"Transport Assessment Tools: CBA utility-based, Multi-criteria regret-based, and CE access based"

CENIT seminar, Barcelona, July 2015

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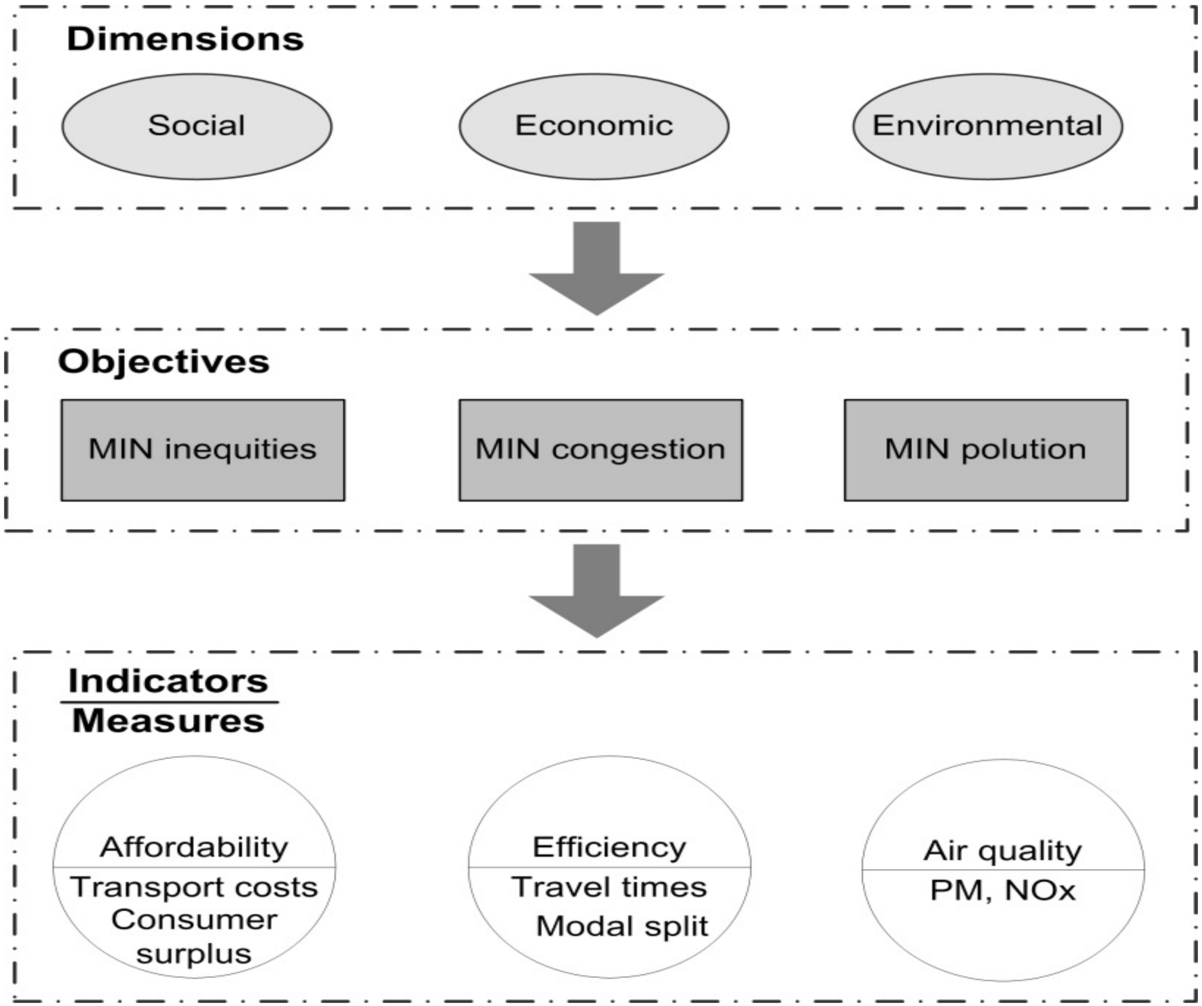
Objectives & Motivations



Conceptual foundation of multidimensional indicators for a toll ring policy
Based in Miller

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Objectives

- To convert sustainable transport issues into a welfare function
- To rank all possible policy combinations in respect of to their contribution to the objectives
- Social welfare depending on a transport system is defined as the sum of social benefits of users, operators and government
- The most important part is how to calculate consumer surplus

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Appraisal Tool: Cost Benefit Analysis

Main objective: Sustainable transport

Sub-objectives: economy, environment and social equity

Appraisal Tool: Cost Benefit Analysis

Simulation by MARS

- Scenario 1: Cordon Toll & Parking Charge
- Scenario 2: PT (Bus) Improvement
- Scenario 3: Integrated Policies Package

Result Analysis

- User benefit
- Social welfare to all objectives

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Welfare function

$$\Delta W(U) = \int_0^n \sum_{ij} \frac{1}{(1+r)^t} \cdot \left[\Delta CS_{ij}(t) + \Delta O_{ij}(t) + \Delta G_{ij}(t) + \Delta E_{ij}(t)\right] dt \qquad (1)$$

Where,

$\Delta W(U)$ = the change in social welfare compared to base case scenario
ΔCS_{ij} = Customer surplus changing from zone *i* to *j*
ΔO_{ij} = Operators benefit changing from zone *i* to *j*
ΔG_{ij} = Government benefit changing from zone *i* to *j*
ΔE_{ij} = External costs from zone *i* to *j*
r = Social discount rate [%]
t = Time (year)
n= number of years (from 0 to 30)

Wang, Y., **Di Ciommo**, F. and Monzón A. 2015. A new approach for user benefit assessment by a LUTI model. The case of Madrid. Innovations in Thill J.C. (Ed), *Spatial analysis and Location Modeling in Urban and Regional Systems,* Advances in Spatial Sciences Series of Springer (*in press*)

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Operator costs

$$\Delta O_{ij} = \sum_t \sum_{ijm} T_{ijm}^1 \cdot (\tau_{ijm}^1 + c_{ijm}^1) - T_{ijm}^0 \cdot (\tau_{ijm}^0 + c_{ijm}^0) \quad (5)$$

τ_{ij} consists of two parts, one of which is revenue from private vehicles in the case of an urban toll or parking charge fee; the other part is revenue collected from public transport services, e.g. trip tickets.

C_{ij} represents the cost of administration, operation and maintenances cost, energy consuming cost, etc.

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Government costs

The government's benefits or losses resulting from changes in the revenue fuel tax (ΔF_{ij}) and changes in the cost of road maintenance (ΔM_{ij}).

$$\sum_t \sum_{ijm} \left(T_{ij}^1 - T_{ij}^0\right) \cdot \left(\Delta F_{ij} + \Delta M_{ij}\right) \qquad (6)$$

Externalities costs

The value of externalities is associated with green-house gas emissions (ΔGHE_{ij}), air pollution (ΔP_{ij}) and safety (ΔS_{ij}).

$$\sum_t \sum_{ijm} \left(T_{ij}^1 - T_{ij}^0\right) \cdot \left(\Delta GHE_{ij} + \Delta P_{ij} + \Delta S_{ij}\right) \qquad (7)$$

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MODIFIED CBA

Consumer surplus variation CSij: from a change in travel times and/or travel costs

$$\Delta CS \approx \frac{1}{2} CW_i \sum_i \sum_j \sum_m \left(T_{ijm}^{E_0} + T_{ijm}^{E_1}\right) \cdot \left(G_{ijm}^{E_0} - G_{ijm}^{E_1}\right) \qquad (2)$$

$$\approx \frac{1}{2} CW_i \sum_i \sum_j \sum_m \left(T_{ijm}^{E_0} + T_{ijm}^{E_1}\right) \cdot \left(C_{ij}^{E_1} + t_{ij}^{E_1} * VOT_i - C_{ij}^{E_0} + t_{ij}^{E_0} * VOT\right)$$

Where,

CW_i = compensating weight in zone *i*

T_{ij}^{k} = trips between *i to j* in scenario *k*

G_{ij}^{k} = travel generalised cost from *i* to *j* in scenario *k*

C_{ij}^{k} = total travel cost including charging and operation cost from *i* to *j* in scenario *k*

t_{ij}^{k} = travel time from *i to j* in scenario *k*

VOT= Value of time (10.45 €/hour during the peak hour and 5.7 €/hour during non-peak hour)

CW_i, compensating weight for compensating the user utility for different levels of user income.

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MODIFIED CBA

	Scenarios		
	1	2	3
User discount rates			
Low	5.5%	Variable: Figure 5	Variable: Figure 5
Medium	5.5%		
High	5.5%		
Other social agents discount rates			
Operators	7.0%	7.0%	7.0%
Government	4.5%	4.5%	4.5%
Society	4.5%	4.5%	4.5%
Toll values	Optimum	Scenario 1	Optimum

Di Ciommo, F, De la Hoz, D & Guzman, L.A. 2014. Exploring users intertemporal preferences for measuring transport social equity effects, Transport Reviews.

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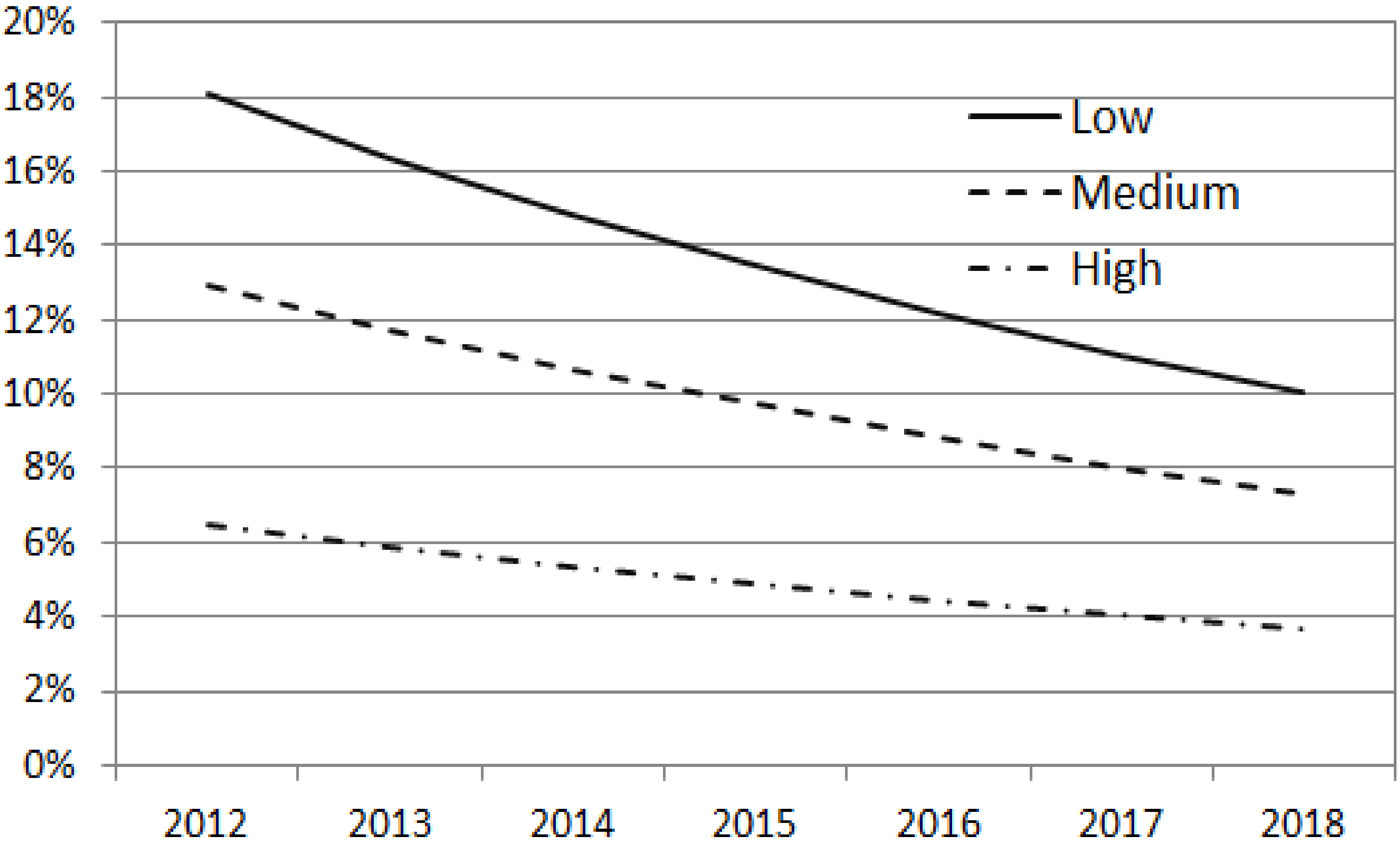
MODIFIED CBA



Discount rates by user type (low, medium and high income)

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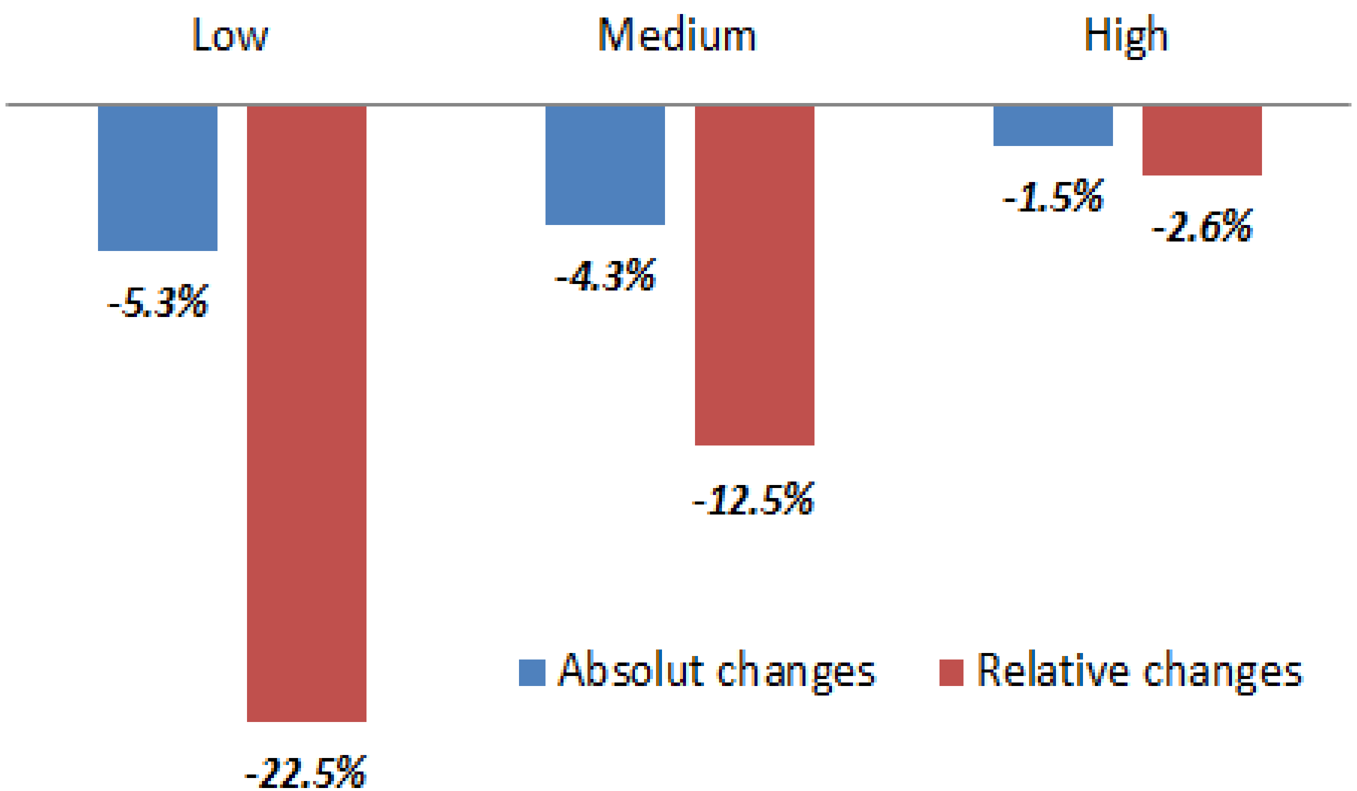
RESULTS

Modal split changes before/after toll ring implementation by income level



While a significant percentage of low and middle-income people change from car to public transport, the high-income group don't leave their cars.

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RESULTS

Indicator	Ratio	Scenario 1	Scenario 2
Time saving per cápita	$X_{\text{high income}} / X_{\text{low income}}$	1.69	2.24
	$X_{\text{high income}} / X_{\text{medium income}}$	1.31	1.54
Cost savings per capita / income	$X_{\text{high income}} / X_{\text{low income}}$	0.61	0.55
	$X_{\text{high income}} / X_{\text{medium income}}$	0.62	0.53

The results are respected when the optimization is done using the same discount rate or different discount rates for each kind of income user-type.

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Key findings

- **new method for defining** and integrating different intertemporal preferences

- **considering different income users** profiles
- **the method is tested by optimizing a cordon** toll scheme in Madrid

- **based on the modified social** welfare function (WF), the results that transport cost are **regressive** don’t’ change

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Policy Contributions

- The usefulness of the measure of congestion toll increases over time.
- CBA is not the best option to have a clear idea of social benefit.
- This result is key for understanding the relationship between transport policies and their impacts.

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Multi-criteria regret-based

An Integrated Transport Planning Framework Involving a Combined Utility-Regret Approach

Wang Y., Monzón A., **Di Ciommo** F., Kaplan S. 2014. An integrated transport planning framework involving a combined utility-regret approach, Transportation Research Record,

Introduction

- Planning sustainable transportation requires the use of strategic planning, impact analysis and evaluation tools.
- The combination of planning tools (Scenario construction, transport models and multi-criteria analysis) has been employed only recently (*Fedra, 2004, López et al, 2012 and Hickman et al, 2012*)
- The existing tools are utility-based and thus their main limitation is that they disregard the feeling of regret deriving from a comparison between the chosen and foregone alternatives

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Research objectives

To embed regret minimization as part of the integrated approach for expert-based scenario construction, model-based impact analysis and optimization, and multi-criteria analysis (MCA)

Contribution

- To embed regret in the scenario building and impact assessment
- To apply the generalized utility function combining utility and regret (Inman et al., 1997)

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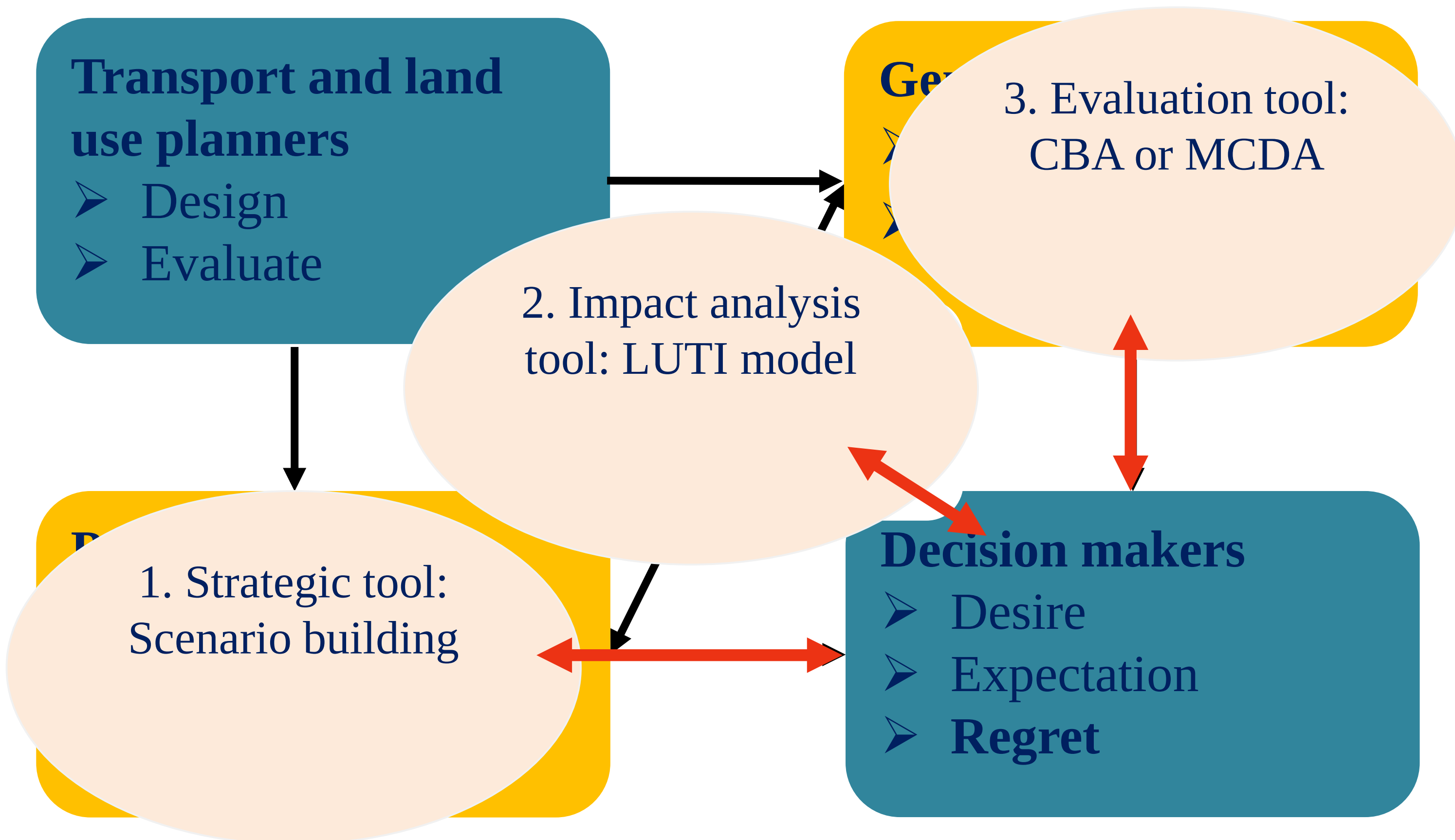
Main components of transport planning



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Research objective

Why Regret?

- Associated with counter-factual thinking in complex decisions
- Associated with a group decision based on majority view
- Associated with policy decisions in transportation
- Tends to favor ‘balanced’ rather than ‘optimal’ solutions

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The Madrid case study

The proposed framework is applied to the case-study of the future implementation of travel demand management (TDM) measures:

TDM Measures	Implementation	
	Time Frame	**Geographic Scale**
Cordon toll	Short term (in 5 years)	City centre
Parking Charge increasing	Middle term (in 10-15 years)	Inside of M30
Bus frequency increasing	Long term (in 20-25 years)	Inside of M40
Bus fare decreasing		

- **Transport system efficiency:** car share, travel time, operation costs
- **Environmental sustainability:** CO_2 , air pollution, land consumption
- **Social equity:** accessibility, number of accidents, travel affordability

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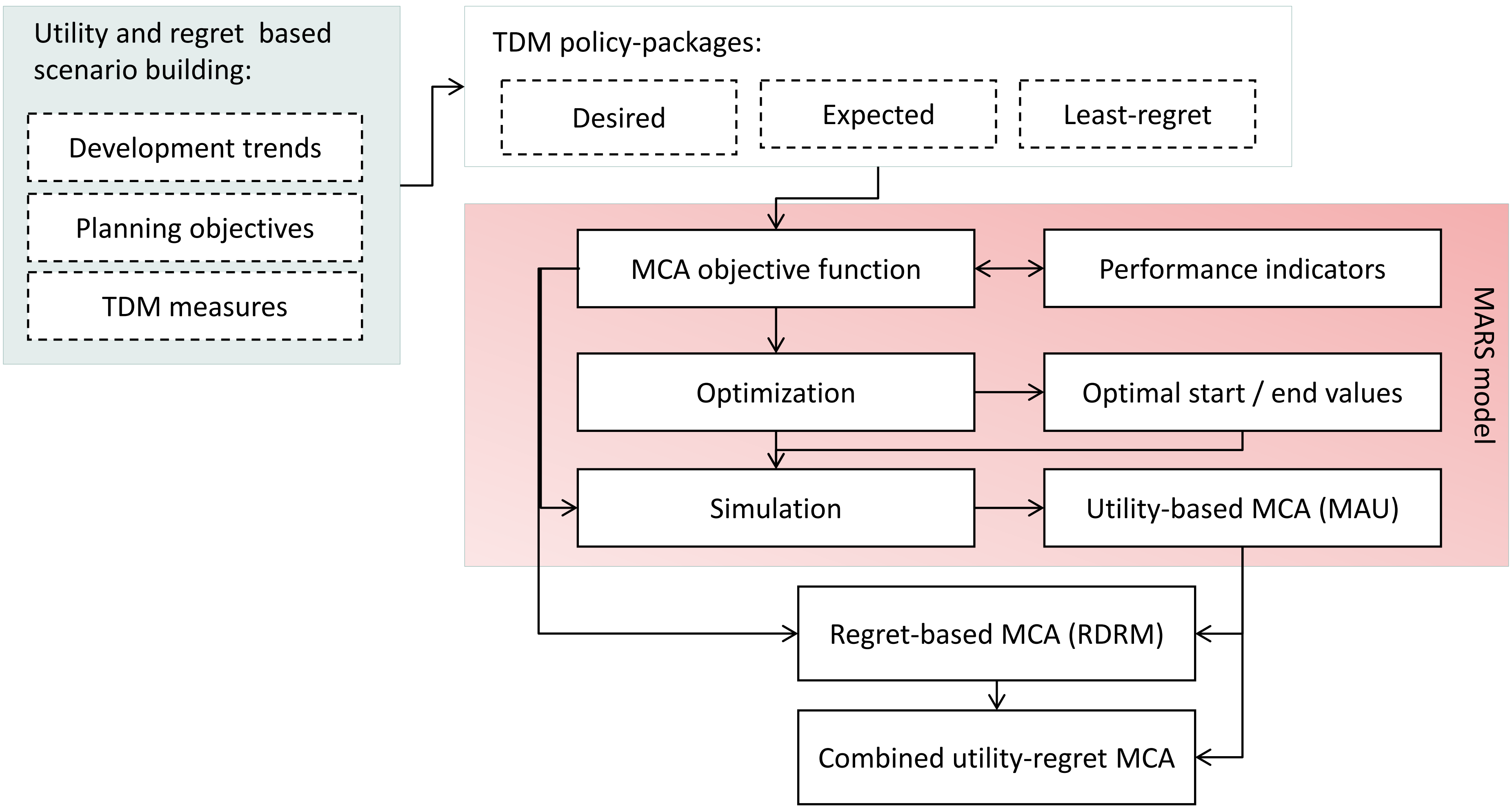
Methodology

Integrated framework for TDM measures design and evaluation:



Methodology

Utility and regret based scenario construction:

1st round: individual TDM measures

Weights of economic, social and environmental goals

Desired time and geographical scope → Expected time and geographical scope → Regret linked to the non-desirable time / geographical scope

2nd round: TDM policy-package

Agreement with the desired, expected and least-regret policy-packages → Drivers and barriers for implementation

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Methodology

Utility and regret based scenario construction:

1st survey round:

- Utility and regret-based weights for the criteria
- Regret linked to the non-desired alternatives for each TDM measure

2nd survey round:

- Regret linked to the majority view of the desired scenario

la demanda de transporte en Madrid

TDM measure - Resultados

La tarifa de estacionamiento en la calle

Madrid ya aplica tasas por aparcar y el modelo establece que lo óptimo sería cobrar 2,5€/hora, que se aplicaría como ahora sólo en el interior de la M-30.

Medida: La tarifa de estacionamiento en la calle (año base 2012)				
Escenarios	**Resultados de la Encuesta**		**Resultados de modelización**	
	Implementación		Valor óptimo comienzo	Valor óptimo final (2034)
	Área	Tiempo		
Más deseable	interior M30	en 5 años (2017)	2,5 €/hora	2,5 €/hora
Más previsible	interior M30	en 5 años (2017)	2,5 €/hora	2,5 €/hora
Menor grado de contrariedad	Distrito Centro	en 10 años (2022)	0,8 €/hora	0 €/hora

3. Por favor, valore su grado de acuerdo con la implementación de la medida dado el escenario resultante

	Totalmente en desacuerdo	algo en desacuerdo	algo de acuerdo	Completamente de acuerdo
Más deseable	○	○	○	○
Más previsible	○	○	○	○
Menor grado de contrariedad	○	○	○	○

4. Por favor, valore su acuerdo con la implementación de la medida dado el escenario y los resultados del modelo con un valor

	Totalmente en desacuerdo	algo en desacuerdo	algo de acuerdo	Completamente de acuerdo
Más deseable	○	○	○	○
Más previsible	○	○	○	○
Menor grado de contrariedad	○	○	○	○

Methodology

Regret based MCA

- According to the reference-dependent regret model (Kujawski, 2005) the regret for choosing alternative A_i over forgone alternative A_j is:

$$R(u_{ik,} u_{jk}) = \begin{cases} G(1-u_{ik}) - G(1-u_{jk}) & , u_{ik} < u_{jk} \\ 0 & otherwise \end{cases}$$

- u_{ij} and u_{ik} are the *k-th* criterion utility scores and *G(x)* is the regret function:

$$G(x) = \begin{cases} \dfrac{1}{1+(B/x)^{2*S*(B+x)}} & , \mathrm{x} > 0 \\ 0 & otherwise \end{cases}$$

- *B* and *S* characterize the shape of G(x) and can be estimated. In this study, *B=0.5*, *S=4* in agreement with previous ones. Using the RRM model (*Chorus, 2012*) yields the same ranking of alternatives

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Regret based MCA

- The regret value of choosing alternative A_i from a set of n alternatives (n ≥ 2) with m criteria is and criteria weights w'_k :

$$R_i^s = \left(\frac{1}{n-1}\right)\sum_{k=1}^{m} w_k' \sum_{j=1}^{n} R\left(u_{ik}, u_{jk}\right)$$

Generalized utility (combined utility regret) based MCA:

$$\mathrm{GU}\left(U_i, R_i^s\right) = \sum_{k=1}^{m} w_k u_{ik} - R_i^s = \sum_{k=1}^{m} w_k u_{ik} - \left(\frac{1}{n-1}\right)\sum_{k=1}^{m} w_k' \sum_{j=1}^{n} R\left(u_{ik}, u_{jk}\right)$$

- U_i represents the aggregate expected-utility of alternative A_i calculated by MAU, and R^s_i is the anticipated-regret computed using RDRM. W_k, and W_k' are the utility and regret based weights

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Results

1st round results:

CORDON TOLL				
Start year	In 5 years	In 10-15 years	In 20-25 years	No
Desired	**60%**	17%	3%	20%
Expected	27%	**45%**	10%	17%
Level of regret	**5.52**	5.87	6.03	
Geographic scope	City Center	Inside M-30	Inside M-40	
Desired	32%	**57%**	12%	
Expected	**63%**	30%	7%	
Level of regret	5.72	**5.66**	6.31	
PARKING FEES				
Start year	In 5 years	In 10-15 years	In 20-25 years	No
Desired	**63%**	15%	3%	19%
Expected	**75%**	17%	1%	7%
Level of regret	4.27	**4.24**	5.71	
Geographic scope	City Center	Inside M-30	Inside M-40	
Desired	31%	**55%**	14%	
Expected	32%	**64%**	3%	
Level of regret	**5.45**	5.5	6.84	
INCREASED BUS FREQUENCY				
Start year	In 5 years	In 10-15 years	In 20-25 years	No
Desired	**71%**	15%	0%	14%
Expected	19%	**40%**	8%	33%
Level of regret	**1.6**	3.3	6.4	
Geographic scope	City Center	Inside M-30	Inside M-40	
Desired	2%	30%	**68%**	
Expected	22%	**43%**	34%	
Level of regret	6.4	**4.2**	5.2	

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Results

MARS simulation model results:

Base year 2012	Combined policy scenario	Survey results		Model output	
		Geographic scope	Time-frame	optimal strat-year value	Optimal end-year value
Desired	Cordon toll	Inside M-30	In 5 years	4.0 €/vehicle*	2.9 €/vehicle
	Parking fee			2.5 €/hour	0 €/hour
	Bus frequency	Inside M-40		52%	34%
Expected	Cordon toll	City center	In 10 years	5.2 €/vehicle	3.7 €/vehicle
	Parking fee	Inside M-30	In 5 years	2.5 €/hour	0 €/hour
	Bus frequency		In 10 years	36%	27%
Least-regret	Cordon toll	Inside M-30	In 5 years	1.1 €/vehicle	6.0 €/vehicle
	Parking fee	City center	In 10 years	0 €/hour	0 €/hour
	Bus frequency	Inside M-30	In 5 years	50%	22%

*Single entry to the cordon area during peak-hour

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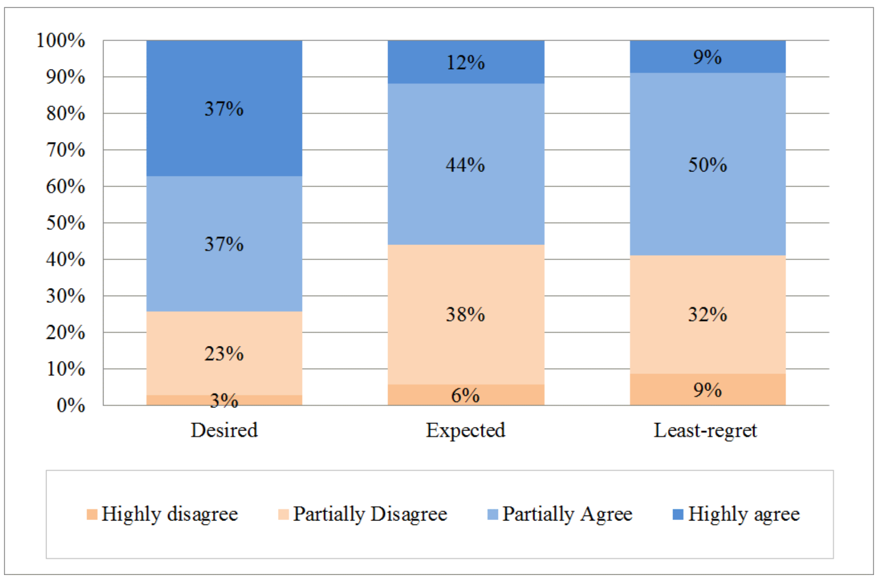
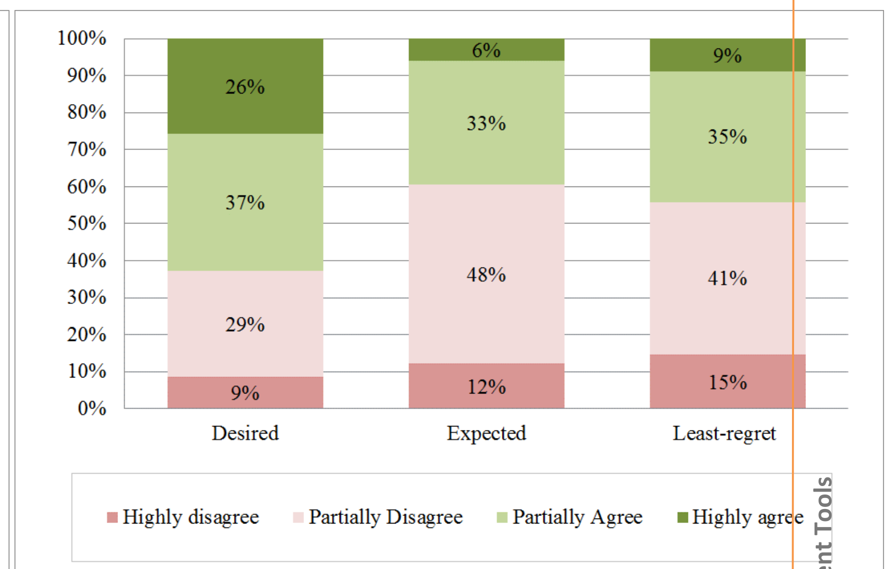
Results

2nd round: agreement with the survey and the model results





Agreement with the survey results

Agreement with the model output

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Results

Generalized utility (utility-regret) MCA:

Scenario scores	Desired	Expected	Least-regret
Transport system efficiency	26.59	17.25	21.59
Car modal share	8.62	-18.87	-7.83
Motorized trip time	45.65	41.46	43.25
Operation car costs	25.58	29.22	29.42
Social Equity	21.23	44.5	37.75
Accessibility	43.04	43.36	42.89
Accidents	20.35	40.94	34.41
Transport cost affordability	4.35	48.72	36.65
Environment	47.89	28.79	37.92
CO_2 emission	29.31	-4	11.81
Air pollution	15.83	5.57	10.71
Land consumption	91.62	91.67	91.54
Utility-based MCA	32.05	29.68	32.14
Regret-based MCA	6.2	12.17	9.8
Combined utility-regret MCA	25.85	17.5	22.33

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Conclusions

- The desired scenario is superior in terms of efficiency and environment, but the expected scenario is better in terms of equity
- The least-regret scenario is a compromise solution between the desired and the expected scenarios
- The least-regret scenario can lead to higher user benefits in the short-term and lower user benefits in the long-term
- The utility-based, regret-based and combined utility-regret-based multi-criteria analysis result in different rankings of policy packages
- The combined utility-regret ranking is more informative compared with utility-based or regret-based ranking

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Cost-effectiveness access-based

Incorporating equity into transport planning: utility, priority and sufficiency approaches

Martens, K., Di Ciommo, F. & Papanikolaus A. 2015. Incorporating equity into transport planning: utility, priority and sufficiency approaches", Transport Reviews

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El enfoque convencional

- **El enfoque convencional** para la evaluación de las intervenciones de transporte (proyectos de infraestructura) se centra en los beneficios y costes.

- **Un ejercicio de evaluación** donde varias alternativas se comparan en términos de costes y beneficios que generan para la sociedad en su conjunto.

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El enfoque convencional

- **La ponderación de beneficios y costes**, **no** está relacionado con las **características del receptor** del coste o beneficio.

- Por lo tanto, **una unidad de beneficio** siempre tiene un peso idéntico, independientemente del receptor de esta unidad de beneficio. Esto se empeora en el caso de utilizar valores de disponibilidad a pagar por atribuir un valor monetario a un beneficio (i.e. surplus del consumidor)

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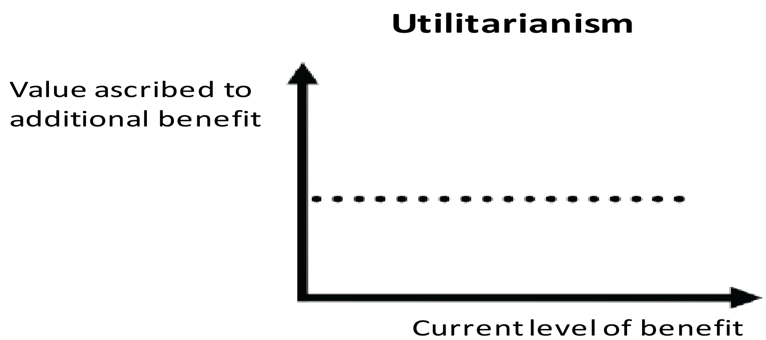
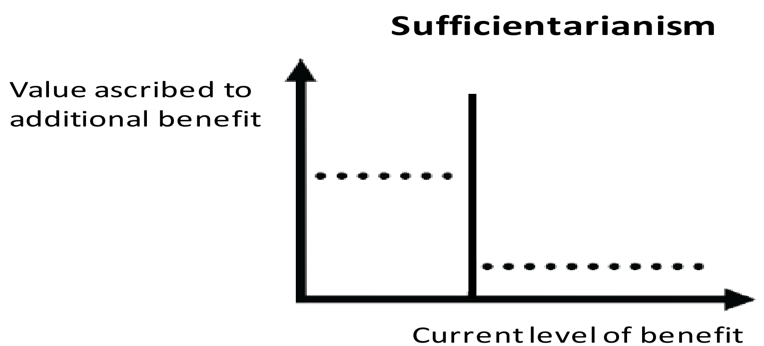
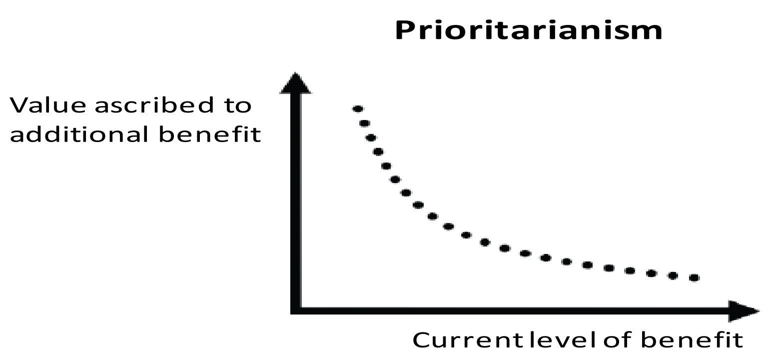
El enfoque convencional







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Critica al enfoque convencional

- Uso y abuso del análisis de **coste-beneficio (CBA).**

- Sin embargo, los responsables políticos y las instituciones políticas (es decir, de la Comisión Europea) son conscientes de que el análisis de coste-beneficio podría esconder los beneficios reales de los nuevos proyectos o inversiones.

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Critica al enfoque convencional

- Por otro lado, la investigación reciente transporte ha demostrado que **el análisis de CBA es una herramienta fácil para la evaluación** de las medidas de política y las inversiones en transporte, pero depende profundamente de los valores subjetivos de un amplio número de elementos de la CBA (es decir, tasa de descuento, los grupos de población que se benefician , los beneficios monetarios y de tiempo).

- Todo lo que podría dar lugar a múltiples soluciones, **sin dar una idea de la magnitud de los beneficios** recibidos por distintos beneficiarios (Guzmán et al. 2014).

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- El análisis de coste-efectividad puede ser útil para analizar el enfoque sufficientarismo así como los enfoques tanto del prioritarismo que del utilitarismo.

- Con el fin de aumentar la comparabilidad de las estimaciones de costo-efectividad que pertenezcan a diversos análisis económico, hemos establecido ocho objetivos:

1. La eficacia se define en términos del cambio en el número medio de las actividades que se puede acceder por diferentes grupos de población.
2. El coste y la eficacia se evalúa desde tres perspectivas diferentes: **utilitarismo, prioritarismo, sufficientarismo**.
3. Sólo incluimos **coste directo**; costes indirectos, como la pérdida de ingresos, están excluidos en nuestra evaluación.
4. **Costes y eficacia deben ser "netos"**. Cualquier ahorro de recursos o disminuciones de accesibilidad debido a la inversión deben ser sustraídos de cualquier mejora.

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5. **Los costes futuros y los cambios en el acceso a las actividades de todos deben ser descontados a su valor actual** a una tasa establecida a raíz de la tasa de las preferencias inter temporales de los grupos de población específicos, operadores o agentes de inversión (Di Ciommo et al. 2015).

6. **Índices de rentabilidad** deberían ser marginales o "incrementales". Tanto los costos y la efectividad deben ser evaluados con respecto a una línea de base alternativa bien definida (escenario base).

7. Los costos se expresarán en años base utilizando el índice general de precios al consumidor.

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- Se distinguen cuatro diferentes proyectos de transporte:

  - (1) aumentar la capacidad vial;
  - (2) aumento de la velocidad del transporte público;
  - (3) la introducción de la demanda de transporte de respuesta (DRT);
  - y (4) La introducción de nuevo material rodante de las líneas de autobuses para permitir el acceso de autobuses para personas con movilidad reducida.

- Los efectos de los proyectos de transporte se clasifican en términos de aumento de la accesibilidad para los propietarios de automóviles, el incremento de la accesibilidad para los cautivos de transporte públicos, y el aumento de la accesibilidad para las personas mayores y discapacitadas.

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Se realiza **un análisis de coste-efectividad** simple para cada uno de los cuatro proyectos de transporte, teniendo en cuenta los siguientes elementos:

- 1. **Configuración espacial** dentro del cual nuestros grupos de población viven y para los que mejorar el sistema de transporte.
- 2. **Grupos diferentes de población**. Los grupos deben ser diferentes en términos de su "situación actual" (por ejemplo, el nivel actual de la accesibilidad o la velocidad de viaje promedio actual experimentada por un grupo), en el enfoque de prioridades y la suficiencia de la ponderación asignada a los beneficios depende de la "situación actual‘
- 3. **Distintas opciones de inversión** (mejora de autobuses, ampliación de carreteras, etc.), ya que queremos comparar cómo se clasifican las diferentes opciones en el caso de la aplicación del enfoque utilitarista, la prioridad y la suficiencia.

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- 4. **Los costes de cada opción de inversión**, ya que necesitamos los costes de cada opción para el cálculo del análisis de costo-efectividad (= efecto por euro invertido).

- 5. **El impacto de cada opción de inversión** en cada uno de los grupos (por ejemplo, el incremento en la accesibilidad (= mejora = efecto = impacto), o el aumento de la velocidad de viaje promedio (= mejora = efecto = impacto).

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Las principales características de nuestros escenarios ficticios son:

1. Configuración espacial
2. Diferentes grupos de población
3. Personas con coches
4. Las personas sin coches, pero sin discapacidad, con acceso a todo tipo de transporte público
5. Las personas con discapacidad sin coches, que sólo pueden acceder a los servicios de transporte público ajustadas.

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- Tabla 1: Distritos características y mejoras de transporte para cada grupo de población.

›vements in travel speeds			19000	19000	19000	19000
	baseline level	Size of neighborouds	alternative 1	alternative 2	alternative 3	alternative 4
			Road improveme	PT improvement	DRT improvemen	Disable accessible
access to car only	1200	50	2.1	0,2	0	0
access to pt only, able-bodied	300	10	0	3,1	1,3	0
access to pt, disabled	20	10	0	0	13,2	17,9
access to car only		200	1,7	2,5	0	0
access to pt only, able-bodied		20	0	2,4	1,6	0
access to pt, disabled		2	0	0	11,2	13,2
access to car only		100	...	...	0	0
access to pt only, able-bodied		50	...	...		
access to pt, disabled		10	...	...		
access to car only		150	...	...	0	0
access to pt only, able-bodied		150	...	...		
access to pt, disabled		30	...	...		

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Crossing cost-effectiveness analysis with utilitarisme, prioritarisme and sufficientarisme approaches, each result weighted for each population group. Estimation for four policies investments using the same amount of investment (i.e. 19,000€).

CEA analysis, it is sufficient to divide Investment among specific population groups of each neighborough/district and use different weights following the three moral approaches of utilitarism, prioritarism and sufficientarism.

For this first fictive example we use data from table1. We test **CE- Access tool methodology**

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Road widening investment =19,000€:

Utilitarism approach: 19,000/50, by using the same weight for all. The result is 380€ for utilitarism approach

An infinitive value for Prioritarism and Sufficientarism approaches because nobody from PT captive people and disable people with a lower accessibility will receive direct benefices by this road investment, at least under the condition of free flow (i.e. without congestion)

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Public transport improvement = 19,000€

Utilitarism: Cost-Effectiveness indicator = 316

Prioritarism: Cost-Effectiveness indicator = 463= 19,000/(0.2*50+3.1*10)

Sufficientarism: CEA = 19,000/0= infinitive value

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DRT introduction = 19,000:

Utilitarism: 19,000/20= 950

Prioritarism: 19,000/(1.3*10+13,2*10)= 131

Sufficientarim: 19,000/(13,2*10)= 143

Introduction of new rolling stock on bus lines =19,000

Utilitarism: 19000:10= 1900

Prioritarism: 19000/ 17.9*10= 106

Sufficientarism: 19000/17.9*10=106

In the case of a specific measure for disable people prioritarisme and sufficientarisme approaches achieve the same result.

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Questions?

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