FINDING FAIRNESS IN TOLLING SCHEMES

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ABSTRACT

Various types of road infrastructure and different political goals lead to a variety of tolling principles implemented on road networks, most usually to generate revenues or to regulate traffic. When a tolling policy is established, the issue of fairness is always raised. Fairness applies not only to road users, but also to the infrastructure owners and service providers. Issues such as traffic congestion and environmental impact are also often taken into consideration when a tolling policy is being developed. Since ancient times, when tolling schemes were first introduced, there has never been a tolling solution in which all involved parties were completely satisfied. From a commercial perspective, someone has to pay for the road infrastructure, capital expenditures, operational services, and road maintenance. When it comes to tolling, political decision-makers are usually forced to choose among a variety of solutions – each being problematic in some form or another, and sure to aggravate a certain group of constituents.

We describe some tolling paradigms which are conducive to achieving fairness in tolling, thanks to the development of advanced technology which enables an optimal approach to more accurately toll a wider variety of road networks. In particular, we elaborate on the recent deployment of state-of-the-art satellite-based tolling technology in Central Europe. Through the use of advanced technologies, regular adaptations to tolling implementation can be easily realized as toll policies are optimized in order to reach a maximum amount of fairness for users of the road infrastructure.

INTRODUCTION

In the world of tolling, many basic principles are used for tolling different types of roads in order achieve infrastructure financing as well as traffic reduction. Different operators and state authorities have implemented tolling rules with the goal of establishing a procedure which is fair to every user. Many different schemes can be seen in the tolling hot-spot of Europe: distance-based charging of Heavy Goods Vehicles in Switzerland; area-based tolling per zone-access for all vehicles in London; and tolling of Heavy Goods Vehicles on motorways - based on the segments driven - in Germany, Austria and in the Czech Republic. There is a recent European trend for tolling trucks in which first class roads or even parts of the secondary road network are subject to tolls. This trend is caused by heavy trucks using the secondary network rather than the (tolled) motorway network, thus bypassing the fees required for use of the dual-carriageway network.

On January 1st, 2010, the Slovak Republic successfully started a truck tolling scheme dominated by first class road segments. The road network consists of 500 km motorways and 1,900 km of the first class road network. For this type of network, new tolling rules had to be established for the usage of relatively long segments. This raised the question whether it is fair to toll the whole segment if only one part of it is used. Or whether it is fair or not to pay any fee unless a long segment is completely driven upon. Given these issues in cases in which long segments may contain many intersections, Siemens proposed to divide the road segments into "atomic sections" – between each individual intersection. After this breakdown of large road segments, such an atomic section can be treated in the same way as a conventional motorway segment, and thus be charged in the same fair manner.

DISTANCE-BASED CHARGING: VERIFICATION VS. REALITY

A first attempt at reaching tolling fairness is to measure the driven distance on a case by case basis, and set a price on it. A good example for this is the kilometer-based tax on heavy goods vehicles in Switzerland, know as LSVA[1]. From a system-engineer's perspective, this clear tolling principle sounds effective but raises some important questions at the same time. How to determine which infrastructure should be subject to tolling and how accurate can such a tolling system be? What sensors shall be used? Is there any way that tolling sensors can be circumvented? The LSVA scheme, launched in 2001, determines the network by the measurement of distance travelled within the Swiss borders. Dedicated Short Range Communication (DSRC) microwave communication infrastructure at all border crossings in Switzerland signal the On Board Units (OBUs) to either start or stop counting the driven distance. The tacho-signal coming from the tachograph is used to count the mileage. A truck's tachograph is a calibrated instrument trusted by everyone, and serves as the legally recognized source of the distance travelled. Nevertheless, derivations from the "true driven mileage" might be up to 4% with respect to this sensor. GPS signals have actually been shown to measure the distance far more accurately, and are therefore used to verify the exact distance travelled.

Another political motivation with regard to tolling fairness is that each movement within Switzerland counts for the toll, even if you are driving in your own backyard. Thus, a main political goal in Switzerland appears to be the protection of the environment by encouraging modal change of goods transportation from roads to railways. Furthermore, the system is fair for non-users (i.e. the public) since the heavy goods vehicles, which cause by far the most wear and tear on the road infrastructure, must bear the greatest financial burden with respect to repair and maintenance of the roads they use.

[1] In German: **LSVA** (**L**eistungsabhängige **S**chwer**v**erkehrs**a**bgabe)

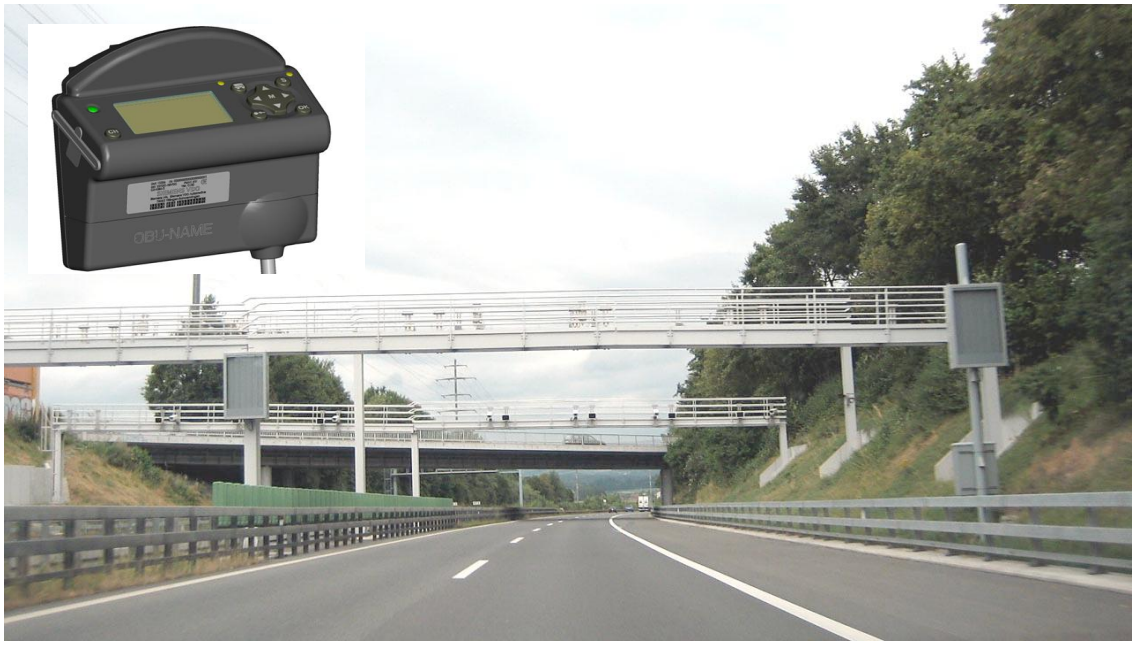

Figure 1. The new On Board Unit solution from Siemens for Switzerland's LSVA

ZONE-BASED TOLLING: EASING TRAFFIC CONGESTION

London launched a city tolling project in its Central Business District in February 2003. The main political goal was to significantly reduce the traffic in this area. The scheme was so successful – causing as much as 30% reduction in traffic - that it was extended to almost double the original size in 2007. Vehicles entering the Central Congestion Zone are required to pay a fixed daily fee. Compliance to the scheme is enforced using cameras at the roadside, equipped with Automatic Number Plate Recognition (ANPR) functionality.

At a first glance, the scheme appears more or less fair, since each vehicle owner must pay the same fee for using the road infrastructure of the zone. For those vehicles which must frequently enter the zone for commercial reasons, e.g. for the delivery of goods to Westminster's shops, the daily fees add up quickly – as opposed to occasional users who are not greatly impacted for paying the fee only a few times per month. This is the reason why London's transport authority (Transport for London) has evaluated various tolling technologies over the last few years in a variety of technical trials. Considerable efforts have been made to find a balance among various interests groups and entities, through the systematic search for new methods and technologies. By implementing new technologies and re-defining the tolling policy from time to time, the responsible authorities demonstrate that they are genuinely interested in fairness for the population - and not only after an additional source of infrastructure financing.

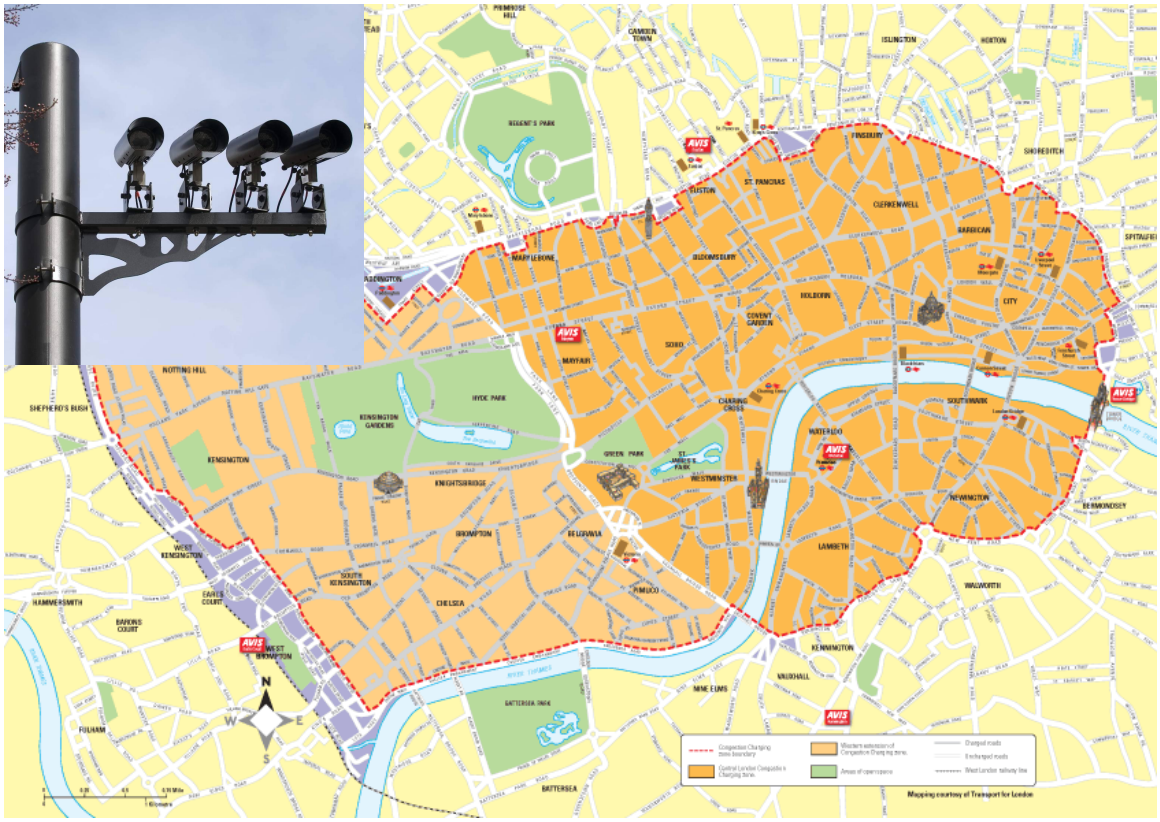

Figure 2: The London congestion charge scheme using the Siemens camera solution

SEGMENT-BASED TOLLING: TOLLING POINTS

When looking at multi-lane-free-flow systems, segment-based tolling schemes are the most technically advanced means for tolling large road networks. Segments are defined by a political authority, each designated with a specific price per vehicle category. As opposed to the mileage counting principle, the main advantage here is that all road users of the same vehicle category always pay the same fee for the same segment. As simple and fair as this principle sounds, it could only implemented on motorways until very recently. Technologies must be deployed which can (automatically) recognize each tolled segment. On motorways, this can be done by building a microwave gantry which identifies a vehicle passing a specific segment by communicating with the OBU via microwave link. This principle was implemented in the heavy goods vehicles tolling schemes in Austria and in the Czech Republic, where microwave infrastructure was installed along the motorway network having lengths between 1000 km and 2000 km. The principle of segment-based tolling is illustrated in Figure 3.

The main disadvantage of those systems is that first class roads - having many intersections within a segment - cannot be tolled precisely without an exorbitant implementation cost. A tolling segment can be broken down into all of the parts between each intersection, so-called "atomic sections," which are very often less than a kilometer in length. The originally planned (and tendered) tolling scheme in the Czech Republic was to consist of 1000 km of motorways and another 1000 km of first-class roads in the second phase. However, the actual implementation of the second phase was scrapped since the cost of implementing microwave-based infrastructure on only half of the road sections would still have become prohibitively expensive. Only months after the first phase was implemented,

the Czech Transportation Minister appointed an expert group to find ways of deploying satellite-based technology on the first-class road network.

Figure 3: Principle of paying for passing a tolling point

STATE OF THE ART: ATOMIC ROAD SECTIONS

On January 1st, 2010, the Slovak government implemented a lorry road user charging scheme on its national road network. The nationwide tolling scheme consisted of approximately 2,400 km of roads, less than one third of which are motorways or expressways (as shown in Figure 4). The Slovak Transportation Minister did not face the same technological limitations experienced by his Czech counterpart to the North. Due to the road network topology of Slovakia, only satellite-based tolling solutions were proposed by the industry.

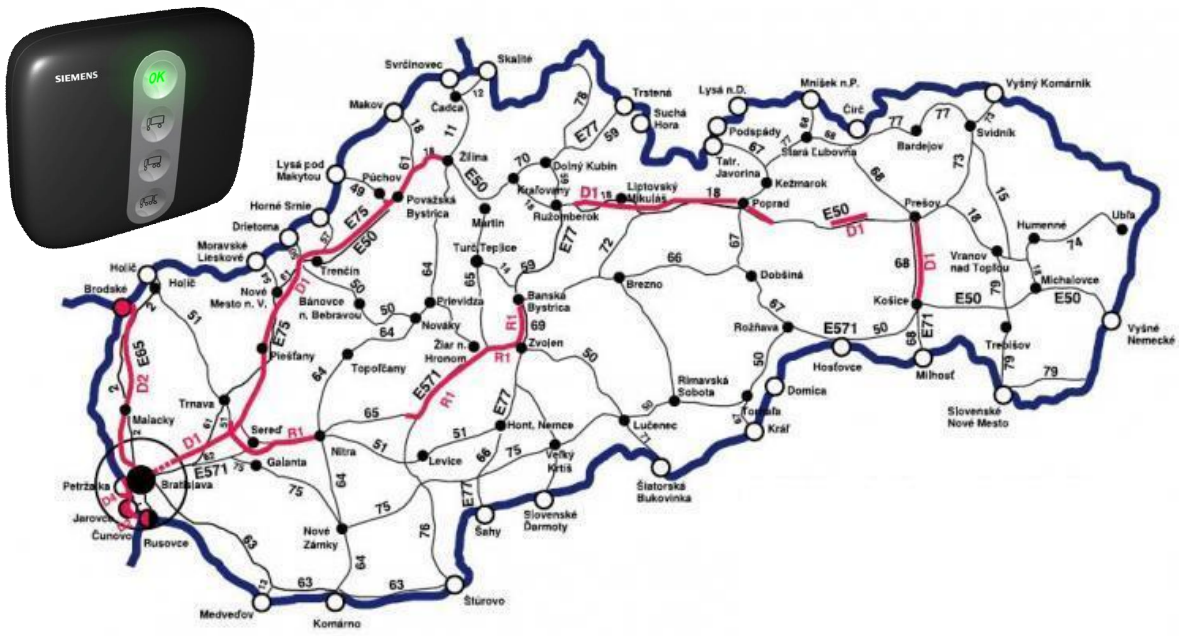

Figure 4: Tolled roads in Slovakia using the latest Satellite-Based OBU from Siemens

Unlike the German satellite-based tolling approach launched in 2005, the GPS-based OBU in Slovakia is not an option, but is obligatory. The Slovak OBU does not require complicated installation by trained professionals, but can be simply mounted on the windshield by the driver within a few minutes. From the driver's perspective, the OBU passes one of the "virtual gantries" and the unit beeps to confirm that a tolled road section is charged. This useful feedback also lets the driver know that the unit is working properly.

The tolling system in Slovakia has achieved an effective section recognition rate exceeding 99.8% from the very start. Prior to the commencement of this scheme, road user charging was never realized in Slovakia. Thus, the newly established tolling policy was put into practice – and issues of fairness were raised by the first users of the scheme. The political authorities reacted promptly and split up all officially declared road segments into atomic sections, so that users would only need to pay tolls for the length of roads actually travelled. Thanks to the flexibility of the state-of-the-art tolling technologies deployed, the adaptation of the revised toll policies could be immediately implemented.

Due to the advancement of satellite-based electronic tolling technologies, the prompt deployment of toll policy adaptations can be realized with a minimum of technical overhead. Thus, the goal of reaching maximum fairness in tolling road infrastructure has been achieved by optimally deploying the most advanced technology. The innovative tolling system solution in Slovakia has already proven itself as being an optimal platform in providing fairness and flexibility to the road users, road operator and policy makers.

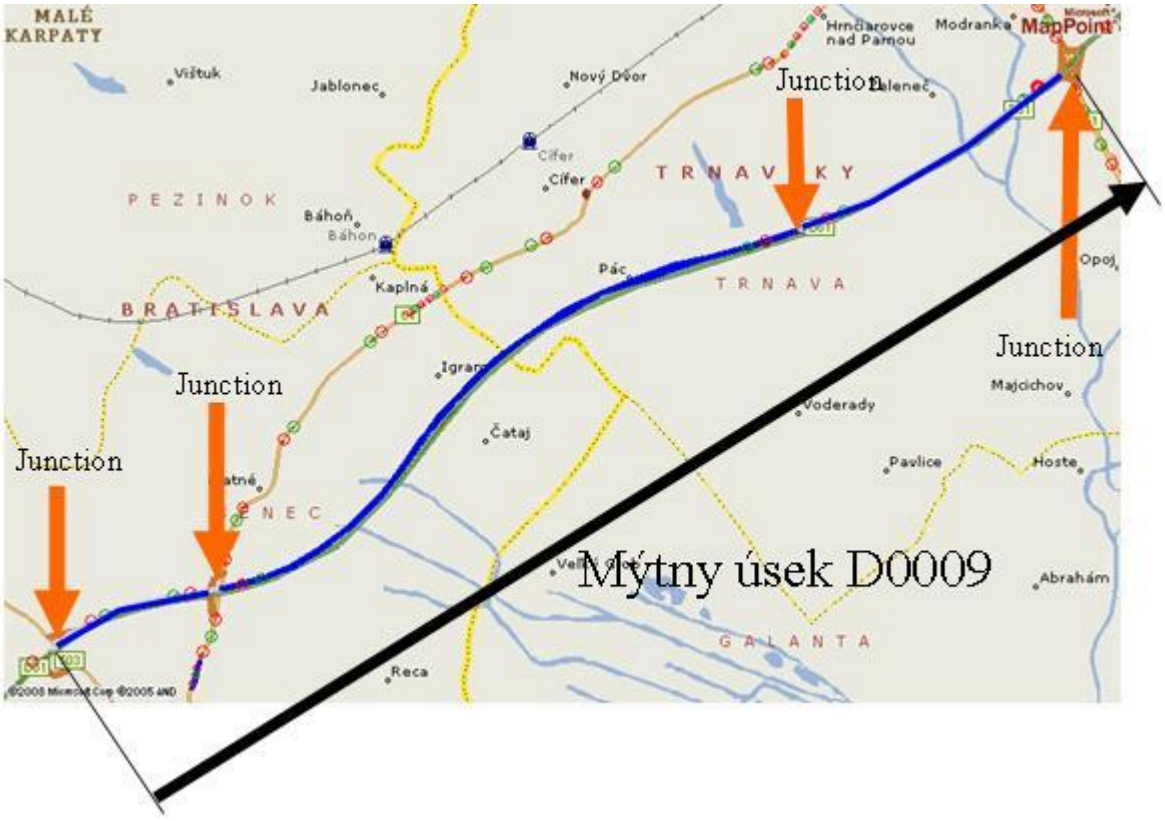

Figure 5: Segment containing three atomic sections near Trnava, Slovakia

Already in the implementation-phase – where Siemens deployed its advanced satellite-based tolling solution – it was decided to split up the given segments into atomic sections,

having no junctions with other roads. Based on this simple principle, the government could easily redefine tolling rules reflecting the political needs. The ability to detect atomic sections allows for the implementation of any tolling policy. One can charge the entire segment, even if just one atomic section is used (as in the Czech Republic); one can charged a segment only once all atomic sections are driven upon; or one can charge each individual atomic section (as illustrated in Figure 5).

Once Slovakia launched the tolling scheme, a public debate took place about the fairest principles for tolling first-class roads. As a result of these discussions, the Slovak government decided to implement a tolling approach which charged the use for each individual atomic section. Due to the flexibility of the tolling system technology provided by Siemens, it was easily possible to adapt the tolling principles according to the government's newly-defined legal procedure. The highly effective process for updating software and data on the Siemens OBU platform supported the immediate and secure implementation of the new tolling legislation in the tolling system.

It is also worth mentioning that the accuracy of measuring an atomic section was fundamental to the successful adaptation of the government's new tolling policy. The false recognition of a toll section ("false positive") would have seriously undermined the new policy. Therefore, the Slovak government decided to test the accuracy of the tolling system before installing – already within one month of the contract award to the system supplier. Figure 6 shows the results of this intense testing with 10 trucks and 20 OBUs on approximately 30,000 kilometers or road network within a single week.

Overall Mass Driving	Distance [m]	Sections
Expected	19.052.606	7.588
Recognized	19.021.612	7.577
Success rate	19.021.612	99,86%

Figure 6: Result of Mass Driving Test for the Functional Test of Concept

Based on the satellite-based technology alone, without any additional supporting roadside infrastructure, the Siemens tolling solution reached a 99.7% recognition rate of sections on a significance interval of +/-0,1% and at a 99.99% security level. At the same time, not a single "false positive" detection took place. Based on the observations take once the large-scale system implementation took place (with an installation base exceeding 200,000 OBUs), the actual the toll recognition rate was found to be significantly above 99.6%.

CONCLUSION

The experiences made with the modification of regulations in Slovakia have shown that a very a high level of operational quality is required to assure fairness in the tolling of a comprehensive network of multiple road categories. The idea of splitting up a long road-segment into proper atomic sections reflects the reaction of policy-makers to achieve

fairness in tolling roads of the secondary road network. This unprecedented case in Slovakia has shown that a satellite-based tolling system is able to support the quick and reliable adaptation of new tolling policies. Thanks to the flexibility of this technical solution, the innovative tolling scheme of Slovakia has been widely accepted. The use of a mandatory plug-and-play On Board Unit, which can be easily installed within a few minutes, further assures that tolling system is non-discriminatory and comfortable to use, thus raising the level of public trust in the chosen tolling policy and the technology supporting it.