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SVI Research Project 2001/523

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Summary

Zurich/Basel, 19 January 2006

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RAPP Trans AG

Hochstrasse 100
CH-4018 Basel
Tel: ++41 61 335 77 77
Fax: ++41 61 335 77 70
trans@rapp.ch
www.rapp.ch

INFRAS AG

Gerechtigkeitsgasse 20
Postfach
CH-8039 Zürich
Tel: ++41 44 205 95 95
Fax: ++41 44 205 95 99
zuerich@infras.ch
www.infras.ch

ROAD PRICING SCHEMES FOR MOTORWAYS AND URBAN AREAS IN SWITZERLAND

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INFRAS:

Daniel Sutter

Markus Maibach

Martin Peter

Mario Keller

RappTrans:

Matthias Rapp

Robert Yen

Christian Egeler

SVI expert group:

Martin Buck, SNZ (chairman)

Ueli Balmer, Bundesamt für Raumentwicklung

Andreas Gantenbein, Bundesamt für Strassen

Philippe Flückiger, Eidg. Zollverwaltung

Ruedi Ott, Tiefbauamt der Stadt Zürich

Katrin Schneeberger, Zentrum für Technologiefolgen-Abschätzung (TA-SWISS)

Urs Schwegler, Büro für Verkehrsplanung

Markus Traber, Elektrowatt Infra AG

SUMMARY

1. OBJECTIVES AND SCOPE OF THE STUDY

Road Pricing is an instrument of the market economy which can influence traffic demand as well as contribute to generating transport revenues. The research project of the Swiss Association of Traffic Engineers analyses the possible implementation scenarios for Switzerland. For this purpose, first the experiences from foreign countries are examined and the individual model parameters are discussed systematically. Then the possible application schemes in Switzerland are sketched and broadly evaluated using four illustrative case studies. The project prepares the ground for further in-depth studies on national and regional level. The project is focussed on road user charges; the other instruments of mobility pricing (e.g. parking fees and public transport fares) are outside the scope of the project.

2. SCHEME KEY WORKING ASSUMPTIONS

The following conclusions have been drawn from the evaluation of the road pricing schemes for motorway networks and in urban areas outside Switzerland and from the analysis of the individual scheme parameters:

- › Road Pricing is working: Numerous examples from foreign countries show the factors for successful implementations of schemes aimed at road financing and travel demand management (TDM). To date, significant developments are visible. Key driving forces are the problems relating to heavy vehicles traffic (heavy vehicles charging), the growing problems related to a lack of capacity and road infrastructure financing, the technological developments of Electronic fee collection systems, and the willingness to apply the user pays principle in transport. Successful models can be seen primarily in urban areas (e.g. London, Oslo, Rome).
- › It makes sense to distinguish between three levels for the scheme parameters:
 - › The strategic level: the integration of road user charging in the overall transport policy and the relationship between the various objectives (in particular financing and/or traffic demand management)
 - › The institutional level: roles and responsibilities of the actors for implementing road user charging, distribution of the generated income
 - › Operations level: how road user charging is implemented with respect to collecting, invoicing, and enforcement.

- › Different basic schemes are identified: for motorways it is object charging (charging on one single section), integral network charging (charging on the entire motorway network) and Value Pricing (charging on individual lanes for bypassing congested sections). For urban areas additional schemes are: Cordon-Pricing (Charging for entering a charging zone), Area Licensing (Charging for the right to drive in a particular zone), and comprehensive area pricing (combination of network charging and area licensing).
- › Two paths can be followed for implementing road user charging: “bottom up” with charging of selected problem areas (urban zones or parts of networks) or “top down” (entire networks or the entire national territory, in the extreme).

3. THE CASE STUDIES

Case Study 1: Technical and operational feasibility of road pricing of the Gotthard Tunnel

Objectives

The case study focuses on the feasibility of charging a single object using the example of the Gotthard Tunnel. Only the technical and operational aspects are analysed including an estimation of the cost of a fee collection system. The traffic planning aspects and the financial and political aspects are not considered because they are being treated in a parallel study “Road Pricing am Gotthard” (Road Pricing on the Gotthard route) which is being conducted by Metron AG. For this reason the present case study is reduced to the question: how would a user fee be technically implemented if ever such a fee was decided politically?

Concept and characteristics

A potential fee for the Gotthard Tunnel would be limited to light vehicles because the heavy vehicles are already subjected to LSVA (the Swiss Heavy Vehicle Fee). An additional lorry charge for crossing the Alps would contradict the Bilateral Treaty between Switzerland and the EU and, therefore, is not being discussed.

The traffic across the Gotthard Tunnel is very variable. It varies between 3,400 and 15,000 vehicles per day and per direction. A fee collection system must be able to handle maximum traffic for avoiding additional congestion during peak conditions.

Technically two methods are available for fee collection of the Gotthard Tunnel: manual/automatic fee collection and electronic fee collection (EFC). For EFC two types must be distinguished:

1. Single lane tolling
2. Free flow multi-lane tolling

For reasons of traffic flow and limited availability of space, free flow multi-lane tolling would be preferable. The problem lies with the occasional users – as is the case with any EFC system. Occasional users, who do not have a registration or an on-board unit, must either be dealt with when they want to use the tunnel or they must be given an opportunity to buy their right to pass in an easy manner at a convenient place. The EFC operator must enforce users who do not comply with the registration and payment obligation. In view of the high number of foreign vehicles passing through the Gotthard, the enforcement cost or the lost revenue are considered too high and for this reason a free flow multi-lane EFC system has been rejected.

Only a traditional toll plaza with a mix of EFC lanes and manual lanes and lanes equipped with cash and credit card machines is possible. Regular users would be equipped with DSRC tags for the EFC lanes whereas occasional users could use other payment means. The non-discrimination rules forbid an obligation that all users be equipped with DSRC tags.

A toll plaza with manual and EFC lanes would have to be placed for each direction at the tunnel entrances. One single toll plaza for both directions is not possible because of restricted space. The toll plazas would have to be integrated with the existing traffic metering system. If the toll plaza is located between the metering signal and the tunnel entrance, this allows the function of metering the approaching traffic to take place in the capacity of the toll plaza.

Preliminary analysis shows the need for three manual lanes with machines for cash and credit cards, and one EFC lane. The EFC lane also handles the heavy goods vehicles that are not subjected to the charge. The manual lanes can be staffed with collecting personnel during times of high traffic capacity. The toll plazas on either side must be arranged on the smallest possible space.

Evaluation, results

- › Fee collection at the Gotthard tunnel is technically feasible but the civil engineering feasibility has yet to be examined
- › Free flow multi-lane EFC is not possible because of the occasional users. Instead, toll plazas have to be installed on either side of the tunnel.
- › Before the toll plazas can be installed the planned lorry compliance centres, on either side of the pass, have to be implemented. The space for the toll gates is taken from the

hard shoulder and extra space where today exceptional loads and dangerous goods vehicles are handled. Only if these tasks are performed in the Compliance Centres will there be space for toll gates.

- › Vehicles subjected to LSVa are not additionally tolled at the Gotthard. They are identified by the classification unit of the EFC lanes.
- › The costs for tolling at the Gotthard are estimated as follows:
 - › Investment cost: approx. CHF 18 million if it turns out that the available surface is sufficient. If not, additional civil engineering costs must be considered.
 - › Annual cost: approx. CHF 8 million per year, including amortisation of investments.

Case Study 2: Value pricing in the Basel Area

Objectives

In the US, value pricing lanes (or pay lanes / HOT lanes) are being installed in several conurbations. On these lanes only vehicles are allowed to travel that have acquired a usage right beforehand. The tariff for the usage is set in a manner that the pay lane picks up as much traffic as possible without ever reaching its capacity limit and thus guaranteeing uncongested flow. Therefore, the tariff is dependent on the traffic volumes.

The example of the A2 motorway Augst – Basel has been selected because this section with three lanes per direction carries one of the highest traffic volumes in Switzerland with frequent experiences of congestion (2004: 273 hours, of which 166 were due to traffic overload). At times of “normal” congestion the travel times increase by 15 minutes.

Concept and characteristics

On the A2 motorway between the Augst junction and the Basel-Süd Exit there are the entrances and exits of Liestal and Pratteln and the Hagnau interchange. The section has three lanes per direction. In the area of the Hagnau interchange the carriageway is reduced to two lanes by means of section control lane signals in order to keep one lane available for the entering traffic. A comprehensive maintenance programme is being executed at present on the Augst – Basel section.

After the 2006/2007 restoration the exit lane of the H18 exit will be extended up to the Schweizerhalle Tunnel so that effectively the motorway will have four lanes on a section of 3 kilometres.

The leftmost lane could be transformed into a pay lane between the Augst Junction and the Exit Basel South. The pay lane would be separated by means of a line with a profile and

additional markers. The lane may be crossed by emergency vehicles. Normal vehicles are not allowed to change from the pay lane to the other lanes and vice versa at the intermediate exits. This arrangement assures that the traffic flow can be kept up and it simplifies the EFC system significantly.

The value pricing concept is based on the assumption that there will be no further bottlenecks downstream, i.e. on the Basel City part of the motorway where a programme of capacity increasing measures are being implemented in the next few years.

In order to reach the optimum capacity on the motorway section the tariff of the pay lane must be in a direct relationship with the traffic situation, i.e. there is no charge when the traffic volume is low and there is a relatively high charge during times of congestion. The aim is to load the pay lane as much as possible (approx. 1,500 to 1,800 veh/hour) but not to exceed the capacity and cause a traffic breakdown. The user must know the amount of the charge when they have to make the decision of whether to use it or not.

As long as there is no solid knowledge about the willingness of the motorists to pay, there are only hypotheses on the tariff schedule. The study assumes charges of 3 to 4 CHF per passage during peak hour. Traffic variation statistics show that these charges could be levied during about 15,000 hours per year. During off-peak hours there will be minimal charges and they are not relevant for the revenues even when the number of hours when they are applied is high.

For estimation the revenues two tariff scenarios are considered:

- › Tariff scenario A: relatively low charges and little variation of tariffs
- › Tariff scenario B: higher charges and more variations

Neither tariff scenario includes variations of the charge according to vehicle categories or to the vehicle occupancy.

The charge will be collected by means of EFC using DSRC technology. Vehicles that want to use the pay lanes must be equipped with an OBU with a DSRC transponder.

The OBU transmits the vehicle ID to the Road Side beacon and this information is used for periodic billing by the central system. There is an automatic enforcement gantry and for the enforcement of non compliant vehicles the same procedures are used as with the speed cameras. For enforcement reasons there is no differentiation of the vehicle occupancy because there is no reliable automatic system available to recognise the number of persons in a vehicle.

Effects

At present there are no quantitative data available about the willingness to pay road user charges by Swiss motorists. This gap will be filled in the Swiss Research Programme about Mobility Pricing commissioned by the Swiss Federal Road Authority FEDRO. Notwithstanding the knowledge gap, the gross revenues of the pay lane scheme have been estimated, as an educated guess based on the following hypotheses:

- › Charge levels according to the tariff schedule
- › Maximum throughput on the pay lane 1,500 veh/hr
- › Average usage 60%–80% of the capacity during peak time and 60% during the other busy times
- › No revenue loss caused by charge evaders but also no additional revenues generated by excess charges or fines

Under these hypotheses the gross revenues are estimated to 5 to 10 million CHF/a and the net revenues after consideration of the operation cost and amortisation of the investments are estimated to 2 to 6 million CHF/a. The relatively poor relationship between revenues and costs comes from the fact that the system is generating income only 1/6 (Tariff Schedule A) or 1/2 (Tariff Schedule B) of the operating time. This phenomenon can be observed at all road user charging schemes that are aimed at reducing peak hour congestion.

The transformation of an existing lane into a pay lane increases the traffic throughput on the entire section by 10% compared to the existing situation within a total gridlock condition. The situation is different when the traffic conditions are unstable, but no total breakdown occurs, when the total throughput is 8% lower because there must always remain a certain reserve capacity on the pay lane for taking traffic variations into account. This means that when traffic volumes increase, the pay lane rather contributes to an earlier happening of a breakdown, but on the other hand it helps that the breakdown is not as severe as without a pay lane. There is reasonable doubt that the tariff schedules can be set so fine as to avoid this contra situation, in particular if one considers that the weather and lighting conditions may influence the throughput of lanes much more than relatively modest charges.

Evaluation, results

The case study shows that a charging scheme can contribute to a higher throughput at traffic bottlenecks because of the flow rates being higher when the traffic density can be

kept lower. This phenomenon only holds true for the gridlock situation. In busy conditions without an outright gridlock, pay lanes will have a lesser throughput than non-pay lanes. Transforming a lane to a pay lane on a busy motorway section will, therefore, provide an extraordinary challenge for traffic control and price setting. In the Augst-Basel case a pay lane would only make sense if the capacity improvement measures downstream of the pass lane section have been implemented.

The relationship between revenues and costs is unsatisfactory because revenues are only generated during a small time period. Value pricing projects are likely not to generate enough income to significantly contribute to the construction costs of additional motorway lanes. In the Swiss climate there is the additional challenge to find flexible lane division markings that are not damaged by snow removal equipment in winter.

Case Study 3: Comprehensive area pricing in the Zurich Area

Objectives

Road Pricing in the Zurich Area aims at better use of the existing road capacities and to reduce congestion and the affiliated cost. The existing traffic management tools can mitigate the problems but do not show an area wide effect and cannot offset the continuous traffic growth and the diminishing traffic quality.

Besides the traffic problems the existing traffic financing system in the Canton of Zurich also reaches its limit. A series of transport investments are planned for the future associated with a high need for financing. The financing of these investments is not assured with the existing instruments.

Therefore, road pricing in the Zurich Area should contribute both to traffic management and to financing, within the City of Zurich and on parts of the network in the surrounding area (in particular suburban motorways).

Concept and characteristics

The scheme evaluated for the Zurich Area is a comprehensive area charging scheme. The city and the surrounding area are divided into zones similar to a zone scheme for public transport.

A zone scheme has the advantage that individual areas can show different charge levels according to the level of traffic problems and that a subtle differentiation is possible. In addition, a zone scheme allows for a staged implementation. Zone schemes are understandable for the users who are familiar with them from public transport fare schemes.

A comprehensive zone charging scheme can be introduced in many ways:

1. **One single City zone** analogous to the Central Charging Zone of London. In Zurich this zone would include the City area. In further stages the scheme could be extended to other parts of the conurbation.
2. **A total sector** with a City zone and two exterior zones in busy areas of the conurbation. In response to the existing problem the charging area would include the Limmat Valley and the Gubrist area, eventually also the Glatt Valley. This scheme, too, could be extended to other parts of the conurbation.
3. **Comprehensive Area Charging** with one City zone and various other charging zones in the urban area as well as the motorway ring around Zurich. In Zurich a scheme with one City zone and five outer zones would make sense.

For all scheme scenarios the residents would be given fee rebates. There are multiple options for using the revenues. The most likely measure would be to reduce the Cantonal motor vehicle taxes. In addition, a part of the revenue could also be used for highway construction and for public transport projects.

The technology applied would be a combination of dedicated short range communication (DSRC) and video technology. Regular users would equip their vehicles with on-board units (OBU) and their journeys would be registered with beacons at the zone boundaries and on the motorway segments. Users without OBU would have to register their usage rights manually (e.g. on the internet, at kiosks or per SMS). Fixed and mobile video enforcement equipment would be used to check the compliance using automatic number plate reading technology (ANPR).

Effects

The first rough calculations show that the proposed road user charging scheme could have significant traffic effects. The hypothesis is a zone fee of 4 CHF per journey, differentiated according to various parameters (peak time, emission class). The total daily traffic demand is lowered by a few percent, excluding the City area. A significant reduction can be shown during peak hours. According to preliminary estimates the traffic reduction at the City entrances during peak hours is between 8% and 18%, at the entrances of the urban area 5% to 10%. This reduction leads to a reduction in the number of traffic breakdowns. In particular during peak times a significant transfer to public transport and to non-motorised travel modes can be observed. The most significant effects can be shown with the comprehensive

multi-zone scheme. In addition, the City through traffic is diverted to the motorway ring around the City.

The gross revenues generated with the charging scheme are significant. According to preliminary estimates they are for the different alternatives: approx. 150 million CHF (City zone only) to 500 million CHF (multi-zone scheme). Some 15% of the revenues are used for building, maintaining and operating the fee collection system. The expected income from charging is comparable to the income of the Cantonal motor vehicle taxes (approx. 260 million CHF/a).

The traffic and financial effects shown are based on numerous hypotheses and relatively rough calculations. For a detailed evaluation of the feasibility of the charging schemes, the traffic effects and the financial effects need to be validated and analysed in a further study, using a bimodal traffic model.

Evaluation, results

The evaluated road user charging scheme is technically feasible because it is based on proven technology. The more complex the charging scheme is and the bigger the charging area, the bigger are the desired effects and the smaller the danger that the traffic is diverted to other towns of the urban area. Schemes with a high complexity (e.g. the multi-zone model) demand a relatively expensive technological implementation. An advantage of the comprehensive area charging scheme is the possibility to adapt the fee levels in the zones individually with a high potential for time and area differentiation.

Case study 4: Distance-based area charging for light vehicles

Objectives

Switzerland has developed, and successfully implemented, a distance-based area charging scheme for heavy goods vehicles, called LSV. In the case study a similar scheme is studied for cars. The aim is to move from the existing transport financing system toward a more usage-based system with more possibilities for traffic demand management. The perspective is more long-term.

Today the fuel tax is reaching limits caused by the increase of petrol prices and possible tax avoidance ("petrol tourism"). The flat national motorway charge ("Motorway Vignette") and the Cantonal motor vehicle taxes do not sufficiently reflect the user pays principle and cannot show a TDM effect. Contrary to the other scheme evaluated in this project the mod-

ern national distance-based fee would include the entire country and it would be implemented in a top-down manner. The following strategic objectives are set:

- › New financing instrument on the national level with the potential for time and area differentiation aimed at TDM
- › Replacement of existing flat tax schemes and recovery of the petrol tax

Concept and characteristics

Basically there are two possible paths for the introduction of a national distance-based charge. The first scheme is a distance-based charge on the national motorway network (network charging). The project would be limited to the federal level. The second scheme is a distance-based charge on the total national territory (area charging). It is possible to move from the first scheme (motorway network charging) to the second scheme when the technological requirements are met. The two schemes have the following characteristics:

1. **Distance-based motorway charging:** The existing EFC technologies allow the implementation of distance-based motorway charging but operational problems arise where the motorways cross the borders. All vehicles would have to be equipped with DSRC tags for capturing charging data. Additionally, all segments of the Swiss motorway network would have to be equipped with DSRC gantries. The distribution and personalisation of tags for all cars at the borders is not practical for reasons of traffic management and therefore it would be necessary for a large number of foreign vehicles to already be equipped with a tag and a contract with the Swiss operator. Fixed enforcement stations and mobile enforcement units would assure compliance based on ANPR. The tariffs would be set in two stages. At the first stage the charge would be set to offset the current motorway vignette, i.e. 1.5 centime per kilometre. At the second stage the charge would be increased in order to additionally offset the national motorway tax (which is charged on top of the petrol duty). This would mean a charge of 9 to 10 centimes per kilometre travelled on motorways. The kilometre charge could be differentiated with extra charges at peak times or in sensitive areas. In addition, there is the potential for extending it to parallel roads.
2. **Distance-based area charging on all roads:** To date, the technology for distance based area charging is not yet available. DSRC is not usable on all roads and a tachograph based system similar to LSVVA would require all cars to have reliable odometers. Only the GPS technology remains which would be ideal for all roads charging including a great potential for differentiations but which is not yet mature enough for charging in all ar-

eas and which would require all cars in Europe to be permanently fitted with OBU. The enforcement would be done using a combination of DSRC and ANPR technology.

Regarding tariffs again two stages are possible: At the first stage the charge level would be determined to offset the Cantonal motor vehicle taxes. At the second stage all road traffic related charges (motorway vignette, cantonal motor vehicle tax, and all earmarked parts of the petrol tax) would be replaced by the distance-based charge so that the financing system would be totally remodelled. The resulting charges would amount to 8 to 9 centimes per kilometre road (including private roads). The area charging scheme would also allow differentiation (area, time, emission class etc.). When the cantonal motor vehicle taxes are replaced, a redistribution of a part of the revenue to the Cantons is necessary.

Effects

The existing flat charges (motorway vignette, cantonal motor vehicle tax, and all earmarked parts of the petrol tax) would become variable and this would create incentives for traffic reduction. According to preliminary estimates traffic will be reduced by 1%–3% on the motorways when the motorway vignette is replaced by a distance-based fee. A replacement of the cantonal motor vehicle taxes and the flat motorway vignette would lead to a traffic reduction of 4%–6% on all roads. The replacement of the petrol tax by an area charge would not have an effect because the petrol tax is usage-based, too. But a distance-based area charge would have the additional advantage to allow TDM by means of area and time differentiation.

When only the motorways are charged there will be traffic diversion on the parallel secondary roads which would have to be mitigated by means of additional traffic regulations. Experience shows, that the possibilities are limited in this respect.

The distance-based charging schemes have no effect on the total income of the road financing instruments because, by definition, the tariffs are determined in accordance with the existing revenues of the replaced flat taxes. Yet the investment costs and the operations costs will be higher than today.

Evaluation, results

Distance-based charging on motorways is technologically feasible but the technological conditions for distance-based area charging for cars are not yet met. The latter is a long-term vision for a totally usage-based road user charging scheme which can be differentiated

according to geographic and temporal criteria. Even if technologically feasible, distance-based charging on the national motorways will cause operational problems at the borders (selling DSRC tags to foreign cars), and, therefore, this option, too, can only be considered for the mid-term in connection with the European Electronic Tolling Service EETS.

To make the existing motorway charges variable could be a first step towards the renovation of the Swiss system of road financing. But when later a distance-based motorway charging EFC system based on DSRC would have to be transformed into a distance-based area charging system the change of technology could perhaps become expensive.

Both schemes of distance-based charging on a national level can be combined with local road user charging schemes, in particular with schemes in urban areas or with value pricing as shown in the case studies 3 (Zurich Area) and 2 (Value Pricing Augst-Basel).

4. FINDINGS AND CONCLUSIONS

General Findings

The four case studies consider quite different aspects and time horizons for road user charging. Therefore, a direct comparison is difficult. The following aspects seem to be interesting:

- › Road user charging comprises the whole spectre from simple tolling of a road section up to the total remodelling of a national road financing system. Basically the whole spectre is thinkable for Switzerland.
- › The characteristics of road user charging on a strategic level depends on the problem and issues, the transport, political and financial policy, the repartition of roles and responsibilities between Cantons and the Confederation.
- › The characteristics of the scheme depend on the technology options. Contrary to other countries manual tolling is considered not opportune and, therefore, EFC technology is to be employed from the very start. With the one exception of Value Pricing, in all cases there must be suitable and non-discriminatory solutions for occasional users. This will be associated with considerable costs. The simpler the scheme the more technology is available at present at reasonable costs (in particular DSRC and ANPR technology). The more schemes are complex and differentiated, the more implementation is only recommended when a European Electronic Tolling Service is available and when there is a requirement of compulsory OBU in all cars travelling in Europe.

- › The traffic effects are heavily dependent on three parameters: the tariff level, the alternative travel options of the users (time, route, travel modes) and of the accompanying measures (e.g. offsetting other taxes, measures against traffic diversion and charge avoidance). The examples of Value Pricing Augst-Basel and Area Charging Zurich show that significant effects can be caused with substantial tariffs, in particular during peak times. The Value Pricing example shows also that contra productive effects on the traffic throughput may be triggered.
- › The financial impacts depend on the charge tariffs and on the traffic impacts. The cases of Zurich and the national schemes show that significant revenues can be generated which may be used to offset existing taxes. In contrast, congestion charging schemes only yield little income. For these schemes generating revenues is secondary. Still, with schemes entirely oriented to traffic management net revenues can be generated.
- › The use of the revenues is a central element of any scheme and important for the acceptance of the scheme. Several alternatives are available, depending on the overall goals:
 - › In a local charging scheme focussed on traffic management (Case Study Value Pricing Augst-Basel and possibly case study Gotthard) the revenues should be used for meeting the traffic objectives (e.g. congestion relief, transferring traffic to other modes, reducing environmental damage of road traffic),
 - › In an area charging scheme there are numerous possibilities of revenue use, most obviously the cutting of existing flat taxes. Only if the net charges are increased is additional income generated. Their use depends on the issues at hand. The use of revenues from road user charging for public transport makes sense if public transport is a useful alternative to using the charged network.

Need for further studies

The case studies must be seen as sketches only aimed at throwing light on different aspects of road user charging. There is a need for an in-depth study on the strategic level (institutional issues, in particular repartition of roles and responsibilities between Confederation, Cantons and Municipalities; relationship to TDM and to the financing system) and on the operational level (detailed characteristics of collection system, technical feasibility, and cost impacts). In-depth studies are required both in terms of basic research and application studies. In parallel, the design of pilot applications would enable the collection of 1:1 experiences and to gain knowledge about the acceptance. The present project has shown that

in any case road user charging should be viewed as a dynamic process and that the solutions must be developed in different stages.