An aerial photograph of a city, likely Copenhagen, showing a mix of traditional red-roofed buildings and modern architecture. A river flows through the foreground, and a large white text box is overlaid on the right side of the image.

Roadpricing for passenger cars - Background and large - scale experiment

26. august

Otto Anker Nielsen,
Professor, head of transport division, DTU Management

Background



Road pricing

Economics: Road pricing is the most efficient way to tax car driving

- Vickry, 1955 building on ideas of Pigou, 1958 proposal on electronic means)

Has turned out to be difficult to implement

- Politically
- Large system costs (technical, IT, admin, legal)

Practical issues and worries regarding:

- Technology
- Surveillance
- Costs
- Distributional effects

Fast development the recent years – some (partial) experiences with road pricings



Denmark, Investigations

Internationally, Real systems



Toll motorways and lanes, USA

Singapore Area licensing Scheme, 1976

Toll- rings (Stockholm, Oslo, Bergen, Trondheim, London, Singapore, Milan..)

MAUT for trucks, Germany, later in many countries

Multi- toll rings (Singapore, Oslo)

GPS- based system was decided and later cancelled in Netherlands

Orego large- scale test and implementation in Oregon

MOBIS experiment Switzerland, 2019-2021

EETS- directive support a marked with various technical solutions (GPS- boxes, "buzzer", number plate registration, OBU car navigation systems, smartphone- based systems)

Denmark, Investigations

Lessons learned / Recommendations

2000	AKTA- experiment 2000 -2004 (Alternative Kørsels og Trængselsafgifter)	Large- scale experiment, technical feasible, negative CBA
	IMV analysis	Less negative CBA when optimizing pricing levels
	DØRS1	Recommendation, but ideal system not practically implementable
	Tornings toll ring	Very negative CBA, large regional distributional effects, large resistance from suburban municipalities
	Congestion commission	Positive CBA, propose large scale experiment
	S&B test of GPS precision	Technical development has made GPS even more accurate, system costs cheaper
	Ministry of transport expert group on future transport	Recommendation, positive CBA, dealt with rural/urban distributional effect, support by Minister (Ole Birk Olesen)
	Eldrup commission	Propose system with self reporting, positive CBA for Copenhagen, propose large- scale experiment
	DØRS2	Positive CBA, propose large tax reform of car taxation
2022	Largescale experiment decided	

Prior road pricing proposals in Cph (1)

- **Toll-rings results in detour driving**
- **Charging very far from marginal costs**
 - Far to expensive for trips crossing the ring
 - No charger for trips within the ring (who have the largest externalities)
 - Detours lead to congestion outside the ring – even reduced mobility over the whole system
- **Large cost for construction and operation**



The control point up to [Essingeleden](#).



Prior road pricing proposals in Cph (1)



- **Km-based systems with OBU (Onboard Units) have large costs**
- **Relative small improvements of mobility**

A socio-economic assessment of proposed road user charging schemes in Copenhagen

Jeppe Rich*, Otto Anker Nielsen

Centre for Traffic and Transport, Technical University of Denmark, Bygningstorvet 1, 2800 Kgs. Lyngby, Denmark

Available online 7 May 2007

Table 9

Social costs and benefits for the four schemes, million euro per. year, 2005^{a,b}

	km charge	Cordon charge	Large toll ring	Small toll ring
Reduced climate and air pollution effects	8	8	3	-1
Reduced accidents	36	33	17	12
Reduced noise	21	21	11	1
Reduced wear damage	1	1	1	0
Improved accessibility	25	-47	0	-84
Producer surplus, public transport	20	13	7	5
Potential for reduced tax distortion	3	-11	5	5
Lost utility from changed trips	-40	-29	-35	-13
System costs ^c	-83	-83	-33	-29
Payments from motorists	-600	-320	-333	-173
Public income (charges)	600	320	333	173
Total	-11	-93	-27	-100


Further attempts to optimise charging levels in Cph. (3)

- **Optimisation of a number of variants in space and time**
- **Km-system now gave a small societal surplus**


Proceedings of the Institution of Civil Engineers
Transport 161
 August 2008 Issue TR3
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 Accepted 14/05/2008

Keywords:
 economics & finance / traffic engineering / transport planning



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Otto Anker Nielsen
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Improving and optimising road pricing proposals for Copenhagen

M. K. Larsen MSc and O. A. Nielsen PhD

System	Chosen alternative	GC user	GC society	Traffic effects	Revenue
Small toll ring	20 DKK most expensive, not adjusted	-194	-73	-66	120
Large toll ring	50c, 50 DKK most expensive, adjusted two times, compare Table 8	-465	-104	7	470
Kilometre charge	5c2, optimised according to congestion costs, rounded to 0.10 DKK, compare Fig. 5	-378	38	45	420

Table 9. Generalised costs for users and society and traffic effects for the best price alternatives for the three systems in million € per year

The Eldrup Commission

Politik

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C25	OMXS30	NIKKEI	EURO	USD	GBP
-24,49↓	-44,05↓	161,44↑	0,00↑	0,01↑	-0,02↓

Ny rapport fra Eldrup-kommissionen anbefaler »trængselsafgift« i miljøzoner

Regeringens bilkommissionen har fredag fremlagt sine anbefalinger for grøn omstilling af personbiler i Danmark.

POLITIK | 12.02.2021 KL. 10:00



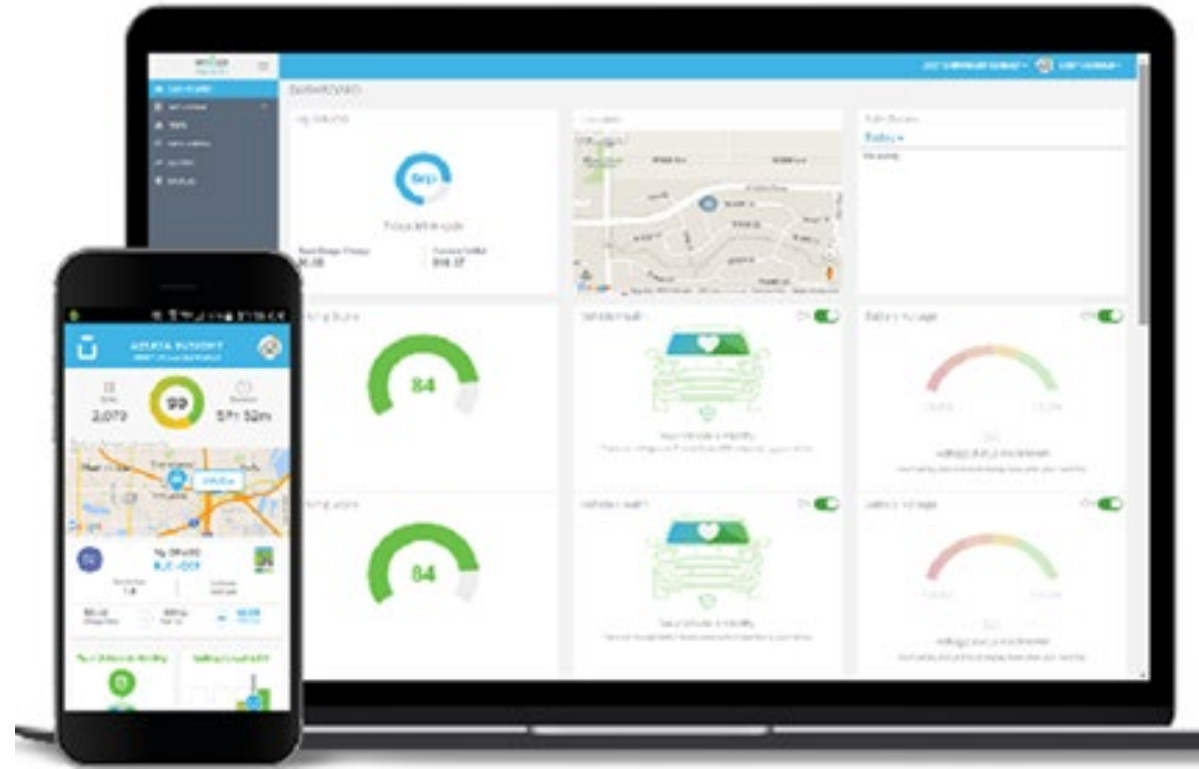
Fredag har elbilkommissionen fremlagt sine anbefalinger for en grøn omstilling af Danmarks bilpark. Arkivfoto

Working group on road pricing



Can there be more efficient technological solutions?

- Compromise between
 - Costs of establishing and operating the system
 - How close it is possible to charge driving relative to the marginal externalities of driving



Miljøzoner.dk

**Ban for trucks and vans
without particle filters**

Large fines

12,500 DKK for trucks and
busses, 1,500 kr. for vans

**Control by cameras and
number plate recognition**

Renere luft til borgerne er målet med miljøzonerne i landets største og tættest befolkede byer.



Possible administrative model



- **Road pricing for all trips in the environmental zone**
- **Self-declaration; The user declare his/her driving e.g. via an app or the systems home-page**
- **Control by camera technology – re-use of stationary and mobile cameras which are used in the existing environmental zone**
- **Data from cameras and payment details are compared after 48 hours, and fines/control fees are sent, where there miss payment**

Very small cost for establishing and operating the system in Copenhagen

0.1% of Denmark's area, relative large share of congestion and local environmental externalities

Small control effort

Level of needed control and hence cost of operations depend on size of fines

Tabel 5.1

Periodebaseret trængselsafgift i miljøzoner – investering og årlige driftsomkostninger

Mio. kr. (2020-priser)

Investeringsomkostninger

Website og webportal til registrering/betaling	3,0
Køretøjsgenkendelsesudstyr, strøm, netværk, installation	0,6
Etablering/udvidelse af billedbehandling og back office systemer	10,5
Projektledelse, kommunikation og markedsføring	9,0
Øvrige omkostninger (usikkerhed)	1,5
Samlede investeringsomkostninger	24,6

Driftsomkostninger (pr. år)

Administration, kommunikation og billedhåndtering	11,7
Kortgebyrer	15,0
Håndtering af kundehenvendelser	10,0
Inddrivelse nettoomkostning (baseret på kontrolafgift)	0,0
Vedligehold af systemer	8,0
Øvrige omkostninger (usikkerhed)	3,5
Samlede driftsomkostninger (pr. år)	48,2

Omkostninger pr. år inkl. afskrivninger	53,6
--	-------------

Three principles for pricing

- 1. The entire day (possible with higher rush hour charge)**
- 2. Per minute**
- 3. Per kilometer**

Extend of data and surveillance

- **Principle 1 (The entire day)**
 - **The need for documentation is minimal (number plate + date)**
- **Principle 2 (minute)**
 - **Moderate need documentation (number plate + date + time interval(s) in the zone)**
- **Principle 3 (km)**
 - **Large need for data (number plate + date + time interval(s) + GPS-coordinates + potential need to map-match or filling gaps between GPS signal fall outs), complex control**

Suggested charge levels



Minute-charge		Car	Truck
Air pollution and noise	Day	0,20	0,80
Congestion	Rush hours	0,45	1,80
[DKK/min]			

Day charge		Car	Truck
Air pollution and noise		10	40
[DKK/day]			

Day charge with rush hour		Car	Truck
Air pollution and noise	Day	10	40
Congestion	Rush hours	20	80
[DKK/day]			

CBA – ELDRUP COMMISSION

(rough calculation)

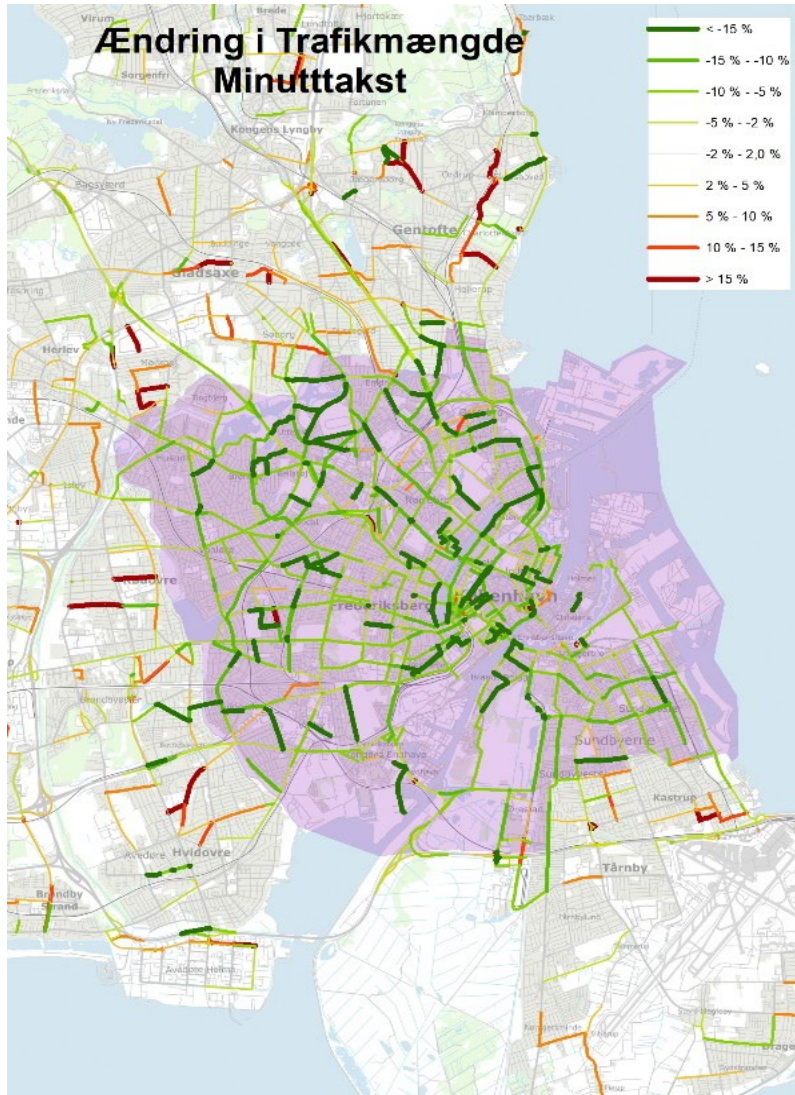
- **Surplus in the minute system (240 million DKK/year, 2025)**
- **160 million congestion**
- **10 million CO2, (40 with the climate council, 20,000 less CO2, negative shadow price)**
- **590 million in tax revenue**
- **Distributional effects**
 - **Car users pay**
 - **Surroundings and the general society wins**
 - **Business transport win, private transport losses (mostly)**

Tabel 5.2

Periodebaseret trængselsafgift i miljøzoner – samfundsøkonomisk resultat 2025 og 2030

	2025 - Minutmodel	2030 - Minutmodel	2025 - Dagsmodel	2030- Dagsmodel
Mio. kr. (2020 priser)				
Effekter for brugerne	-630	-630	-910	-900
Vejafgift	-670	-670	-930	-930
Andre omkostninger ved kørsel	60	60	100	110
Ændret turvalg ¹⁾	-30	-20	-80	-80
Effekter for staten	590	600	750	750
Afgifter ²⁾	650	650	800	810
Administration ³⁾	-50	-50	-60	-60
Eksternaliteter	240	250	140	150
Drift, vej	-10	-10	-10	-10
Trængsel ⁴⁾	160	160	40	50
Uheld	40	40	50	50
Støj	50	50	30	40
Lufforurening	10	10	10	10
Klima (CO2)	10	10	10	10
Arbejdsudbud	30	30	20	20
Arbejdsudbudsforvridning	60	60	70	70
Arbejdsudbudsgevinst	-30	-30	-50	-50
Effekter i alt	240	250	0	10

Why are the results so positive?



- A minute-based system turned out to be a smart way to price congestions
 - Time-use reflects congestions
 - Time gains are experienced most places
- Detour driving is limited, because it seldom saves time
 - Good for congestions and CO2
- Payment is larger on local roads and smaller on large roads
 - Generally good for safety and local emissions to move traffic from small to big roads
 - May require more speed-control enforcement outside rush hours

Political decision on experiment with road pricing for passenger cars

Nyhed

Forsøg med vejafgifter for personbiler kan sættes i gang

Et udviklingsforsøg med vejafgifter for personbiler skal give indblik i, hvilken effekt afgifter vil have på trængsel og CO₂-udledningen fra trafikken. DTU skal stå bag forsøget.

25. feb. 2022



- 20 Februar 2012



Thorning: Der kommer en rigtig god løsning i morgen

En smilende statsminister gentog igen og igen, at der kommer en rigtig god løsning på spørgsmålet om betalingsringen i morgen. Men hun indrømmede, at de havde lyttet til debatten.



- Experiment with road pricing from 2022-2024 with final reporting 2025

Retrospective:

We might decide upon a good solution in 13 years

And we might obtain a good solution in 16 years

About the experiment

Purpose of the experiment

Political agreement

Political agreement of 4. december 2020 with Radikale Venstre, SF and Enhedslisten about 'Green transition of road transport'

Include large-scale experiment with roadpricing for passenger cars. Parties agreed that road pricing will be a better taxation of **congestion and damage – and health costs** related with car driving.

DTU was awarded the project together with **Sund & Bælt** in February 2022, grant letter in July

Purpose

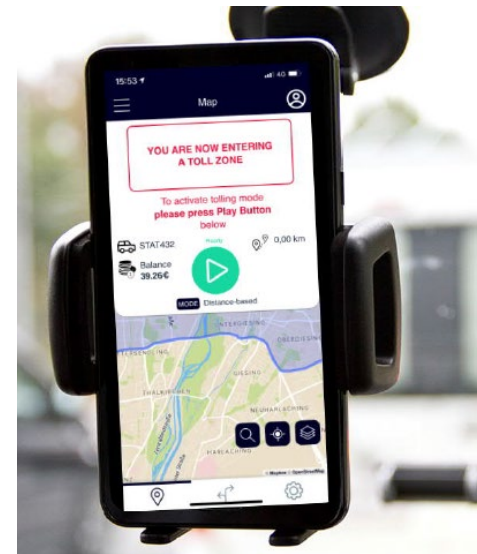
An overall **evaluation of the possibilities for roadpricing**

Focus on;

- Technology
- System costs
- Practical implementability
- How users can understand it
- Handling of privacy (GDPR)
- Economics (CBA) and distributional effects

FROM THEORY TO PRACTICE

Technology exist and works –
it should therefore not (only) be a technology
test



Different types of technical solutions

- Parking apps and other apps
- On-board Units (OBU), eg. speed control alarm devices
- Cars built in navigation equipment or other built in tracing



Saphe - Saphe Drive Fartkontrol
695,00 kr.
hessel.dk
By Google

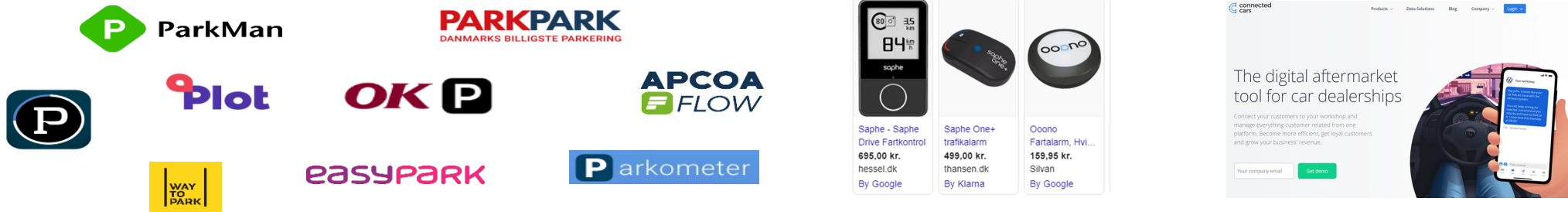


Saphe One+ trafikalarm
499,00 kr.
thansen.dk
By Klarna



Oono Fartalarm, Hvi...
159,95 kr.
Silvan
By Google

Benefit with external provider model



- **Secure competition on solutions and costs**
- **Countrywide (international) instead of local solutions**
- **Solutions for private and business**
- **Provider responsible for GDPR**

Example from OReGO



WHY IT MATTERS

HOW IT WORKS

GET STARTED

CONNECT

Directly compare account managers:



- Pay: Pay as you go
- Method: credit or debit card
- GPS: GPS and non-GPS options
- Out-of-state miles credited
- Value-added services
- EV compatible

LEARN MORE



- Pay: post-pay quarterly
- Method: credit or debit card
- GPS: yes
- Out-of-state miles credited
- Value-added services
- EV compatible

LEARN MORE

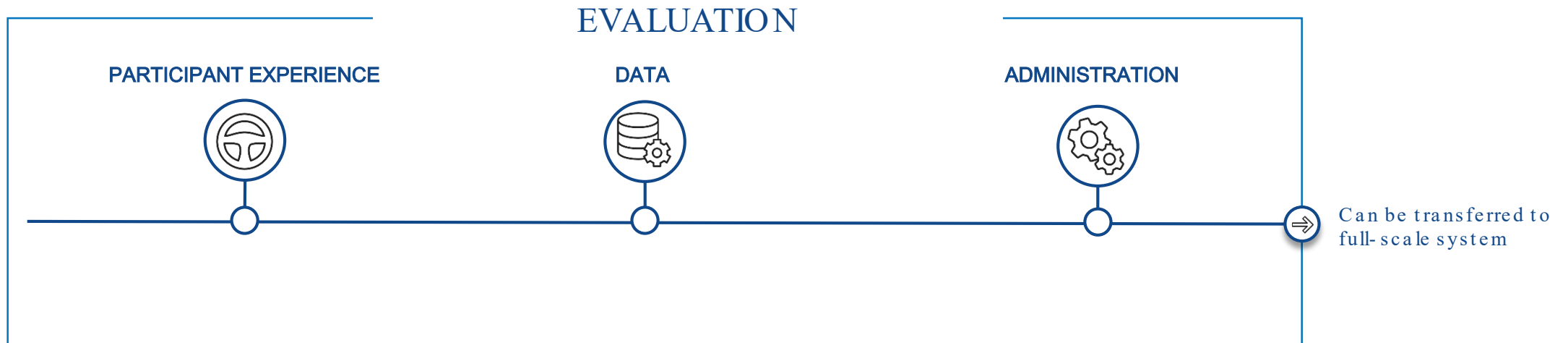
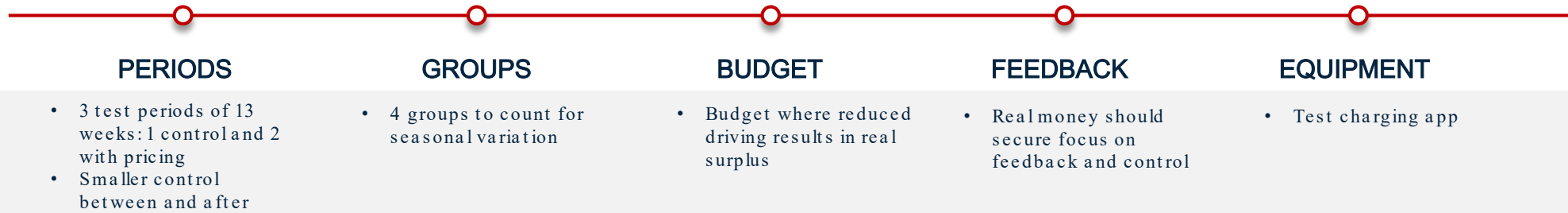


- Pay: post-pay quarterly
- Method: credit or debit card
- GPS: No
- No out-of-state miles credited
- Not EV compatible

LEARN MORE

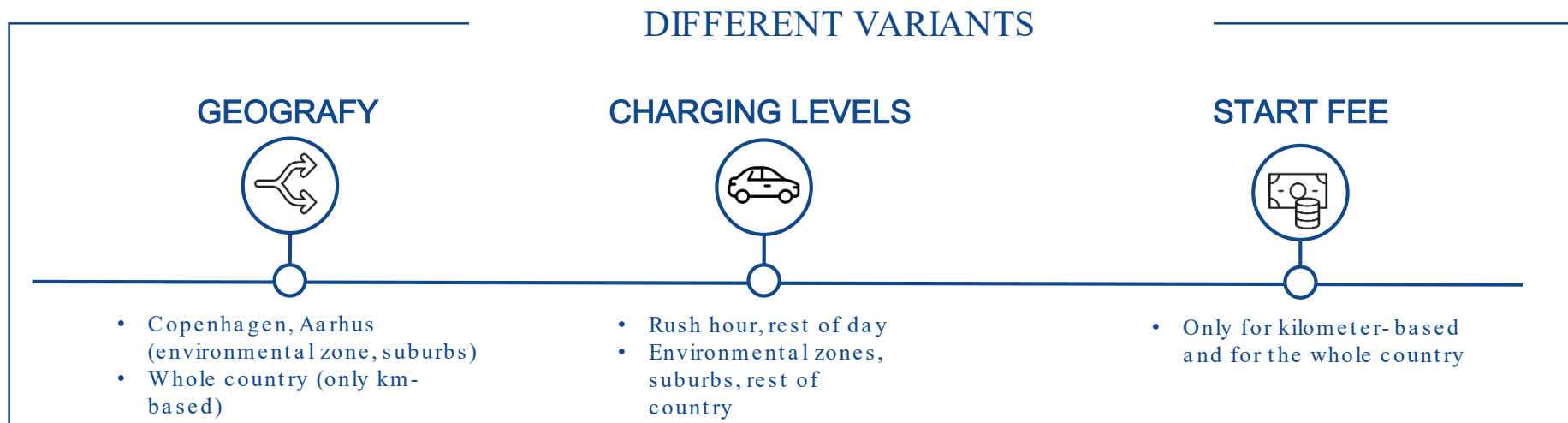
As realistic as possible

2.500 PARTICIPANTS – INVITED AND STRATIFIED



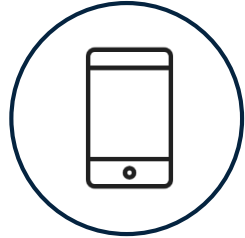
Different charging paradigms in different variants

	Km - based	Time - based
Charging	Per kilometer	Per minute
Registration of trip	Automatic, manually or post-registration via homepage	Automatic, manually or post-registration via homepage
Control	Cameras and number plate recognition	Cameras and number plate recognition
Data need	Exact route	Areas and time-intervals



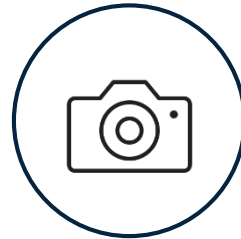
Different systems and variants clarify benefits versus complexity of the system

...technical and operational part of the experiment



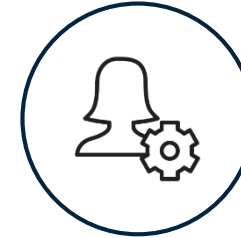
MODIFIED TECHNICAL SOLUTION

- Modified App
- Central system for handling of users, driving data and control data



EXISTING TECHNOLOGY

- Reuse of existing cameras
- Both stationary and floating cars in the environmental zones
- Possible a few more cars



ORGANISATION

- Home page
- Customer support
- Technical surveillance
- Communication with test users
- Manual picture valuation

Time schedule

	2022				2023				2024				2025		
Phases	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Design	█														
Development			█												
Test & pilot					█										
Analysis		█				▨					█				
Experiment						█									
Evaluation								▨			█				

To conclude; why is road pricing better now?

- Cheaper to implement and operate
- More traffic and more congestions
- Possible to target pricing more efficient to marginal costs (externalities)

Some reflections and key takeaways

- The technology works, and is an order of magnitude cheaper than a few years ago
- Road pricing can target congestion very efficiently compared to other taxes
- Also potentially more efficient on externalities like accidents, noise, emissions
- Clever designed schemes may result in positive CBA
 - Conditional upon that the revenue is used wisely

BUT

- Less clever designed schemes may lead to loss
 - Benefits smaller than the cost of implementing and operating the system
 - Toll-rings lead to detours
 - National road systems leads to more traffic on local roads, more accidents, noise and particle emissions in cities
 - Zero-emission zones leads to loss in car-marked
- Simple fuel tax (or CO₂ tax) may address CO₂ target cheaper (issue with border trade)
- Electric cars can be promoted through car-taxation, less taxation on electricity and fuel tax, not road pricing

DTU



Sund ≈ Bælt
Sund ≈ Bælt



Questions ?

