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REVERSE GEOCODING BASED ROUTE DISTANCE CALCULATOR

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Abstract. This paper presents a calculator that can determine the distance by road types and calculate the toll fee for trucks. This requires a reverse geocoding process to determine some textual attributes from GPS coordinates such as country code and identifier of a road. Based on public information, a detailed overview is given on the toll fees of some neighbor countries. A database built up for the calculation is created. The paper presents a prototype application which uses reverse geocoding based distance and toll fee calculation.

Keywords: reverse geocoding, distance calculator

1. Introduction

Trucks are large, heavy road vehicles designed to carry goods, materials or troops. All vehicles belong to this category that are not passenger cars, buses, trolleybuses or agricultural tractors. Larger vehicles with trailers are also called trucks, which have a rigid frame.
We can classify them according to gross combination of mass:

- small (3.5 t),
- light (3.5–7.5 t),
- medium heavy (7.5–12 t) and
- heavy (12–40 ton) trucks.

Trucks have certain rules that differ from other vehicles.

Their speed limit is hugely different from that of an average car. Within a residential area, the maximum permitted speed is the same as that of a car, but on other road types, you can only drive at a reduced speed.

Just like their speed limits, the tolls of trucks also differ from those of an average car. In Hungary, starting July 1, 2013, it is no longer necessary to buy a sticker for a specific period, but to pay the appropriate amount according to the distance traveled. When determining the cost, the different road types, environmental classification and vehicle category must be considered. When determining the toll fee to be paid, an important question is where the traffic takes

place: on a highway or a main road.
It is also important which category the vehicle falls into. This can be J2, J3 or J4. If a truck has two axles, it belongs to the J2 category, if it has three axles, it is classified as the J3 category, and finally, the J4 category is the group of vehicles with four or more axles.

T the environmental classification is also important. There are six types of EURO classifications. They are as follows:

- A: The EURO III-VI group,
- B: EURO II group,
- C: EURO I group.

1.1. Toll fee calculator software

As you can see the calculation of the toll free to pay depends on

- the country you travel – this determines the calculation rules as well
- the classification of the truck
- the distance you travel.

To calculate the cost of certain logistic operations by truck you need to be able to calculate or estimate the exact cost. Section 3 gives an overview on the toll systems of some selected European countries. These are based on public information. However, a lot of manual operation are required to calculate these hence we aimed to implement a software that does the calculation.

2. Literature search

Technically, a route consists of GPS coordinates. There are free/paid apps that can display those routes between a source and destination POIs (Point of Interest). This process is called geocoding, [12] gives an overview of its current state. Early systems back to the 60's used numerical codes for postal addresses [13]. Plenty of research focused on improving the accuracy [14] [15] [16] and uncertainty [17] [18].

For this application, a reverse geocoding is required. Reverse geocoding is defined as the extraction of textual information, such as a name or an address, from geographic coordinates. This technique is common in many geo-application scenarios, e.g., in freely available online-based mapping services [19]. Although there can be accuracy issues for this service [20] for this application we need to resolve the country name (or country code, e.g.: HU) and the motorway name (e.g.: M0). An overview is given on the available services in [21].

3. An overview on toll systems

In this chapter an overview is given about the road toll systems for trucks in some countries.

On the map, green colour indicates the targeted countries.

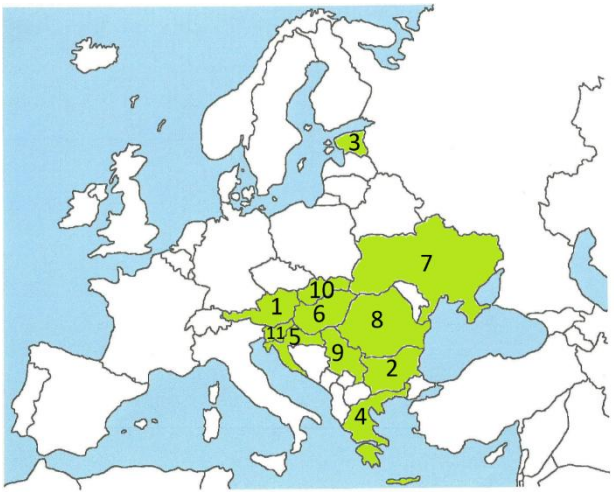

Figure 1. Selected countries [11]

3.1. Austria

It is necessary to install the GO-box in vehicles over 3.5 tons. The device uses microwaves to record the passage through toll gates.

The payment depends on the size of the truck and the emission category. It costs 0.145–0.187 euros for two-axle trucks, 0.203–0.2618 euros for three-axle trucks, and 0.3045–0.3927 euros for four- or more-axle trucks, plus 20% VAT.

3.2. Bulgaria

In Bulgaria, from March 1, 2020, an electronic toll system has replaced the sticker system for trucks and buses over 3.5 tons. The sticker system worked in such a way that you had to buy a motorway sticker when entering the country, regardless of whether you wanted to use the track or not. Table 1 presents the fees to be paid.

Table 1. Toll for trucks in Bulgaria

Vehicle		**All road types (BGN / km)**
Truck between 3.5 t and 12 t	EURO VI	0.04
	EURO VI	0.04
	EURO III, IV	0.05
	EURO 0, I, II	0.07

3.3. Estonia

From the first of January 2018, it was introduced that vehicles over 3.5 tons are already required to pay a toll in Estonia. Its rate depends on the duration of use, the number of axles and the environmental classification. Regarding these, the daily sticker is between 9–12 euros, and the weekly sticker is between 25–65 euros.[1]

3.4. Greece

A gate system works. On average, trucks have to pay 8.2 euros per gate, but we you can see a different price. [2]

3.5. Croatia

The toll of the roads is done by a toll gate system. We can also manage the payment with a device called OBU.

There are five vehicle categories, all of which have different prices. Calculating the costs of transportation in the country is quite complicated. Our journey can lead to many cities, and the tariffs differ from one to another. For example, if we want to get from Zagreb to Rijeka, it costs 170 Croatian Kuna for a two- or three-axle truck. [3]

3.6. Hungary

Hungarian system calculates the toll by categories of trucks roads and euro classifications.

Table 2. Toll for trucks in Hungary

	J2		J3		J4	
Class	Motorway	Main road	Expressway	Main road	Expressway	Main road
A	42.12	20.04	66.11	34.71	102.34	63.84
B	55.44	23.58	77.78	40.83	120.40	75.10
C	63.76	27.12	89.45	46.96	144.48	90.12

3.7. Ukraine

Toll calculation: The length of the route in kilometers is multiplied by a value between 0.1 and 0.75 euros, which varies depending on the size and weight. [4]

3.8. Romania

Unlike in Hungary, here you do not have to pay based on kilometers, but you need to buy a day ticket [7]:

Table 3. Toll for trucks in EUR for Romania

	1 day	**7 days**	**30 days**	**90 days**	**12 months**
A	–	3	7	13	28
B	–	6	16	36	96
C	4	16	32	92	320
D	7	28	56	260	560
E	9	36	72	206	720
F	11	55	121	345	1210
G	4	20	52	120	320
H	7	35	91	210	560

A: Motor vehicles
B: Max. 3.5 t vehicle
C: 3.5–7.5 tons, goods carrier
D: 7.5–12 tons, goods carrier
E: 3-axle vehicle over twelve tons
F: 4 or more axle vehicles of more than twelve tons
G: up to 9–23 persons, passenger transport
H: passenger transport of over 23 people

3.9. Serbia

As in Croatia, there are five vehicle categories, and the prices depend on where you want to go. For example, the toll for a four- or multi-axle truck from Belgrade to Subotica is 3,740 Serbian Dinars or 32 euros, which is roughly equivalent to 11,000 HUF [5].

3.10. Slovakia

Toll payments must be made with a device based on GPS technology. This is called OBU. Payment can be made in advance, or it is possible to pay later in Post-pay mode after using the road. In Pre-Pay mode the given amount must be uploaded to the OBU account before taking the sections you want to use. [6]

Table 4. Toll for trucks

Vehicle			**Class**		
			EURO 0, I, II	EURO II, IV	EURO V, VI
Trucks	3.5 t–12 t		0.108	0.098	0.085
	Above 12t	2 axles	0.231	0.209	1.181
		3 axles	0.244	0.220	0.190
		4 axles	0,253	1,228	0,198
		5 axles	0.244	0.220	0.190

3.11. Slovenia

From April 1, 2018, we can make payments with the DarsGo electronic toll collector. We have to register ourselves in the system. This records the registration number and the EURO classification. The gates on the highway will detect the DarsGo using the signals from the microwave sensor. The device cannot be moved from one vehicle to another. The payment methods are as follows:

- Advance payment by cash, fuel card or bank card through customer service.
- On the website or directly to the company by bank transfer.
- Cash on delivery to the company.
- With the fuel card connected to the device. [8]

4. Designing a toll fee calculator application

As you can see, we need the number of axles the truck has, the energy is the energy classification, and the price is the corresponding price.

The database has been built also contains all toll roads.

The image shows the structure of the database.

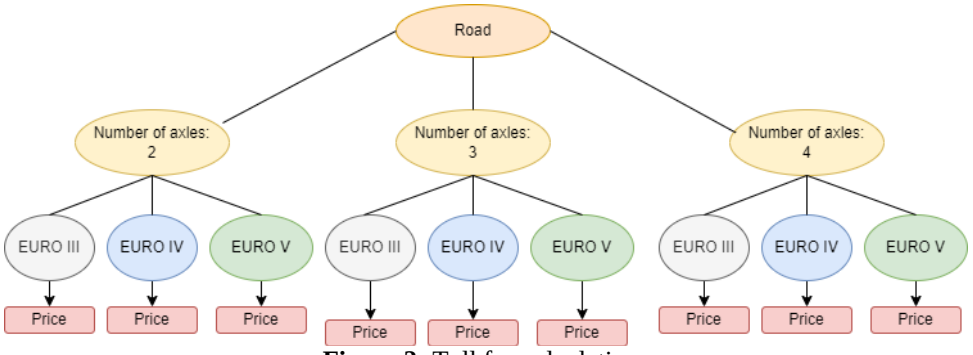

Figure 2. Toll fee calculation

After selecting the road, the user enters the number of axles, then the energy classification, and then receives the price based on this.

4.1. Determine distance from geographic coordinates

To complete the task, the GPS coordinates given by truck drivers will be converted into distances. Most likely, these converters can be wrong by a few meters, but when measuring such a long distance as a truck driver does during his journey, this is negligible.

In geodesy, the conversion between geographic coordinate systems is necessary due to the different geographic coordinate systems used worldwide and over time. Coordinate transformation consists of several distinct types of transformations:

- from the format change of geographic coordinates,
- or from the transformation of the coordinate systems
- from conversion into different geodetic reference points.

In geodesy, the transformation of geographic coordinates is defined as the translation between different coordinate formats or map projections, all with reference to the same geodetic reference point. A geographic coordinate transformation is a translation between different geodetic reference points.[9]

4.2. Geocoding of geographic coordinates

In the next step, the application defines the country by the geographical coordinates I use.

There are two types of geocoding:

- (forward) geocoding,
- reverse geocoding.

The task of geocoding is to identify the GPS coordinates of a specific location from an address. Its counterpart is reverse geocoding.

With reverse geocoding, the coordinates will be transformed back into an address.

These applications need Reverse Geocoding, in other words determine the latitude and longitude values. After that, a JSON code extracts the name of the country from the previously received response structure [10].

The following code uses Google Map API to determine the country code of a location:

```
   fetch("https://maps.googleapis.com/maps/api/geocode/json?l
atlng="+ myText9+","+myText10+"&key=YOUR_KEY")
                .then(function (response) {
        return response.json();
                        })
                .then(function (myJson) {
                        for(var i = 0; i <
myJson.results.length; i++) {
                        if (myJson.results[i].types[0] ==
'country') {

        document.getElementById("myText6").value = (
"Country: " + myJson.results[i].formatted_address);

                }}
        }}
```

4.3. Routes database

A database was created in which routes with payment obligations were stored. This includes motorways and main roads. The calculation must take into account the type of road, the energy classification of the truck and the number of axles. Based on all of these, a part of the database can be seen as follows:

```
        { "type": "M0", "number": 2, "energy": "A", "price":
42.12 },
        { "type": "M0", "number": 3, "energy": "A", "price":
66.11 },
        { "type": "M0", "number": 4, "energy": "A", "price":
102.34 },
```

```
        { "type": "M0", "number": 2, "energy": "B", "price":
55.44 },
        { "type": "M0", "number": 3, "energy": "B", "price":
77.78 },
        { "type": "M0", "number": 4, "energy": "B", "price":
120.4 },
        { "type": "M0", "number": 2, "energy": "C", "price":
63.76 },
        { "type": "M0", "number": 3, "energy": "C", "price":
89.45 },
        { "type": "M0", "number": 4, "energy": "C", "price":
144.48 },
```

4.4. Determine road type

The extraction of the road type was done by obtaining their PlaceID based on the coordinates entered, and then the type of roads based on these IDs. However, after testing it on several routes, option did not give valid results for all pairs of coordinates.

The road type was determined using the using the following geocode API:

```
fetch("https://maps.googleapis.com/maps/api/geocode/json?latl
ng="+lat_arr[i]+","+lng_arr[i]+"&key=YOUR_KEY")
                .then(function (response) {
                        return response.json();
                }).then(function (myJson));
```

The response is formatted like:

```
   "results" : [
      {
         "address_components" : [
            {
               "long_name" : "279",
               "short_name" : "279",
               "types" : [ "street_number" ]
            },
```

This contains the road type information. The longitude and latitude information come from another geocode call, which uses the starting POI and destination POI. Once we have the street number returned by the call, we can determine the km price using the routes database for the truck category.

4.5. Calculate the toll

Now we have everything in place to calculate the toll to pay using the following formula:

$$C_{total} = C_F + c \, . \, d$$

where C_{total} is the total toll cost, C_F is the country specific fixed cost, c is the country specific cost of 1km travel for the specified truck category and d is the distance calculated.

The calculation works for countries where there is a fixed cost only (like Romania), in this case $c = 0$. Also, the formula is valid for countries where there is only a distance specific fee, in this case $C_F = 0$.

4.6. A case study

The application can display the distance travelled and calculate the toll fee. The route is also displayed as depicted on the following picture:

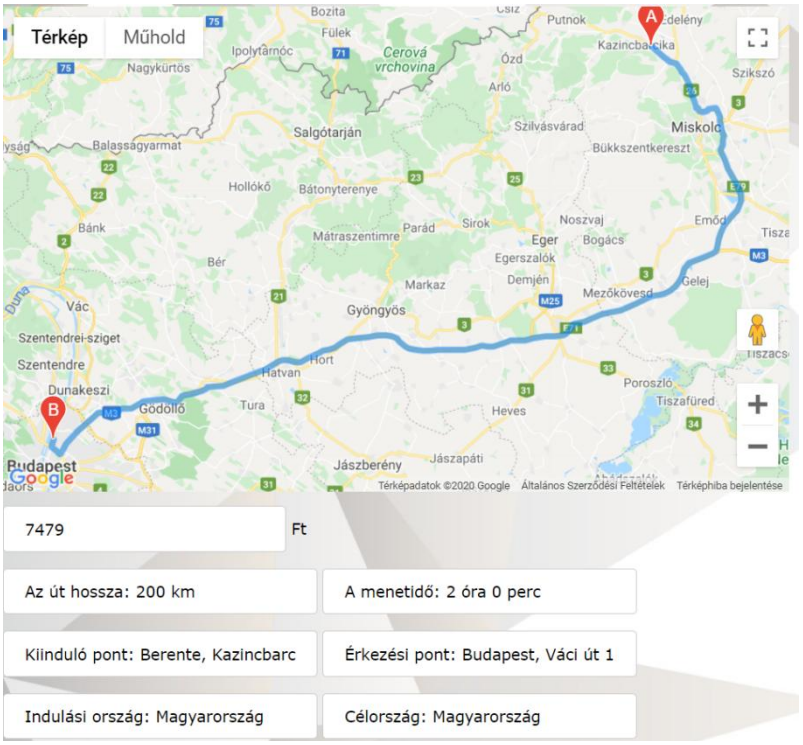

Figure 3. Road and toll fee display [11]

5. Summary

A distance-based toll fee calculator for truck was presented. The calculation formula used is generic enough to cover the toll fee calculation methods for the investigated countries. An application was developed that uses reverse geocoding to determine the country code and route parameters. Based on these extracted parameters, a country specific database was built which was used as the basis of the calculation. The benefit of the proposed method is that it works for both in the route designing phases e.g.: for toll fee estimation and also when the GPS

coordinates of the route are tracked by on onboard device e.g.: toll fee accounting. A prototype application was prepared for Hungarian fee paying roads.

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