ESTIMATION OF MARGINAL SOCIAL COSTS, ISSUES AND SUGGESTIONS: THE CASE FOR NAMIBIAN ROADS

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ABSTRACT

Road infrastructure while delivering economic benefits, generates negative externalities and places a heavy burden on the fiscus for funding. Road users impose various costs on fellow users, and the rest of the society when making use of the network. Normally, vehicles cause insubstantial damage to the road surface and may not only emit some emissions, but also add significant congestion costs in urban areas and increase the risk of accidents. What is generally less explored in developing countries is the internalisation of negative externalities into road pricing which do influence the present and future price of road use. The price road users pay for their road use hardly reflects the true cost of a trip. Failure by the road users to factor in the external costs when deciding to undertake a journey gives rise to various problems that have repercussions for the transport system, the environment and the society. In order to bring about more efficiency in the transport system, economists advocate charging road users at an efficient price, the so-called short-run marginal cost of road use. This paper explores the possibility of using the pavement management system (PMS) model mostly used by road agencies in Namibia. The model is used to plan and estimate the marginal externality cost of road use. The results demonstrate that it is possible to attain estimates of the marginal cost of road use in Namibia. Importantly, setting road use charge equal to the correct price does lead to road funding deficit, as reported in literature. These findings may indicate a dilemma faced by many developing countries with expansive road networks and a small vehicle population. The paper concludes with various options of how to address the deficit and support road funding without deviating from the efficient pricing principle.

Keywords: Marginal social costs, pavement management system, externalities, road-pricing.

1. INTRODUCTION

An increased interest for transport policy to tackle the negative externalities by means of charging instruments have attracted notable studies on estimating marginal social costs (MSC) of road user over the past two decades. Research conducted on how to measure the marginal social costs and assign monetary value towards the efforts of road pricing were predominantly in developed countries. Remarkable European Union (EU) studies which seem to form the fundamental methodology on estimating MSC of transport includes UNITE (2003), GRACE (2008), and IMPACT (2008). In contrary, the concept of estimating MSC of road use in most developing countries and Sub-Saharan Africa in particular is still at its infant stage. The user-pay principle aimed at holding road user accountable for the costs they impose on the infrastructure, to other drivers using the same facility (in terms of congestion and accidents risks), and to the society form part of the policies document without further knowledge on the value of such negative externalities. The Namibian

Transport policy (2017) called for the refinement of the current Road User Charges System (RUCs) in order to assess the feasibility of implementing the user-pay principle, and ensure full-cost recovery from those who consume the road network for economically justification of road projects and programmes.

Road transport abounds with externalities and the implication of not accounting for these externalities and internalise them into road pricing so that they influence present and future price or road use, is generally less known. The Road Authority (RA) uses a Pavement Management System (PMS) to strategise maintenance expenditures and motivate investment required for the national road network. Unfortunately, the use of the PMS to influence the present and future road pricing remained a grey area in the authority domain despite the fact that road pricing presents a more efficient way of allocating resources (road space). Although road users in Namibia pay road-user charges in form of the fuel levy, vehicle registration and licence, cross border charges, mass distance change and abnormal load levies, most of these instruments do not follow the user-pay principle. In line with this fundamental concept, the theoretical framework guiding this paper was the failure of implementing the road user charges set at the economically efficient price based on the SRMC principle.

In order to maximize net economic benefits, road pricing should be set equal to the short-run marginal social cost (SRMC) of road use (Nash & Matthews, 2005). The road price is reflected as short-run because charges only consider the use of existing roads without putting any consideration of how the expansion or new road investments should be funded. In the same token, while marginal component stands to reflect an additional costs associated with additional vehicle kilometre travelled given that the infrastructure capacity is held constant (Matthews, 2010), social component implies costs to the society (both positive and negative externalities). Marginal social costs also comprise of two main components including the marginal private cost (MPC), and marginal external cost (MEC) of road use. The MEC is the cost that arises with the use of the road, and it is neither that the road users consider nor bear such costs when undertaking a journey. On the other hand, the MPC represents the cost that road users bear or take into consideration before undertaking a journey.

Several shortcomings of the SRMC principle are well outlined by (Rothengatter, 2003). Implementing the principle of marginal social cost for road use is quite a challenging exercise, it is time consuming and it requires an extensive budget (Khan, 1988, Link et al., 2016). The marginal external costs are situation based and location specific making it difficult for practical use (Shepherd, 2003). Despite the difficulty in implementing the marginal social costs principle, road pricing should aim at attaining economic efficiency in order to ensure correct allocation of resources as well as reduce vehicle operation cost, safety, revenue generation and significantly to bring about gains to the economic development.

Setting price equal to SRMC does not guarantee that marginal revenue exceed marginal costs or the revenue covers marginal costs. Road user charges set at the SRMC could lead to revenue deficit or surplus (Proost & van Dender, 2003; Heggie 1995). Kahn (1988) outlined the principal challenge of setting the price at SRMC, in that networks defined by low demand and excess capacity, SRMC pricing is likely not to cover the fixed cost (return on capital investment) that the road agency ought to recoup from the road users. Literature suggested the calculation of the optimal user charges in order to assess whether it yields into a deficit or surplus, while the results should serve as a point of departure (Walter, 1968). In the case of excess demand, short-run marginal pricing is likely to generate excessive revenue.

In Namibia, the studies on Road Management System (RMS) focus on the use of PMS, in particular, the HDM-4 model for planning especially for budgeting purposes on motivating more funding for the network needs (Tekie, 2015). The use of PMS is yet to be extended to road pricing, especially on marginal costing basis. Thus, this study seeks to fill this gap. This paper follows Bruzelius' (2004) argument that if road agencies use pavement management system (PMS) such as the Highway Development and Management (HDM-4) model for planning purposes, then why not use the same planning models to determine the marginal costs of road use and set road user tariffs. To the knowledge of the authors, estimating MSC of road user has not been conducted in Namibia.

This paper attempts to address the gap between the proposed user pay principle as a road pricing policy and a strategy towards its implementation. The paper further describes the methodology for using the HDM-4 to estimate the marginal external costs. The main objective of this paper is to demystify marginal external cost estimations and assist road agencies to internalise externalities into road pricing. The paper is organised as follows. Section 2 provides a brief review of the surveyed literature in determining the marginal external costs. Section 3 discusses the methodology used to estimate marginal external costs. Section 4 discusses the results in comparison with the average costs and the paper concluded with recommendations for future work.

2. LITERATURE ON ESTIMATING MARGINAL EXTERNAL COSTS TRANSPORT

This section provides a survey of some studies that contributed to the literature of MEC (Ghadi et al., 2018, Gavanas et al. 2017

2.1 Accident costs

Traditionally, accident costs relied on two methodologies including human cost approach, and the value of statistical life (willingness to pay) to determine the costs. The human capital approach involves an observation of present and future expenditure as a result of accidents and include medical and hospital costs, legal and administrative costs and property damage (Ghadi et al, 2018). The willingness to pay includes risk values such as loss of productivity to the economy due to premature death, and thus the willingness to pay in order to reduce accident risks. Ghadi et al., (2018) used the human capital approach to estimate the total and unit cost of traffic accidents in Jordan for the period of 2011-2013. The study estimated total costs of accident at US $ 3814, US $ 4718 and US $ 5146 for the year 2011, 2012 and 2013 respectively. The latter constituted about 2.5%, 2.3% and 2.25% respectively of the total country's GDP. In Namibia, the cost of vehicle accidents to the Namibian economy was estimated at N$ 512 million [US$ 35 million] (NRSC, 2016). In 2015, the average cost of an accident in Namibia was estimated at N$ 19 047, an equivalent of US$ 1 320, and about N$ 1 604 (US$ 111) per registered motor vehicle (NSRC, 2016).

2.2 Congestion costs

Congestion builds up when an additional vehicle join the network and potentially reduce the speed of other vehicles thereby causing journey delay and high fuel consumption. Therefore, it is essential to calculate the time lost due to third party influence by an additional vehicle on the network. Congestion costs is highly influenced by the marginal time costs. The marginal external time cost is calculated by the difference in a journey time caused by an additional vehicle on a specific network multiplied by the estimated value of the journey time (Blauwens et al., 2012). The marginal external congestion cost is therefore obtained after the congestion charges are determined. Another methodology used in the literature is the speed-flow relationship used to estimate changes in the journey time. Gavanas et al. (2017) used the speed flow function to assess the congestion costs which served as an input to further estimate the marginal and total social cost using the floating car data. The study utilised the following equations to estimate marginal and total social cost for congestion along Tsimiki Street in Thessaloniki, Greece:

$$\text{Marginal Social Costs congestion} = F.C + V.O.T\,\frac{S+395.791}{395.791\,S} \quad ,(When\ S = 25.72)\ldots. \quad (1)$$

$$\text{Total Social Costs congestion} = 1.275.e^{x3.204+X}.\left(F.C + V.O.T.\frac{1+X}{395.791}\right)\ldots \quad (2)$$

Where F.C represents fixed cost and V.O.T represents the value of time and S represents speed. The finding of their study is summarised in (Table 1) presenting the difference in marginal and total social costs due to congestion between the values that correspond to the average hourly speed during a workday and the 85 percentile hourly speed of a workday.

Table 1: Marginal and total social costs for congestion along Tsimiski Street

Speed (km/h)	*Flow (PCU/h)*	*MSC(€/passenger.km)*	*MSC(€/passenger.km)*	*TSC (€/km)*
Daily average hourly 29.6	1425	0.496	0.513	731.025
85 percentile hourly 32.4	923	0.456	0.473	436.579

Source: Gavanas et al., 2017

2.3 Environmental costs

Environmental costs mostly consist of the three main components including air pollution, global warming and noise. The common approach to air pollution is mainly the impact pathway (bottom-up) which models the emission, their dispersion, risk exposure and then monetise the value obtained. The standard approach for estimating the global warming costs involves multiplying the amount of the carbon dioxide equivalents emitted by the cost factor then multiply by the global warming potential of the associated gas. In South Africa, Lotz and Brent (2017) conducted a study on carbon footprint that seems to be one of the leading guidelines to many practitioners and companies in calculating carbon footprints. The intended national determined contributions' (INDC) report covers three direct gases including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The report uses the IPCC 2006 guidelines, software, and adopted the Global Warming Potentials (GWP) mainly carbon dioxide (1), Methane (21), and Nitrous Oxide (310). Namibia contributes less than 0.1 percent to global emission (NDC Partnership Support Unit, 2017), and the country's carbon dioxide-equivalent (CO_2e) emission outlooks indicates a 63 percent contribution of carbon dioxide, 21 percent of methane, and 16 percent of nitrous oxide respectively.

2.4 Infrastructure damage

The marginal cost of road use associated with an additional vehicle utilising a specific network comprises three components including road damage externality, road wear and damage (Bruzelius, 2004). Road damage externality implies the increased road use costs imposed on other vehicles because of an additional vehicle that joins the network leading to a faster deterioration. Road wear and damage are conditions which cause the road authority to take an earlier action (routine and periodic maintenance) to remedy the wear and damage at an early stage that the case would have been without an extra vehicle. The amount of damage caused by vehicles is often associated with axle load to the fourth power (Blauwens, et al., 2012). Furthermore, the marginal infrastructure costs has been estimated using four main approaches. First, is the direct approach which mostly uses the pavement management models and yield estimates in the form of a discounted value. The second is the indirect method that based on David Newbery's fundamental theorem, and it assumes that road damage externality is equal to zero. The club approach is the third, and it is often based on equity and not compatible with marginal cost principle. The fourth is econometric approach which often estimates marginal cost after the cost function built on the microeconomic production theory.

The study by Bruzelius (2004) was based on the direct method to estimate the marginal infrastructure cost on a section of the Swedish national road network. The study utilised a PMS model to estimate the net present value (NPV) of a defined action. The cost of the marginal user was determined by calculating the difference between two NPV alternatives, one with an increase AADT by one unit (with a case) compared to a do-nothing case. A run was performed with HDM-4 for the identified road in Southern Sweden. The results indicated that the road damage externality was found more important than the wear and damage in Sweden. He concluded that marginal based pricing presents a promising chance to recover costs associated with road damage externality than with wear and damage for the period of 50 years in Sweden.

3. THE HDM-4 MODEL AND METHODOLOGY FOR ESTIMATE MARGINAL EXTERNAL COST

The Highway Development Management (HDM-4) model of the World Bank is commonly used in developing countries including Namibia. The model is mainly used for the economic appraisal on road investment needs and maintenance strategies. The Road Authority of Namibia makes use of HDM-4 primarily for determining the appropriate maintenance strategy and investment needs for the national road network. This section explores the use of the same model for estimating the marginal external cost of road use for Namibia.

HDM-4 allows calculation of all the marginal external cost components including infrastructure damage, accident costs, congestion costs, and environmental costs for a wide range of vehicle classes with further modifications. The physical description of the road section or network including length and types of road, traffic characteristics such as speed-flow, fuel consumption, passenger car space equivalence etc., are used to calibrate the model. In case where network data is not available, the model allows for default values that could be calibrated to the Namibian environment.

A workspace was obtained from the Namibian Road Authority. Estimations were based on a case study representing a paved road sampled from the district roads of the national road network. The road section is assumed homogeneous in order to aggregate network capacity into one speed-flow relationship. The section is classified as standard two lanes, road width and aggregate calibration include climate zones, length (km) and AADT. The vehicle fleet comprises six representative vehicle categories: 4x4 sport utility vehicle, articulated truck, bus, heavy truck, medium car, and minibus. The output from the HDM-4 include the NPV, fuel consumption per 1000 vehicle kilometres, emission per vehicle categories and speed flow formed the basis for the calculations. The marginal estimated costs were compared to estimated fuel levy income per vehicle per kilometres and the average cost per vehicle per kilometre of using the sampled road section.

3.1 Fuel levy

Fuel levy forms part of the current road user charges (RUC). The fuel levy charged per litre of petrol and diesel is the only instrument among other RUC that could be related to variable cost (per litre) of road use. Thus, fuel levy charged per km and per road section estimated to determine what users are paying. It was on this basis that we opted to estimate the fuel levy income generated from the sampled section of the road and compared such to the average cost per vehicle per kilometre and the marginal cost per vehicle per km estimates from the same portion of the road section. Motor vehicle owner and road users pay in total N$ 180.30 cents fuel levy per litre of petrol/diesel of which N$ 1.30 cents is road user charges towards the Road Fund Administration (RFA), and N$ 50.30 cents accrue to the Motor Vehicle Accident (MVA) fund (Ministry of Mines and Energy, 2019). Factors necessary for consideration in the calculation of the fuel levy income generated per vehicle per kilometre of the sampled section includes the type of vehicle and fuel consumption, type and quality of the road network and traffic conditions. The results of the fuel levy generated per vehicle per kilometre on the 61.05 km road section are presented in Table 3.

3.2 The average costs

Average cost implies the total cost of infrastructure divided by a measure of output such as vehicle-kms (Commission of European Communities, 1998). The average cost shows the road provision and use per unit of traffic and mostly used for cost-recovery. The average total cost of each external components of road use was calculated by taking the average total costs dividing by the total annual AADT per section. For instance, the average infrastructure costs of road use were calculated by taking the annual net present value (NPV) of maintenance costs divided by the AADT for all the vehicle types per road section. In addition, cost allocation was done using the apportionment formula that consider the size and weight of the vehicle. However, there are various factors that could potentially influence the value calculated and the details of each component are discussed under section 3.3. The average costs estimates are illustrated in Table 3.

3.3 Marginal external costs

Table 2: Steps and factors that influence estimating of the marginal social cost

Externalities	Descriptions
Marginal infrastructure costs	The marginal infrastructure costs was calculated from an output of an HDM-4 run mainly an estimate of the NPV of an action. Considering the outline maintenance strategy, two cases (do nothing with AADT and do minimum with AADT increased by one additional unit) are compared, and the difference between the NPV of the two cases are calculated. Therefore, the cost of the marginal user may be determined. The major factor for consideration for estimating the marginal infrastructure costs is the ESAL factor. In order to obtain the marginal cost of one vehicle, corrections were made to account for the analysis that was based on an increase in one unit a day, and future days, and not just that specific occasion. The results of the estimates are presented in Table 4.

Table 2: cont'd

Externalities	Descriptions
Marginal congestion costs	The estimate of the marginal congestion costs relies on the speed-flow relationship. An output of an analysis using HDM-4 model is an estimation of the net time loss of a certain action. Typically, two alternatives are compared in terms of hourly flows of a given period as a proportion of AADT. The marginal time was determined by the difference between two actions, one having an increase in the AADT by one additional vehicle in comparison to another. For the purpose of calculation, it was assumed that time loss is valued at N$ 5 per minute. A correction was made to account for the homogeneous stream in terms of passenger car space equivalences (PCSE) for all vehicles. Another factor considered was that analyses were based on an increase in one unit per minute, thus a need to cater for all minutes in a given year and not just that particular point.
Marginal accident costs	An output of an analysis using HDM-4 model provides input data for calculating the total accident cost per causality including fatalities, injuries and damage only costs. The major factors considered on the estimation of the marginal accident costs are mainly the accident rate per 100 million per vehicle per kilometre, the road category, and the annual kilometres travelled.
Marginal environmental costs	Marginal environmental costs defined in section 2.3 include three components. However, calculation considered here are only those associated with global warming. Global warming costs are calculated by multiplying the greenhouse (GHG) gases emitted by the global warming potential (GWP), and obtain the carbon dioxide equivalent (CO_2e). The main factor of necessity to global warming costs is fuel consumption per 1000 km. The Namibian environmental levy rate value of N$ 40 of CO_2 emission exceeding 120g/km was used to assign a monetary value per vehicle per km.

3.4 Application of the HDM-4 Model for estimating the marginal external costs

The case study presents a sampled section of a district-paved road of the national road network. The road is 61.05 km in length, 6.78 width and carries averaged daily traffic of 224 motor vehicles including 69 pick-ups, 20 articulated trucks, 1 bus, 12 heavy trucks, 105 medium cars and, 17 mini-buses. Analysis period of 20 years was used and, a discount rate of 12% was applied. The road was assumed to have been newly constructed at the beginning of the period. The assumed maintenance strategy is that the road is subjected to overlay when roughness (IRI) exceeds 5.23, a partial resurfacing if more than 10.61% of the road area suffer all structural cracking, or a partial overlay if rutting exceeds 13 mm. This maintenance strategies could apply to a paved road in the Hardap region.

4. RESULTS

Table (3 and 4) presents the results for the average social cost and marginal social cost of road use in comparison to the revenue generated (fuel levy) per vehicle per kilometre. The comparison of average social costs to revenue (Table 3) presented results that differ slightly in terms of vehicle type for the sampled case study. The district paved road with the exemption of heavy articulated trucks which impose high costs on the network, thus revenue generated per vehicle per kilometre for all vehicle classes exceed costs per vehicle per kilometre on the sample section.

The comparison of marginal costs of road use to fuel levies revenues (Table 4) results yielded into greater difference in terms of costs and revenue generated per vehicle per kilometre. This implies that charging for marginal external costs on the sampled section of the road network is worse off in comparison to the fuel levy as instrument for charging for road use. These results are in line with Heggie (1995) who made an observation that most roads in developing countries do not experience persistent congestion. Setting road user charges equal to (short-run) marginal social cost will result in financial deficits for low volume rural roads, which is the case with Namibia. In this paper for instance, district paved road sampled, congestion was found to be insignificant or equal to zero. The case is however different in developing world. For instance, results from study by Sansom et al., (2001) indicated that marginal congestion costs alone exceeded the revenue generated per vehicle per kilometre for all representative vehicles. Marginal external cost results for Namibia also indicate a slightly higher accident costs associated with light vehicles as compare to heavy good vehicles (Table 5), whereas, marginal infrastructure presented higher costs for heavy goods vehicles as compared to light vehicles

Table 3: Average Costs and Fuel levies revenue analysis (Cents/Km, Case A- District Road)

Average Costs					Fuel Levies Revenue			Difference
Vehicle categories	Infrastructure Costs	Accident Costs	Environmental Costs	**Total Costs**	RFA Levy (N$ 1.30/l)	Accident Levy (N$ 0.503/l)	**Total Revenue**	Cost-Revenues
4x4	0.180	1.846	0.081	**2.107**	14.612	5.654	**20.266**	-18.159
Articulated Truck	128.324	0.535	2.195	**131.054**	71.027	27.482	**98.509**	32.545
Bus	41.570	0.027	0.483	**42.080**	37.440	14.486	**51.926**	-9.846
Heavy Truck	59.643	0.321	1.509	**61.473**	58.903	22.791	**81.694**	-20.222
Medium Car	0.000	2.808	0.081	**2.889**	14.524	5.620	**20.144**	-17.255
Mini Bus	0.181	0.455	4.471	**5.107**	17.867	6.913	**24.780**	-19.673

Source: Own construct

Table 4: Marginal costs and Fuel levies revenue analysis (Cents/Km, Case A-District Road)

Marginal External Costs						Fuel Levies Revenue			Difference
Vehicle categories	Infrastructure Costs	Accident Costs	Environ-mental Costs	Congestion Costs	**Total Costs**	RFA Levy (N$ 1.30/l)	Accident Levy (N$ 0.503/l)	**Total Revenue**	Cost-Revenues
4x4	0.000	0.043	0.081	0.000	**0.124**	14.612	5.654	**20.266**	-20.142
Articulated Truck	13.660	0.012	2.195	0.000	**15.866**	71.027	27.482	**98.509**	-82.643
Bus	1.433	0.001	0.483	0.000	**1.917**	37.440	14.486	**51.926**	-50.009
Heavy Truck	2.951	0.007	1.509	0.000	**4.467**	58.903	22.791	**81.694**	-77.227
Medium Car	0.000	0.065	0.081	0.000	**0.147**	14.524	5.620	**20.144**	-19.998
Mini Bus	0.000	0.011	0.123	0.000	**0.133**	17.867	6.913	**24.780**	-24.647

Source: Own Calculation

Table 5: MSC and AC of road transport in Namibia, 2019 (Cents/km)

	Marginal External Costs		**Average Costs**	
Roads	**District**		**District**	
Costs components	Light Vehicles	Heavy Vehicles	Light Vehicles	Heavy Vehicles
Infrastructure	0.000	18.044	0.361	229.537
Accidents	0.119	0.020	5.109	0.883
Environmental	0.285	4.186	4.634	4.186
Congestion	0.000	0.000	-	-
Total	**0.369**	**22.244**	**10.104**	**234.606**

Source: Own calculation

5. CONCLUSION

The paper demystified the marginal external costs for road use in Namibia. The Road Authority pavement management system (PMS) HDM-4 model plays an important role in the economic valuation of road infrastructure and subsequently the road pricing. The paper follows Bruzelius (Bruzelius, 2004) that this model can also be used to assist with road pricing. The Road Authority relies on PMS for network investment and maintenance strategy. The PMS however, seems to be more popular for funding motivation and maintenance strategy with a very little investigation done on utilising the same model for influencing the present and future prices of road use.

The results indicated that it is possible to use the HDM-4 model to estimate the marginal externality costs of road use depending on the available data, quality and that the model specification and calibration are accurate. We have demonstrated the applicability of this tool with a case study of a paved road sampled from the national road network. Our case study results suggest that for external cost of road use, heavy vehicles constitute about 97% of both average and marginal external cost of road use with exemption to accident cost where light vehicle show a slightly higher cost. Of all the external costs components infrastructure costs, environmental costs and accident costs appears to be more important costs than congestion costs that turned to be less significant in Namibia. Our results stress that external costs of road use are relevant cost, and should form part of road pricing policy. Furthermore, reforming the current road user charges should be considered most effective and efficient instruments that could reduce global warming costs, reduce accident risks and raise revenue for infrastructure maintenance and development.

Given that the major factor influence of marginal environmental (global warming) cost is fuel consumption, Link et al., (2016) share a similar conclusion that global warming cost are better internalised into fuel levy as a direct proportion with the carbon content of fuel. Given that the heavy goods vehicles contribute the highest to the marginal infrastructure costs, internalisation of this particular cost calls for a revamping of the current mass distance charges. The quantification presented in this paper forms a basis of marginal externality costs estimation that the road agencies could explore to internalise externalities into road pricing, and to ensure that those who consume the scarce resource bear the cost of maintaining and where possible development of new facilities. The marginal external cost pricing as a first-best pricing approach seems not to be a desirable cost recovery for the Namibia national road network as it is likely to lead to financial deficit. A second best pricing alternative is worth exploring. There is a need to classify road infrastructure into categories, separate budget for each category and design pricing for each category. An attempt could still be made to utilise estimates presented in this paper at a broader network level, compare the current road user charges to charges based on marginal costs by applying several policy scenario, and assess their implications on road funding and financing.

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