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Simplified Equation Models for Greenhouses Gases Assessment in Road Transport Sector in Burkina Faso

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ABSTRACT

Transport sector is cited among the key emitted sector. In Burkina Faso, road transport occupies more than 60% of the emissions of the entire transport sector. However, there is no model equation for greenhouse gases modelling in transport sector. A methodology combining literature review and survey has been adopted to develop the simplified model equation in transport sector. The vehicle type survey allowed the identification of the type of vehicle and the literature review allowed the identification of the key parameters used for greenhouses gases modelling. The results revealed 10 vehicle types for road transport in Burkina Faso such as: Private cars, Public Transport/Buses, Special Vehicle (Ambulances, Fire bus, Funeral vehicles), other vehicle, Motorcycles, Wheeler, Rail, Van, Lorries and Truck Tractor. The keys parameters for greenhouse gases modelling are Fleet availability, Average annual distance travelled, Fuel Economy and Fuel emission factor. For all vehicle type identified simplified model equation was developed to support Burkina Faso, assessing greenhouse gases emission in the sector of transport. This approach could be replicated in other countries in the sub-Saharan Region.

1. Introduction

Burkina Faso's geographic position, at the center of Sudano-Sahelian zone in West Africa, makes it particularly vulnerable to the adverse effects of climate variability and change. Burkina Faso's economy is essentially based on a rainfed agriculture (plant and animal production) which contribute mostly to the country Gross Domestic Product (GDP). According to the national statistic and demography agency data, the population is growing at the rate of about 2.4 % per year; and 46,4% of the populations (11,849,520 habitants among which 51,1% are women)

lives below the poverty line, estimated at 82,672 FCFA in 2004 (US $ 165).

Over the past two decades, Burkina Faso has suffered from the adverse effects of the climate. The most important among these climatic shocks are droughts due to insufficient rainfall and its uneven distribution, floods from exceptional heavy rains, heat waves and intense dust layers. The persistence of climate change will inevitably lead to an increase in the frequency and magnitude of extreme weather events; their repercussion in terms of impacts will be detrimental to certain sectors and to socio-professional strata with limited means. As the country is potentially vulnerable to projected climatic shocks, it urges to develop adaptation and mitigation measures.

Reducing greenhouse gases to fight against the adverse effects of climate change is one of the world's major development challenges [1-3]. The increase in atmospheric carbon dioxide (CO_2) is cited as the main factor and cause of global warming and is attributed, in large part, to human activities [4]. To address these observed global challenges, all 195 members' countries of the United Nations Framework Convention on Climate Change (UNFCCC) have committed to reduce their greenhouse gas emissions to stabilize the increase in global terrestrial temperature to 2°C through their commitment materialized in a Nationally Determined Contribution (NDC) in Paris in 2015. Since then, the Paris Accord reiterated the wish that every member country of the UNFCCC should submit a revised Determined Contribution at the national level every five years, and more ambitious than the previous NDCs; to effectively contribute to this global effort of fighting against the negatives effects of climate change, through a significant reduction of greenhouse gas emissions into the atmosphere.

Burkina Faso's contribution to the fight against the effects of climate change on natural, economic, and human systems has been materialized by the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1993 as well as its implementing texts; the signing of the Paris Agreement on Adaptation to Climate Change in 2015. Thus, to better contribute to the global effort of greenhouse gas reduction, Burkina Faso as UNFCCC member country, and signatory to the Paris Agreement in 2015, has submitted its nationally determined contribution (NDC) in 2015. Burkina Faso has committed to reduce his greenhouse gas emissions by about 6% through its unconditional scenario and about 11.6% through its conditional scenario. After five years of implementation of the first generation of Burkina Faso's NDC, the year 2020 marks the deadline for revising the reviewed NDCs in accordance with the provisions of the Paris Agreement adopted in 2015. It is in this global context of NDC revision that Burkina Faso is resolutely committed to reviewing its Nationally Determined Contribution, to comply with the requirements and recommendations of the Paris Agreement. As the principle and objective of revising the NDCs is to revise the greenhouse gas emission reduction targets upwards, it was necessary that the GHG reduction potential of the actions to be included in Burkina Faso's new NDC be assessed to enable Burkina Faso to set new ambitious, realistic, and achievable targets.

However, it is important at mention that at this moment, there is no greenhouses gas model to enable technician/ practitioners to easily assess capacities in term of GHG reduction. The present paper will provide interesting elements to support the prioritization of actions with high GHG reduction potential to be included in the NDC and to help decision-makers to make strategic choices, improving their contribution to the international effort of stabilizing the earth's temperature in the range of 1.5 to 20 C. Therefore, to better support this objective, it become urgent, the establishment of a greenhouse gas modelling for the sector of Transport. The model will support and help practitioners in their everyday work.

2. Materials and Method

2.1 Vehicle Type Identification

To identify the type of vehicle 10 years' time series data of vehicle from 2010 to 2020 were collected through the statistical office of the Ministry of Transport urban mobility and Road Secure of Burkina Faso. For each time series the type of the vehicle was recorded in order to establish a complete list of vehicles imported in Burkina Faso. To get a broad idea on vehicle number increasing, Gross Domestic Product (GDP) elasticity (0.8) and average (3.47%) from historical data have been used. For that 2017 was used as baseline year given the availability of data to cover the analysis.

2.2 Greenhouses Gas Model Development

For each type of vehicle identified, a specific model was developed using the general Equation (1)

$$E = N \times D \times F \times E_f \times \frac{A}{100} \qquad (1)$$

Where :
-N: Number of vehicle in given type of vehicle
-D: Annual average travelled distance in (Km)
-F: Fuel economy per type of vehicle (Liter/100 Km)

-Ef: Emission factor of fuel type.

-A: Fleet availability /Availability of the vehicle or percentage of vehicle use (%)

For all parameters in greenhouses gases modelling, Fuel economy, Emission factor of fuel type and vehicle availability were considered as constant parameters while only Number of vehicle and Annual average travelled distance were variable parameters. All the constants parameters were obtained through literatures reviews and previous published works within the country, in West Africa and over the world [5,6].

2.3 Greenhouses Gas Vehicle Model Calibration and Validation

For model's calibration and validation, data from 2017 were used as baseline year according to the availability of data. Moreover, fuel consumption data used for 2018 National greenhouse gases inventory in transport sector were used to calibrate and validate the model. The testing and calibration allowed performing each model per type of vehicle.

3. Results and Discussions

3.1 Vehicle Type in Burkina Faso

In Burkina Faso 10 vehicles types were identified in road transport sector (Table 1).

Table 1. type of vehicle identified following the Ministry of Transport classification in Burkina Faso

N0	Type of vehicle	Observation
01	Private cars	Widely uses
02	Public Transport - Buses	Minority uses
03	Special Vehicle	Minority uses
04	Other vehicle	Minority uses
05	Motor Cycles	Minority uses
06	Wheeler	Minority uses
07	Rail	Minority uses
08	Van	Average uses
09	Lorries	Average uses
10	Truck Tractor	Minority uses

3.2 Projection in the Number of Vehicles, Per Type, from 2017 to 2040

Vehicles trend analysis shown a huge increase in motorbikes from 2.3 million in 2017 to 7.7 million in 2040 (Figure 1).

The exponential increasing of motorbike could contribute to the worsening of air pollution in the country and lead to some disease development and climate change. The World Health Organization (WHO) estimates that urban air pollution contributes to approximately 800,000

deaths per year in the world [7] and the principal gases affecting human health are among other PM10; Nitrogen Dioxide (NO_2); Sulphur Dioxide (SO_2) and O_3 and are more generated by transport sector. However In Burkina Faso the average NO_2 concentration increased from 24.9 $\mu g/m^3$ in 2007 to 94.7 $\mu g/m^3$ in 2012 [8-10]. The PM10 concentration has also increased from 1800 $\mu g/m^3$ in 2007 to about 2800 $\mu g/m^3$ in 2019 [11] and will become worse in the future given the vehicle and motorbike park increasing rate.
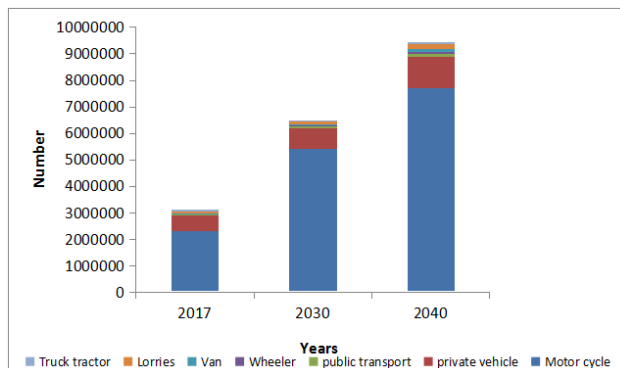
Figure 1. Vehicle number.

Source: data source from the survey

3.3 Values of Constant Parameters Used

For each vehicle type five parameters were used to calibrate the model using the baseline year data of 2017 (Table 2).

Table 2. type of vehicle and constant parameters used for Greenhouses gases modelling calibration and Validation.

Type of vehicle	Type of fuel	Fleet availability (%)	km/vehicle/year	Fuel Economy - L/100km	Emission F - kgCO2e/L
Private cars	gasoline	0.75	15 000	9	2.62
Public Transport - Buses	Diesel	0.66	20000	40	2.77
Special Vehicle	Diesel	0.75	10000	15	2.77
Other vehicle	Diesel	0.75	10000	15	2.77
Motor Cycles	Gasoline	0.75	7000	2	2.62
Wheeler	Gasoline	0.75	7000	5	2.62
Rail	Diesel	-	-	11.6	2.77
Van	Diesel	0.66	30000	15	2.77
Lorries	Diesel	0.66	30000	25	2.77
Truck tractor	Diesel	0.66	40000	30	2.77

Among the recorded parameters only gasoline emission

factor has been developed in Burkina Faso [12] the other parameters are default value developed by previous work outside the country [4,13].

3.4 Vehicle Type Model for Greenhouses Gases Assessment in Road Transport Sector

3.4.1 Private Vehicle Model Equation

The model for private vehicle CO2 equivalent assessment is given by Equation (2).

$$E_{pc}(Teqco_2) = (1.7685 D_{PC} \sum N_{Pc}) 10^{-10} \qquad (2)$$

Where E_{Pc}: CO$_2$ equivalent emitted by private vehicle
N_{pc}: Number of private vehicle
D_{Pc}: Average annual distance travelled

3.4.2 Special Vehicle Model Equation

The model for Special vehicle CO$_2$ equivalent assessment is given by Equation (3).

$$E_{Sv}(Teqco_2) = (3.11625 D_{Sv} \sum Nv) 10^{-10} \qquad (3)$$

where E_{Sv}: CO$_2$ equivalent emitted by Special vehicle
N_{Sv}: Number of Special vehicle
D_{Sv}: Average annual distance travelled

3.4.3 Public Transport - Buses Model Equation

The model for Public Transport/Buses CO$_2$ equivalent assessment is given by Equation (4).

$$E_{Pt}(Teqco_2) = (7.3128 D_{Pt} \sum Nt) 10^{-10} \qquad (4)$$

where E_{Pt}: CO$_2$ equivalent emitted public transport / buses
N_{Pt}: Number of public transport/buses
D_{Pt}: Average annual distance travelled

3.4.4 Van Model Equation

The model for Van CO$_2$ equivalent assessment is given by Equation (5).

$$E_v(Teqco_2) = (2.7423 D_v \sum Nv) 10^{-10} \qquad (5)$$

E_V: CO$_2$ equivalent emitted Van
N_V: Number of Van
D_V: Average annual distance travelled

3.4.5 Lorries Model Equation

The model for Lorries CO$_2$ equivalent assessment is given by Equation (6).

$$E_L(Teqco_2) = (4.5705 D_L \sum N_L) 10^{-10} \qquad (6)$$

where E_L; CO$_2$ equivalent emitted Lorries
N_L: number of Lorries
D_L: Average annual distance travelled

3.4.6 Motor Cycles Model Equation

The model for Motor Cycles CO$_2$ equivalent assessment is given by Equation (7).

$$E_{Mc}(Teqco_2) = (3.93 D_{Mc} \sum N_{Mc}) 10^{-11} \qquad (7)$$

Where E_{Mc}: CO$_2$ equivalent emitted Motor Cycles
N_{Mc} number of motor-cycle
D_{Mc}: Average annual distance travelled

3.4.7 Wheeler Model Equation

The model for Wheeler CO$_2$ equivalent assessment is given by Equation (8).

$$E_w(Teqco_2) = (9.825 D_w \sum N_w) 10^{-11} \qquad (8)$$

Where : E_W: CO$_2$ equivalent emitted wheeler
N_W Number of wheeler
D_W: Average annual distance travelled (Km)

3.4.8 Truck Tractors Model Equation

The model for Truck Tractors CO$_2$ equivalent assessment is given by Equation (9).

$$E_{Tr}(Teqco_2) = (5.4846 D_{Tr} \sum N_{Tr}) 10^{-10} \qquad (9)$$

Where E_{Tr}: CO$_2$ equivalent emitted from truck tractor
N_{Tr}: Number of Truck Tractor
D_T: Average annual distance travelled (Km)

3.4.9 Other Vehicle Model Equation

The model for Truck Tractors CO$_2$ equivalent assessment is given by Equation (10).

$$E_{Ov}(Teqco_2) = (3.11625 D_{Ov} \sum N_{Ov}) 10^{-10} \qquad (10)$$

Where E_{Ov}: CO$_2$ equivalent emitted from other vehicle
N_{Ov}: Number of other vehicle
D_{Ov}: Average annual distance travelled (Km)

3.5 Potential of Greenhouses Gases Emission

3.5.1 Greenhouse Gases Emission Per Type of Vehicle

The application of the formulas above leads to the fol-

lowing values of GHG emissions for the transportation sector for the reference year 2017:

Table 3. Amount of CO_2 emitted for the base year 2017 (in $MtCO_2eq$)

Vehicle type	Amount of GHG emitted ($MtCO_2eq$)
Motorbike	0.64
Private cars	0.63
Public Transport /Buses	0.18
Three-wheeler	0.01
Pickup/Van	0.36
Truck/Lorries	0.44
Trucks (cabs)	0.52
Road Passenger	1.47
Road Freight	1.32
Rail	0.03
Total	2.82

3.5.2 BAU Greenhouses Gases Emission Scenario Projections

With the various elements of emissions projections prepared for the BAU scenario, results can be simulated, starting with the baseline year 2017 and historical trends (growth rates). The results of the projections are presented up to 2040, which is the target year used in this study (Figure 2).
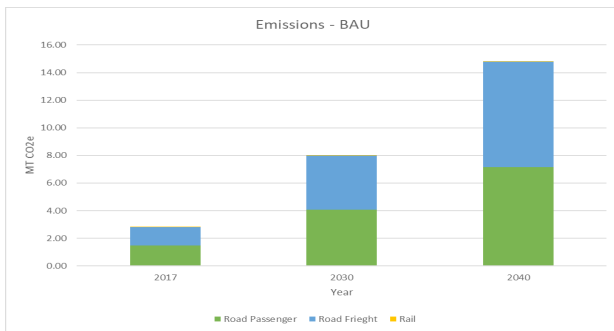

Figure 2. Evolution of GHGs emissions in transport sector from 2017 to 2040

The model shows that BAU emissions will increase from 2.82 MT in 2017 to 8.04 MT in 2030 and to 14.84 MT in 2040 (Figure 3). It should be noted that this figure is higher than the current CDN forecast (6.9 MT in 2030). However, the current NDC is solely based on fuel data and an assumption of 8% annual emissions growth. In addition, the current NDC includes aviation emissions with the assumption of increasing emissions from rail transport, unlike the present analysis which excludes aviation and assumes a constant evolution of rail emissions, due to the difficulties in deriving a future trend in rail fuel consumption from the available data.
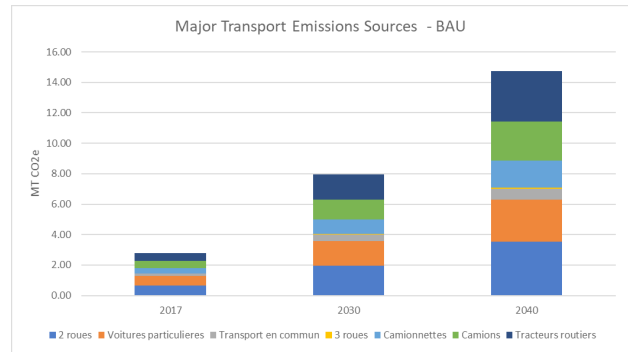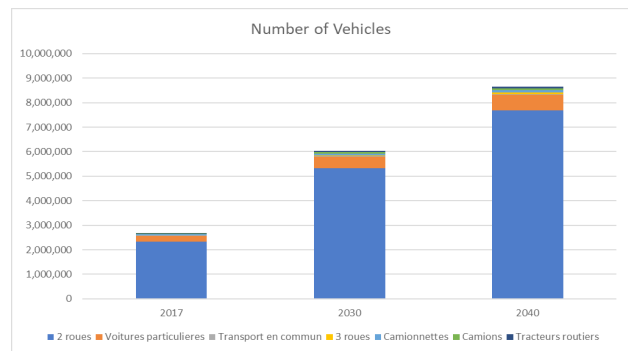

Figure 3. Contribution to Transport GHG Emissions by Vehicle Type from 2017 to 2040

Most of the sector's emissions come from freight transport vehicles (trucks and road tractors) with about 40% of total emissions. This mode is followed by 2-wheelers, which account for 25% of emissions, then by passenger cars (18%). 1These contributions show the need for an approach that addresses both passenger and freight vehicle emissions through the implementation of options that would absorb and reduce the growing volumes of the concerned vehicle types traffic, as shown in Figure 4 and Figure 5, where we see a considerable increase in the number of motorbike from 2.3 million in 2017 to 7.7 million in 2040 and passenger vehicles from 238,551 in 2027 to 626,042 in 2040.
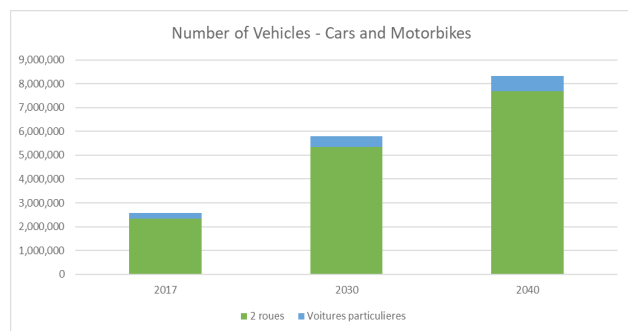
**Figure 4.** Evolution of vehicles number from 2017 to 2040

Figure 5. Evolution of vehicle fleet by type from 2017 to 2040

As shown in Figure 5, the volume of motorbikes dwarfs other modes of transport. But it is important to remember that in terms of relative contribution to total emissions - as mentioned previously - an approach from government to tackle all forms of emissions (from passengers and freight) will be needed.

It is also important to note that the problem of air quality arises in Ouagadougou. This situation will worsen in the future and requires further analysis on the issue. Air pollution has become a major concern because of its adverse effects on the environment (climate change) and human beings (health problems). According to the World Health Organization, urban air pollution contributes to about 800,000 deaths per year worldwide [7], and the main gases affecting human health include PM_{10}, NO_2, SO_2, and O_3, which are generated more by the transport sector. For Burkina Faso, the average NO_2 concentration has increased from 24.9 μg/m^3 in 2007 to 94.7 μg/m^3 in 2012. PM_{10} concentration also increased from 1,800 μg /m^3 in 2007 to about 2,800 μg /m^3 in 2019 [12]. The results of projections of future changes in vehicle ownership show that this problem will worsen in the future, if public transport policies or cleaner forms of transport are not introduced.

The results are consistent with those observed in other Asian cities and lead to major challenges in terms of air quality and road congestion, on the assumption that trends in GNI and hence in vehicle ownership would increase at historical rates. If GNI per capita were to increase (even at an average of 7 percent per year), traffic would grow at an even faster rate (see box on Vietnam).

It was not possible to predict the evolution of rail consumption due to lack of data. The analysis of existing data has showed a decreasing trend in fuel consumption, which motivated the choice of a constant evolution assumption in rail emissions compared to the 2017 level. The change in rail transport fuel consumption over the period 2010-2017 is shown in Figure 6:
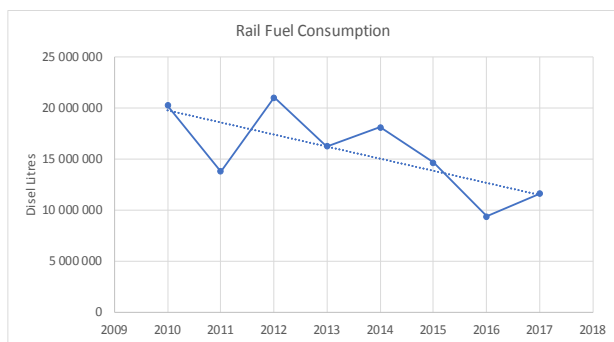
Figure 6. Change in rail transport fuel consumption from 2010 to 2017

3.6 Comparison with Viet Nam - Should GDP Increase Much Faster than 3.4%

Viet Nam is one of the world's development success stories, with rapid economic development since the 1990s, due to market reforms and the end of the US-led trade embargo. During this time GDP per capita has increased from US $96 in 1990 to US $ 2,715 in 2019, with subsequent dramatic falls in poverty, and increases in life expectancy, literacy, and numeracy. During this time, vehicle ownership has sky-rocketed, with the number of motorbikes having increased 48-fold over the last three decades, from 1.2 million in 1990 to over 58 million in 2018, according to the Department of Traffic Safety at the Ministry of Transport. The two major cities of Hanoi and Ho Chi Minh City (HCMC) have the largest number, with nearly 6 million and 8.5 million, respectively. This rise in vehicle ownership has brought about several challenges in deteriorating air quality and traffic congestion. Indeed, Hanoi has the ominous record of being the second-worst city in South East Asia for air quality and even recorded an unprecedented level of 385 on the AQI in 2019, with road traffic being one of the major causes (along with coal fired power stations, heavy industry and agricultural emissions).

The case of Viet Nam offers a warning and an opportunity for Burkina Faso, Burkina Faso is at a similar development stage to what Viet Nam was in the late 1990s, and like Viet Nam, there exists aspirational demand for vehicle ownership, in particular that of motorbikes. Though our analysis has shown that motorbike ownership will grow to from 0.11 in 2017 to around 0.25 per person in 2040 (assuming a population of 30 million in 2040), Viet Nam today has around 0.6 bikes per person (58 million bikes per 96 million people) - so even though the 7.7 million bikes predicted by our model in 2040 for Burkina Faso looks large, the stark reality is that this could be a large underestimation. Should Gross Domestic Product (GDP) growth advance at a faster rate, which would be very desirable, and the government fail to invest in public transportation, Ouagadougou, like Hanoi and HCMC today, could be beset with air quality and road traffic problems.

There exists a golden opportunity to prioritize public transportation that is fast, green, efficient and affordable that is backed up by the correct policy environment, to encourage as many Burkinabe to take public transport over their motorbike or car.

4. Conclusions

There is somewhat of a "time bomb" of emissions in the motorbikes and the preference for this as the preferred

mode of transport. Without the correct government policies, including supporting public transport, we can expect a dramatic increase in motorbike ownership from today's levels bringing with its air quality and congestion issues. And the lack of investment in rail will push more and more freight into trucks, further increasing emissions.

The results from this study help to close the existing knowledge gap with respect to Greenhouses gases estimation in road transport sector. It will help developing countries to easily assess their yearly Greenhouses gases emission in transport sector and to meet the IPCCC 2006 guidelines for tier 2. The simplified model equation will be used as decision making tool to guide decision maker in developing and implementing a low emissions action in the transport sector. Given the fact that the simplified models equation has been established using secondary and default data. We recommends that following work to come out with specific parameters to increase the accuracy on greenhouses gases estimation in the road transport sector (i) survey on KMs travelled per year and fleet availability in Burkina Faso and overs West Africa, (ii) establishment of specific emission factor of Gasoline and Diesel fuel and (iii) survey on Fuel economy information in Burkina Faso and over west Africa. Better data would strengthen the model, for example on average KMs driven and fuel economy of vehicles. These data should be collected via surveys and can be fed into the model in future.

Authors' Contributions

This work was carried out in collaboration between all authors. TN designed the study, performed the statistical analysis, and wrote the first draft of the manuscript. GY, BY, ON and SW and guided the design of the study and supervised data collection and analyses of the study.

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Conflict of interests

Authors have declared that no competing interests exist.

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