Comparison of congestion charge systems (tokens vs tolls vs taxes) from a modeling perspective: how can we measure efficiency, effectiveness, and equity?

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The transport models consist of at least 3 fundamental models.
- A demand model (trip generation, trip distribution, mode choice, and time of travel)
- A highway assignment model (road-based public transport, private vehicles, freight, and other commercial vehicles)
- A rail, bus, and ferry assignment model (public transport and freight).

Transport Modelling enables planners to
Plan public transport services.
Conduct traffic analyses and forecasts.
Setting the framework to adapt to new mobility services such as autonomous driving.
Develop advanced and future-proofed transport strategies and solutions

	London	Singapore	Stockholm	Milan	Gothenburg	Rome
Traffic volume	-16% (2006) -30% chargeable vehicles, +25% busses, +15% taxis, +49% bicycle -21% (2002-2008)	-44% after ALS -10%-15% after ERP compared to ALS - 20%-30% for other extensions of the system	-20% across the cordon	-34% (-49% in user of heavy polluting vehicles)	-10% across cordon, -2.5% vehicle-km in Gothenburg	-20% over cordon +15% motorcycles
Travel times	-30% delays	speed criteria charge levels between 20-30 kph and 45-65 kph	-33% in delays	-17% in congestion +7% bus speed, +4.7% tram speed	-10-20% reduction median travel time on corridors	+4% in speeds +5% speeds PT
Public transit ridership	+18%	n.a.	+5%	n.a.	+6%	+5%

The performance of any transportation is measured by three factors.

Efficiency: The ability of a congestion charge system to effectively reduce traffic congestion and improve the overall flow of traffic is referred to as efficiency.
Effectiveness:
The levels to which pre-estimated objectives and targets have been achieved by a congestion charge system is called effectiveness.
Equity: Equity checks the distributional impacts and fairness of a congestion charge system
by several communities and socioeconomic groups.

Some approaches to evaluate different transportation models are. Cost-Benefit Analysis (CBA), Multi-Objective Optimization Models, Equity Impact Assessment Models, Traffic Microsimulation Models, Travel Demand Models.

	Tolls/Taxes	Tokens
Efficiency	$t_a(x_a)=[t_a^0\,[1+\alpha\left(\frac{x_a}{c}\right)^{\beta}]$ $s=\alpha-\beta q$ $C_A(t)=\tau(t)+\alpha_A T_A(t)+\beta\,max[0,t^*-\Delta-t-T_A(t)]+\gamma\,max[0,t+T_A(t)-t^*-\Delta]$	$\tau(t)=t_v(t)+t_f$ $\tau_{\bar{s}}(\bar{f})=\frac{Q_{\bar{s}}(\bar{f})}{s}+t_f$ $\psi_e=\alpha_2 v^2-\alpha_2 v+\alpha_3$
Effectiveness	$U=\alpha T+\beta D+C,$ $\sigma=const*travel\,time^{12}*\sqrt{\frac{travel\,time}{free-flow\,travel\,time}-1}$ $\omega\equiv\frac{TC^n-TC^i}{TC^n-TC^f},i=t,q,$	$E_A=\frac{Q-Q^0}{0.5(Q^0+Q)}/\frac{C-C^0}{0.5(C^0+C)}$
Equity	car: $C_a(x_a)=t_a(x_a)/\gamma_2+l_a.Opri+u_a*e_{ctax}e_2p_2l_a\times10^{-3}$ bus: $\bar{C}_a(\bar{x}_a)=\bar{t}_a(\bar{x}_a)/\gamma_2+\bar{\gamma}+e_{ctax}e_2P_2l_a\times10^{-3}$ $C=t(D)+\tau$ $\Delta v_a.d=\alpha(T_a^0-T_a^1).$	$\sum_{a\in A}K_a v_a\le K$ $p=\left[\sum_{w\in W}d_w\,D^-(d_w)-\sum_{a\in A}v_a.S_a(v_a)\right]/\sum_{a\in A}l_a v_a$ $p^*=\frac{\tau^1_{1,w}-\tau^0_{1,w}}{K_{1,w}-K_{r,w}}$

	Tolls	Taxes	Tokens
Efficiency	They are the most efficient in terms of generating revenue and reducing the congestion in big cities as everyone must pay.	They are effective in terms of efficiency as they can be renewed and revised if required.	They are least effective in terms of efficiency as a certain amount is provided to everyone for a certain period.
Effectiveness	They are second best in terms of effectiveness after taxes as they are designed according to the aims of the system.	They are the most effective in terms of effectiveness as the charge can be revised at any time and can influence the outcomes.	They are very effective in reaching the pre-designed aims as they are distributed according to the capacity of the network.
Equity	They perform worst in terms of equity as everyone has to pay the same amount of money when they cross the toll.	They are second to Tokens in terms of equity as the charge changes with time and specific groups receive reduced charges.	They are the best for equity among all as everyone is provides with same no of tokens.

There is no single perfect model for modelling of congestion charge systems instead several congestion charging models can me put together to produce a suitable model for various traffic and political situations. Such as Carbon charging, changing tool fees based on the available capacity of the network etc. Every city has its own requirements and challenges and every operating authority has their own prospective and limitations. The mathematical models which calculate Efficiency, Effectiveness, Equity can be based on several factors such as (Travel Time, Traffic Flow, Mode Shift) for efficiency. For effectiveness these factors can be (Policy Compliance, Revenue Generated, Emission Reduction) and for Equity it can be factors such as (Distributional Analysis, Accessibility, Disproportionate Impact).