TNSL06 Teknik och logistik

Intelligenta transportsystem I:

Elektroniska betalsystem som styrmedel

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Bilderna finns på: http://webstaff.itn.liu.se/~clryd/KURSER/TNSL06/
What is ITS?

“The application of informed technology to transport operations in order to reduce operating costs, improve safety and maximize the capacity of existing infrastructure.”

“ITS are the marriage of information and communication technologies with the vehicles and networks that move people and goods. Intelligent because they bring extra knowledge to travellers and operators”

- Travel and transportation management
  - Driver information, route guidance etc.
- Travel demand management
  - Pre-trip information etc.
- Public transport operations
  - En-route information, personalized transports etc.
- Electronic payment
  - Electronic toll collection (ETC) and parking payment (EPS)
- Commercial vehicle operations
  - Electronic clearance, safety monitoring etc.
- Emergency management
  - Emergency notification, emergency vehicle management
- Advanced vehicle control and safety systems
  - Collision avoidance, safety readiness etc
Agenda

• Short introduction
• Enabler: Electronic payment systems (EPS)
  – Transit; bus and rail payment systems
  – Parking systems
  – Tolling systems
• Application: Electronic Toll Collection (ETC) systems
  – Congestion pricing
  – Tolling heavy goods vehicles (HGV)
• Aim: Give an introduction and overview of the literature for pricing and electronic payments
Applications in transportation

- Public transport payments
  - Stripe cards/Smart cards

- Parking payments
  - Stripe cards/Smart cards/Mobile payment

- Tolling (congestion pricing and heavy vehicle taxation)
  - Transponders/Camera/Mobile communication

- Payments as a mean for regulating traffic and transports (control measures) in order to increase efficiency of available resources
- Marginal cost pricing
- More convenient, more cost efficient, more flexible and faster than manual payments

Combined at Park’n’Ride
Public transportation payments

• Electronic system for paying public transport fares
• Increase customer *convenience*
• Increase traveler throughput
  – Lower boarding times
  – Buses: Lower driver stress
• Payment models
  – The proprietary closed-loop model
  – Shared-card model
  – Open Acceptance model
Parking payments

- Electronic or mobile system for payment of parking fees
- Reduce parking revenue collection costs
- Increase parking meter up-time
- Reduce parking meter theft and vandalism
- More flexible pricing (remote)
- *Convenience*
- Park and ride (same card for parking and p.t.)
- Combined with parking management systems
Tolling systems

• Congestion charging
  – Payments as a mean for efficient road usage and mobility management
  – Require fast payments without stopping the car
  – Payment may vary depending on vehicle type and time of day
• Tolling of heavy goods vehicles
  – Alternative to manual road taxation of trucks
  – Kilometer based charging for transport of goods
• Tolling as a mean for road financing
  – Charge used for financing highways and bridges
  – Examples are the Öresunds- and Svinnesunds-bridges, car tolling in Oslo, Norway etc.
  – Manual payments still in use (toll booths)
Congestion charging: overview

- Car use and increase in mobility?
- Why congestion charging?
- Systems and infrastructure
- Setting the toll level
- Implementations in Europe
- Stockholm field trial 2006
- Stockholm implementation
- Göteborg implementation
Future demand for car use Sweden

Earlier

• Indications of a lower car share for urban trips
• The estimated population increase in Stockholm the coming 20 years is approximately the population of Göteborg
• Demand for space efficient solutions for housing and transport

Today

Sources: Trafa 2011, SIKA, 2005
Road congestion and mobility management

- Cities with much car traffic experience congestion
- During congestion, the road network is operating at far from maximal capacity
- Using congestion pricing, the demand for car transports can be controlled such that the road network operates close to capacity
- Motivated by its ability to better internalize the environmental externalities of traffic and congestion costs
- Car congestion pricing requires efficient alternative transportation modes: buses, trams, underground, etc.

Technologies for charging (in order of flexibility):
Transponder-based user charging

- Vehicle account number is transferred or an electronic fee is directly transferred from the on-board unit (OBU) to roadside system
- Charge is levied or account number validated and sent to the processing office
- License plate details of unequipped or those not paying the correct charge are recorded
- High speed requirements – communicate with car at 160km/h
- Time differentiated charges
- Usually located as a “toll ring” around inner city

Source: Blythe, 2005
Video-based user charging

- Usually located as a “toll ring” around inner city, charged when passing “toll portals”
- Image of license plates are recorded. Read automatically, or when difficulties occur, manually (identification from photos)
- License plate of non-registered vehicles are recorded
- Time differentiated charges

- Driver registers his/her intent to use roads within the charging cordon prior to setting out on journey (register license), or pay when invoiced.

Source: Blythe, 2005
Mobile positioning-based user charging

- On-board unit calculates position and/or distance traveled and matches to digital map of charged roads
- On-board unit periodically transmit to control/enforcement stations and sent to processing office
- License plate details of unequipped vehicles are recorded by camera
- Enables distance and location based charges

Source: Blythe, 2005
When is congestion pricing good?

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Toll charges</th>
<th>Adaptation costs (Anpassnings-kostnader)</th>
<th>Value of time gain</th>
<th>Paybacks/tax reductions</th>
</tr>
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<tbody>
<tr>
<td>Benefit</td>
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Setting the toll level: Marginal cost pricing

Let's say that, at the current traffic flow of 1000 cars/hour, one additional car makes the travel time 0.1 second larger.

This results in social marginal cost of $1000 \times 0.1 = 100$ in larger total time.

By marginal cost pricing, the external costs are added to the individual travelers in form of a monetary cost.

\[ c(f) + f \cdot c'(f) \]
Implementations of congestion pricing in Europe

- London, England
- Stockholm, Sweden (presided by unique trial)
- Göteborg, Sweden, 1th January 2013
- Revenue used for investments in public transport alternatives (and road infrastructure expansion)

- Many others have road charges and toll highways, e.g. France, Netherlands, Norway etc.
Sweden: Stockholmsförsöket

- Congestion charging field trial 3 January to 31 June 2006
- Extended public transport 22 August 2005 to 31 December 2006
- Referendum on permanent implementation, September 2006

- Technology: Transponder-based toll collection with video enforcement system

- Aim: reduced congestion, increased accessibility, improved environment

Source: Stockholmsforsoket.se
Stockholmsförsöket

- Field test results
  - 20% reduction in car flows
  - Doubling peak hour speeds
  - Marginal(?) increase in traffic going around/outside the tolled region (Essingeleden)
  - Small increase in the use of Park-n-ride.

Source: Stockholmsforsoket.se
Results from the referendum

Valnämnden
TELEFON: 08-508 29 000
E-POST: valnämnden@stadshuset.stockholm.se

Resultat från folkomröstningen – hela staden
Folkomröstning miljöavgifter/trängselskatt i Stockholms stad.

Total röstsammanställning – slutresultat
461 distrikt av 461 har räknats

<table>
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<tr>
<th>Röst</th>
<th>Antal</th>
<th>Procent</th>
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<tbody>
<tr>
<td>Ja</td>
<td>243055</td>
<td>51,3%</td>
</tr>
<tr>
<td>Nej</td>
<td>215731</td>
<td>45,5%</td>
</tr>
<tr>
<td>Blanka</td>
<td>9535</td>
<td>2%</td>
</tr>
<tr>
<td>Ogiltiga*</td>
<td>5825</td>
<td>1,2%</td>
</tr>
</tbody>
</table>

Antal avgivna röster: 474146
Antal röstberättigade: 620915
Andel röstdeeltaende (%): 76,4%

* = Ogiltiga röster kan vara röster från andra kommuners folkomröstningar eller röster där någon skrivit, ritat eller på annat sätt påverkat innehållet.
Estimated economic results of a permanent congestion charging system in Stockholm

• Rémy Prud’homme and Pierre Kopp, August 24, 2006, University Paris XII and University Paris I (Sorbonne)
  – “Overall, costs outweigh the very real benefits of the toll by nearly 900 MSEK per year”

• Jonas Eliasson, Transek AB:
  – “Our analysis shows that the Stockholm system yields a large social surplus, well enough to cover both investment and operational costs.”
Stockholm implementation

- **Video cameras** is used for the identification of cars
- Revenue mostly used for financing of new road infrastructure
- Suggestions on minor changes in toll levels, toll cordon design, and in payment and exemption rules
- Still an expensive system, mostly due to the extreme requirements on the level of service
Effects in traffic flows

"antalet passager (medianvärde per vecka) in till och ut ur Stockholm vid betalstationerna för trängselskatt. Passager registreras på vardagar (utom på lördagar) mellan 06.00 och 19.00."
• Start January 1th 2013
• Same system technology as in Stockholm (IBM/Qfree)
• Part of financing of ”Västsvenska paketet” which includes investments in new rail and road infrastructure and more attractive public transports. Total cost 34 billion kronor, where of 17 from government, 14 billion from road tolls (25 years) and 3 from the region.
• Estimated effects (WSP): Central parts of Göteborg (day): -10%, at tolling points: -14%. At 7-9am: -13% and -20% respectively
• Referendum September 2014 with question ”Anser du att trängselskatten ska fortsätta i Göteborg efter valet 2014? Ja/Nej”
The newspaper GP writes, in May 2013:
- ”Trängselskatten i Göteborg drog in 65,2 miljoner kronor under april. Det var pengar som betalades av bilister som gjorde 11,7 miljoner passager.”
- ”Under april var det 14 procent lägre biltrafik genom betalstationerna, jämfört med samma månad för ett år sedan.”
- ”Minskningarna av trafikflödet har avtagit månad för månad sedan trängselskatten infördes i januari.”
Referendum 14th September

• När så gott som alla distrikt var räknade på natten mot måndag stod det klart att nejsidan hade segrat.
• - Nästan svårast tänkbara läge, säger Ulf Kamne (MP).
• När 295 av 297 distrikt är räknade strax efter klockan 07 på måndagen säger 56,84 procent nej och 43,16 procent ja till trängselskatt.
• http://www.gp.se/nyheter/val2014/val/1.2489969-goteborgarna-nej-till-trangselskatt
National system?

Nationellt system för trafikavgifter på gång

Av Kann Myrén

I samband med att trängselsskatt införts i Göteborg byggs ett nationellt system för att hantera skatter och avgifter i trafiken. Nu utreds vad som kan återanvändas från systemet i Stockholm och vad som ska nyutvecklas för att klara de nya kraven.


Upphandlingen av systemet för betalstationerna i Göteborg är redan avslutad och även den här gången valde Qfree som leverantör. Om inte bidraget överklagas före den 19 april, anses det vara 165 miljoner kronor och Qfree vann den i konkurrensen med Kapsch TrafficCom, Siemens och ACS Solutions.

Sädet mot det inte bestämt exakt hur det blir med de centrala delarna som bearbetar informationen från betalstationerna, kopplar ihop registreringsnummer med rätt fordonssagare för att slutligen skriva ut betalningsaviser.


Nu håller Transportsstyrelsen på att undersöka hur man på bästa sätt kan åstadkomma det, uråldrig kostnad, risk och tid, enligt Emma Hermansson, Transportsstyrelsen, som är projektledare för införandet av trängselsskatt i Göteborg.

– Vi ser över hur mycket av det befintliga systemet som IBM har utvecklat som går att återanvända för ett nationellt system. I mesta möjliga mån utgåer vi från det. Men sedan sitter vi på vilka delar som måste bytas ut, och vad av det som vi ska utveckla själva och vad som ska upphandlas extern.

Sedan systemet infördes i Stockholm har Transportsstyrelsen hämtat hem systemet och skapat drift, kundtjänst och produkt av aviser på Trafikregistret i Örebro. Där ska också den nationella löningen finnas när den är klar.

IBM står för närvarande för förvaltning av delar av centralelementet. Hur stor del IBM får i det nya systemet kan inte Emma Hermansson svara på i dagsläget. Det beror på vilken systemlösning som väljs.

Huru som helst kommer Transportsstyrelsen att behöva ta in resurser utifrån för att klara anpassningar och nyutveckling av systemet.

– Om vi driver utvecklingen själva handlar det om att projekten som mest sysselsätter runt 50-60 personer, säger Emma Hermansson.

Ett exempel på anpassningar som måste göras i det nya systemet är att även utländska fordon ska registreras eftersom broavgifter ska betalas av alla oavsett varifrån man kommer. Trängselsskatt gäller an så länge bara svenskskriverade fordon.
Literature sources


*Stockholmsförsöket, Analysgruppens sammanfattning*, February 2005, from [www.stockholmsforsoket.se](http://www.stockholmsforsoket.se)


*Jonas Eliasson, Cost-benefit analysis of the Stockholm congestion charging system*,

Electronic tolling of HGVs: Overview

- Increased demand for road transports
- History of heavy vehicle tolling
- Infrastructure for kilometer based charging
  - May be motivated by its ability to better internalize the environmental externalities of traffic and congestion costs
- Enforcement systems
- Revenue use
Estimated demand for transport of goods Sweden

Sources: Trafa 2011, SIKA, 2005
History of charging for heavy vehicle transports

• Eurovignette system for heavy vehicle tolling
  – Usage based taxation (over 12 tonnes)
  – Based on manual reports from transport companies
  – Only applicable to a few major roads in Sweden, Denmark, Holland, Belgium and Germany

• Other HGV charging elements
  – Fuel price, Fuel duty, vehicle tax (annual charge)

• Germany introduced its own system (Toll Collect)
  – Introduced 1 January 2005
  – Positioning-based kilometer charging
  – On major roads, flexible
The EC directives towards efficient road transport taxes

- EC policy (2001-) on fair and efficient pricing of transports
- Taxes and charges shall reflect socio-economic marginal costs
  - Toll charge levied based on truck weight and environmental classification. Toll level to cover road wear and road expansion.
  - Differentiated toll levels for heavy vehicle management – encourage trucks to use larger and safer roads
- Current road transport taxes based on flat fee
- EC directives favor kilometer charges for road use for heavy vehicle transports
Toll Collect system

- German federal government decided to introduce distance based HGV tolling in 1999
- System activated 1 January 2005, has worked since then “without any problems”
- Tolls apply to vehicle > 12 tonnes
- Position-based kilometer charging, 12.4 euro cent per kilometer
- Tolling on “autobahns” only, smaller road closed for HGVs
- Around 1.2-1.4 million vehicles of which 500k has OBUs
- Toll revenue for financing of road, rail, inland waterways
Vehicle equipment

- OBU with GPS and GSM
- Automatic detection of toll road and charges on entrance
- Information registered in OBU (location and speed) is encrypted and sent to centralized host using GSM
- OBUs are provided free of charge to transport companies
Roadside equipment and enforcement

- Enforcement needed to make sure the system is effective
- Stationary portals with DSRC and video/license plate recognition
- Mobile control units
HGV tolling in Sweden (ARENA)

- In planning stage
- Toll for HGVs > 3.5 tonnes
- Applicable on all public roads

Authorities provide price list and receives declared route

Payment agent declare route and calculate tax

Light OBU with GPS and GSM in truck to register trajectory

Enforcement?
Implementations in Europe

- **Germany:**
  - Toll Collect
  - Introduced 1 January 2005
  - GNSS Positioning-based system

- **Switzerland:**
  - Introduced 1 January 2001
  - Kilometer charge on all roads
  - Transponder-based and additional GNSS charging
  - Toll level dependent on vehicle emissions, vehicle weight

- **Slovakia**
  - SkyToll
  - Introduced 1 January 2010
  - GNSS

- **UK**
  - Test cancelled
  - No current plans

- **Sweden**
  - No current plans
Revenue use from HGV tolling

- Switzerland: Financing of infrastructure, improve rail network, shift transports from road to rail
- Germany: Financing of road, rail, inland waterways
- Sweden: Financing of road wear, reduce emissions, increase safety

Taxation shifts

- Purchase taxes on vehicles, road tax and fuel taxes are exchanged for a distance-based road charging (grön skatteväxling)

Source: Tango Collect, 2003
The Motala bridge

• The bridge is anoint the 9th of October 2013.
• The bridge aims at diverting HGV traffic from the city center. The bridge is finansed by Trafikverket and the local municipality
• No agreement has yet been made about the toll lovel for cars and HGVs
• From MVT.se, 28 of August: "Händer det ingenting i förhandlingarna mellan kommunen och Trafikverket är det mest troliga att det avtal som redan finns kommer att gälla. Tio kronor per resa för personbilar, 100 kronor för lastbilar och ett tak på 100 kronor i månaden för privatbilister blir det i så fall. – Det är jätteovisst. De signaler jag har fått är att det inte kommer att vara klart till den 9 oktober, då är det gällande avtal som gäller, vilket strider mot EU-vinjetten."
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• From NT.se January 2014: The charges will be introduced in 2015, and the charge will be lower than 10kr; also the lorries will be charged a lower amount than 100kr, almost as low as the cars.
ETC and interoperability

- Commercially, interoperability does not pay off
  - Costly for operators
  - HGVs can use manual system, without EPS, at the same cost
- Unlike GSM roaming, the ETC systems in operation are very different in
  - Charging concept and technology
  - Tariffs
  - Legal issues
- Interoperability does not have a high priority today
Does the future include interoperable road user charging? Forecast 2005

Source: IBM, 2005
Future: Ad hoc network-based user charging

- Network communication “mote” unit on-board communicates with mote on, for example, lamp posts and calculates distance traveled
- Data is downloaded at predetermined points, when storage is full or charge limit is reached
- License plate details on unequipped vehicles or those not paying the correct charge are recorded by video
- Enables distance and location based charges

Source: Blythe, 2005
Future: Privacy and security

Judge orders halt to Defcon speech on subway card hacking

August 9, 2006 10:31 AM PDT

LAS VEGAS--A federal judge on Saturday granted the Massachusetts transit authority's request for an injunction preventing three MIT students from giving a presentation about hacking smartcards used in the Boston subway system.

The Electronic Frontier Foundation, which is representing the students, anticipates appealing the ruling, said EFF senior staff attorney Kurt Opsahl.

The undergraduate students had been scheduled to give a presentation Sunday afternoon at the Defcon hacker conference here that they had said would describe "several attacks to completely break the CharlieCard," an RFID card that the Massachusetts Bay Transportation Authority uses on the Boston T subway line. They also planned to release card-hacking software they had created, but canceled both the presentation and the release of
Road Tolls Hacked

A researcher claims that toll transponders can be cloned, allowing drivers to pass for free.

By Duncan Graham-Rowe

Drivers using the automated FasTrak toll system on roads and bridges in California’s Bay Area could be vulnerable to fraud, according to a computer security firm in Oakland, CA.

Despite previous reassurances about the security of the system, Nate Lawson of Root Labs claims that the unique identity numbers used to identify the FasTrak wireless transponders carried in cars can be copied or overwritten with relative ease.

This means that fraudsters could clone transponders, says Lawson, by copying the ID of another driver onto their device. As a result, they could travel for free while others unwittingly foot the bill. "It's trivial to done a device," Lawson says. "In fact, I have several clones with my own ID already."
Summary

- Overview of electronic payment applications
- Congestion pricing
- Tolling of heavy goods vehicles
- The future of road user charging and electronic payments
Literature sources


*Toll Collect, User Information*, 2006. From [www.toll-collect.de](http://www.toll-collect.de)

Assignment questions on “Intelligenta transportsystem I”

• Three questions on transit fare payments, and tolling payments based on three scientific articles
• The questions and the articles are available on the web page: http://webstaff.itn.liu.se/~clryd/KURSER/TNSL06/
The link to the articles needs login “tnsl06” and password “2014”
• Read through the articles before you try to answer the questions.
• Your answer shall be emailed as a PDF file to clas.rydergren@liu.se no later than 23th of September 2014.
• Aim at around 3 pages of text.
• The assignment is graded Pass or Fail.
Assignment questions on “Intelligenta transportsystem I”

• The articles are:

