generates a conservative estimate of future energy use and emissions as people are likely to replace walking and cycling trips with private vehicles as they acquire them. The proportion of trips made by heavy transport increases with the rate of population growth to reflect growing demand. This is a conservative estimate of future energy use and emissions as economic growth is likely to drive higher levels of consumption. The number of trips by bus is assumed to increase with the expected number of buses (holding occupancy constant) with planned infrastructure investments in Kigali drawn from the Kigali City Transport Master Plan (2013b), City of Kigali (2013a), RTDA (2012), MINIFRA (2011b) and from consultation with stakeholders. Trips by motos (motorcycle taxis) is estimated as the residual from the SSI (2011a, 2011b) estimate of total 2032 travel demand after travel by other transport modes has been considered. The rate of population growth, a key factor in transport demand growth, is drawn from the United Nations World Urbanisation Prospects 2015 (UNPD, 2015).

3.2. Assessment of economic case for low-carbon investment in transport

Extensive reviews of the literature and consultations with local stakeholders were undertaken to develop a list of the low carbon measures that could be adopted across the transport sector in Kigali between 2015 and 2032. Each measure is chosen for its potential to reduce emissions from transport while improving mobility in the city, thereby providing both a climate and social case for investment. For each transport measure, data were gathered from primary sources or interviews and then discussed at stakeholder working groups to assess their validity and applicability in the context of Kigali.

Deployment potential for each measure was based on consulting reports, for example, Kigali City Transport Master Plan (2013b), City of Kigali (2013a), RTDA (2012), MINIFRA (2011b), and the resulting figures were then further refined through a series of stakeholder consultation sessions. Where consulting reports did not provide estimates of deployment potential, comparisons were made with other East

African cities were made to develop informed estimates, which were then refined during stakeholder sessions.

The mitigation potential of each measure is calculated by determining the energy savings relative to the conventional or business as usual option—for example, the fuel consumption avoided by choosing a more efficient vehicle or a non-motorised transport mode—and then multiplying those savings by the appropriate emissions factor for that energy type. The net impact on carbon emissions from Kigali is calculated by assessing the extent that the measure would impact trips taken by existing transport modes in the baseline scenario. When measures do not simply replace an existing transit option (for example, electric motorbikes replacing conventional motorbikes), it is assumed that new transit options draw proportionately from inter-zonal transit modes. For example, if 30% of inter-zonal trips were taken by motos and a new bus service is development, 30% of the ridership of the new bus service is drawn from moto transport. Given the high proportion of trips taken by non-motorised transport, this assumption means that there is very limited switching from private vehicles to public transport.

The economic case for each measure is assessed from the perspective of a private investor and from the perspective of the city as an economic unit. The private case is based on the net present value of all costs incurred by the investor and all financial benefits recovered by them. A real discount rate of 7.5% per annum is applied in the calculation of the net present value for the private case based on consultation. Typically, a 'private investor' refers to any non-state actors that may make an investment for their own economic wellbeing, such as individuals, households and businesses. However, for the 'import age restriction' measures, the 'private actor' is the Rwandan Revenue Authority as they are the government body with the legal authority to regulate the import of vehicles. Under the public investment scenario, all financial costs and benefits incurred within the city as a result of the measure are included in the assessment of the net present value. In other words, any energy savings are counted whether or not they are enjoyed by the actor who made the original investment. A real discount rate of 5.0% per annum is applied in the calculation of the net present value for the public case.

The difference between the public and private case can be illustrated by comparing the analyses of the Bus Rapid Transit system. The private case includes capital and operating costs, which are deducted from expected revenue from bus fares (whose rates are set by the government). The public case includes capital and operating costs, which are deducted from expected city-wide fuel savings due to modal shift away from private vehicles towards the public transport system. In both the public and private cases, operating costs and energy prices are assumed to rise by 2% per year (Table 1).

The results from the assessment of the performance of each measure were drawn together to form investment scenarios, one from the perspective of the public and one from the perspective of private investors. The private scenario includes all measures that individually generate a real, private return of 7.5% or more after considering potential interactions. The public scenario includes all measures that collectively generate real returns of 5% or more (whether those returns could be recovered by the investor or not) after considering potential interactions. In the public scenario, therefore, some highly economic measures, such as parking meters, subsidize measures that are not economic on an individual basis.

3.3. Limitations

Detailed feasibility studies were outside of scope of this analysis and would be required before investment decision. Analysis of each measure should therefore be seen as an informed evaluation of the likely business case for each measure given current market conditions and based on the best available information. Where local data were not available, informed estimates were made by local stakeholders and validated by stakeholder groups.

The key constraint on this methodology is the complexity of modelling transport energy use patterns at the city scale. Future levels of energy consumption in this sector will depend on rates of economic growth, national and local policy decisions, investments in urban infrastructure and the evolution of new technologies, business models, social practices and cultural norms relating to mobility. Rather than trying to predict or model highly uncertain transformative changes, this study assumes that trends in Kigali will continue in the near future as they have in the recent past. This may not be the case of course—increasing gridlock or an expansion of bus capacity could slow rates of motorisation or new technologies could alter transport supply and demand radically.

Table 1
Key assumptions and data sources for transport measure in Kigali.

Measure	Summary and key assumptions
Bike lane investments	40 km of protected cycle-ways are built in Kigali. Capital costs and maintenance costs are drawn from international cases (C40, 2013) and the 'Share the Road' cycling project in Nairobi UNEP (2015). Impacts on transport modal share are estimated from a combination of focus groups, consultation with members of the transport industry and international case studies C40 (2013) and Sietchiping et al. (2012). The location of bike lanes is informed by MINIFRA (2011a).
Parking meters in CBD	Under this scenario parking meters are deployed over 10 km of roads in the central business district. 35 m are installed per km and operate 12 h per day. Cost for installation and maintenance are drawn from Litman (2009). The occupied rate (50%) and cost per hour (100 RWF) were determined by consultation. The effect of parking meters on travel to the city centre was informed by Litman (2009) with adjustments made from discussions at workshops.
Import age restrictions (<15, <10, Euro IV)	These measures assess the impact from banning the import of vehicles older than a specified age (10 or 15 years). Analysis of the impact drew from work completed by the Rwandan Transport Development Agency (RTDA) who provided data on vehicle imports, prices, import taxes, vehicle efficiencies and the elasticity of demand for vehicles in Rwanda. When modelled from the perspective of the private actor (in this case, the Rwandan Revenue Authority), lost revenue from vehicles not imported is deducted from additional revenue from the purchase of younger vehicles. For the public or city-scale perspective, the costs of purchasing more expensive vehicles and additional motos and buses to accommodate travel needs are compared against the fuel savings from more efficient vehicles and fewer total imported vehicles. In both cases, the assumption is made that total trips within Kigali remain constant and that, after three years, the total number of vehicles purchased returns to the baseline number.
BRT lines (1 and 2 and 3)	These measures model the impact of three planned Bus Rapid Transit lines: One from the central business district to Rusororo, a second from the central business district to Gahanga, and a third from the central business district to the international airport. Key data for these measures, including the total cost of building the BRTs, operating days, operating hours and tariffs are drawn from the Kigali Masterplan (2013a), MINIFRA (2011b) and RTDA (2012). The fuel efficiency of vehicles is assumed to be 2.5 km/L. Fuel costs are assumed to be 35% of total operating costs based on SSI (2011a, 2011b). The number of trips per hour is estimated to be 6000 for BRT line 1, 6500 for BRT line 2, and 3000 per hour for line 3, based on consultation and review of the previously listed documents.
Electric motorbikes	In this scenario electric motorbikes grow to 5% of total passenger trips by 2032 by taking modal share from fossil-fuel based moto transport. Electric bike costs, efficiencies, annual kilometres and lifetimes were obtained through personal consultation. The scenario was developed through consultation with members of industry. Under the public scenario, investment costs are the cost of electric bikes and electricity, while savings are transport fuel not consumed and conventional motorbikes not purchased. Under the private scenario, individuals are required to finance their electric bike at an annual interest rate of 34.5% over two years.
Bus network expansion (standard buses and Euro IV buses)	The impact of doubling and quadrupling the existing fleet of mini and large buses in the metropolitan Kigali area by 2032 is modelled. Capital cost, operating costs, fuel efficiencies, operating days, operating hours, vehicle lifespans and travel tariffs are drawn from MINIFRA (2011b) and City of Kigali (2013a, 2013b). Minor changes to these data were made during stakeholder workshops. It is assumed that bus occupancy remains constant to 2032. Under the Euro IV scenario, it is assumed that buses operate at 20% higher efficiency and cost 40% more than conventional buses, and that current programs to train mechanics to service Euro IV vehicles accelerates over the period to 2032. All other variables are the same.

Further, although the economic and carbon savings of individual measures can be considered reliable in the near-term, the assessment of the city-scale impacts over the longer term is more tentative since changing energy prices, fluctuations in economic growth rates and changing behaviours will all impact transport choices in Kigali. For example, improvements in energy efficiency can free up resources for expenditure on other, energy-intensive activities and investments: the so-called rebound effect. While there is continued debate around the extent of rebound effects (Gillingham et al., 2013), their magnitude is generally agreed to be

larger in developing contexts such as Rwanda (Chakravarty et al., 2013). Some estimates have even found rebound effects to be so larger as to almost entirely negate the potential for energy savings (Wang et al., 2012; Roy, 2000; Fouquet, 2012). It is important to note, however, that the majority of research suggests that net savings exist for policy measures and interventions similar to those assessed here (see Gillingham et al., 2013; IEA, 2013). In this work, rebound effects have been considered on a measure-by-measure basis, for example, through vehicle demand elasticities provided by the Rwandan Transport Development Authority.[1]

Above all, it should be recognised that the climate implications of different measures in the transport sector are very much a secondary consideration for both public and private investors. Investments in roads, walking paths, public transport, parking spaces and other infrastructure are motivated by wider socio-economic goals such as access to services and employment, urban productivity and local environmental quality (particularly noise and air pollution) (UN-HABITAT, 2009). Such factors will be the primary factors shaping investment decisions in urban transport in East Africa and elsewhere. However, in light of the constrained capital budgets of local and national governments in the region, as well as many low-income countries' commitment to pursuing more climate-friendly forms of development, a quantified understanding of the potential economic and climate case is a valuable starting point for policymakers and investors.

4. Results

4.1. Business-as-usual scenario

The period 2000–2015 saw rapid increases in transport energy use (9.0% per annum), energy expenditure (19.7% per annum) and greenhouse gas emissions (8.9% per annum) in Kigali. This means that emissions from transport rose at the fastest pace of any sector in the city, followed by the buildings sector (8.1%) and the waste sector (6.4%).

Under the business-as-usual scenario, energy use, energy expenditure and emissions are expected to continue growing rapidly to 2032,[2] albeit at a slightly moderated pace: by 6.4%, 6.3% and 8.6% per annum respectively. This increase is led by increased private vehicle ownership, rising from 7.1% of households in 2015 to 16.2% of households in 2032. This means that the total stock of private cars in Kigali will rise from approximately 20,000 today to nearly 90,000 in 2032, leading the modal share of private vehicles to grow from 18% to 24%. Combined with an annual increase in real energy prices of 2% per annum, expenditure on fuel will rise >350% over the same period (Figs. 1 and 2).

4.2. Private case for low-carbon investment

In the 'private scenario', where private investors deploy all measures that they find economically attractive at scale, the rate of increase in, energy use and energy expenditure and emissions is very slightly slowed. Specifically, this bundle of measures would reduce energy use by 8.2%, energy expenditure by 9.1% and emissions by 7.9% in 2032, relative to business as usual trends. However, the general trend of rapid growth in energy demand, bills and emissions remains pronounced. These investments would require 190.0 million USD in investment, but would have a net present value of 123.8 million USD, an internal rate of return (IRR) of 21% and a payback period of 3.8 years, due to significant energy savings accruing to private investors (Fig. 3).

Three of the ten measures investigated proved to have a positive business case for a private investor. Electric motorbikes are the most cost-effective option as they are both cheaper to purchase and less expensive to operate than conventional motorbikes. Bringing electric motorbikes to Kigali, however, will require clarification of the legal code as well as upfront investment from investors seeking to bring electric motorbikes from China. Expanding the bus network also seems to have a strong private business case, although it will depend on public investment to expand and improve the road network. Parking meters in the central business district generate significant revenue but are expected to have a very limited impact on emissions or energy use. The economic and carbon savings of each option (if deployed at scale) are detailed in Table 3. Those measures in green are included in the 'private scenario' (Table 2).

[1] The Kigali transport authority has estimated that an elasticity of demand for vehicles that are 1–5 years of age of −0.44 in a scenario where vehicles only vehicles 10 years or younger in age are allowed to be imported (RTDA, 2012).

[2] 2032 is used as the endpoint for analysis to match with the Kigali City Masterplan (2013b).

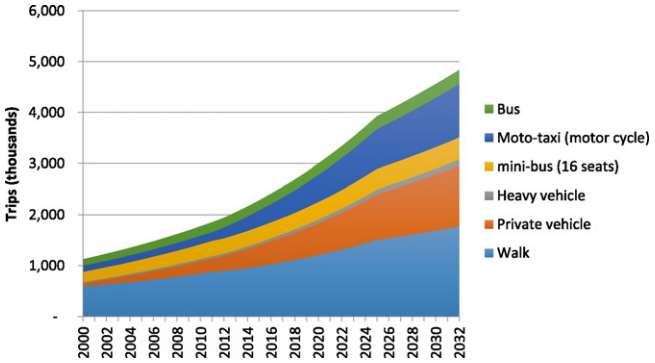

Fig. 1. Annual trips by mode under the business-as-usual scenario, 2000–2032.

4.3. Public case for low-carbon investment

In the 'public scenario', all measures are deployed that collectively have a positive net present value even if the returns are not captured by the investor. These investments have a more significant impact on the annual increase in energy use and energy expenditure and emissions: compared with the business-as-usual scenario, energy use would be reduced by 18.6%, energy expenditure by 19.9% and emissions by 18.2% in 2032. The general trend however, remains that, energy use, and energy expenditure and emissions rise rapidly. As a package, these investments would cost 816.2 million USD, but would have a net present value of 294.2 million USD, an IRR of 13% and pay for themselves in 8.2 years (Fig. 4).

Nearly all measures evaluated showed a positive economic case when city-wide energy savings were included in the cost-benefit analysis. Exceptions were, 'bus network expansion 4× 2015 capacity' and 'BRT line 3', two of the most ambitious measures considered in this analysis. Parking meters in the central business district show that strongest economic case while expanding the bus network presents the largest opportunity to reduce emissions.

5. Discussion

There is growing optimism that the private sector can finance important parts of a low carbon transition. The cost of low carbon investments, including solar panels, wind turbines, more efficient vehicles and batteries, have been falling precipitously (IEA, 2015), and a growing body of work outlines the economic case for low carbon investment (IEA, 2015; Global Commission on the Economy and Climate, 2014).

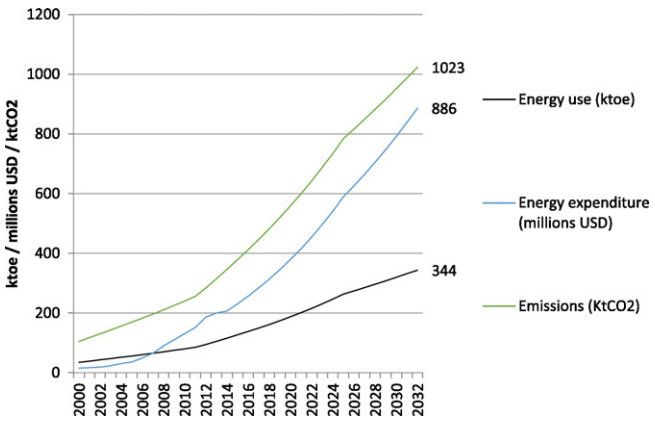

Fig. 2. Emissions, energy use and energy expenditure from transport in Kigali under the business-as-usual scenario.

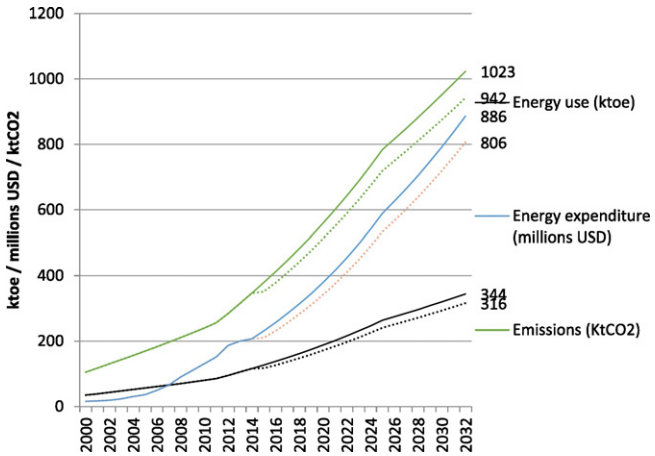

Fig. 3. Emissions, energy use and energy expenditure from transport in Kigali in the private scenario (broken lines), compared to the business as usual scenario (unbroken lines).

However, a business case on paper can be vastly different from the reality facing investors. Access to capital, amenable political and legal frameworks, and available suppliers are just some of the challenges which can prevent private investors from taking advantage of potentially profitable opportunities (Pauw, 2014; Sudmant et al., 2015). The sheer complexity of designing and implementing mass transit projects (in contrast to, for example, electricity generation infrastructure) further deters private actors.

In other cases, the economic justification for an investment may be strong, but a business case may not exist without enabling policy frameworks or financing mechanisms. The IEA (2015) found that fuel savings could finance investments which would stabilize global temperature increases to no more than 2°. Similarly, analysis of the transport sector suggests that Kigali could reduce of emissions from the transport sector by an additional 10.3% if fuel savings were re-invested in other low carbon measures. Filling the 'climate finance gap', however, requires addressing a principal-agent problem: finding ways to make those who save energy, finance investments.

Finally, there are investments which are necessary for a low carbon transition because they promote compact urban form and well-connected, multi-modal transport systems—but offer neither a conventional business case nor a wider urban economic case. These measures often have the largest impact on emissions, and may offer un-monetized social benefits such as improved public health, enhanced mobility and informal employment (Stanley et al., 2011; Colenbrander et al., 2016). Realising these benefits requires careful analysis

Table 2
Potential carbon and economic savings of low-carbon transport measures with a real discount rate of 7.5% per annum, ranked in order of decreasing net present value, in the *private scenario*. Measures in green are considered economically attractive to private investors while measures in red have a negative net present value, and are therefore not attractive to investors. The key investor, the government (government), or private investors (private) are noted in brackets.

Measure	KtCO2 2015–2032	2015 USD/tCO2e
Electric bike—5% of trips 2032 (private case)	355.3	−646.9
Bus network expansion—2 × 2015 capacity by 2032 (private case)	1300.3	−12.3
Parking meters in CBD (private case)	155.0	−4.1
Import age restrictions <10 (government case)	596.8	0.0
Euro IV standards (government case)	864.9	0.4
Import age restrictions <15 (government case)	201.4	2.7
Bike lane investments (private case)	148.9	56.3
Bus network expansion—4 × 2015 capacity by 2032 (private case)	2310.4	299.6
BRT Line 1—CBD to Rususoro (private case)	279.4	546.6
BRT Line 2—CBD to Gahanga (private case)	302.7	597.7
BRT Line 3—CBD to KIA (private case)	235.2	845.1

Table 3
Potential carbon and economic savings of low-carbon transport measures deployed at scale in Kigali, ranked in order of decreasing net present value, in the *public scenario*. Measures in red were mutually exclusive with more economically attractive options or were not economically feasible.

Measure	KtCO2 2015–2032	2015 USD/tCO2e
Parking meters in CBD (public case)	155.0	−690.9
Bike lane investments (public case)	148.9	−675.6
Electric bike—5% of trips 2032 (public case)	355.3	−649.9
Import age restrictions <15 (public case)	201.4	−359.6
Import age restrictions <10 (public case)	596.8	−233.8
Euro IV standards (public case)	864.9	−180.4
Bus network expansion—2 × 2015 capacity by 2032 (public case)	1300.3	−70.5
BRT Line 1—CBD to Rususoro (public case)	279.4	−57.7
BRT Line 2—CBD to Gahanga (public case)	302.7	−6.5
Bus network expansion—4 × 2015 capacity by 2032 (public case)	235.2	80.1
BRT Line 3—CBD to KIA (public case)	235.2	240.8

of the wider value such options generate, and recognising the anchoring role that public finance and public policy must play in delivering these investments.

Urban policymakers worldwide, but especially in low-income countries, are faced with demands that far exceed their capacities and resources. For this reason, engaging private sector capabilities and capital will be key to delivering urban infrastructure at scale. The question of how to do this is the topic of a growing body of literature. For example, Schmidt (2014) discusses the barriers to low carbon investment faced by private actors; Barnard (2015) investigates the options available to international climate funds to engage the private sector; and Junghans and Dorsch (2016) investigate municipal policy levers to direct and mobilise private finance. Section 5.1 brings these strands of literature together with the new evidence presented above to provide a more complete picture of the policy approaches that can realise specific opportunities in the transport sector. Section 5.2 then acknowledges the limitations of a project-based approach, particularly considering the long-term significance of transport infrastructure for urban economies and societies. It therefore presents a range of programmatic alternatives that can mobilise the resources needed bring about a low carbon transition in the transport sector of fast growing cities in the Global South.

5.1. Supporting private investment in low carbon measures

Broadly speaking, two classes of non-exclusive barriers face prospective investors: unsatisfactory returns on investments, and unsatisfactory risk of investments (Schmidt, 2014). Investment returns across many low

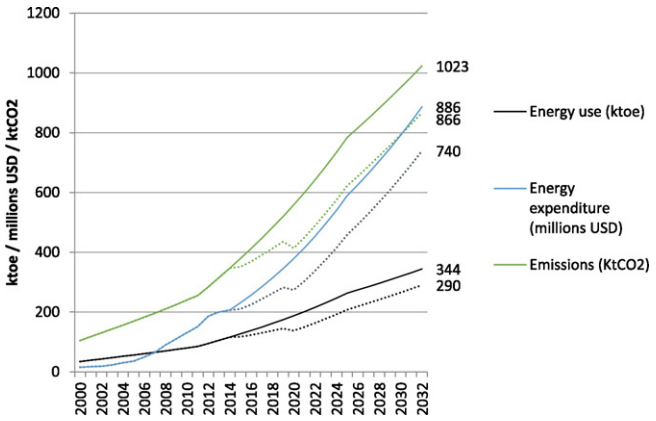

Fig. 4. Emissions, energy use and energy expenditure from transport in Kigali in the public scenario (broken lines), compared to the business as usual scenario (unbroken lines).

carbon technologies are lower than for conventional alternatives due to higher capital costs and falling fossil fuel prices, even though advances in technology have seen the prices of wind turbines, solar panels, electric cars, and other technologies, falling dramatically (IEA, 2015). Investment risk includes financial risks, such as exchange and interest rate uncertainty, and non-financial risks, including policy risks and legal risks. Combined, these barriers manifest in constraints over the amount of finance available to investors, the rate at which finance is available and the timescales over which finance is to be paid back (Schmidt, 2014; Ward, 2010).

In developing country contexts, access to capital constitutes one of the most significant challenges for start-ups and small businesses. Both as a response to financial and non-financial risks, loans are often not available or only available at prohibitively high interest rates. In Kigali, for example, moto drivers pay effective interest rates on their loans exceeding 100% annually. Measures to cap such rates present an attractive target for policymakers, however such interventions may risk cutting off one of the few sources of finance available to small businesses who lack capital and have limited credit history or assets to provide security.

As an alternative, policymakers can take action to support small businesses directly and to make the credit market easier to access for small investors. Supporting low-carbon options that are both economically attractive and institutionally straightforward can help to develop local capacities, demonstrate technical feasibility and build political appetite for more ambitious and complex initiatives (Colenbrander et al., 2015). Direct support can come in the form of targeted grants, low cost loans and tax abatement schemes. In Rwanda, the Fund for the Environment and Climate Change (FONERWA) provided 25 grants to private actors for climate change and environmental initiatives over the last year (FONERWA, 2016) and expanding such support at the urban level can play an important part in addressing businesses need for capital.

In order to deliver low-carbon measures at scale, however, it is necessary to link local capital with local investments. Most discussion of low carbon financing has focused on international and institutional investors (UNPD, 2015), yet >80% of climate finance is provided by investors from within the same country (Buchner et al., 2014). Further, for many investments in low carbon transport, such as electric motorbikes, buses, and especially more prosaic investments such as bicycles and scooters, the transaction costs of international finance are likely to be prohibitively large. Well-functioning local banking and credit markets are therefore an essential part of a low carbon transition.

Support for business plan development, both for small investors and for local governments can play an important role in this context. An example comes from The Private Sector Federation of Rwanda, an industry group that has formed a partnership with the national government to train small and medium-sized businesses to explore financial opportunities around climate change (PSF, 2016). Similar programs elsewhere in sub-Saharan Africa have found significant impacts at a relatively low cost (Mano et al., 2012).

While support for single investments can demonstrate proof-of-concept and generate targeted impact, effective urban planning and policy can mobilise substantial new streams of investment by dismantling non-financial barriers (Buntaine et al., 2015). To illustrate, electric motorbikes currently face the default 25% duty when they are imported into Rwanda, putting them at a substantial financial disadvantage compared with conventional motorbikes, which face a 10% duty. However, businesses report that it is not the duty (which is likely to be updated in accordance with the World Customs Organisation in 2017), but lengthy waiting periods for imports to clear customs that constitute the primary barrier to their businesses. Expedited customs procedures, rather than changes to import duties, would therefore be more likely to encourage investment. Similarly, private bus companies in Kigali are willing to invest in new bus lines and more efficient buses, but are concerned that their contracts with the city are too short to guarantee adequate returns on investment. Kigali City Council could therefore mobilise additional private investment in mass transit by offering longer contracts to existing operators. As the capital costs of low carbon options continue to fall (IEA, 2015), there is reason to believe that tackling non-financial barriers to investment will be of even greater importance to mobilise private finance for climate action.

Many large-scale transport options show a poor business case for private investors but attractive city-scale returns. In many cases, financing for these measures can be unlocked through strategic government interventions or private-public partnerships (PPPs). PPPs are an arrangement whereby an individual company or a consortium of companies work with the government to provide the necessary investment for a selected project. Public finance may be used to increase the return to private investors. Meanwhile, from the perspective of

governments, this model is intended to distribute risk among a wider array of investors and secure the management and technical capacities of the private sector for the project (Glemarec and Connelly, 2011). The need for public sector involvement to reduce private risks may be especially acute in the transport sector. Transport projects are particularly prone to budget overruns, with Flyvbjerg (2009) finding average cost overruns of 44.7% for rail, 33.8% for bridges and 20.4% for roads across a large sample of international investments. In contrast with purchasing municipal bonds, however, private companies will be expecting to cover their costs and earn a profit, by way of user fees or other means, directly from the project in question.

Careful design of these financing instruments is crucial, especially in developing contexts. PPPs, for instance, need to be designed in a way that ensures benefits and risks are equitably shared, public accountability is maintained, and so that public interest, rather than profitmaking, is the key metric used to gauge success (Wettenhall, 2003; Zhang, 2005). Kenya offers a model for low-income countries, having established a Special Purpose Unit within the National Treasury with the mandate to assess and approve PPP projects.

5.2. Financing low-carbon transitions

Targeted government support to enable private action can yield substantial investment in low carbon measures. However, it is not clear that privately profitable actions, or indeed, even actions which generate financial returns at the urban level (using the urban fuel savings approach found here or in other academic literature (IEA, 2015)), achieve the level of ambition needed if transport networks are to rapidly decarbonise and transition to low-carbon pathways. This analysis finds that 8.9% of business as usual emissions could be avoided by the actions of private investors, and 18.2% of emissions if these returns were directed to additional low-carbon measures, but some of the most ambitious actions (specifically a third BRT line and a fourfold expansion of the bus network) are not feasible under either scenario. Considering their potentially transformative impacts on urban form and function, however, governments must play a key role in planning and overseeing projects at this scale. Where the public sector lacks the resources and capacities to deliver infrastructure investment at this scale, there is a need for business models and financing mechanisms that are not dependent on a (relatively) narrow economic case.

A long-term and integrated approach to urban planning can allow governments to capture some of the increases in value associated with major infrastructure investments. For instance, development charges and the additional taxes raised from new residents can be used to finance investments in transit (tax-increment financing). Measures such as bike lanes, wide sidewalks and public greenery can be mandatory elements of large scale developments and tax abatement offered to incentivize developers to exceed standards. For transit measures affecting existing neighbourhoods, housing taxes or a regional sales tax are two means of raising funds (Junghans and Dorsch, 2016).

In addition to new government revenue, governments can also save expenditure in other areas from the wider economic benefits large-scale transport investments can generate. For example, reductions in air pollution and increases in physical activity brought about by improved transit networks can lead to savings for public health programs. These so-called 'co-benefits' are more often than not the primary justification for public investments, and recent research emphasises the far-reaching benefits of low-carbon multimodal transport networks, arising from improved mobility (Banister, 2008; Miranda and Rodrigues da Silva, 2012; Litman, 2008), increased employment opportunities (Sietchiping et al., 2012), reduced congestion (Goodwin, 2004; Creutzig and He, 2009), improved social inclusion (Miranda and Rodrigues da Silva, 2012), increased traffic safety (Sonkin et al., 2006; Rabl and De Nazelle, 2012), and improved air quality (DfT, 2004; Woodcock et al., 2009; Creutzig and He, 2009).

However, these benefits are diffuse, non-monetary and long term, and are consequently often excluded from traditional cost-benefit analysis for transit infrastructure. Further, in developing country contexts policymakers face two major, jointly reinforcing, challenges which make the consideration of such benefits more challenging. First, governments often do not have the capabilities to capture the wider economic benefits of investments. Formal tax registries may be incomplete, limiting the possibilities for additional tax revenue, and public spending on health and other public programs is often low, giving the impression that savings on future health expenditure will be low. Second, prospective investors of all kinds—households, corporations, government agencies—often face severe resource shortfalls, making it challenging for investors to embrace long term benefits.

Local and national governments will therefore only be able to mobilise project finance for a subset of transport investments. Those with relatively well-developed urban planning capacities (including Kigali) may also be able to guide other streams of private finance to ensure that they align with urban development plans. However, recognising the reality of resource constraints in these contexts, policymakers in low-income countries need to draw on a wider, and more innovative, set of financing tools.

Municipal bonds are regaining popularity as a means for urban governments to attract capital for large scale projects. These instruments are backed by the balance sheet of the municipality, so the city government does not depend on the returns of a single investment to mobilise the necessary finance. Bonds can also be paid back over long periods of time, as investments contribute to broad-based economic development and increases in tax revenue. This is an especially valuable option when direct financial returns are too limited to secure private sector investment (many transport projects can only recover their investment through user charges, despite generating substantial energy savings for users) or when a business model to create a clear financial return does not exist, for example, from bicycle lanes or pedestrianisation of urban centres.

In the context of low carbon development, green municipal bonds have recently emerged as a multi-billion dollar source of environmental finance, with the 'green' label making such bonds attractive for international sources of finance (Junghans and Dorsch, 2016). For example, Johannesburg (South Africa) raised $143 million USD in 2014 for investments in buildings, sewers and transport from the world's first municipal green bond issue (Junghans and Dorsch, 2016). Historically, only a small percentage of cities in developing countries have been deemed creditworthy by international investors. However, programs such as the World Bank/C40 Cities Climate Leadership Group City Creditworthiness Academy Public Investment Advisory Facility (PPIAF) are seeing significant progress in improving municipal access to global capital markets (World Bank, 2014). Kampala (Uganda) is currently preparing to issue green municipal bonds; and Dakar (Senegal) was also prepared to issue such bonds, but was prevented by political objections from national government. While repaying municipal bonds is likely to remain a challenge for cities in low-income countries, this financing mechanism allows governments to access private capital while reducing their exposure to risk for particular projects or with specific investors.

Urban policymakers in developing cities can also look to international sources of finance. The transport sector and urban areas in general have received a small share of international low-carbon investment flows relative to their mitigation potential. According to the Climate Policy Initiative, more than three-quarters of global climate finance been 2011 and 2013 (the latest years available) was directed towards low carbon electricity (Buchner et al., 2015), and an analysis of multilateral climate funds by Barnard (2016) found that only one in ten dollars of expenditure went to urban actions. Of this amount, a further one in ten dollars went to cities in low-income countries. However, global climate funds have recently turned their attention towards cities and the transport sector, with both the Global Environmental Facility and the Green Climate Fund introducing an urban focus to their latest investment programs (Barnard, 2016).

Climate finance and development assistance can be deployed through different instruments with low cost (concessionary) debt remaining the most common (Buchner et al., 2015). In East Africa, the French Agency for Development (AFD) has provided concessionary finance for a BRT pilot project in Addis Ababa (Ethiopia) (Kiepsch, 2016), while the World Bank is likely to provide similar support for a BRT planned in Nairobi (Kenya) (Kiarie, 2016). This type of support means that the borrowing governments have lower interest rates and a longer timeframe to repay investments compared with the terms offered by private investors, relieving pressure on government finances. Climate funds and development banks also have more innovative financing means available to them. Risk guarantees and credit guarantees, for instance, can secure private co-financing for individual transport projects, as well as help with the development of local credit markets for infrastructure investment (Schwartz et al., 2014).

International sources of funding can also support the research that is needed for social and environmental considerations to be valued alongside economic ones when transport projects are evaluated. Research suggests that the total value of co-benefits can be comparable, and in cases greater, than the economic benefits of fuel savings or the potential returns to investors for a wide range of low carbon actions (Stern, 2015; Ürge-Vorsatz et al., 2014; Creutzig and He, 2009; von Stechow et al., 2015). However these is an urgent need for a better understanding of these co-benefits in different contexts. Developing these lines of research, and incorporating their findings into the methodologies used to plan urban transport networks, may be the most important long-term investment that can be made to encourage the development of low carbon cities.

6. Conclusion

Analysis of Kigali's transport network provides an opportunity to explore wider questions about the opportunities and obstacles facing a transition to a low carbon transport network in urban areas. For a relatively small number of low carbon transport measures, a private financial case means that private actors can drive climate action. However, policymakers need to be cognisant that private actors rely on the government for political and legal structures, and can be discouraged by financial and non-financial risks. For a larger set of measures, an economic case exists from a public perspective, but governments will need to establish enabling policies and partnerships to secure the necessary private capital. In these instances, policymakers need to carefully match government and private sector capabilities, and ensure that cooperation between the public and private sectors are designed for the public good.

This research also suggests that there may be a relatively narrow economic case for the ambitious actions need to shift cities away from business-as-usual paths of urban sprawl and car-based transport networks. Such investments may yield substantial benefits for a city, including enhanced economic productivity and competitiveness, but they typically do not generate financial returns for prospective investors in the short- to medium-term. However, there remain a range of financing mechanisms available to governments to fund decarbonisation and urban transformation, including some with scope to attract private finance, such as bonds and concessionary loans. For urban policymakers, climate funds and development agencies alike, these findings emphasise the importance of early strategic investment in urban transport systems and the need for ambitious projects that ultimately lay the foundations for compact, connected, low-carbon cities.

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