toll; electronic toll system; road transport

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ELECTRONIC ROAD TOLL SYSTEMS IN SLOVAKIA AND A COUNTRY SELECTED FROM CENTRAL EUROPE

Summary. The goal of this paper is to analyse selected electronic toll systems that are currently used in Slovakia and Poland. In this paper we discuss imposed methods to charge infrastructure used in Slovakia and abroad. Further analysed are various electronic toll systems applied in chosen Central European country and Slovakia. All the electronic toll systems used in the Slovak Republic and Poland are successively analysed. The last section of this thesis focuses on the electronic toll system in Slovakia and its impact on road freight transport via comparison of fixed transport route costs using highway signs and electronic toll collection.

ELEKTRONICZNE SYSTEMY POBORU OPŁAT DROGOWYCH NA SŁOWACJI I W PAŃSTWIE WYBRANYM Z CENTRALNEJ EUROPY

Streszczenie. Celem niniejszego artykułu jest analiza wybranych systemów poboru opłat drogowych, które są obecnie używane na Słowacji i w Polsce. W tym artykule rozważamy narzucone metody infrastruktury poboru opłat używane na Słowacji za granicą. Dodatkowo, analizowane są różne elektroniczne systemy poboru opłat drogowych w wybranym państwie Europy Centralnej i na Słowacji. Wszystkie elektroniczne systemy poboru opłat używane na Słowacji i w Polsce są kolejno przeanalizowane. Ostatni rozdział tej pracy skupia się na elektronicznym systemie poboru opłat na Słowacji i jego wpływie na drogowy transport towarowy przez porównanie ze stałymi kosztami transportu drogowego używając znaków drogowych i systemy poboru opłat drogowych.

1. INTRODUCTION

The European Union promotes a uniform system of charging and financing transport infrastructure. The uniform integrated system of payments for the use of road infrastructure with the by-product of provision of paid services has also a no-negligible political aspect – the possibility to influence and regulate traffic.

The conception of direct imposed charge where the road users are charged according to the distance moved and transport output has been known for several decades. Implementation of modern toll systems is a response to the growing problems faced by public and private tour operators. The first applications of electronic fee collection (EFC) focused on charging urban roads; later highways in the

USA, Canada, Australia and Western Europe are nowadays widespread in 25 countries around the world.

The most widely used technologies for charging are based on positioning methods of the vehicle via a global navigation satellite system with cellular mobile system GNSS / CN using GPS and GSM satellite systems connected to onboard equipment OBU with the infrastructure of choice. A combination of both systems (DSRC hybrid system + GPS / GSM) is used in small scale. Systems containing satellite localization dependent on the accuracy of positioning make the latter European satellite system Galileo possible.

2. ANALYSIS OF SELECTED ELECTRONIC TOLL SYSTEMS

Electronic toll system is a set of means of telecommunications and computer technology, including software and data which is operated by the system operator. Through the technical equipment usage it ensures to have tolls collection done particularly while driving a vehicle without being stopped, reducing speed or having to use the designated lane or binding by obligation setting the route in advance [19].

Various systems are used for the electronic toll collection and these systems are differentiated according to the technology they operate. Nowadays, three types of systems are used, they are namely:

- short-range microwave technology (Dedicated Short Range Communication, DSRC),
- global positioning technology based on GPS (Global Navigation Satellite Systems, GNSS),
- hybrid technology - a combination of the previous technologies into a single integrated whole [4].

From June 2008, till November 2010 the Institute ran the project – „Functional structure of the National Automatic Toll Collection System for the use of motorways and expressways".

The effectiveness of the vehicle recognition (ANPR - Automatic Number Plate Recognition and DSRC - Dedicated Short Range Communication) was 99,9%. Data was 90% of the ideal values and 8 % of the superb ones. During the positioning in the GPS system there were from 5 to 11 available satellites, which covered 99% of all measurements.

The system is interoperable, and can co-operate with GPS/GSM type systems (e.g. implemented in Germany and Slovakia), and also DSRC systems (implemented in Austria, Czech Rep., Spain, France and Italy) [5].

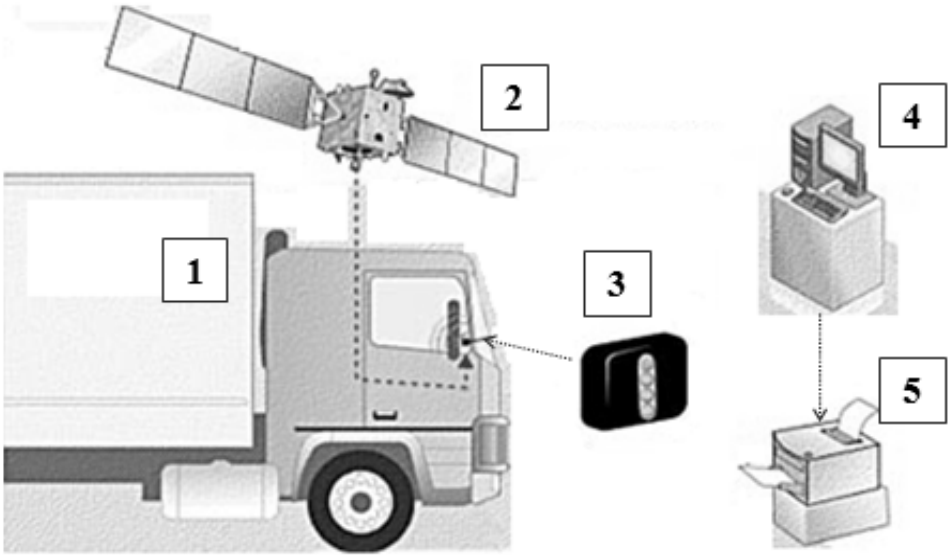
2.1. Electronic toll system in Slovakia

Electronic tolling system using satellite technology which by means of GPS determines whether the vehicle is on the fee section and allows the calculation and levying tolls while driving a vehicle without reducing speed limits or drive in any lane. The motor vehicles obligated to reimburse the toll have to have an on-board unit and registered in the system of electronic toll collection [16].

On-board units set the position of the vehicle based on knowledge of the time, the mathematical model of the motion of satellites and signals that are registered. If the vehicle is located in the demarcated sections of roads, the on-board unit sends the position of the demarcated section of the road and the vehicle identification data to the central information system using mobile GSM network. The central information system based on this information calculates the toll charge. The vehicle operator (or the driver) is responsible for the correctness of the settings, use and control of on-board unit. The following figure (Fig. 1) shows the detailed description of the electronic toll collection by the satellite technology.

2.2. Toll operator in Slovakia

Firm SkyToll, was assigned to establish and operate the electronic toll collection. In January 13 2009, SkyToll signed a contract with the toll administrator, National Highway Company, a. s., where is further stipulated that the toll is a revenue for the toll administrator.



Description:
1. A truck comes to a toll road section.
2. Satellite system detects that the vehicle is on the tolled section of the road and sends a signal to a on-board unit.
3. The on-board unit notify the driver by a sign that he is being charged for the mileage on the toll road sections
4. When the vehicle leaves the tolled section of the road, the system on-board starts to count the mileage and sends the information to the central system.
5. The software calculates how much the carrier has to pay. Carrier will be sent an invoice.

Fig. 1.Satellite system of electronic toll collection [12]
Rys. 1. Satelitarny system elektronicznego poboru opłat [12]

2.2.1. The on-board unit in Slovakia

Board Unit is an electronic technical device that allows unambiguous identification of the position of the vehicle through an electronic toll system. The operator of the vehicle is required to use it in the vehicle that is subjected to responsibility of payment the toll when driving on specified sections of roads from 1 January 2010 on [16].

The on-board unit is owned by the system operator. The vehicle operator is provided with it under contract to provide on-board unit and further in accordance with the regulation no. 25/2007 Z. on electronic toll collection, as amended. The operator of the vehicle is obligated to use only the onboard unit which is provided by the system operator [11].

The system operator provides the operator of the vehicle (or his accredited representative) after signing the contract to provide on-board unit with on-board unit together with accessories right in the place of payment or it is delivered by a courier. If the toll is prepaid the on-board unit can be taken also by the driver of the vehicle [1].

2.2.2. Toll rates in SR

The toll rate per 1 km of the specified road section is to be defined according to the vehicle category with a gross weight of 3.5 t to 12 t, 12 t and more of the total weight of the vehicle and the vehicles allowing the transport of more than nine persons including the driver. The method of calculation must take into consideration the number of axles of the vehicle and at least EURO emission class [11].

Fig. 2. On-board unit OBU 1374 [16]
Rys. 2. Pokładowa jednostka OBU 1374 [16]

2.3. Electronic toll system in Poland

The use of the viaTOLL system is obligatory for the drivers of:

- tractor with semi-trailer with a maximum permissible weight of over 3.5 tones,
- tractor with trailer with a maximum permissible weight of over 3.5 tones.

2.3.1. Toll operator in Poland

System Operator ViaTOLL is a consortium led by Austrian company Kapsch. This company is a designer and supplier of the system ViaTOLL.

2.3.2. Toll rates in Poland

Toll rates are set by the Ministry of Infrastructure in the Council of Ministers on the list of state roads and its sections on which the electronic fees will be charged [14].

2.3.3. Vehicles with a total weight over 3.5 tones

In Poland the electronic toll collection system is based on short-range microwave technology communication (DSRC).

Since July 1 2011, system ViaToll has been used in Poland and it is based on short-range wireless technology. Toll has been paid for motor vehicles and combinations of vehicles with a gross weight of 3.5 tons, which run on the toll road segments [2].

Over the toll road sections are toll gates equipped with antennas that provide communication between ViaBOX placed in the vehicle and transmitters. Toll Fee will be deducted automatically without stopping or slowing down the vehicle at the time when the vehicle passes underneath the toll gate. The driver is informed about the toll deduction by a signal from the ViaBOX [14].

2.3.4. Vehicles with a total weight up to 3.5 tons

Since June 1 2012, drivers of passenger vehicles and combinations of vehicles with the total weight up to 3.5 tons have been able to use an electronic form of payment of fees for a passage across the specific section of motorways. The driver can choose whether to pay a fee at toll booths manually or electronically via ViaTOLL [14].

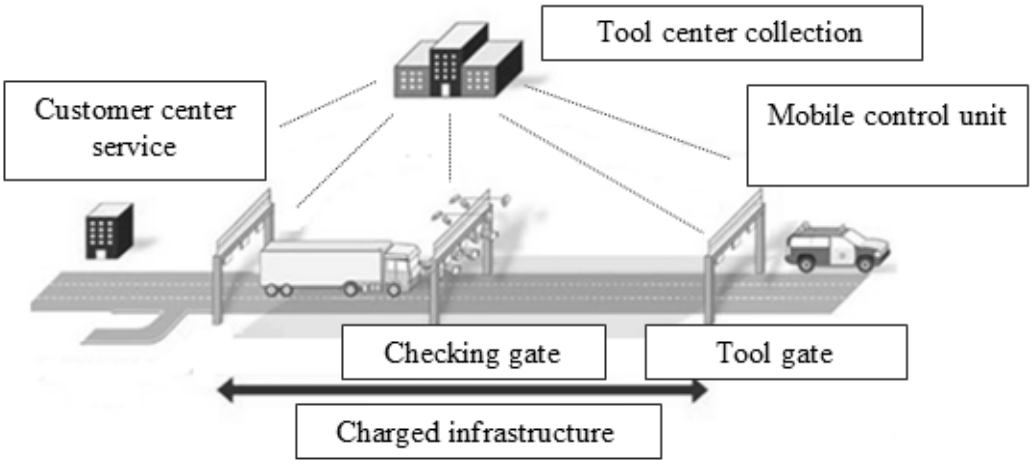


Fig. 3. ViaToll system [13]
Rys. 3. System ViaToll [13]

Vehicles enter the toll highway through the toll booths. The gate opens automatically at the moment the vehicle, respectively, the vehicle combination utilizing the system ViaTOLL, get closer to the tax collector. Mutual communication, between transmitters and ViaAUTO located in the vehicle, allows the antenna placed at toll gates. Toll fee for the use of the toll road section shall be deducted when the vehicle leaves the highway. The system ViaAuto informs the driver about the deduction by signal. If at the entrance to the highway it is found out that the user account is of low or zero balance or the user does utilize passive ViaAUTO, the gate will not open. In this case, the driver has to take a transit ticket and pay the toll manually [6].

Manual system is implemented in a closed mode. The driver takes the ticket at the entrance to the toll road section based on which by the exit of the toll road section he pays the toll fee.The fee is determined based on the vehicle type and the mileage [14].

3. ADVANTAGES AND DISADVANTAGES OF THE ELECTRONIC TOLL SYSTEMS USED IN SELECTED COUNTRIES

When using microwave technology, the low cost on-board units are utilized that are easy to install.

The advantage of these units is their continuous usability. If they are once used for the needs of national power charging, they can also be used for local electronic toll payment.

The advantage of satellite technology over the microwave is that it requires a low number of toll gates. This allows the toll duty to expand quickly to other road sections. The disadvantage of the on-board units is higher costs [6].

Vehicles with the total weight exceeding 12 tones are charged by the electronic toll in selected EU countries. Conversely vehicles with the total weight of 3.5 tons are charged by electronic toll only in Poland. Vehicles up to 3.5t are charged only when buying toll sticker in Slovak Republic.

Electronic toll system was introduced in selected countries in the years 2010 and 2011. Poland was the last country, which introduced the electronic toll system. Toll sections of the road network with the highest number of kilometers among the countries analyzed are in Poland. Vehicles are required to have a board unit due to the electronic toll payment in both of these countries.

Table 1

Selected countries use satellite or microwave technology of electronic toll collection

Selected countries	The technology used		
	Satellite technology	Microwave technology	Hybrid technology
Slovak republic	X	-	-
Poland	-	X	-

Table 2

Vehicle charging by the electronic toll on the total weight in the selected countries

Selected countries	Vehicle charged electronic tolls from the total weight of		
	up to 3,5 t	over 3,5 t	over 12 t
Slovak republic	-	X	X
Poland	X	X	X

Table 3

Main characteristics of electronic road toll systems in selected countries

Selected countries	Year of introduction of tolls	Total Electronic Road pricingat 1.1. 2013 [km]	Toll operator	On-Board Unit
Slovak republic	2010	2 037,602	SkyToll, a. s.	OBU 1374, Sitraffic Sensus Unit
Poland	2011	4 366,192	Kapsch	ViaBox, ViaAuto

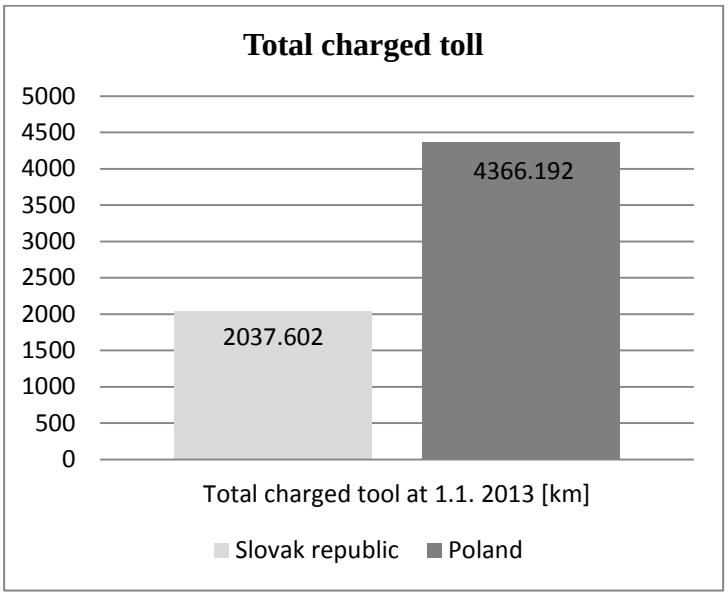


Fig. 4. Depiction of comparison of toll km in Slovakia and Poland (1.1.2013)
Rys. 4. Przedstawienie porównania kilometrowej opłaty drogowej w Słowacji i w Polsce (1.1.2013)

4. THE IMPACT OF THE E-TOLL SYSTEM FOR ROAD FREIGHT TRANSPORT IN SLOVAKIA

The costs are divided into variable costs depending on the distance travelled and the hours of operation of the vehicle, and fixed costs. When calculating the cost of the total annual cost, variable unit costs are calculated depending on the number of kilometers travelled while taking into account the total annual driving performance of the vehicle. These costs are exclusive the downtime so the operator do not bear the costs for it. The calculation is not counted according the hour units. In the case of fixed costs, the same procedure is followed as for the variable costs dependent on the hours of operation of the vehicle. On the basis of fixed and variable costs is calculated a fixed rate for 1 kilometer and downtime for hour. These rates do not takeninto consideration the mark-up [8].

Effect of changes in charges for using the roads has not only changed with the height of the charges, but also with the change of their pricing range. In the following analysis is a model sample worked out where the payments for the infrastructure usage of a particular carrier changes. In the model sample the vehicle consist of five axles with a total weight of 40 t and meets the EURO emission class five [6].

4.1. Analysis of the carriage rates with a toll sticker and electronic toll collection

When calculating the costs by the use of a toll sticker is the set rate per hour of operating a vehicle downtime € 30,7135.

By taking into consideration the coefficient which stands for the rate of all km run and represents 85%, it is calculated as following:

$$\text{rate per}_{km} = \frac{\text{rate per all km}}{\text{coefficient utilization of rides } (\beta)} \quad (1)$$

$$\text{rate per}_{km} = \frac{0{,}7769}{0{,}85} = 0{,}9140\ €/\text{km}$$

The analysis is performed on the transmission line Žilina – Bratislava – figure 5.

Transportation price on specific routes while using toll sticker:

$$Total\ price = 0{,}9140 \frac{€}{km} \,.\, 201\ km = 183{,}71\ € \quad (2)$$

Transportation price on specific routes using while using electronic toll:

Rate for 1 km without toll sticker is:

$$\text{Rate per}_{km} = 0{,}7769 - 0{,}0027 = 0{,}7742\ €/\text{km}$$

The toll rate for semitrailer train vehicles with 5 axles, EURO 5 is € 0.189 / km. This means that the rate for 1 km by taking into consideration the toll is

$$\text{Rate per}_{km} = 0{,}7742 + 0{,}189 = 0{,}9632\ €/\text{km}$$

Rate for 1 km by taking into consideration the coefficient utilization of rides 85%:

$$\text{Rate per}_{km} = \frac{0{,}9632}{0{,}85} = 1{,}1332\ €/\text{km}$$

The total price for transport:

By the day of implementation of toll in Slovakia, on the route Žilina – Bratislava was 175,041 km paid by the electronic toll.

Table 4

Toll calculation for the selected route

Route	The total length of the route [km]	Length of payment of toll motorway section for motor vehicles [km]	Length of toll road of sections I. class [km]	Total length of toll sections [km]
Žilina - Bratislava	201	172,614	2,427	175,041

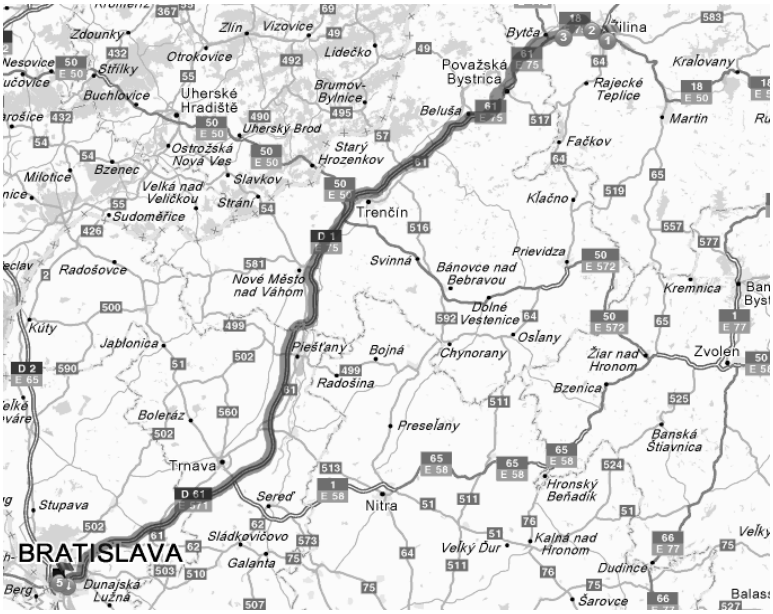


Fig. 5. Route traffic Žilina – Bratislava – 201 km [15]
Rys. 5. Droga Žilina – Bratislava – 201 km [15]

$$Total\ price = 1{,}1332\ \frac{€}{\text{km}} . 201\ \text{km} = \ 198{,}36\ €$$

Table 5

Rate comparison in € / km and the total transportation costs by using toll stickers and electronic toll

	With using a vignette	With using the electronic toll
Rate [€/km]	0,9140	1,1332
Total cost per transportation [€]	183,71	227,7732

The rate for 1 km by using the electronic toll rose to € 0,2191 which meant also an increase in the total transportation costs of € 44,0632.

The following graphs show an increase and the overall price difference per kilometer and change in the entire carriage on the transport route Žilina - Bratislava with the toll sticker and after the introduction of e-tolling.

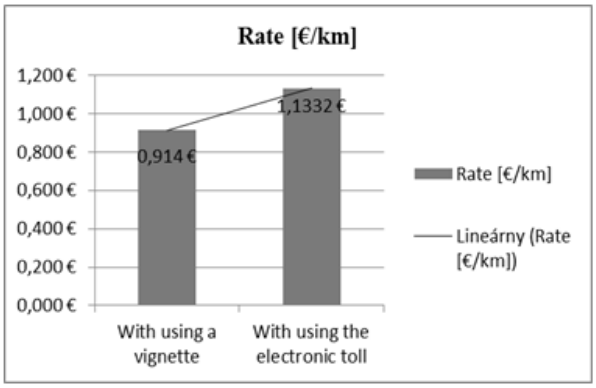


Fig. 6. Comparison of the rate for km in € / km
Rys. 6. Porównanie stawki za kilometr w € / km

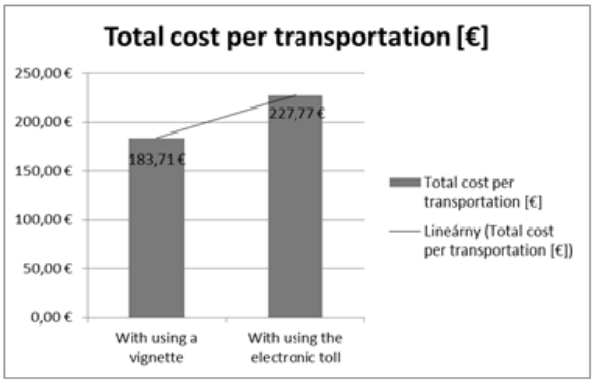


Fig. 7.Comparison of total shipping costs in €/transportation
Rys. 7. Porównanie całkowitych kosztów zakupów w €

When converted to a percentage the increase in the price per kilometre represents 13,32% and the total price for the transport by the introduction of the toll rose by 23,99% on the analyzed route.

5. CONCLUSION

After the introduction of e-tolls in Slovakia, the costs for road carrier has increased in SR for road use. It is not possible to determine clearly the average rate per km, because the cost increase is significantly affected by transport routes on the toll roads.

When using the toll sticker, the rate per kilometre represents € 0,9140 and the total cost for transport across the specified transmission route is € 183,71. After the introduction of the toll, the rate per kilometerstands at € 1,1332 and the price for transporting is € 227,7732. This means that after the introduction of electronic toll rate per 1 km, the price increased to € 0,2192 which meant also an increase in the total transportation costs of € 44,0632.

In practice, Slovak carriers do not very often calculate the total cost but if the carrier once considers the efficiency of the transport realization, his decision is based on the cost-sharing division into direct and indirect. With such cost allocation and determination of the final price per kilometer there is a risk that the all-day performance with very low carrier vehicle driving performance the carrier will not achieve any profit [7].

In order to prevent such a situation, the carrier should not concentrate on the division of the direct and indirect costs, but he should rather monitor the distribution of the variable and fixed, which allows the dynamic calculation of costs of road transport [4].

Practical result of application geo information systems at diagnostics and an estimation of a condition of highways are information base for the decision of technical and administrative problems, definitions of a technological level, consumer properties of roads, and also managements of a condition of a high system on the basis of rational use of financial assets and material resources.

The complex of the problems connected with a data control at diagnosing and engineering researches, demands from information system not only possibility of reception, storage, updating, processing, visualization of various kinds of geographically adhered information (maps and shirts and a database). Analytical tools are necessary for operative complex forecasting, modeling and decision-making on management engineering a construction (mapping, researches, designing, building, operation, condition monitoring), for function of interpolation of a relief and a finding of the characteristics connected with surfaces, possibility of programming of specialized problems [9, 17].

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