



TRANS-URBAN-EU-CHINA

Transition towards urban sustainability through socially integrative cities in the EU and in China

Deliverable

D4.2 Critical review of the state of the art in SCBA in both Europe and China and recommended approaches and methods for the use of SCBA in urban planning and decision-making

WP4 Integrated transition pathways towards sustainable urban planning and governance

Task 4.2 Social Cost Benefit Analysis (SCBA) to support urban planning and governance



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EXECUTIVE SUMMARY

This Deliverable explores the potential along with the limitations arising from the application of Social Cost Benefit Analysis (SCBA) techniques to foster the transition to sustainable urban planning and governance in EU and China. The analysis addresses several intertwined objectives:

- a) reviewing the state-of-the-art knowledge in the field of SCBA applied to urbanisation activities in EU and China;
- b) identifying methods and tools to facilitate the integration of externalities into urban governance and policy making, on the basis of evidence and case studies examined through the common framework of the Impact Pathways Approach (IPA);
- c) showing the contributions of SCBA in establishing socially integrative cities;
- d) drawing conclusions in terms of the likely approaches, their potential and limitations, methods and tools amenable to be used in terms of cross-fertilisation between EU and China, to be possibly tested during the project Urban Living Labs (ULLs).

The review of the state-of-the-art knowledge in the field of SCBA applied to urbanisation activities in EU and China has classified the contributions in six topics, whose key characteristic in a EU-China cross-comparison perspective is the predominance of quantitative approaches in the OECD/EU countries and policy-led drivers in China, as summarised in the following table.

Topics	Methods, tools and data availability for SCBA application in urban planning	
	Europe	China
1. Literature addressing the general background of urbanisation processes	Tools and indicators for measurement and evaluation of urban sprawl. Data on land take, soil consumption, urbanisation processes are available at EU and national level.	Identification of policy drivers (e.g. China Urbanisation Plans) and socio-economic trends, e.g. migration, underpinning urbanisation processes. Data are available at national and regional level.
2. Externalities from transportation activities (accidents, noise, air pollution, etc.)	Handbooks and manual for the calculation of external costs from transportation activities. Unitary values (e.g. €/vehicle kilometre) are provided by main cost categories. Key methods: damage cost approaches, b) avoidance cost approaches and c) replacement cost approaches.	Main focus on the design of urban mobility strategies (sustainable urban mobility strategies) to overcome externalities. In general, there is a lack of quantitative assessment of transport external costs, with notable exceptions, as the evaluation of external costs of transport activities in Beijing, reported below in section 3.4.
3. Air pollution and built environment	Contingency evaluations, e.g. willingness to pay for greener built environment are available in some EU countries, e.g. Finland. Cost benefit analysis on built environment (e.g. green roofs) are also available, e.g. the Netherlands (LIFE Urban Roofs, 2018).	Urban growth management strategies designed to curb urban sprawl. Reforms of land prices and compensation, local government autonomy and fiscal responsibility are advocated. Data on soil degradation, water damage and threats to wildlife are available, but monetisation is lacking.
4. Ecosystem services and biodiversity loss	Meta-analysis on monetary evaluations of ecosystem services and biodiversity losses, multi-criteria decision analysis and non-market evaluation methods are available in some EU countries, e.g. Germany	Impacts on rural land (idle farmland, loss of arable land) of urbanisation processes. Reforms of land management and administrations, e.g. concession rights, as strategies to over-

Topics	Methods, tools and data availability for SCBA application in urban planning	
	Europe	China
		come rural land degradation. Monetisation of ecosystem services losses is lacking.
5. Management of public services and infrastructure	Statistical analysis, e.g. elasticities, and engineering approaches applied to infrastructure and public service provision costs under different urban forms (e.g. urban sprawl).	Estimations of infrastructure costs and revenues of urbanisation patterns. News strategies, e.g. village urbanization" are advocated to tackle traditional houses scattered around villages.
6. Quality of life, health and cultural values	Statistical correlations between quality of life, including public health, and urban forms are available in EU countries.	Strategies to improve quality of life of migrant workers and farmers as consequence of past urbanisation patterns. Quantification of economic costs is lacking.

The identification of methods and tools to facilitate the integration of externalities into urban governance and policy making on the basis of evidence and case studies has been conducted through the analysis of 6 types of externalities (three in Europe and three in China), following the Impact Pathways Approaches, and two in-depth case studies on external costs of transportation activities in Rome and Beijing, with a special focus on road congestion costs, as indicated in the following table.

OECD/EU	China
1. Land use policies and loss of ecosystem services	1. Tourism growth and overloading of public services
2. Urban sprawl and cost-effective provision of public services	2. Outdoor sports and ecological environment damages
3. Urban sprawl and costs of infrastructure provision	3. Waste incineration and increased environmental and health risks
4. Case study: Road congestion costs in the city of Rome	3. Case study: Negative externality and congestion costs in the city of Beijing

The different types of externalities examined in the OECD/EU countries and in China reflects the different degree of development of SCBA applied to urbanisation activities. In the OECD/EU cases, SCBA contributions tend to address overarching land use policies as the development of urban forms (e.g. sprawled vs compacted cities) or the implications of land take and loss of arable land (loss of ecosystem services). In such cases, the identification of the key drivers leading to externalities is associated with the quantification of the negative external effects and the affected end points, paving the way to the internalisation of such effects in urban planning and land management policies.

On the other hand, the Chinese experience focuses on specific aspects of urbanisation activities, in particular the side-effects from rapid urbanisation growth on the quality of life of residents in urban areas (traffic congestion and air pollution, public services provision). Strategic policy options, such as urbanisation and rural-urban relationships or the implications of the Chinese version of urban sprawl

(urban fragmentation, unbalanced growth of urban land in peri-urban areas) are generally not supported by SCBA evaluations, denoting a general undersized provision of monetary evaluations supporting the analysis of external effects from urbanisation.

From a comparative perspective, looking at the potential of cross-fertilisation of SCBA in Europe and China, the promising contributions to the application of SCBA in urban planning are likely to come from those methodologies developed in OECD/EU countries, whose results imply the set-up of calculation tools and guidelines. In such cases, methodologies, indicators and quantifiable impacts are amenable to be transferred from one context, e.g. European, to another, e.g. Chinese. In particular, the research streams taking stock of the “benefit transfer” techniques, e.g. transfer units (monetary values) and procedures, may represent a potential tool for transferring knowledge.

In a decreasing order in terms of potential contribution, three different types of contributions can be identified:

1. **Methodologies and guidelines for the evaluation of externalities from transportation activities.** In Europe, this research stream produces Handbooks, which provide a full-fledged tool (from methodology to indications for generalisation) for practitioners, experts, academic and policy makers, searching for methodologies, procedures and reference values addressing externalities from transportation activities. Definition and scope of the key externalities considered in the Handbooks are the following: accident costs, air pollution costs, climate change costs, noise costs, congestion costs and costs of well-to-tank emissions. A minor role is played by impacts on crop losses, material and building damages and biodiversity. Recommended methodologies, input values and output values for total/average and marginal cost figures are also presented. Figure and data are usually accompanied by considerations on the robustness of the recommended input and output values. In China, similar exercises aiming at the evaluation of the key externalities of transport have been carried out, e.g. in Beijing. There is therefore a common understanding of challenges and evaluation techniques, which makes this stream of research highly promising.
2. **Tools for the measurement and evaluation of urban sprawl.** As showed in the Annex II, there is a consolidated tradition in Europe (EEA, 2016) concerning the analysis of drivers and the definition of metrics and indicators (quantification) for the assessment of urban sprawl effects (e.g. infrastructure provision and management of public services). From this stream of research tools and calculation sheets can be derived, supporting the assessment of urban sprawl impacts and the identification of key variables for the monitoring of urban sprawl dynamic also in the Chinese context, e.g. the pace of rural land take.
1. **Contingency values and meta-analysis for the loss of biodiversity and amenities.** This stream of research includes outcomes from case studies and meta-analysis on the quantification (monetary evaluation) of biodiversity services for which quantification is uncertain and generally lacking. These studies, developed in Europe, acknowledge uncertainties and caveats for the transferability of results in contexts different from the original case study, e.g. in the Chinese context.

Looking at the limitations and challenges, using the analytical framework of the impact pathways approach, the analysis of Chinese and OECD/EU applications of SCBA to urbanisation activities has shown

that in China the monetization of negative externalities is still largely lacking, despite notable exceptions discussed in the Chinese case study in this report (monetary evaluation of externalities from transport activities), and that, as a consequence, this can be considered as a key area that needs to be strengthened through further researches.

Evidence from case studies and meta-analysis collected across the EU countries over the past years show that monetary evaluation is in most cases available, taking stock of a wide array of techniques and methodologies, from market-based evaluations to surveys (stated preference methods).

However, the simple observation of the wide range between minimum and maximum values of the results for each end-point, suggests that a straightforward utilization of the evaluations in contexts different from the original case study, e.g. in China, by the way of average values, may be not reliable.

2. What is at stake, is not the availability of a specific monetary evaluation of an end-point, but the transferability of such evaluations. It is worthwhile to note that in TRANS-URBAN-EU-CHINA the latter issue (transferability) represents an important aspect, namely with reference to the transfer of knowledge between EU and China. This is a topic which deserves additional research.

Concerning **the contributions of SCBA to the establishing socially integrative cities**, the key conclusions are summarised in the following table. The analysis distinguishes direct contributions, i.e. for which the SCBA insights are relevant, and indirect contributions, for which SCBA insights may need accompanying policies and initiatives to be fully effective. It is worthwhile to note that there are priorities for which SCBA contributions are limited, if not null.

Characteristics and priorities of the socially integrative cities (TRANS-URBAN-EU-CHINA Del 3.1)	Contribution of the SCBA insights applied to urbanisation activities
Collaborative urban planning and design	
1. Reducing urban sprawl and promoting well-balanced land conversion from “ <i>rural</i> ” to “ <i>urban</i> ” and appropriate access to urban land.	Direct. The internalisation of externalities, e.g. natural resource management, environmental protection and regional transportation, would ultimately lead to a more efficient use of land, raising its price and compensations to farmers. The increased values of land could limit conversion from “ <i>rural</i> ” to “ <i>urban</i> ” in particular around urban fringes, reducing urban sprawl.
2. Involving the different stakeholders in collaborative and participative planning and design processes on the different politico-administrative levels.	Indirect. SCBA applied to the evaluation of eco-systems may need new approaches in decision making processes, reflecting views and values of multiple stakeholders. The evaluation of biodiversity, landscape beauty, cultural heritages imply evaluation methods which can address specific contexts at local level, indirectly paving the way to the involvement of local stakeholder preferences in land use and urban planning decisions.
Urban environment and living conditions	
3. Improving the environment and living conditions in urban areas	Direct. Externalities caused by the interaction between transportation activities and the environment, human capital and other non-renewable resources represent a key factor in affecting living conditions in urban areas. The application of SCBA in the assessment of the costs of accidents, noise and air pollution emissions, congestion and greenhouse effects may provide a direct contribution to the design of sustainable transport policies.

Characteristics and priorities of the socially integrative cities (TRANS-URBAN-EU-CHINA Del 3.1)	Contribution of the SCBA insights applied to urbanisation activities
4. Upgrading the physical environment in distressed areas	Indirect. SCBA methodologies may provide an indirect contribution to improving built environment in distressed urban areas, for example through the evaluation of citizens preferences and willingness to pay for green spaces and infrastructure.
5. Promoting efficient and affordable urban transport	Direct. SCBA insights on the relationships between urban transport costs variability and urban configuration, e.g. urban sprawl vs compacted cities, represent a knowledge base with a direct contribution to major efficiency and affordability of urban transport services.
6. Assuring equal access to municipal services	Indirect. Urban forms affect the provision (in quality and quantity) of public services; in particular those for which density represents an important factor influencing service costs and performances (e.g. waste management). SCBA applied to the analysis of the performance of public services in different urban areas may provide an indirect contribution to improve accessibility.
Local economy and labour market	
7. Strengthening the local economy and labour market	Limited. Minor and uncertain impacts are expected with reference to labour market and local economy in presence of application of SCBA to urbanisation activities.
8. Strengthening (technical and social) innovation in cities and neighbourhoods opening up new possibilities for the local population.	Limited. As for the impacts on local economy, it's difficult to elicit likely impacts of SCBA on technical or social innovation in neighbourhoods.
Socio-cultural development and social capital	
9. Fostering proactive education and training policies for children and young people in disadvantaged neighbourhoods	Limited. Impacts of SCBA on training policies for disadvantaged people in urban areas are limited and of difficult evaluations.
10. Preserving cultural heritage and fostering the identity of neighbourhoods and their inhabitants	Direct. One of the fields of application of SCBA methodologies and tools concerns with the evaluation of eco-systems. Therefore, direct contributions to the evaluation and preservation of cultural heritage may derive from methodologies of evaluation that involve local stakeholder preferences and attitudes.
11. Fostering social capital and engagement of local stakeholders	Indirect. Fostering social capital in terms of empowering of local communities' identity and values may found an indirect contribution from the application of SCBA methodology in the evaluation of eco-systems assets.
Institutional development and urban finance	
12. Supporting adequate institutional and financial conditions and mechanisms	Indirect. To the extent to which SCBA leads to raising land price in urban fringe, indirect contributions towards changes of the public finance system could be expected. In particular, changes in land value may support the reduction of the dependency of local governments on land

Characteristics and priorities of the socially integrative cities (TRANS-URBAN-EU-CHINA Del 3.1)	Contribution of the SCBA insights applied to urbanisation activities
	conversation and land auctioning as a major local tax base.

In sum, the application of SCBA to urban planning and management turns out to be relevant in favouring collaborative urban planning and in improving urban environment and quality of life. Due to the implications on land value, SCBA may have indirect impacts on financial conditions and mechanisms in urban finance as well. In general, it is likely that a consistent and growing use of SCBA may provide **better data for better urbanisation policies.**

1 INTRODUCTION

D4.2 “Critical review of the state of the art in SCBA in both Europe and China and recommended approaches and methods for the use of SCBA in urban planning and decision-making” is part of the WP4 concerning “Integrated transition pathways towards sustainable urban planning and governance”.

As such, it aims at developing one of the three components of the integrated transition pathways towards sustainable urban planning and governance; namely, that related to the Social Cost Benefit Analysis (SCBA) to support urban planning and governance¹.

The structure of report follows the three-stages approach typical of TRANS-URBAN-EU-CHINA: the first stage is the analysis of the knowledge-base, i.e. the bulk of information, evidence and data which represent the background scene of the analysis. The second stage is the transformative knowledge, in which from data and evidence are derived possible tools and methods that show potential attitude in favouring cross-fertilisation, generalisation and transferability of good practices in the context of the EU-China cooperation. The last stage is to draw recommendations, possibly tested and verified during the project Urban Living Labs (ULLs).

Against this background, this Deliverable first provides (chapter 2) an overview of OECD/EU and China examples of application of SCBA to urbanisation activities (land use, urban expansion). The overview is carried out through an extensive literature review, which ultimately leads to the classification of the contributions by key categories and to the identification of the potential approaches amenable to favour cross-fertilisation, transferability and generalisation of best practices.

The categories under examination are the following:

1. General framework, illustrating the backdrop to the urbanisation processes in EU and China, the key framework conditions and definitions;
2. Overview of externalities from transportation activities (accidents, noise, air pollution, etc.), having as object the external costs caused by transport activities in urban areas;
3. Air pollution and built environment; analysing the influence of built environment in urban areas on environment and quality of life in general;
4. Ecosystem services and biodiversity, focussing on the side-effects of land use and urbanisation activities on the quality of eco-systems;
5. Management of public services and infrastructure, whose object is the influence of urbanisation patterns on management and efficiency of public service and infrastructure provision;
6. Quality of life, health and cultural values, focussed on intangible effects as citizens well-being arising from urban patterns, or quality of life and health in presence of compact vs sprawled urban developments.

Chapter 3 addresses the transformative knowledge, firstly looking at concrete examples of EU and Chinese application of SCBA in urbanisation activities, providing, when possible, data and reference values, and then examining in details two case studies on the evaluation of external costs of road congestion respectively in Rome and Beijing.

¹ The other two components are “the digital transition in urban governance and planning” and the “storylines for framing and illustrating the integrated transition pathways towards sustainable urban planning and governance”. Both will be object of dedicated Deliverables respectively issued lately in month 30 and 36.

The analysis of EU and Chinese application of SCBA to urbanisation activities is carried out according to the Impact Pathways Approach (IPA) methodology. It focuses on the relationship between causes and impacts, on the basis of the identification of causal-effect chains from activities (causes) to end-points (effects) applied to specific externalities, e.g. air pollution. This approach has been applied to 6 IPAs in OECD/EU countries and in China, in addition to 2 in-depth case studies.

Chapter 4 carries out the comparison between the OECD/EU and Chinese case studies, drawing conclusions and recommendations for the uptake of SCBA in urban planning and governance. The two case studies address in general external costs from transportation activities (air pollution, accidents, noise, climate change in Beijing), with a particular focus on road congestion costs in Rome and Beijing. The comparison of the two case studies allows to stress similarities and differences in terms of key components of the road congestion costs formula (similarities) and different compositions of the factors determining the value of time.

The conclusions and recommendations are drawn with reference to the SCBA potential in supporting the transition to socially integrative cities in EU and China, following in that the framework described in the TRANS-URBAN-EU-CHINA Deliverable 3.1 with reference to which topics and priorities may identify a socially integrated city.

Chapter 5 focuses on the further steps to be undertaken. It is suggested that the importance of SCBA contributions developed in form of Handbooks and guidelines, as the EU Handbook for the calculation of external costs of transport, could be further exploited in the next Urban Living Labs (ULLs).

2 KNOWLEDGE BASE: COMPARATIVE EU/CHINA ASSESSMENT OF THE STATE-OF-THE ART KNOWLEDGE IN THE FIELD OF SCBA

The consolidation of the knowledge base of methods and indicators concerning the application of Social Cost Benefit Analysis (SCBA) in urbanisation activities implies the comparative EU/China review of a series of interlinked and complex areas of research, ranging from the evaluation of social externalities in transportation activities, such as congestion and air pollution, to the impacts of urbanisation activities, e.g. land take, on quality of life, public health, well-being and loss of amenities and ecosystem services.

As it may be expected, the areas of research that are related to the application of SCBA in urbanisation activities (urban expansion and renewal) are characterised by an uneven degree of development, different scientific maturity and availability of information and evidence. For example, the evaluation of externalities from transport activities, a typical by-product of urbanisation, can rely on a long tradition of outstanding academical analysis and research of about 100 years; from the conceptualisation of external costs, when Arthur Pigou first postulated the idea in 'The Economics of Welfare' (Pigou, 1924), to the further conceptual developments provided by the seminal Coase approach (Coase, 1960). On the other hand, it is only from the past few decades that the evaluation of ecosystem services has been gaining attention (at least in the academical sphere) as a tool in land use management, regional planning and urban development (Tammi, 2017).

The heterogeneity in background and analytical frameworks makes necessary a preliminary analysis of the available sources, classified by relevant categories, whose results are discussed in the following sections.

2.1 INSIGHTS FROM LITERATURE REVIEW

The analytical tool considered appropriate to carry out the analysis is an extensive literature review.

In total, 73 reports and studies have been reviewed (see Annex I for details). The review has been conducted according to the following set of key categories:

- *Year of publication*, to provide an assessment of period and time horizons of available literature (a special effort has been spent in making most of the reviewed literature freely available on-line, so that only 15% of the reviewed documentation is available against payment);
- *Geographical scope*, showing the geographical origins of contributions, in which a particular focus has been devoted to review European/Chinese contributions;
- *Type of contribution*, in which contributions have been classified according to the prevalent type of analysis, e.g. if based on empirical analysis, or focussed basically on methodological and theoretical aspects, etc.;
- *Type of activity*, addressing the classification of contributions by main areas of interest and field activity, e.g. transport, agriculture and land use, etc.;
- *Domain of externalities*, in which the end-points of externalities are identified, e.g. ecosystems, health, quality of life, air, etc.

The analysis by year of publication (Table 1) shows the prevalence of recent publications, i.e. publications issued in the last 5 years (2015-2020), which amount to 52%. Only 14% of total publications have been issued in a period later than 10 years (from 1993 to 2009).

Table 1: Reviewed literature by year of publication

Year	Number of publications
1993	1
1998	3
2003	1
2007	2
2008	2
2009	1
2010	4
2011	4
2012	4
2013	6
2014	7
2015	8
2016	10
2017	6
2018	8
2019	4
2020	2
Total	73

The geographical origin of publications (Table 2) indicates the prevalence of European contributions (45%, including publications from UK) and China (29%). The geographical focus on European and Chinese sources depends on the mandate of the TRANS-URBAN-EU-CHINA project, which is devoted to the cross-fertilization of European and Chinese practices on the matter of SCBA in urbanisation. Publications in US amount to 7%, while the remaining 19% are scattered around the world, e.g. Brazil, Canada, India, New Zealand, including a number of publications (10%) focussed on worldwide reviews not related to specific countries.

Table 2: Reviewed literature by region

Europe	33
China	21
US	5
Worldwide	14
Total	73

The analysis by type of publication (Table 3) allows the classification of the literature reviewed according to different types of results and prevailing approaches. In general, three types of publications/results can be identified:

1. *Publications dealing with both theoretical/methodological aspects and evidence (quantifications).* This group amounts to 59% of the total publications, and can be divided in two sub-groups, in which evidence are mainly characterised respectively by a strong emphasis on theoretical (21%) and methodological aspects (38%). It must be stressed that theoretical and methodological approaches may in some cases overlap, being the theoretical approaches more oriented towards the definition of principles and general frameworks of analysis, while methodological approaches usually support evidence and quantifications with guidelines and formalised procedures.
2. *Publications resulting in a focus on political implications on the governance of urbanisation.* This group of contributions (amounting to 19% of total publications) is typical of the Chinese approach, in which the identification and analysis of externalities are usually accompanied by political and strategical implications in terms of governance, e.g. measures tackling ecological footprints arising from urbanisation (Lu, 2014).
3. *Publications whose background is mainly theoretical,* focussing on definitions and conceptual frameworks (22%), with scarce or limited references to quantifications.

Table 3: Reviewed literature by type of publication

Both theory and evidence	15
Methodology/empirical evidence	28
Policy/Solutions and impacts	14
Theory/definitions	16
Total	73

The analysis by type of activity (Table 4) exhibits the relevance of literature dealing with a general overview of externalities arising from urbanisation activities, i.e. without a focus on a specific type of externality, amounting to 48% of total publications. This group of publications is followed by publications dealing with specific analysis addressing externalities from transport activities and agriculture/land-use (respectively at 18% of the total), and construction-buildings (14%).

Table 4: Reviewed literature by type of activity

Agriculture/ Land use	13
Construction/buildings	10
General	35
Migration	2
Transport	13
Total	73

The analysis by types of externalities (Table 5) can be considered as a further specification of the analysis carried out in Table 4. Table 5 provides indeed an overview of the type of externalities examined in literature. It shows that the recent literature dealing with impacts on ecosystem services and biodiversity plays an important role in terms of share on total available literature (25%), followed by literature addressing respectively air pollution and built environment, quality of life, health and cultural values and literature dealing with an overview of externalities from transportation activities (e.g. accidents, noise, air pollution, etc), each one with a coverage of about 15%.

Externalities concerning the management of infrastructure and public services, together with quality of life and cultural values follow closely (each one at 12%). A minor role is played by externalities concerning health, well-being and society (8%) and by literature dealing with the general framework of externalities, providing indications on the background conditions underpinning the application of SCBA in urbanisation activities, e.g. socio-economic drivers (4%).

Table 5: Reviewed literature by type of externalities

Air pollution and built environment	11
Ecosystem services, biodiversity	18
Environment	7
General framework	3
Management of public services, infrastructure	9
Quality of life, health, cultural values	9
Wellbeing & society	6
Wide range of externalities (accidents, noise, air pollution, etc.)	10
Total	73

The reviewed literature outcomes concern with the identification of keywords, annotated comments on type of impacts and additional specifications, e.g. main topics of analysis, caveat and considerations on data limitations. These results are shown in the boxes of which at the below sections 2.1.1-2.1.6, each related to the main topic under examination.

The topics correspond to the categories shown in Table 5, further aggregated in six categories obtained as aggregation of similar topics, resulting at the end in the following six research streams:

7. General framework
8. Overview of externalities from transportation activities (accidents, noise, air pollution, etc.)
9. Air pollution and built environment
10. Ecosystem services and biodiversity
11. Management of public services and infrastructure
12. Quality of life, health and cultural values

Section 2.2 draws conclusions on the relevance of literature insights in the context of the TRANS-URBAN-EU-CHINA objectives, in particular focusing on those results amenable to provide a contribution towards the generalisation of tools and methods for the application of SCBA in urbanisation activities in China and Europe.

2.1.1 GENERAL FRAMEWORK

A small share of sources (4%) deals with the definition of the general framework in which externalities occur. This type of literature is important, for it allows to depict the backdrop to the urbanisation processes, the key framework conditions leading to externalities. As far as Europe is concerned, a key reference is the report issued by the Environmental European Agency in 2016, setting the scene for the analysis of the key determinants and processes underlying urban sprawl in Europe (EEA, 2016).

According to the EEA report, the negative impacts of urban sprawl in Europe are numerous. Impacts on environment, quality of life and economy are referenced through literature review and best practices. The report points out the lack of internalisation of externalities, due to the problematic identification and evaluation of impacts. Besides, uncertainties on the theoretical framework can also play a role. For example, it is stressed that the lack of terminological clarity may, to some degree, be a reason for differing views in the literature regarding whether certain effects of urban sprawl are positive or negative.

If the external costs are neglected, then the benefits from urban sprawl, e.g. low-density housing that offer more privacy and larger green areas, may appear much more positive than they really are, because others will have to pay for these costs (e.g. future generations). Some effects can even be viewed from two perspectives in cases in which an overall negative effect of sprawl is diluted over a large area resulting in a lower concentration; this could be interpreted by some authors as a positive effect of sprawl. For example, total air pollutant emissions are significantly higher in more dispersed urban areas, than in less dispersed urban areas with the same number of housing, but concentrations in sprawled areas are lower.

Two aspects in the EEA report are of particular interest in the context of TRANS-URBAN-EU-CHINA. Firstly, the analysis of metrics and indicators for the measurement of urban sprawl, which can provide a useful knowledge base in terms of data needed for the quantification of the components leading to urban sprawl, e.g. built-up area, intensity of urbanisation, etc. Secondly, the report provides the basics for the definition of a methodology for the assessment of the contribution to urban sprawl of urbanisation activities, e.g. in case of new constructions and urban expansion. This can lead to the internalisation of negative impacts from urbanisation (see Annex II for details.)

On the Chinese side, a clear picture of urbanisation drivers and relevant issues is provided by the joint World Bank and the Development Research Centre of the State Council, PR China report (World Bank/Development Research Centre of the State Council, P.R. China, 2014).

The issue of negative externalities arising from urbanisation and the need of their evaluation and inclusion in the context of a rational management of land use, i.e. enhancing market pricing to reflect environmental externalities in market transactions, is repeatedly acknowledged across the report. In particular, two topics address different aspects of this issue:

- Analysis of externalities within agglomeration, in which noise, congestion, waste, infectious disease and other externalities are becoming more severe as people locate near one another in large agglomerations;
- Analysis of externalities from urban sprawl, e.g. impacts on unit costs for public services and infrastructure provision.

Type of available data and references	
EU	CHINA
Mechanisms leading to land take and urban sprawl. Selection of key indicators: percentage of built-up area, land uptake per person (EEA, 2016)	Urban population increase, migration from rural to urban areas. Selection of key indicators: percentage changes in population density (World

Type of available data and references	
EU	CHINA
	Bank and the Development Research Center of the State Council, P. R. CHINA. 2014)

2.1.2 OVERVIEW OF EXTERNALITIES FROM TRANSPORT ACTIVITIES (ACCIDENTS, NOISE, AIR POLLUTION, CONGESTION)

The reviewed literature included in this category amounts to 14% of the total sources. It basically deals with an overall assessment of externalities from urbanisation activities, in particular arising from urban sprawl and agglomeration effects through the provision and use of transport infrastructure. Transport externalities, which include air pollution, accidents, noise emissions, climate change and congestion, are in some cases examined in the form of handbooks, including guidelines on methods of calculation and reference values.

These sources are relevant for TRANS-URBAN-EU-CHINA, in so far as they can provide the knowledge base for setting up tools for the internalisation of external costs in urbanisation processes as well as reference values that can be transferred in different contexts in case of lack of information, i.e. the so-called “benefit-transfer method” (NEEDS, 2009).

Milestones in this field of research are the European handbooks on the evaluation of external costs of transport (Ricardo-AEA, 2014 and CE Delft, 2019). The structure of the handbooks is set to show best practices on the methodology to estimate different categories of external costs of transport. Additionally, it provides an overview of state-of-the-art input values (e.g. the value of time or the value of a statistical life) that can be used to produce estimations of external costs by users of the Handbook themselves. Finally, the Handbooks show external cost figures (mostly presented in €/vehicle kilometre), which can be used directly as reference values in case of calculations.

Besides, from a methodological point of view, the handbooks rely on the Impacts Pathway Approach, which plays an important role in the overall methodology for the identification of externalities according to a cause-effect relationship. The principles and key approaches stemming from this methodology are applied in chapter 3 for the analysis of samples of externalities in Europe and China.

In other cases, externalities arising from land use, e.g. separation effects from land take, are also included, providing taxonomies of externalities beyond those that can be allocated to transport activities. In such cases, the geographical scope is mainly European, with examples from the US and New Zealand experiences (Nunns, 2016). The New Zealand contribution is of particular interest, to the extent that it embraces urban planning at large (not only with a focus on externalities from transport), providing empirical evidence on the impact of urban planning policies on land and development markets in cities. The methodological approach proposes several simple models that capture, at least to some degree, the costs and benefits that may arise under more or less efficient urban planning policies.

Concerning the Chinese experience, the approach is more pronounced toward policy prescriptions for tackling externalities, rather than the provision of handbooks and guidelines, as in the OECD countries.

For example, a Chinese study (Jin, 2008) describes the mechanisms of negative externalities from the perspective of property right, and supports a mixed property right mechanism which is beneficial to the internalization of negative externalities. The focus is on externalities from transport (pollution emissions, noise, traffic congestion).

Type of available data and references	
EU	CHINA
Selection of key indicators: average, total and marginal external costs of transport activities (passengers and freight) by vehicle types and traffic conditions at country level (CE Delft, 2019)	Selection of key indicators: variation of air pollution and noise pollution indexes, energy consumption by vehicle types, accident costs in Beijing (Zong, G., 2014)

2.1.3 AIR POLLUTION AND BUILT ENVIRONMENT

This group of references amounts to 15% of the total sources. It mainly focuses on the contribution of built environment on air pollution and CO₂ emissions, as side-effects of urban sprawl and urbanisation activities (e.g. urban expansion, land take, infrastructure provision). In US, a meta-analysis from 100 metropolitan regions showed that compact development cities plus other strategies could reduce U.S. transportation CO₂ emissions by 7-10%. Study of 45 metro regions also showed that the least compact regions had 60% more high ozone days than most compact regions (Kramer, M., G., 2013). In China, urban sprawl assumes a different feature, being linked to fragmentation and dispersion, e.g. leapfrog development patterns, arising from excessive conversion rates of rural land in urban land, resulting in high vacancy of rural land after being acquired for development (Fand, J., 2016).

In some cases, built environment as resulting from urbanisation can affect water pollution (Ando, 2013). For example, a proper design of infrastructure for stormwater management (e.g. sewage, low-impact or green infrastructure, etc) can reduce water pollution, turning investment costs in benefits. Other contributions carried out contingent evaluation surveys to derive the willingness to pay for better built environment in urban areas reducing air pollution and emissions (Tyrväinen, L, 1998 and Latinopoulos, 2016), as green areas, urban forest, parks, etc. Excerpts of the abstracts of the two studies carried out in Thessaloniki and North Carelia (Finland) show the following results:

Thessaloniki (Latinopoulos, 2016): *“a contingent valuation survey was designed and implemented aiming to estimate the willingness to pay of local residents for the provision of a park in the urban area, as well as to determine the spatial scale at which these values are assessed. The main finding of this study is that people living within 20 min from the reference site are willing to contribute a significant amount of money to support this project. Another interesting outcome is that the willingness to pay for this project was not considerably modified during a period of economic recession (2010–2013), which is mainly due to the growing public awareness of the importance of green spaces, as well as of the benefits of the planned park”.*

North Carelia, Finland (Tyrväinen, L., 1998) *“The suitability of the contingent valuation method in assessing urban forest benefits, has been evaluated as results of an empirical study conducted in Joensuu, the capital of North Carelia, Finland. The study was designed to measure the use-values of urban wooded recreation areas, and the residents' willingness to pay for small forest parks contributing to the quality of the housing environment. The results suggest that most visitors were willing to pay for*

the use of wooded recreation areas. Furthermore, approximately half of the respondents were willing to pay to prevent the conversion of forested parks to another land-use. The results are useful in assessing the value of green space benefits in different land use options”.

There is a wide consensus among citizens and local administrators that green spaces incorporate important amenity values contributing to the quality of urban life. In land-use planning, therefore, amenity values should be systematically assessed and measured, e.g. in monetary terms as well as material goods.

However, the relevance of contingency evaluation surveys in TRANS-URBAN-EU-CHINA may be limited, due to the fact that contingencies evaluations outcomes are in general strongly dependent on local conditions and therefore transferability in other contexts may be problematic.

Type of available data and references	
EU	CHINA
Selection of key indicators: cost-benefit data (capital and maintenance/operating costs) on green infrastructure in urban areas: green roofs, infiltration trenches, permeable pavements (Luca Locatelli et al, 2020)	Selection of key indicators: Soil degradation, vegetation deterioration, water damage , threat to wildlife: qualitative data from experts' interviews (Liu Huarong, Wang Huazhuo, 2016)

2.1.4 ECOSYSTEM SERVICES, BIODIVERSITY

Literature on the assessment of impacts on human well-being from land degradation and loss of biodiversity, a side effect of urbanisation activities, is growing over the past years. It is acknowledged that the imbalance in information, compared for example, to the evaluation of services with market values (e.g. loss from agricultural crop production) is likely to contribute to the distortion in land-use policies, giving preference to maximizing provisioning services in agricultural production and forestry, while neglecting the societal relevance of regulating and cultural services.

The reviewed literature on the matter amounts to 22% of the total, mainly relates to EU countries. These sources are relevant insofar as they can provide reference values (monetary values) for social and cultural services, e.g. recreation, for which the quantification in monetary terms is complex, uncertain and generally lacking.

However, the insights from literature (Forster, 2019) points out a series of caveats against the use of monetary evaluations without specifications and adaptations. Indeed, given that monetary valuation is done on a case-by-case basis, the judgment of the credibility and suitability of monetary values for informing decision making should also follow a case-by-case approach. Literature has stressed that monetary values of a change in an ecosystem services depend on the particular biophysical and socioeconomic site conditions. It may be the case that monetary values cannot be directly transferred and applied to other sites without careful adjustment to the particular local conditions of the target site. Due to the diversity in the biophysical and socioeconomic context of study sites and the diversity in valuation methods, the suitability of monetary values for benefit transfer should require a thorough review of the primary valuation studies. When using benefit transfer, it should be also demonstrated and justified why a monetary value fits the context and purpose of the particular decision-making

context. If an original monetary valuation study insufficiently describes the biophysical and socio-economic conditions of the study site and lacks clarity in the used methods, the general recommendation is to not use the monetary values for benefit transfer. Furthermore, as ecosystem service valuation studies use a great diversity of methods, in general is not advised to aggregate monetary values across different valuation studies. Instead, ranges of minimum and maximum values should be used for ecosystem services in order to reflect the diversity in valuation methods and socio-ecological contexts.

Taking into account such limitations and drawbacks in the use of monetary evaluations, literature shows that decision makers and urban planners could prefer a mix of multiple indicators that allow weighing decision options for different criteria within a specific decision context.

Multi-dimensional frameworks as, for example, multi-criteria decision analysis (MCDA), allow for the inclusion of quantitative and qualitative information on multiple values of biodiversity and ecosystems. This can open up new approaches in decision making processes, reflecting views and values of multiple stakeholders.

It can be finally concluded that the use of monetary values of ecosystem services should also be accompanied by information on other not-monetary indicators in order to allow for inclusive decision-making processes that take into account the multiple values of biodiversity and ecosystem services.

Type of available data and references	
EU	CHINA
Selection of key indicators: Connectivity of urban green spaces (%), land annually taken for built-up areas per person (m ² /person/year), (European Commission, Mapping and Assessment of Ecosystems and their Services, 2018)	Selection of key indicators soil erosion control, water conservation, nutrient recycling and atmospheric environment purification. (Rui Jie Wang, Lian Wei Yang, Miao Jia, 2011)

2.1.5 MANAGEMENT OF PUBLIC SERVICES AND INFRASTRUCTURE

Literature addressing the management of public services as well as infrastructure provision under different patterns of urbanisation, e.g. compact vs sprawled cities, amounts to 12% of total. European/US and Chinese sources differ with reference to the approach. In general, EU and US sources try to quantify the impacts of different urban forms on construction and management of public services costs, while in China the focus is rather on the identification of the challenges from the past urbanisation processes, e.g. migration, questioning along the overall long-term sustainability (Nobuiro, O., 2017).

In US (Ford, 2010) two case study projects carried out for the EPA (Environmental Protection Agency) compared CSD (Conventional Suburban Development, characterised by the typical sprawled suburban models) and TND (Smart Growth “compact” Development Model) infrastructure costs. Several CSD and TND development alternatives were prepared for the two case study sites, and then the total infrastructure costs were calculated. Variables that drive infrastructure costs, including lot size, product type, residential density, main roads cross sections and network patterns, were studied in order to quantify and compare the impacts, calculating elasticities.

Litman, T., 2015, with reference to a panel of OECD countries, estimated the impacts of urban sprawl on public infrastructure management and services cost-efficiency. Evidence indicated that compact development urban areas can significantly reduce infrastructure and public service management costs, although some of these costs may increase at very high densities. The greatest savings are achieved by shifting from dispersed development at low densities (under 5 residents per hectare), to infill or urban fringe development at moderate densities (40-60 residents per hectare). On the other hand, very high densities (more than 80 residents per hectare) are generally not correlated to higher infrastructure efficiency.

In China, estimates of the order of magnitude of the “bill of urbanisation” are also available using input-output models (scenario based on past trends on investments, revenues and GDP growth experienced in the Chinese process of urbanisation). Although the cost estimated are underestimated compared to other researchers due to the exclusion of public services costs (Nobuiro, 2017), the result illustrates that the expected revenues of the government could be lower than public spending, resulting in the long-term un-sustainability of the past Chinese urbanisation patterns.

The contribution of this group of analysis to TRANS-URBAN-EU-CHINA is important, for they address the issue of how agglomeration economies can capture the benefits/costs arising from proximity between households and firms. The costs of infrastructure are, on average, lower in high density developments than low density developments, although outcomes can vary considerably between sites. Generally, new developments in green field areas on the urban fringe tend to incur higher infrastructure and public services provision costs than infill or brown field development. However, costs variability can be extremely site-specific and depend upon the existence of capacity constraints within existing infrastructure networks.

The methodology for the assessment of social costs implies the development of engineering approaches, including territorial typology analysis, streetscape design and utility design. The statistical analysis of correlations between the incremental costs of public services and sprawled urban development may also be used for deriving elasticities.

Type of available data and references	
EU	CHINA
Selection of key indicators: public service provision costs, diseconomies of scale in sprawled cities, higher transportation costs (EEA, 2016)	Selection of key indicators: energy use for transport and costs for energy and water supply infrastructure. (World Bank and the Development Research Center of the State Council, P. R. CHINA. 2014)

2.1.6 QUALITY OF LIFE, HEALTH AND CULTURAL VALUES

This category, amounting to 12% of total, addresses the relationships between quality of life/well-being and urban forms. Available studies concern with statistical analysis involving samples of cities at worldwide level (with a particular focus on EU cities) about factors explaining the insurgency of distress and social inequalities in large cities (Nabielek, K., 2016). Correlations between urban forms and quality of life are also available from a worldwide perspective, e.g. India (Bardhan, R. 2015).

Along this line of research, it is worthwhile to flag contributions investigating the population health associated with land-use policies and built environment that influence the city's inhabitants transport modal choice.

Modelling exercises estimate how urban design interventions, e.g. planning a compact city, can reduce transport activities and promote healthier lifestyles, quantifying the potential health gains that residents would obtain by adopting low motorised mobility patterns.

From the methodological point of view, the causal chain assumes that an increase in land-use density by $x\%$, may reduce the average distances to public transport options by $y\%$, and as consequence increase the use of public transport by $z\%$. In addition, these changes are complemented with an additional transport policy initiative determining a $s\%$ modal shift away from private motor vehicle driver and passenger vehicle kilometres (excluding motorcycles) to either cycling or walking.

This modal shift is similar to the goals of transport policies currently being implemented in a number of European cities that impose barriers to private motor vehicle use. The percentages of land-use changes and transport modal shifts across each city can be selected as to be pragmatic and likely to be implemented over a reasonable time frame. Examples of this literature are mainly related to European urban areas (Stevenson, M., 2016).

Concerning the Chinese contributions, social well-being and quality of life are generally addressed in the light of the negative impacts from urbanisation processes on migrant workers, reflecting in that the important urban-rural relationships.

Studies (e.g. Houkai, W., 2011) point out the negative externalities of China's urbanization, such as the idle farmland in development zones, the reduction of social equity, urban poverty, and the rights and interests of migrant workers. Other contributions (Mingfei, M., 2012) focus on the negative externalities of the current policy of village relocation, for it leads to the increase of construction costs, the extension of the construction period, the loss of rural farmers' land and jobs, and the shortage of affordable housing. In such a context, a new solution of cooperative adjustment of land is proposed.

In conclusion, most of the contributions classified under this category provide evidence from scenarios and statistical correlations between urban forms and social well-being (particularly in the European and US cases). In China, the analysis is accompanied by hypothesis on possible future changes in trends and approaches established during the past urbanisation processes.

The contribution of this research stream to the TRANS-URBAN-EU-CHINA objectives is mainly methodological, i.e. providing the knowledge base on which drivers influence social well-being and more in general the quality of life. Quantification of the impacts is sometimes provided, though a limited capability of generalising results from one context to another should be considered.

Type of available data and references	
EU	CHINA
Selection of key indicators: Share of walking and cycling (urban mobility), km of cycle paths, population health Disability-adjusted life years (DALYs) lost. Stevenson, M., et al. (2016).	Selection of key indicators: migrant workers access to public services, housing and education, index of urban-rural disparities (World Bank and the Development Research Center of the State Council, P. R. CHINA. 2014).

2.2 CONCLUSIONS

The following table summarises the key insights from the state-of-the-art-knowledge base on SCBA and its relationship with possible approaches, methods and tools for an extensive application of SCBA in urban planning and governance in Europe and China. Considerations on data availability and quality, e.g. the extent to which monetisation is possible, are also included.

Table 6: Summary table of SCBA methods and tools in Europe and China

Topics	Methods and tools for SCBA application in urban planning	
	Europe	China
1. General framework	Tools and indicators for measurement and evaluation of urban sprawl. Data on land take, soil consumption, urbanisation processes are available at EU and national level.	Identification of policy drivers (e.g. China Urbanisation Plans) and socio-economic trends, e.g. migration, underpinning urbanisation processes. Data are available at national and regional level.
Externalities from transportation activities (accidents, noise, air pollution, etc.)	Handbooks and manual for the calculation of external costs from transportation activities. Unitary values (e.g. €/vehicle kilometre) are provided by main cost categories. Key methods: damage cost approaches, b) avoidance cost approaches and c) replacement cost approaches.	Main focus on the design of urban mobility strategies (sustainable urban mobility strategies) to overcome externalities. In general, there is a lack of quantitative assessment of transport external costs, with notable exceptions, as the evaluation of external costs of transport activities in Beijing, reported below in section 3.4. Some limited data usually comes from surveys conducted by researchers.
3. Air pollution and built environment	Contingency evaluations, e.g. willingness to pay for greener built environment are available in some EU countries, e.g. Finland. Cost benefit analysis on built environment (e.g. green roofs) are also available, e.g. the Netherlands (LIFE Urban Roofs, 2018).	Urban growth management strategies designed to curb urban sprawl. Reforms of land prices and compensation, local government autonomy and fiscal responsibility are advocated. Data on soil degradation, water damage and threats to wildlife are available, but monetisation is lacking.
4. Ecosystem services and biodiversity loss	Meta-analysis on monetary evaluations of ecosystem services and biodiversity losses, multi-criteria decision analysis and non-market evaluation methods are available in some EU countries, e.g. Germany.	Impacts on rural land (idle farmland, loss of arable land) of urbanisation processes. Reforms of land management and administrations, e.g. concession rights, as strategies to overcome rural land degradation. Monetisation of ecosystem services losses is lacking.
5. Management of public services and infrastructure	Statistical analysis, e.g. elasticities, and engineering approaches applied to infrastructure and public service provision costs under different urban forms (e.g. urban sprawl).	Estimations of infrastructure costs and revenues of urbanisation patterns area available. News strategies, e.g. "village urbanization" are advocated to tackle traditional houses scattered around villages.

6. Quality of life, health and cultural values	Statistical correlations between quality of life, including public health, and urban forms are available in EU countries	Strategies to improve quality of life of migrant workers and farmers as consequence of past urbanisation patterns. Quantification of economic costs is lacking.
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From a comparative perspective, looking at the potential of cross-fertilisation of SCBA in Europe and China, the promising contributions to the application of SCBA in urban planning are likely to come from those methodologies developed in OECD/EU countries, whose results imply the set-up of calculation tools and guidelines. In such cases, methodologies, indicators and quantifiable impacts are amenable to be transferred from one context, e.g. European, to another, e.g. Chinese. In particular, the following research streams take stock of the “benefit transfer” techniques, e.g. transfer units (monetary values) and procedures, which represent a potential tool for transferring knowledge. Benefit transfer techniques are necessary tools in consideration of the wide range of unitary external costs. For example, in transportation, unitary external costs of accidents per passenger.kilometre range between €12,8 in Austria and €5.4 in Slovenia².

In a decreasing order in terms of potential contribution, three different results can be identified:

3. **Methodologies and guidelines for the evaluation of externalities from transportation activities.** In Europe, this research stream produces Handbooks, which provide a full-fledged tool (from methodology to indications for generalisation) for practitioners, experts, academic and policy makers, searching for methodologies, procedures and reference values addressing externalities from transportation activities. Definition and scope of the key externalities considered in the Handbooks are the following: accident costs, air pollution costs, climate change costs, noise costs, congestion costs and costs of well-to-tank emissions. A minor role is played by impacts on crop losses, material and building damages and biodiversity. Recommended methodologies, input values and output values for total/average and marginal cost figures are also presented. Figure and data are usually accompanied by considerations on the robustness of the recommended input and output values. In China, similar exercises aiming at the evaluation of the key externalities of transport have been carried out, e.g. in Beijing. There is therefore a common understanding of challenges and evaluation techniques, which makes this stream of research highly promising.
4. **Tools for the measurement and evaluation of urban sprawl.** As showed in the Annex II, there is a consolidated tradition in Europe (EEA, 2016) concerning the analysis of drivers and the definition of metrics and indicators (quantification) for the assessment of urban sprawl effects (e.g. infrastructure provision and management of public services). From this stream of research tools and calculation sheets can be derived, supporting the assessment of urban sprawl impacts and the identification of key variables for the monitoring of urban sprawl dynamic also in the Chinese context, e.g. the pace of rural land take
5. **Contingency values and meta-analysis for the loss of biodiversity and amenities.** This stream of research includes outcomes from case studies and meta-analysis on the quantification (monetary evaluation) of biodiversity services for which quantification is uncertain and generally lacking. These studies, developed in Europe, acknowledge uncertainties and caveats for

² Data per passenger kilometre (pkm) in 2016 (CE DELFT 2019)

the transferability of results in contexts different from the original case study, e.g. in the Chinese context.

It is important to mention that from a methodological point of view the different research streams identified in Table 6 may in some cases overlap. For example, researches on the impacts of built environment (urban forms) represents a common background both for the analyses of impacts on health, management of public services, infrastructure and transportation external costs.

Therefore, the guidelines for the calculation of externalities from transportation activities, the tools for measurement of urban sprawl and the studies on the evaluation of eco-system services may spread their insights over a complex array of externalities.

In order to specify the potential contribution to the development and adoption of SCBA in urban planning, the three streams of research have been assumed as methodological guidelines for the analysis of 6 types of externalities (three in Europe and three in China) following the Impact Pathways Approaches, and two in-depth case studies on external costs in transportation in Rome and Beijing.

3 TRASFORMATIVE KNOWLEDGE: TOOLS AND METHODS TO FACILITATE THE INTEGRATION OF EXTERNALITIES INTO URBAN GOVERNANCE IN EUROPEAN AND CHINESE CITIES

3.1 THE IMPACT PATHWAYS APPROACH (IPA)

The Impact Pathways Approach (IPA) methodology focuses on the relationship between causes and impacts, on the basis of the identification of causal-effect chains from activities (causes) to end-points (effects) applied to specific externalities, e.g. air pollution.

The background of the methodology traces the roots back in the past 30 years, when it was used in several international research projects initiated by the European Commission, starting with the ExternE Project series implemented from the mid-1990s onward (ExternE, 2005).

Another milestone along the consolidation and update of the methodology was carried out during the European Union funded NEEDS (2008) project, generalising the approach to several end-points (other than population).

The formalisation of IPA follows a logical, stepwise progression from the origin to the determination of impacts and subsequently to the quantification of economic damage in monetary terms. The key steps of the IPA are illustrated in Figure I, with reference to air pollution:

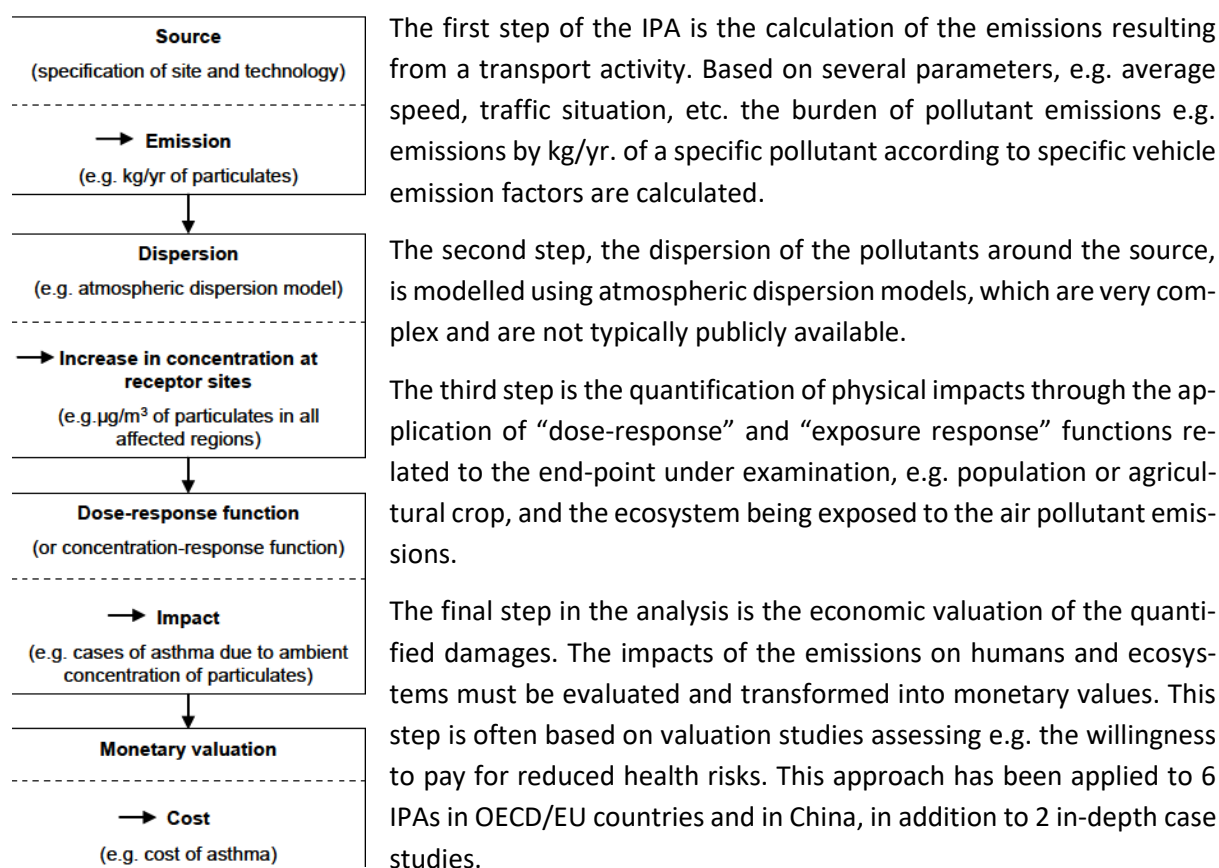


Figure I: The Impact Pathways Approach

Source: CE DELFT (2019)

3.2 CHINESE IPAs

3.2.1 INTRODUCTION

China's rapid urbanization has become an important engine of economic and employment growth in the past 30 years, but it also faces many challenges of sustainable urban planning and externalities governance. In particular, with the increase of Chinese residents' income and the rapid arrival of an aging society, Chinese residents have an increasing demand for old-age care, health and leisure, etc. These needs have inspired new urban activities and residents' concerns about environmental and health risks. This section applies the impact pathway analysis approach (IPA) to show the results of several studies on negative externalities of urban activities and to identify the main drivers leading to externalities. The IPAs are applied to the following side-effects of rapid urbanization: 1) tourism growth, 2) outdoor sports development and 3) waste incineration.

3.2.2 TOURISM GROWTH AND OVERLOADING OF PUBLIC SERVICES

3.2.2.1 Description

Tourism endowment is a new phenomenon emerging in China's aging society. As an international tourist island with favourable climate conditions, the Hainan Province attracts about 450,000 elderly people to spend the holiday winter season every year, which creates opportunities for local tourist-driven economic growth. But increasing seasonal migration also puts enormous pressure on local municipalities and public services, creating negative externalities. For example, the city's public transport is operating in seasonal overload, the household garbage disposal system is overwhelmed, medical services are in short supply, and public space is more crowded. All of these reduce the welfare of local people, but the cost is not borne by seasonal tourists.

3.2.2.2 Impact pathways

The causal chain of negative externalities is presented as follow:

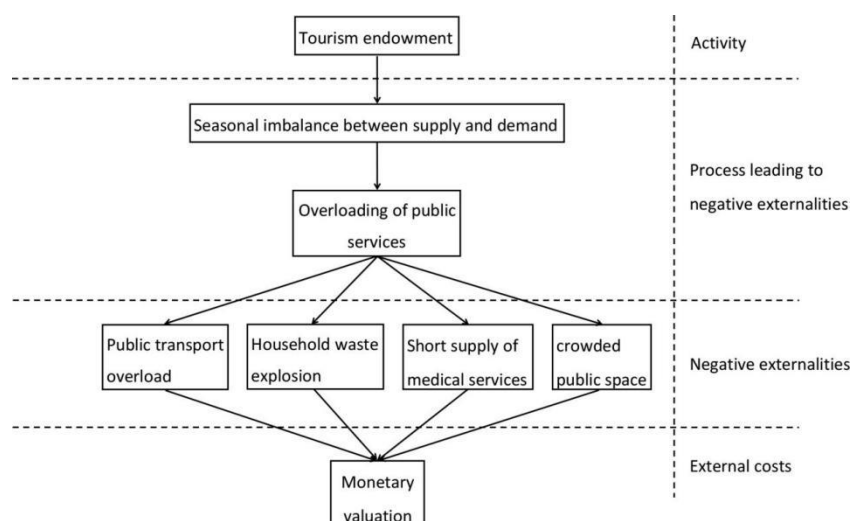


Figure II: Tourism growth and overload of public services

Bibliographic references/sources

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3.2.2.3 Results

Results

- ✓ Survey and simple statistical analysis
- ✓ No conversion to monetary valuation
- ✓ This paper analyses the negative externalities of tourism pension on municipal and public service facilities in Hainan Province, and focuses on the impact of seasonal tourists on public transportation, waste disposal, medical services, public space, prices and social resource utilization in tourist destinations.

Indicators

- 1) **Seasonal touristic in-flow:** 450,000 elderlies, of whom 200,000 are in Sanya, two-thirds of the local population;
- 2) **Bus capacity:** During the tourist season, more than 60 people took the bus with a maximum capacity of 50;
- 3) **Free tickets subsidy** for the elderly: The budget is 3 million CNY, but the actual subsidy is 3.754 million CNY;
- 4) **Waste disposal capacity:** The amount of waste produced per day exceeds the maximum capacity of waste treatment plant;
- 5) **Hospital waiting time:** The increase in the number of patients leads to longer waiting times;
- 6) **Number of people in public space:** Seasonal tourists make public spaces crowded;
- 7) **Food and housing prices:** Seasonal fluctuations in food and housing prices have increased;
- 8) **Vacancy rates** during the off-season: With the arrival of the off-season, 90% of seasonal visitors leave, leading to an increase in the vacancy rate of housing and public facilities.

Data accuracy

The data for the above case study came from a field survey conducted by a group of researchers from Hainan University in Haikou and Sanya, two large cities in Hainan province and the home city of the researcher group, so it should be credible and trustful. However, these data are not detailed enough to illustrate the performance of negative externalities rather than make a monetization estimation. In this case, the negative externalities manifest themselves as overloading of public facilities, exceeding the budget for welfare subsidies, crowding of public spaces, and increased waiting times, etc.

3.2.3 OUTDOOR SPORTS DEVELOPMENT AND ECOLOGICAL ENVIRONMENT DAMAGE

3.2.3.1 Description

In recent years, China's outdoor sports and recreation industry has been developing rapidly. Although it has made some contributions to the economic transformation, the development without effective regulation has produced obvious negative externalities. Since the wild environment is taken for granted as a common national resource, it can be easily damaged by excessive and unregulated outdoor activities. These damages include compaction of soil, accelerated soil erosion, vegetation destruction (trampling and breaking), invasion of alien species, habitat loss or transfer, change of animal behavior, water damage, etc. In the development of outdoor sports and recreation industry, neither enterprises nor tourists have paid for these negative effects.

3.2.3.2 Impact Pathways

The causal chain is presented as follow:

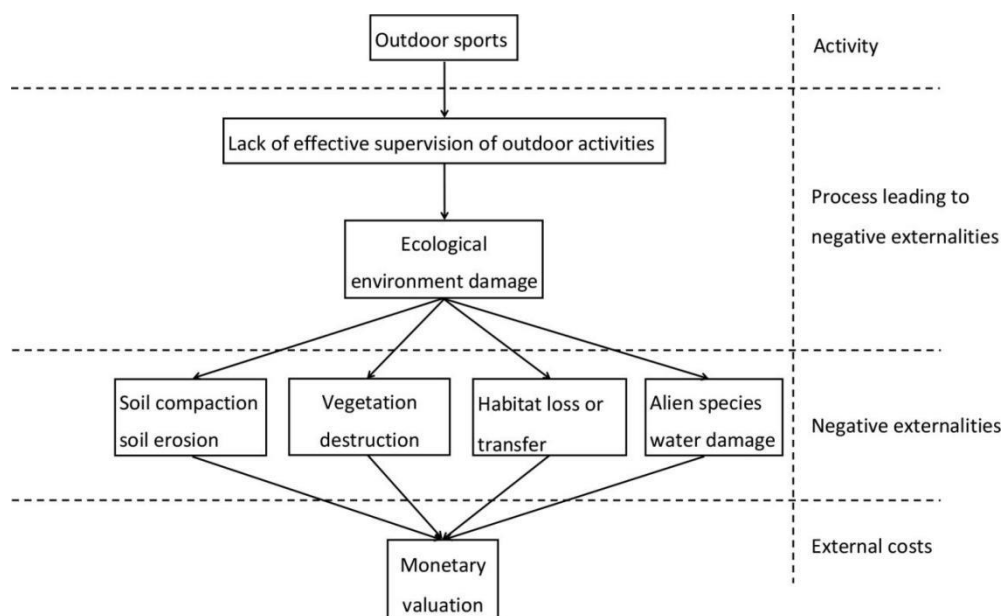


Figure III: IPA: Outdoor sports development

Bibliographic references/sources

Liu Huarong, Wang Huazhuo. Cause analysis on negative externality of ecological damage behavior in outdoor sports recreation site and its countermeasure[J].Journal of Beijing Sport University, 2016, 39(4):29-33. [刘华荣, 王华倬.户外运动游憩地生态环境破坏行为的负外部性成因分析与治理方策[J].北京体育大学学报, 2016, 39(4):29-33.]

3.2.3.3 Results

- ✓ Documentation method (More than 200 relevant literatures were retrieved from CNKI and EBSCO, and more than 20 literatures which were highly relevant to the research topic were screened and referred in the selected case study.); surveys and expert interviews (Several experts from China Mountaineering Association, Sichuan Mountaineering Association and China University of Geosciences (Wuhan) were interviewed in the selected case study.); qualitative examination
- ✓ No detail monetary valuation
- ✓ This paper mainly discusses the forms, causes and countermeasures of outdoor sports damaging the ecological environment of recreation areas.

Indicators

- 1) **Soil degradation:** Including soil compaction, soil organic and mineral loss, humidity decreases, porosity decreases, soil erosion, soil microbial activity decreases;
- 2) **Vegetation deterioration:** Including shortening of vegetation length, vegetation decline, vulnerable species disappear, invasive species or weeds;
- 3) **Threat to wildlife:** Including habitat loss or displacement, animal migration, invasion of alien species, changes in animal behavior and species, poor health and reduced reproductive capacity, increased mortality;
- 4) **Water damage:** Including the outbreak of pathogenic bacteria in water, turbid water, eutrophication, water quality decline and destruction of water ecosystem.

Data accuracy

Although this study combines the views of the literature and expert knowledge, it provides only very limited data. To be frank, there are challenges in accurately measuring land loss, vegetation degradation and threats to habitats, not to mention the ecological impact of outdoor activity. This also suggests that site-specific experimental studies are urgently needed to measure broad environmental negative externalities.

3.2.4 WASTE INCINERATION AND INCREASED ENVIRONMENTAL AND HEALTH RISKS

3.2.4.1 Description

With the rapid growth of municipal solid waste, incineration has become an effective alternative treatment. However, as a typical NIMBY (Not In My Backyard) facility, the operation of waste incinerator will significantly increase environmental and health risks in the surrounding area. In China, due to the lack of public participation in the planning process and the lack of foresight in the planning itself, the pre-location of nimby facilities soon became part of the urban expansion area, which brought serious negative impacts to the surrounding residents. These serious effects include the generation of toxic gases such as dioxin, harm to the health of residents, property devaluation, and the generation of fear and disgust, etc. Obviously, the incinerator is a city-wide solution, but the costs are borne primarily by the people who live around it.

3.2.4.2 Impact Pathways

The causal chain is presented as follow:

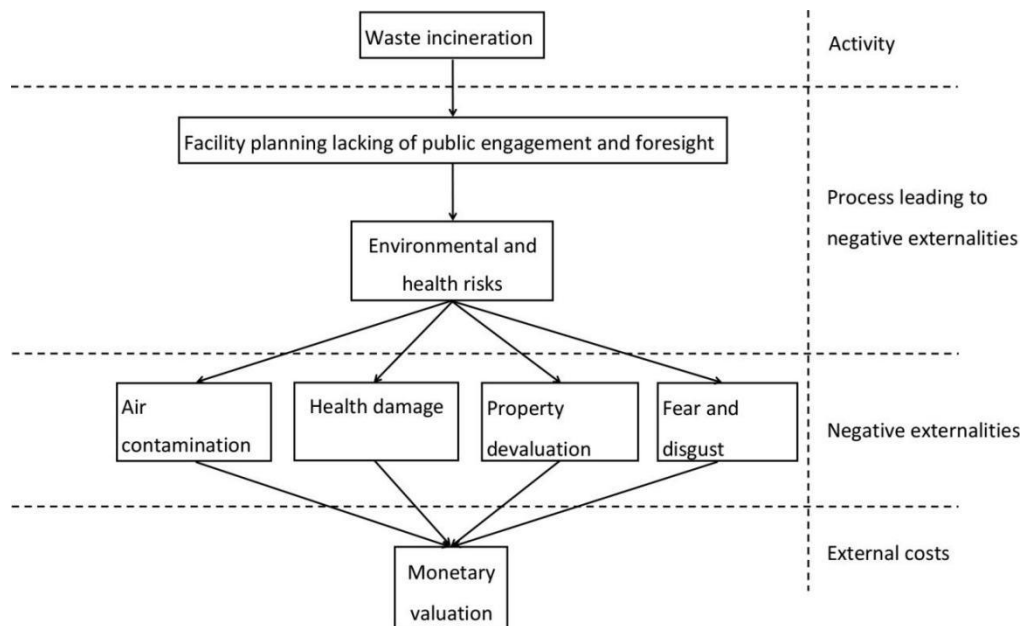


Figure IV: IPA: Waste incineration

Bibliographic references/sources

Feng Lin, Wang Hua, Pang Yuting, et al. Countermeasures to relieve NIMBY conflict in site selection of municipal solid waste incineration plant[J]. Environmental Protection, 2018, 46(19):49-51. [冯琳, 王华, 庞玉亭, 等.城市垃圾焚烧厂选址邻避冲突的对策探讨[J].环境保护, 2018, 46(19):49-51.]

3.2.4.3 Results

Documentation method(Four official documents were referred to, including “Plan for the construction of harmless disposal facilities of domestic garbage in cities and towns during the 13th Five-Year Plan Period”, “Standard for pollution control of domestic waste incineration(GB 18485-2014)”, “Implementation plan of household waste classification system”, etc.); Event statistics was conducted to show the major NIMBY conflicts in China's waste incineration projects in recent years(See the following table); qualitative examination.

Province/city	Proposed location	Time of event	NIMBY event process	Event handling
Beijing	Liuli Tun	2006	Residents complained against the construction of a large-scale waste incineration project by internet post.	Change the location
	A'Su Wei	2009	Neighbours posted a large number of posts on online forums and signed a joint petition against the construction	Change the location
Shanghai	Song Jiang	2009	Hundreds of residents hung signs and gathered at the factory, demanding that it be moved or shut down	The expansion of the plant was stopped

Jiangsu Province	Wu Jiang	2009	More than 20,000 people took to the streets to protest against the incineration plant	Change the location
	Jiang Bei	2009	More than 5,000 people signed a petition against the plant and took the provincial environmental protection bureau to court	Change the location
Zhejiang Province	Yu Hang	2014	More than 5,000 villagers demonstrated against a new waste incineration plant	Not reported
Guangdong Province	Pan Yu	2009	Hundreds of residents from around the factory went to the local government to protest the construction	Change the location
	Shen Zhen	2009	Hundreds of residents gathered at the site to demand that construction of the White Pigeon Lake waste incinerator be halted	To stop the construction
	Dong Guan	2010	Hundreds of online posts have been posted, and villagers have signed their signatures against the Ma Chung project	Suspend the construction
		2018	Thousands of online posts have been posted against the expansion of the Haixinsha incineration plant	Not reported

- ✓ No monetary valuation
- ✓ This paper qualitatively analyses the negative externalities of waste incineration plants and the nimby conflict in the site selection.

Indicators

- 1) **Air contamination:** Including AQI, PM10, PM2.5, gas concentration of carbon monoxide, carbon dioxide, dioxins and benzopyrene;
- 2) **Health damage:** Incidence of air pollution-related diseases, such as respiratory diseases, lung cancer, leukemia, etc.
- 3) **Property devaluation:** Including housing prices, housing vacancy rate, etc.;
- 4) **Un-healthy emotions:** Incidence of mental illness, percentage of people who have fear and nausea reactions. Field surveys are often used to measure these indicators.

Data accuracy

Qualitative and quantitative data for the selected case were derived from official documents. For example, data on the development of waste incineration plants in China came from the Statistical Yearbook of Urban and Rural Development (2008 -- 2017), and information on the NIMBY conflict incident in waste incineration projects came from news reports. It should also be noted that this study is still qualitative rather than monetising for assessing the negative externalities of waste incineration plants.

3.2.5 CONCLUSIONS

Negative externalities are generally generated in public and quasi-public domains, which are characterized by non-competitive resource utilization, such as urban roads, municipal facilities, atmosphere and wild environment. These issues have also received extensive attention in China, but there are still many deficiencies in the analysis and quantification of negative externalities in existing studies. Although case studies have dealt with many indicators that represent negative externalities, most of them only qualitatively analyze negative externalities, or only conduct statistical analysis on specific indicators, lacking in general of monetary valuation of negative externalities. This is a key area that needs to be strengthened in further research.

3.3 OECD/EUROPEAN IPAs

3.3.1 INTRODUCTION

This section examines examples of applications of SCBA in urban planning in Europe. The methodological approach follows the IPA approach, in which the urbanisation activities (e.g. urban expansion, land take) trigger processes, e.g. land conversion and urban sprawl, incurring in externalities, as the loss of eco-systems services, whose costs are not borne by those causing them, e.g. land developers. The IPAs aim at providing the monetary evaluation (quantification) of these costs. The identified IPAs analysed in this section concern with the loss of ecosystem services and the costs of urban sprawl. In the latter, externalities can be analysed in the framework of two different urban forms: compacted vs sprawled, due to the fact that most externalities, which are not paid directly by city users, arise when the urban form progressively moves towards urban sprawl. The specific cases analysed in this section relate to additional costs for infrastructure provision and management and delivering of public services. Other than in Europe, urban sprawl as well as loss of amenities and ecosystem services, also represent side-effects in China urbanisation patterns, in particular addressing excessive urban sprawling and costs of public services provision, and therefore internalisation practices and evaluations developed in the EU context may improve knowledge transfer.

3.3.2 LAND USE POLICIES AND LOSS OF ECOSYSTEM SERVICES

3.3.2.1 Description

Land use is the way in which urbanisation takes place. The transformation of rural land in urban land can cause the loss of ecosystems and their services, which has negative consequences for society. For example, land sealing for infrastructure and settlements causes a decline in water quality, the emission of soil carbon and damages from flood events, other than determining loss of arable land. Current land-use decisions often focus only on a few of ecosystem services, e.g. prioritizing provisioning services with market value (e.g. agricultural crop production) over regulating services (e.g. water provision) and cultural services (e.g. landscape aesthetics), that are typically not valued in markets. Hence, land-use decisions often aim at increasing private benefits from market goods, for example from crop and timber production, while neglecting public costs and benefits related to ecosystem services, such as water regulation, carbon sequestration and landscape aesthetics. Table 7 shows the complexity of

the eco-system services involved in land use and land conversion, that, according to an integrated approach, can be classified in four categories.

Table 7: Classification of eco-system services

Eco-system services	
1. Provisioning services	Water quality, raw material, genetic resources, medicinal resources, ornamental resources
2. Regulating services	Air quality regulation, regulation of water flows, erosion prevention, nutrient cycling, pollination, waste treatment and energy shortages
3. Habitat services	Providing species with habitat, Protecting genetic biodiversity
4. Cultural	Aesthetic information, recreation, cognitive development, spiritual experience, cultural heritage

Source: adaptation from De Groot, R. (2012) and EPRS (2015)

The analytical framework underpinning this broad definition of eco-system services include socio-cultural domains, bridging natural science and economics, conservation and development, public and private policies. It addresses both the ecosystem services delivery, regulating sphere (supply-side) and their use (cultural services), enjoyment and value by diverse stakeholders (demand-side) from local to global scales.

Despite the progressive affirmation of the above-mentioned broad definition of eco-system services, it is important to stress that the definition and classification of eco-system services is still debated (Pandeya, B., 2016). Indeed, over the last decade and a half, the concept has gained considerable importance across science and policy arenas, raising issues like how ecosystem services can be defined, valued and integrated into conservation and sustainable development agendas. Though the delimitation of the concept of eco-system services is still under discussion, in this Deliverable we assume the “integrated” broad valuation of ecosystem services as shown above in Table 7.

3.3.2.2 Impact Pathways

The following figure depicts the IPA addressing eco-system services.

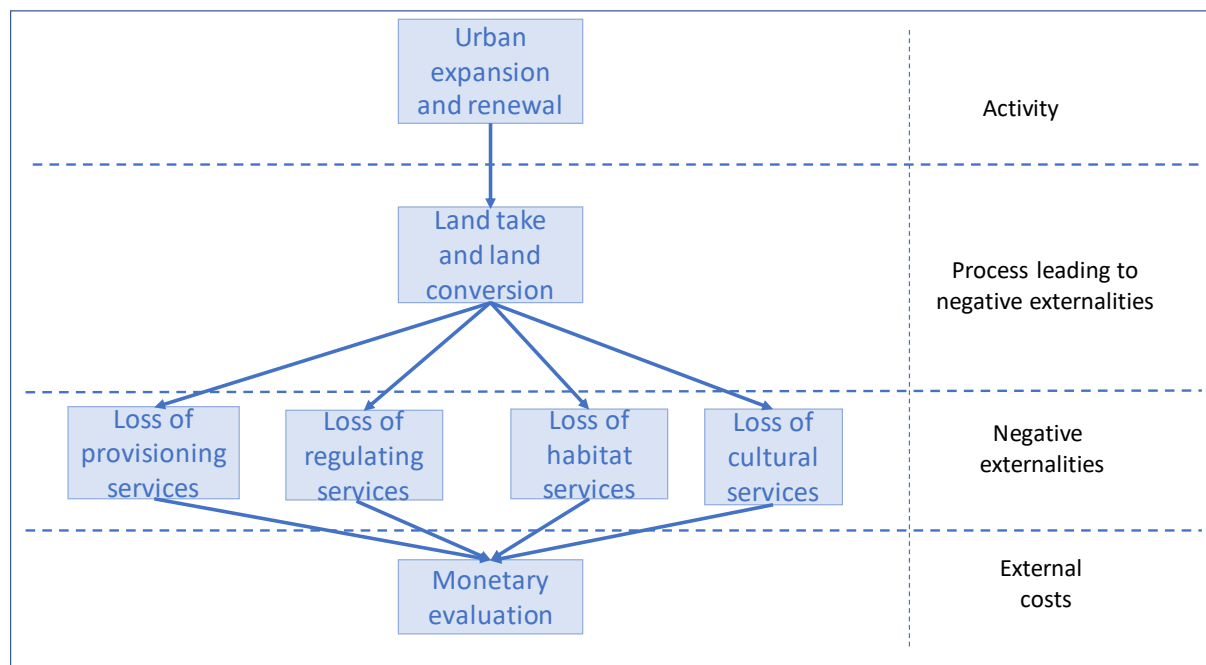


Figure V: IPA: Land use policies and loss of eco-system services

The key urbanisation activity triggering side-effects and externalities is land use, from which two processes may arise: land take and land conversion for urban expansion or urban renewal. The type of land subjected to conversion depends on site-specific conditions. For example, in Germany (Forster, J., 2019) the major land conversion processes concern with:

- I. Conversion of extensively or intensively used grassland into arable land (including loss of fringes of water bodies and small forest formations and coppice);
- II. Conversion of grassland, arable land, forests and accompanying vegetation to sealed surfaces including settlements and roads;
- III. Drainage of wetlands.

3.3.2.3 Results

Monetary evaluation of eco-systems implies the use of different and heterogenic techniques. Both market and non-market valuation methods can be used to estimate the change of economic values associated with the changes in ecosystem services. Market valuation implies that economic values are derived from different techniques based on market prices; e.g. the forgone economic value of agricultural products or timber due to land take on the basis of their market prices (market analysis) or the costs of offset activities to compensate for urban renewal, as in the set-up of new roads (restoration costs) or increased water treatment costs due to soil erosion when grassland is converted to arable land (damage cost).

Non-market evaluations are carried out through direct or indirect non-market valuation methods. Direct methods (also called stated preference methods) refer to contingent valuation (CV) and choice experiments (CE). In these methods a survey directly asks the concerned users for their willingness to pay (WTP) to obtain a land-use change (to value the benefits of an increased ecosystem services flow) or their WTP to avoid a land-use change (to value the costs of a decreased ecosystem services flow). Indirect methods assume that economic value is reflected in the costs incurred by travelling to specific

sites, such as recreational visits to wetland areas (travel cost method), or additional property prices paid to live in specific environment, e.g. in the vicinity of a forest (hedonic pricing method).

Table 8: Summary of monetary values for ecosystem services per biome (value in int.\$/ha/year 2007 price levels)

	Marine	Coral reefs	Coastal systems	Coastal wetlands ^a	Inland wetlands	Fresh water (rivers/lakes)	Tropical forest	Temperate forest	Woodlands	Grasslands
Provisioning services	102	55,724	2396	2998	1659	1914	1828	671	253	1305
1 Food	93	677	2384	1111	614	106	200	299	52	1192
2 Water				1217	408	1808	27	191		60
3 Raw materials	8	21,528	12	358	425		84	181	170	53
4 Genetic resources		33,048		10			13			
5 Medicinal resources				301	99		1504			1
6 Ornamental resources		472			114				32	
Regulating services	65	171,478	25,847	171,515	17,364	187	2529	491	51	159
7 Air quality regulation							12			
8 Climate regulation	65	1188	479	65	488		2044	152	7	40
9 Disturbance moderation		16,991		5351	2986		66			
10 Regulation of water flows					5606		342			
11 Waste treatment		85		162,125	3015	187	6	7		75
12 Erosion prevention		153,214	25,368	3929	2607		15	5	13	44
13 Nutrient cycling				45	1713		3	93		
14 Pollination							30		31	
15 Biological control					948		11	235		
Habitat services	5	16,210	375	17,138	2455	0	39	862	1277	1214
16 Nursery service		0	194	10,648	1287		16		1273	
17 Genetic diversity	5	16,210	180	6490	1168		23	862	3	1214
Cultural services	319	108,837	300	2193	4203	2166	867	990	7	193
18 Esthetic information		11,390			1292					167
19 Recreation	319	96,302	256	2193	2211	2166	867	989	7	26
20 Inspiration		0			700					
21 Spiritual experience			21							
22 Cognitive development		1145	22					1		
Total economic value	491	352,249	28,917	193,845	25,682	4267	5264	3013	1588	2,871

Source: Pandeya, B., 2016

Table 8 shows large value ranges across biomes, due to the fact that value estimates are based on individual case studies. “Biome” is here used as shorthand definition for the 10 main types of ecosystem-complexes for which the monetary value of the services they provide has been analysed. The indication of the number of estimates, average, minimum and maximum values per type of ecosystem are shown in Table 9.

Table 9: Average, minimum and maximum value per biome (value in int.\$/ha/year 2007 price levels)

Ecosystems	Number of estimates	Average cost	Minimum value	Maximum value
Open oceans	14	491	85	1664
Coral reefs	94	352915	36794	2129122
Coastal systems	28	28917	26167	42063
Coastal wetlands	139	193845	300	887828
Inland wetlands	168	25682	3018	104924
Rivers and lakes	15	4267	1446	7757
Tropical forest	95	5264	1581	20851

Temperate forest	58	3013	278	16406
Woodlands	21	1588	1373	2188
Grasslands	32	2871	124	5930

Source: Pandeya, B., 2016

As far as the monetary evaluation methods are concerned, direct market evaluations (direct market pricing, payment for ecosystem services, etc) show the higher share (53%), followed by cost method approaches (avoided costs, mitigation and restoration costs) with 19% and stated preferences (contingent evaluation) by 16%. Revealed preferences (e.g. travel costs, hedonic prices) account for 4%.

A part from monetary evaluations, it should be mention that **non-monetary evaluations** have gained growing attention in recent years, marking an explicit distinction from the evaluation methods based on neoclassical economics. The key difference is that non-monetary evaluations stress the importance of preferences, needs, or demands different from the simple willingness-to-pay for ecosystem services.

Data accuracy

Despite the radically different approach in using non-monetary evaluations, which could pave the way for the adoption of alternative evaluation frameworks, it should be pointed out that the broad range of non-monetary methods that have been used to value ecosystem services, such as surveys, interviews, participatory and deliberative tools, etc, are based on heterogenic assumptions. Therefore, the interpretation of results needs to be carefully scrutinised.

In general, the economic valuation of ecosystem services undergoes weaknesses, both in case of monetary and non-monetary evaluation techniques. The key point is that ecosystem services values are always context-specific, as the importance of an ecosystem (say, a coastal buffer zone) varies according to local conditions. In particular, due to the fact that studies have only been carried out for a few localities, the transferability of results in different contexts, i.e. through the application of the 'benefit transfer' (also called 'value transfer') approach, may be subjected to uncertainties and must be interpreted with caution.

3.3.3 URBAN SPRAWL AND COST-EFFECTIVE PROVISION OF PUBLIC SERVICES

3.3.3.1 Description

The relationships between urban sprawl and cost-effective provision of local public services have been widely discussed. The topic under examination is whether or not urban sprawl undermines the cost-effective provision of urban services. Urban sprawl has here to be intended as a shortcut term for “low-density, discontinuous, suburban-style development, often characterized as the result of rapid, unplanned, and/or uncoordinated growth” (Carruthers, J., 2003).

In presence of urban expansion, it is likely that public goods and services need to be increased to maintain a given level of public services for all its residents. If urban expansion develops in terms of suburbanization and fragmentation, the cost-effective provision of local public services, such as waste collection and management, police and fire protection, public transport and road cleaning services,

etc, is expected to rise. Economies of scale in the provision of public services are in consequence likely to be undermined, resulting in inefficient cost increases.

Due to the fact that public goods and services are in general priced according to their average as opposed to their marginal costs at urban level, an implicit subsidisation of urban sprawl is under way, producing externalities and inefficient use of public services.

Sometimes, density (e.g. number of inhabitants/working population per km) is assumed as a proxy of urban sprawl. Considering for example two municipalities having the same population and similar size but different densities. It is likely that in the less dense of the two, the management of specific public services must face additional costs: waste collection needs more vehicles or, alternatively, vehicles available will have to cover longer routes in order to provide the same quality of service. In such a case, waste management costs vary directly with distance. Therefore, the provision of such services is more expensive in less dense municipalities.

However, assuming density as the key variable underpinning empirical analysis on the relationships between urban sprawl and costs of public services may be misleading, and, in fact, this relationship remains ambiguous and controversial.

In US, regression-based analyses suggested that greater densities are associated with higher, not lower, public service expenditures. The analyses found that the cost of services rises with density, contradicting the findings of earlier site-based analyses. Specifically, the relationship may be U-shaped, first declining as density increases but then increasing sharply, leading to average costs that exceed the minimum by as much as 43% in very dense areas (Carruthers, J., 2003).

On the other hand, other empirical literature examining the impact of urban sprawl on the provision costs of local public services not considering density in isolation, but including the influence of high land values and other public expenditure determinants, e.g. fragmentation, produced different results, i.e. a clear correlation between urban sprawl (including density) and costs of public services (Ewing, R., 1997).

Focusing solely on density may come up with misleading results because dense urban areas also have high land values generating greater property taxes. In such a case, density is likely to be positively correlated with the cost-of-service delivery, because of the greater spending through property tax revenues, not because of the “physical form” of the development itself.

Most of the studies examining the relationship between urban sprawl and costs of public services were issued in America, in the 1960s, just following the first major post-war boom of suburban development in the United States.

Other studies from Europe, using a huge cross-sectional dataset of municipalities as in the Spanish Mediterranean Arch and Madrid, have showed a positive relation between waste collection costs and factors such as higher wages, coastal municipalities, tourist areas, population and separated collection; in contrast, the increase in urban population density contributes to lower costs of waste collection, as well as indirect management costs of the service (Aracil, F., 2017).

In sum, despite uncertainties, this report supports the statement that public spending on the whole (total direct expenditure) for most of public services shows per capita costs decreasing as densities increase.

3.3.3.2 Impact Pathways

The following figure depicts the IPA addressing urban sprawl and cost-effective provision of public services.

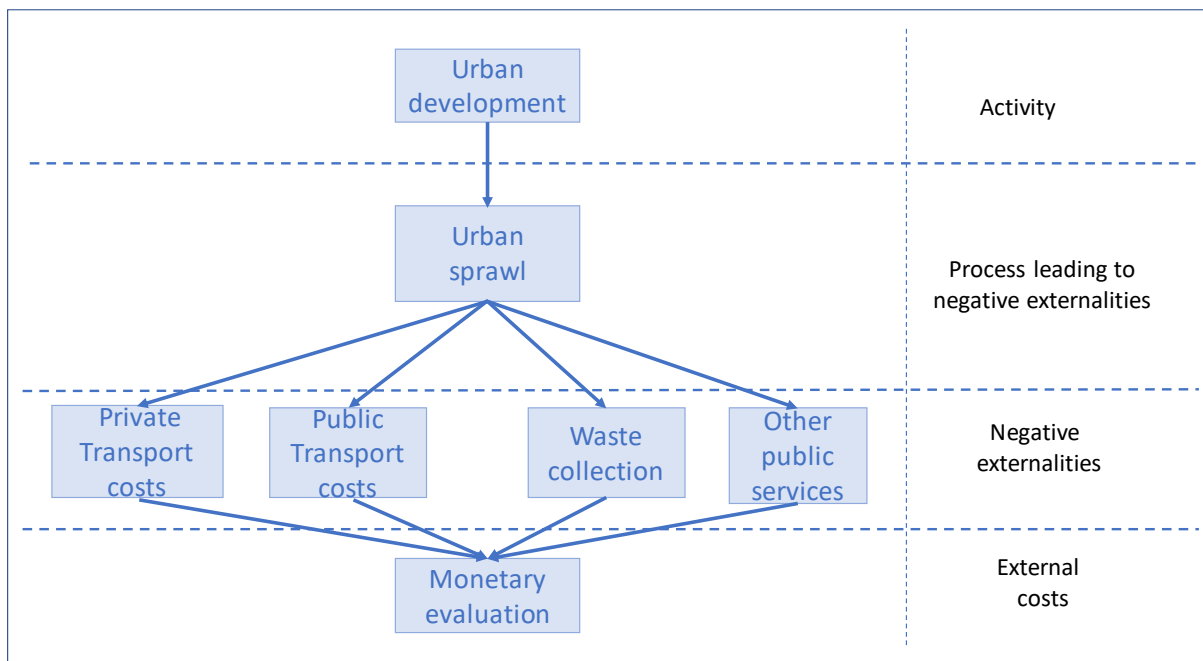


Figure VI: IPA: Urban sprawl and cost-effective provision of public services

Four categories of negative externalities arising from urban sprawl have been identified:

1. Higher vehicle kilometres travelled;
2. Higher public transport costs
3. Higher costs of waste collection and management service;
4. Higher costs of other public services.

Higher vehicle kilometres travelled. Despite some contributions stating the opposite, the positive relationships between urban sprawl and rise of vehicle kilometres travelled can be considered as unquestionable (Ewing, R., 1997). The average higher speed in sub-urban connections can relieve congestions costs, but does not offset the higher vehicle kilometres, at least taking into account of the negative impacts on emissions and accidents.

As density rises, trips are in general shorter, with an association of growing active transport modes (walking and cycling). Urban sprawl also tends to increase distances between homes, workplaces and shopping places, which makes people more dependent on automobiles, particularly in areas in which the service levels of the public transport system are low.

Higher public transport costs. Linkage between density and efficient provision of public transport services are acknowledged (EEA, 2016). The ease with which settlements can be linked together by means of public transport largely depends on the density of the built-up areas. A minimum density of inhabitants or jobs to justify the provision of services can be considered as a technical parameter. A high level of sprawl is accompanied by highly dispersed buildings and low land utilisation, making the presence of a minimum threshold of density difficult to reach.

From researchers and empirical studies (EEA, 2016), an urban area is regarded as adequately served by bus or tramway if the nearest bus or tram stop is no more than 400 m away. The time required to walk to the stop is also important, but for the sake of simplicity, it can be assumed that there are no obstacles in the way.

Higher management costs of waste collection. Empirical studies based on large database of public services expenditures (Aracil, F. et al, 2018) examine the factors that determine solid waste collection costs in 2014, using a cross-sectional dataset of municipalities of the Spanish Mediterranean Arch and Madrid, with special reference to urban development. The results of the regression reveal a positive relation between waste collection costs and factors such as higher wages, coastal municipalities, tourist areas, population and separated collection; in contrast, the increase in urban population density contributes to lower costs of waste collection, as well as indirect management of the service is cheaper than direct public delivery.

Higher costs of other public services. With a similar approach as in the analysis of waste collection provision and management costs, the analysis of variability of management costs with reference to a basket of public services (sewerage, school transportation services, etc.) shows the influence of density (Carruthers, J. 2003). Regression studies based on data for public services expenditures has shown the role of urban sprawl. For example, an analysis of the 159 counties forming the 25 largest metropolitan areas in the United States, finds that public indebtedness is associated with urban sprawl. Although the direction of causation may sometimes be questioned by the value of property tax (influencing the level of indebtedness of municipalities in the management of public services), the implication is that low-density development patterns require greater public expenditures to support them than do high-density development patterns.

Results

Empirical studies and evidence on the causal-effect relationships between urban sprawl and public services management costs, via higher transportation costs and lower densities, basically are rooted in the US research tradition.

Since 1998 (Federal Highway Administration, 1998), studies funded by US Government and institutions have been delivering estimates on social costs of alternative land use patterns. Modelling tools are generally used at this purpose. The physical development path models the consumption of land, the projected mixture of new housing units, the local infrastructure cost and annual operating cost of sewer, water and storm water. Sometimes, it is also possible to project the average amount of non-residential building space needed to support new developments. The total travel cost path then models the annual operating cost of peak and non-peak travel on a passenger-miles travelled basis.

A meta-analysis of these contributions, expressed in a generalised form through the set-up of an excel spreadsheet model has been carried out by the Victoria Transport Policy Institute (Litman, T. 2015). For this analysis, the Sprawl Cost Analysis Spreadsheet Model was built to calculate sprawl costs. It categorizes U.S. urban regions into quintiles (fifths) from 1 (Smartest Growth) to 5 (Most Sprawled). This model incorporates Sprawl Factors which reflect the average percentage change in an impact's magnitude resulting from a one-Quintile shift. Quintile 1 (Q1) used as a baseline. The interpretation of the results (Table 10) must consider that a 10% Sprawl Factor for infrastructure costs indicates that, compared with Q1, infrastructure costs average 10% higher in Q2, 20% higher in Q3, 30% higher in Q4, and 40% higher in Q5 cities.

Table 10: Summary of monetary values for public services management costs due to urban sprawl (value in US \$, year 2014)

Impact	Units	Sprawl Factor	Sprawl Quintiles				
			1	2	3	4	5
Urban density	People/hectare	40%	23,5	16,8	12,0	7,2	4,3
Public service costs	Annual \$/capita	10%	\$1.201	\$1.334	\$1.482	\$1.631	\$1.794
Motor vehicle travel	Annual km/capita	17%	10.389	13.182	15.117	17.684	22.896
Fuel consumption	Annual litres/capita	17%	1.039	1.318	1.512	1.768	2.290
Vehicle internal costs	Annual \$/capita	17%	\$4.603	\$5.840	\$6.698	\$7.835	\$10.144
Vehicle external costs	Annual \$/capita	17%	\$3.082	\$3.911	\$4.485	\$5.246	\$6.793
Active transport	Annual km/capita	20%	360	300	250	200	160
Active transport value	\$/km walked/biked	\$1,00	-\$360	-\$300	-\$250	-\$200	-\$160
Traffic fatalities	Deaths/100,000 residents	28%	4,3	5,9	8,2	10,5	13,4

Data accuracy

It is important to stress that results are strongly influenced by the US specific urban shapes. For example, the Smartest Growth quintile (Q1) has an average density of 23.5 residents per hectare, which is dense by North American standards but about half the typical densities found in European cities, and about a tenth of the densities found in some Asian cities. On the other hand, per capita vehicle ownership is about 700 vehicles per 1,000 residents in most North American cities, compared to an average of about 570 per capita vehicle ownership rate (year 2019) in European countries ³.

Evidence from Europe is less available. Researchers on urban sprawl are typically limited to case studies of selected metropolitan areas in national contexts. Generalisation at European level of results is therefore lacking.

3.3.4 URBAN SPRAWL AND COSTS OF INFRASTRUCTURE PROVISION

3.3.4.1 Description

Per capita costs of fixed infrastructure costs tend to fall as density rises. Evidence (Nunns, P., Denne, Y. 2016) confirm that in Auckland (NZ) new developments in greenfield areas (with a lower density) on the urban fringe tend to incur higher infrastructure costs than infill or brownfield development. However, it should be considered that infrastructure costs can be extremely site-specific and depend on the existence of capacity constraints within existing infrastructure networks.

Site planners and engineers have investigated how alternative development patterns affect the cost of delivering physical infrastructure, including roads, schools, sewers, and other public facilities. Most of the interest in evaluating the causes and consequences of alternative development patterns emerged in the 1960s, just following the first major post-war boom of suburban development in the

³ <https://www.acea.auto/figure/motorisation-rates-in-the-eu-by-country-and-vehicle-type/>.

United States. At that time, urban sprawl was a relatively new phenomenon, so much of the early research focused on defining its key characteristics and its relationship to newly evolving land markets.

The outcomes of the analysis gave rise to discussion, i.e. some of the results suggested that greater densities are associated with higher, not lower, public service expenditures. Drawing on cross-sectional data and controlling for other determinants of spending, researchers (Ladd, 1992) found that the cost of services rises with density, contradicting the findings of earlier site-based analyses. It was stressed that at very high density, special needs and requirements may turn cost functions upward, e.g. increased density may require more traffic lights and control officers.

However, despite uncertainties linked to specific situations, it may be concluded that for what concerns infrastructure of a wide scope— e.g., local and regional roads, water and sewer systems, and schools, in general their management is more expensive under sprawl than under compact development. These statements may be extended to infrastructure that is primarily public (i.e., state, county, or local government roads; public utility systems; and public schools) and occasionally private (i.e., privately owned utility systems and subdivision-level roads that are not dedicated to the public sector, including electricity supply, gas supply and communications networks).

The key insights from contributions have been to provide empirical evidence of the widely held but largely unfounded belief among planners that urban sprawl raises the cost of infrastructure provision (and public services, as discussed above).

Urban sprawl may undermine economies of scale of a wide range of infrastructure-based services, including police protection and public education, by lowering the density of individual consumers. Given that public goods and services are mostly priced according to their average as opposed to their marginal cost, it adds to the problem, as land developers have scarce motivation to help maintain a cost-effective urban form, raising subsidisation.

3.3.4.2 Impact Pathways

The following figure depicts the IPA addressing urban sprawl and cost-effective provision of infrastructure.

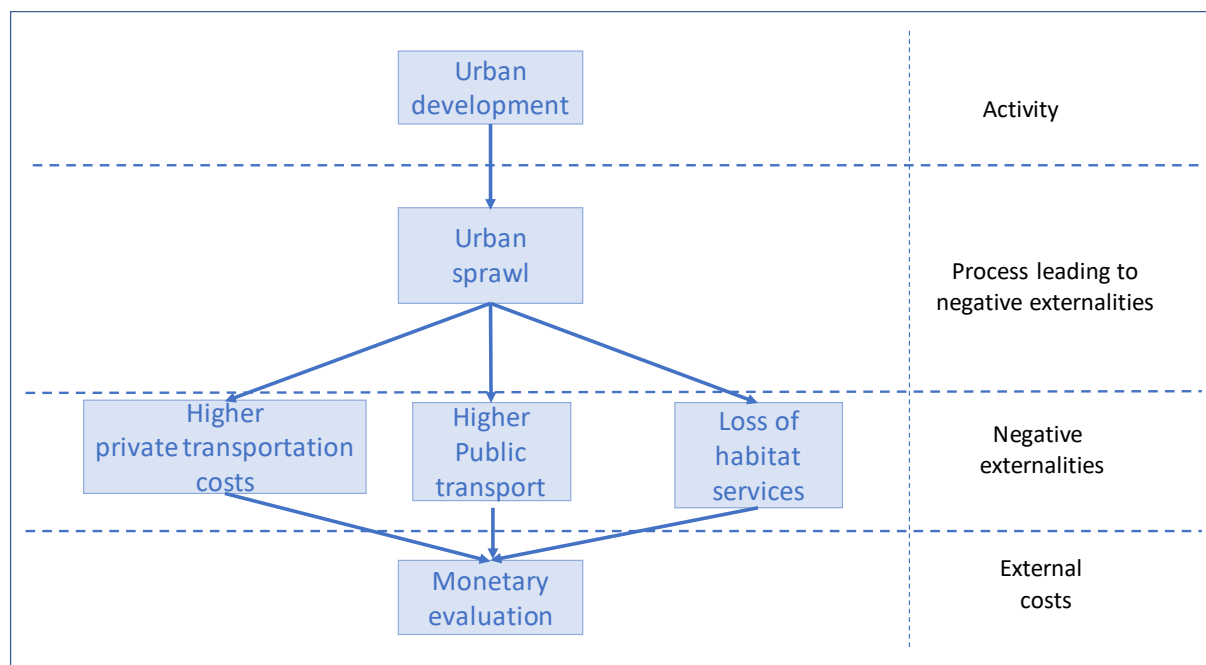


Figure VII: IPA: Urban sprawl and cost-effective provision of urban infrastructure

In more details, the impacts of urban sprawl and low densities in terms of external costs on the provision and management of infrastructure, are the following:

1. Higher infrastructure costs;
2. Higher public operating costs (examined in details in the above section);
3. More expensive private residential and non-residential development costs;
4. More adverse public fiscal impacts (in the form of subsidisation);
5. Higher aggregate land costs.

In such IPA, the end points affected basically correspond to citizens, public finances and, ultimately, a rational land price. The location of new development indeed continues to be determined by land speculation and potential for profit instead of its impact on aggregate public welfare. As an outcome, growth commonly enjoys significant subsidies, as the costs it imposes end up being financed through collective property tax revenues.

It has been pointed out, indeed, that one of the principal complaints of urban sprawl is that it often ends up being financed by the public-at-large through average cost pricing mechanisms. The price of greenfield results lower than it should be, favouring non rational allocation of resources during urban planning.

3.3.4.3 Results

A concrete estimation of the external costs arising from the management and provision of infrastructure in compact and sprawled urban developments has been done in Perth, Australia (Designperth, 2016).

The study represents a plea of infill and urban regeneration vs greenfield developments. Scenarios and case studies have been defined to give an estimate of the costs of a range of infrastructure services for inner city infill developments and greenfield developments on the urban fringe in 2014.

The results are shown in Table 11 with reference to the government infrastructure. Indeed, the results for private travel costs and for broader social costs (including transportation costs) are not included in the study. Only Government infrastructure costs are used in the analysis for Table 11 and no private developer contributions were included within the per lot costs.

Table 11: Monetary values for management and provision of infrastructure -comparison between infill and greenfield – data in Australian \$, 2016

TABLE 11	INFILL	GREENFIELD	COMPARISON
	cost per lot	cost per lot	cost per lot
Government Infrastructure Costs (upfront costs)			
Roads	\$5,623	\$33,583	\$27,960
Water and Sewerage	\$16,303	\$24,738	\$8,435
Telecommunications	\$2,847	\$4,103	\$1,256
Electricity	\$4,512	\$10,719	\$6,207
Gas	\$0	\$4,080	\$4,080
Fire and Ambulance	\$0	\$334	\$334
Police	\$0	\$429	\$429
Education	\$4,306	\$36,644	\$32,338
Health (Hospitals, etc)	\$22,237	\$35,759	\$13,522
TOTAL COST PER LOT	\$55,828	\$150,389	\$94,561

Source: Trubka, Newman and Bilsborough (2010); Future Perth (2001)

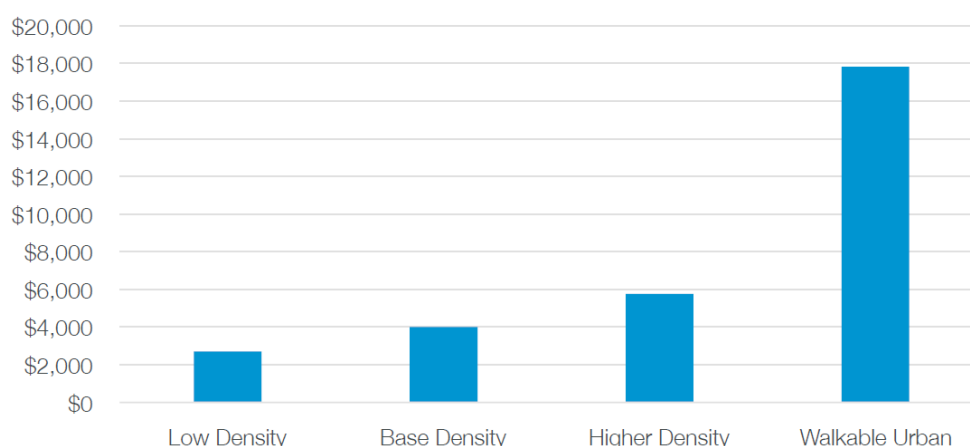
Other evidence on the influence of urban development patterns on infrastructure costs are provided by the US Smart Growth America Programme (<https://smartgrowthamerica.org/>). Using GIS, grids of equal-sized cells have been drawn across some US municipalities, determining the number of residents and employees, estimating density as well as the road and public infrastructure length and area in each cell. In Des Moines (Iowa) with reference to road and water and sewer infrastructure provision and maintenance scenarios on alternative developments have been defined, calculating for each scenario the total annual net fiscal impact (revenues minus expenditures).

Table 12 highlights the enormous opportunity cost associated with low density development: the net fiscal impact in the walkable urban scenario (the most compact one) is about \$16k per acre compared to the low-density scenario.

Table 12: Infrastructure costs by alternative development patterns in Des Moines (Iowa), US, data in US \$, 2014

Net fiscal impact per acre of by scenario

Combined impact on the City of West Des Moines and West Des Moines School District



Data accuracy

Several studies in the EU and US have analysed the relationship between development patterns (urban sprawl or compacted cities) and the management of public services (Albert Solé-Ollé, Miriam Hortas Ricoc, 2008). Data available from econometric analysis provide evidence of causal relations between urban forms and costs of public services, including on the nature of the relationships, i.e. the extent to which density explains higher provision costs may be uncertain and subjected to several conditions (e.g. quality of data across time and space, disaggregation and granularity of input data).

3.3.5 CONCLUSIONS

Drawing conclusions, the analysis of the IPAs results leads to the following considerations:

1. *Quantification is available, but transferability is complex.* The IPAs concerning urban expansion and renewal, when land take and urban sprawl are involved, address several end points: amenities, cultural and ecosystem services, public and private transportation costs, management and provision of infrastructure and public services. Evidence from case studies and meta-analysis collected across the OECD countries over the past years show that monetary evaluation is for the most cases available, taking stock of a wide array of techniques and methodologies, from market-based evaluations to surveys (stated preference methods). However, the simple observation of the wide range between minimum and maximum values of the results for each end-point, suggests that a straightforward utilisation of the evaluations in contexts different from the original case study, e.g. using average values, may be not reliable. What is at stake, is not the individual monetary evaluation of an end-point, but the transferability of such evaluations. It is worthwhile to note that in TRANS-URBAN-EU-CHINA the latter issue (transferability) represents an important aspect, namely with reference to the transfer of knowledge between EU and China. Whatever the monetary evaluation is carried out, the

availability of transferability techniques could make available the evaluation in different contexts, when there is no data or resources to perform new primary valuation studies.

2. *Guidelines for transferability.* The methodology with which the evaluation carried out in the primary site is transferred in a different one is addressed as “benefit transfer” or “value transfer”. In general, due to the inherent uncertainty in value transfers, it would be better to limit value transfer when the need for accuracy is of primary interest, e.g. when the estimated values have direct impacts on stakeholder/interest groups. For example, as in the evaluation of air pollution costs from transportation activities, if the polluter (road vehicle) could end up paying the estimated value in compensation to those affected by the pollution.

In literature, two main approaches to benefit or value transfer can be identified (NEEDS, 2009):

1. Unit Value Transfer
 - Simple unit value transfer
 - Unit value transfer with adjustment for income differences
2. Function Transfer
 - Benefit function transfer
 - Meta-analysis

In the unit value approach, the primary study site is assumed to be representative for the destination site; either without (a) or with (b) adjustments for differences in income levels between the two sites (using GDP per capita) and/or differences in the costs of living (using Purchase Power Parity (PPP) indices). In the function transfer approach, a benefit function is estimated at the primary study site and transferred to the destination site, or a benefit function is estimated from several study sites using meta-analysis.

Each technique or approach has pros and cons. If the primary site object (a vehicle, a land area) is considered to be similar to the destination study site, unit value transfer can be used, further adjusted for time and space factors. For unit transfers between countries, differences in currency, income and cost of living between countries can be corrected for by using Purchase Power Parity (PPP) corrected exchange rates. The value estimate should be adjusted from the time of data collection to current currency using the Consumer Price Index (CPI) for the destination site country. If we transfer values from a study site outside the policy site country, we could first convert to local currency in the year of data-collection, using PPP (Purchase Power Parity) corrected exchange rates in the year of data collection, and then use the local CPI to update to current-currency values.

Function transfer is conceptually more appealing than unit value, but it can be used if value functions have sufficient explanatory power and contain variables for which data is readily available at the policy site, which is not always the case.

If relevant meta-analyses are identified from several valuation studies (as in the function transfer case), estimates from these could also be used in order to elaborate one common benefit function.

To conclude, unit value transfer is recommended as the simplest and most transparent way of transfer both within and between countries. This transfer method has in general also been

found to be just as reliable as the more complex procedures of value function transfers and meta-analysis.

3.4 CHINESE CASE STUDY: NEGATIVE EXTERNALITY OF BEIJING TRANSPORTATION SYSTEM

3.4.1 INTRODUCTION

Externalities are also known as spill-over effects or external effects, which refer to the harmful or beneficial effects of the economic activities of one economic subject on others. According to its effects, externalities can be divided into positive and negative. Positive externality is a phenomenon that the activities of an economic subject benefit others or the society, but the beneficiaries do not need to pay the price. Negative externality refers to the phenomenon that the activities of a subject (an enterprise, a citizen, an administration) cause damage to others or the society, while the subject causing the relevant impact does not bear the cost (Zong, G., 2014). These phenomena occur mainly in the public and quasi-public sphere.

The roads and stations on which traffic behaviour occurs are quasi-public goods with lower competitiveness in use and non-exclusiveness in benefit. Therefore, transportation becomes one of the main areas where externalities (especially negative externalities) occur. In fact, there are many externalities in transportation, including:

- (1) the externalities generated by the interaction within the transportation system, such as traffic congestion;
- (2) the externalities caused by the interaction between transportation and the environment, human capital and other non-renewable resources, such as environmental pollution and traffic accidents;
- (3) externalities arising from the interaction between transportation and government, private producers and consumers, such as price control in transportation (Rothengatter, 1993).

Therefore, in a strict sense, the above aspects should be considered in the measurement of negative externalities of transportation.

As a megacity with a population of 21.542 million and car ownership of 6.084 million (in 2018), Beijing is faced with severe traffic problems and is one of the most congested metropolises in China. This poses a challenge for Beijing to build a liveable and sustainable world city. In order to measure the negative impact of traffic system on Beijing, it is necessary to estimate its negative externalities. As one of the few quantitative studies on negative externalities in China, Zong Gang and Li Cong estimated the negative externalities of Beijing's transportation system from five aspects: 1) traffic accidents, 2) noise pollution, 3) air pollution, 4) greenhouse effect and 5) traffic congestion (Zong, G., 2014). The results were published in May 2014 in *Eco-Economics* 30, no. 5. The following part of this section will introduce and review the case study of Beijing under the framework of the IPA.

3.4.2 NEGATIVE EXTERNALITIES RELATED TO TRANSPORTATION SYSTEM

Traffic related problem is a global urban problem, which brings hidden socio-economical loss and environmental damage to cities. Although widely noted and discussed, it is rarely accurately measured, especially in China, where most of the research on externality remains in the qualitative discussion.

Nevertheless, the existing studies have made the mechanism of negative externalities related to transportation system more and more clear. For example, Zong and Li's have achieved a quantitative assessment of negative externalities in the transportation system of Beijing.

As we all know, urban road is a typical quasi-public product, which is non-competitive and insufficiently exclusive in the consumption process. Imagine an urban road with a certain designed traffic flow. When the actual traffic flow (f_x) is lower than the designed traffic flow (f_0), the road traffic will remain unobstructed. At this time, the marginal cost of a new car in this section is 0, making the private cost equal to the social cost. However, when the actual flow exceeds the designed flow, the new vehicles entering this section will make the lane become crowded and force the vehicles nearby to slow down. Other vehicles will also slow down correspondingly, thus externalities are generated.

When f_x is greater than f_0 , any vehicle entering the road will make the lane more crowded and affect the driving of all vehicles to varying degrees. Therefore, as the traffic flow increases, the marginal social cost will increase at a higher rate than the marginal personal cost. As a result, the marginal social cost will always be higher than the marginal personal cost.

It is worth noting that although f_x generates negative externalities when it is greater than f_0 , as long as the marginal benefit of road traffic is greater than the marginal personal cost, other vehicles will continue to enter the road section. The equilibrium point of traffic flow cannot be reached until the demand curve intersects the cost curve. Since the marginal social cost is always higher than the marginal personal cost within the interval of $[f_0, +\infty)$, it is obvious that the marginal social cost curve will reach the equilibrium point before the marginal personal cost curve. In other words, the optimal traffic flow in the overall context will be lower than that in the individual context. It is generally believed that the optimal traffic flow acceptable on a road segment occurs at the intersection of the demand curve and the marginal social cost curve (with negative externalities but no congestion), while traffic congestion will occur after passing this point (Figure VIII).

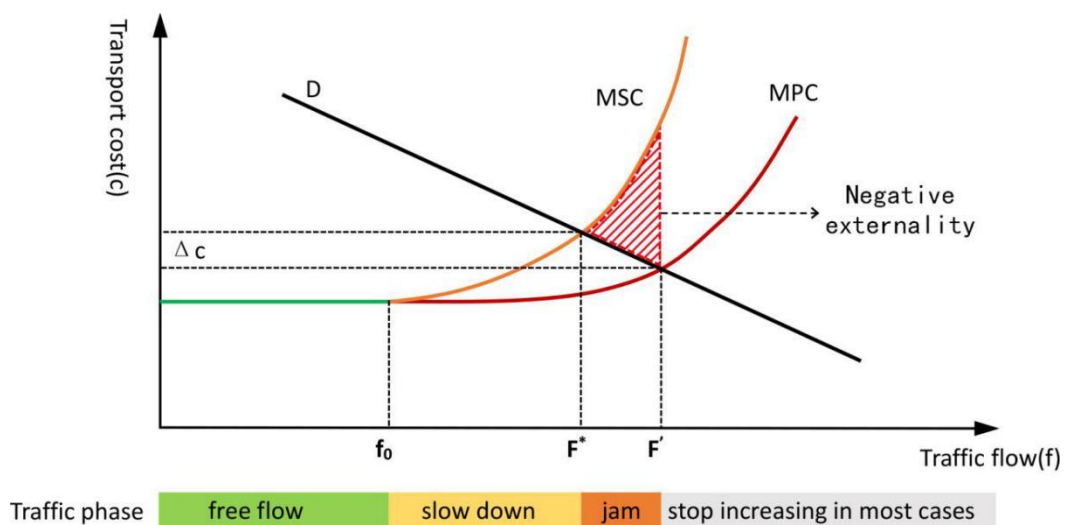


Figure VIII: The formation of negative externalities of traffic congestion

Annotation: f_0 =The designed traffic flow; F^* =The maximum traffic flow under the overall optimal condition; F' =The maximum actual traffic flow; Δc =The difference between the marginal social cost

and the marginal personal cost when the equilibrium points are reached; D: Traffic demand; MSC: Marginal social cost; MPC: Marginal personal cost.

Traffic congestion is the most concerned aspect of negative externalities of traffic system, which means time waste in the first place, and therefore reduces the time input to create value or utility. At the same time, when cars are in a state of congestion, insufficient gasoline combustion increases the emission of CO and other harmful gases and aggravates air pollution. In addition, traffic accidents, noise pollution and greenhouse effect are also negative effects that cannot be ignored. Traffic accidents are harmful events that the transportation system tries to reduce but is difficult to completely avoid. It will not only directly damage the safety of life and property of the parties involved in the accident, but also cause roadblocks and road jams and affect the travel of other non-parties. Noise pollution is another public environmental impact from traffic activities, which can damage the health of residents along the road or reduce work efficiency, thus causing indirect losses. In addition, the carbon dioxide emission from fuel powered vehicle exhaust is one of the causes of global greenhouse effect, its impact spans political and ecosystem boundaries and disproportionately affects people who rely on small-scale agriculture. Based on the above knowledge, the selected case study estimated the negative externalities of Beijing's traffic system from five aspects: traffic congestion, air pollution, traffic accidents, noise pollution and greenhouse effect (Figure IX).

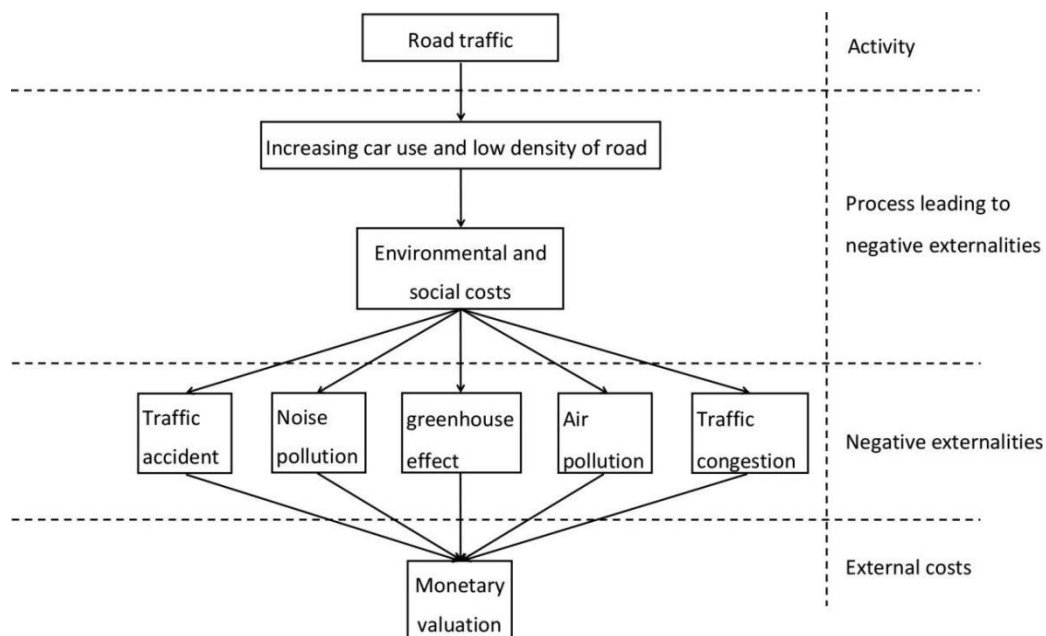


Figure IX: The impact pathway of road traffic in Beijing

3.4.3 METHODS FOR MEASURING NEGATIVE EXTERNALITIES OF TRANSPORTATION SYSTEM

The methods used in the case study is as follows:

3.4.3.1 The Cost Calculation Method of Traffic Congestion

The external cost of traffic congestion can be regarded as the time-value cost of extra travel time consumed by travelers, the formula is expressed as:

$$C_{congestion} = [S/V_p - S/V_q] \times V_t \times N \times M \times \varepsilon \quad (1)$$

In which, S is the average travel distance of a unit commuter vehicle; V_p is the average driving speed of vehicles in congestion; V_q is the minimum acceptable speed for travelers; V_t is the traveler's unit time value; N is the number of times the commuter vehicle is used in a certain period of time; M is the average number of commuting vehicles in a unit time; ε is the influence factor of time. The external cost of traffic congestion is the sum of the congestion costs calculated by several travel modes respectively.

3.4.3.2 The Cost Calculation Method of Air Pollution

Air pollutants emitted by traffic activities that affect and damage human health are mainly nitrogen oxides, SO_2 and inhalable particles ($PM_{2.5}$ and PM_{10}). Since inhalable particles are closely related to the incidence of diseases, inhalable particles are taken as the main evaluation index, and SO_2 and NO_2 are converted into inhalable particles according to the health risk. The external cost of air pollution can be divided into the loss of life value of those who died of respiratory diseases, the loss of labor value of those infected with respiratory diseases, the loss of medical expenses and the loss of value of limited time of activities (Di, J., 2010). The calculation formula is as follows:

$$C_{pollution} = Q \cdot (P - P_0) \cdot \sum_{i=1}^n F_i \cdot V_i \cdot \mu \cdot W / 100 \quad (2)$$

In which, Q is the exposed population in millions; P is the weighted average concentration of atmospheric particulate matter; P_0 is the reference concentration of atmospheric particulate matter; F_i is the fixed bottom line increment of the i_{th} health effect terminal; V_i is the intended value of payment for the i_{th} health effect terminal; μ is the share of air pollution in transportation systems; W is the consumer price index in the estimated year relative to the base year.

The external cost of air pollution is the sum of the loss of life value, the loss of labor value, the loss of medical expenses and the loss of limited time of activities of people infected with respiratory diseases.

3.4.3.3 The Cost Calculation Method of Traffic Accidents

The case study classifies the cost of traffic accidents into five aspects, including the loss of life and property of people who died in traffic accidents and the loss of labor value of people who were injured; Mental loss of relatives of the dead and the injured; Medical expenses and funeral expenses; Direct loss of property resulting from the accident; And social service loss. The above five aspects are divided into direct loss and indirect loss (Figure X).

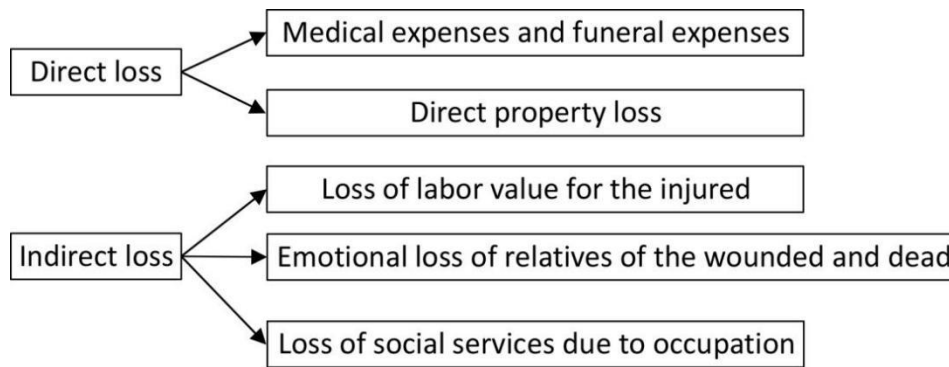


Figure X: Direct and indirect loss of traffic accidents

Direct loss can be directly found in the traffic yearbook of each province and city (China Transport Yearbook: <https://data.cnki.net/Yearbook/Single/N2021040154>). According to the total production method, the author calculated the loss of labor value and mental loss of relatives of the injured and the dead, plus the consumption loss of social service institutions calculated according to the data of insurance institutions, the external cost of traffic accidents can be obtained.

3.4.3.4 The Cost Calculation Method of Noise Pollution

Environmental noise standard for urban areas (GB3096-93) specifies the classification standard of environmental noise. Among the many studies of the willingness to pay for noise in Europe, roads and air travel are considered quiet at 55 decibels and railways at 60 decibels. While in the study of the impact of noise on human health, the general limit is 65 decibels. In the selected case study, Zong Gang et al. integrated various factors and selected 65 db as the threshold to evaluate the impact of noise. Thus, the total cost of noise includes the medical costs of people suffering from traffic noise greater than 65 decibels, willingness to pay, and the risk of death in patients with acute myocardial infarction caused by traffic noise. According to the Beijing environmental protection bureau, the city's average noise level is around 69 decibels, with little change over the years, and above the critical level of 65 decibels, on a par with European levels. Therefore, when calculating the noise cost, it is only necessary to adjust the influencing factors of population density and per capita GDP according to the European noise cost formula. The calculation formula is as follows:

$$C_{\text{Beijing-ij}} = C_{\text{EU-ij}} \times \alpha_{\text{pop}} \times \alpha_{\text{GDP}} \quad (3)$$

In which, i represents the mode of transportation, including road, rail, air, water and pipeline; j includes passenger and freight; $C_{\text{Beijing-ij}}$ is the average noise cost in Beijing; $C_{\text{EU-ij}}$ is the average noise cost in Europe; α_{pop} is the population-adjusted factor ratio, which is equal to the ratio of population density of Beijing and EU; α_{GDP} is the adjusted ratio of GDP per capita, which is equal to the ratio of Beijing's per capita GDP and EU's per capita GDP.

3.4.3.5 The Cost Calculation Method of Greenhouse Effect

Greenhouse gases produced by transportation systems include CO₂, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, chlorofluorocarbons, ozone, water vapor, etc. Among them, CO₂ is the main greenhouse gas emitted by the transportation system, which has a major impact on the greenhouse effect. When calculating the impact of the greenhouse effect, Zong Gang

et al. converted the fuel consumed by transportation into CO₂, so as to measure the cost of the greenhouse effect. For the external cost of greenhouse gas emission, shadow price of CO₂ (carbon tax) and CO₂ emission are used to calculate the external cost of greenhouse effect. In which, the carbon tax value adopts the average value recommended by the Ministry of Finance and the Ministry of Environmental Protection (see Table 13).

Table 13: Carbon tax proposed by different departments

	Carbon tax (CNY/t)		Weight adopted
	2012	2020	
Recommended by the Ministry of Finance	10	40	0.5
Recommended by the Ministry of Environmental Protection	20	50	0.5
Value used in the case study (CNY/t)	15		

Data source: Report on Chinese carbon tax framework design

The selected case study adopts the carbon tax standard in 2012 and takes 2010 as the research year. According to Table 13, the value of CO₂ emission reduction is 15 CNY/t. According to this, the external cost of greenhouse effect can be calculated as follows:

$$C_{\text{greenhouse}} = \text{CO}_2 \text{ emission} \times 15. \quad (4)$$

3.4.4 RESULTS

3.4.4.1 The Negative Externalities of Traffic Congestion

As for the negative externalities of traffic congestion, since walking, bicycles and electric bicycles are less affected by the congestion, and the subway is completely unaffected by the ground traffic, it is not necessary to consider the above transportation modes, we only need to calculate the congestion costs of cars, buses and taxis. According to the 2011 Beijing traffic development annual report, the average daily travel volume of cars, buses and taxis in Beijing in 2010 is obtained, as shown in table 14.

Table 14: Average daily bus, car and taxi trips in Beijing in 2010

Trip mode	Accounts for the percentage of total trips	Daily trips (Thousands of people)
Car	34.2%	993
Bus	28.2%	818
Taxi	6.6%	192

Formula (1) can be converted into: $C_{\text{congestion}} = (T_p - T_q) \times V_t \times L \times \varepsilon. \quad (5)$

According to a survey conducted by the Beijing Municipal Commission of Transport, the minimum car speed most travelers can tolerate is 16 km/h, while the bus speed is 12 km/h (Beijing Municipal Commission of Transport). Based on this, the maximum time that can be tolerated to travel unit distance in a particular traffic mode can be calculated. In formula (5), T_q represents the maximum travel time that can be tolerated; T_p represents the average travel time of a particular mode of travel; V_t is the traveler's unit time value; L is the average daily travel volume; ε is the influence factor of time. Since the calculation is completely based on time, the influence factor of time (ε) is taken as 1. The time

value cost of passengers and drivers is calculated according to the per capita hourly GDP unit of Beijing in 2010, and the value is 19.247 CNY/hour.

According to the time consuming in various ways during peak travel hours in Beijing in 2010, travel time in different ways is calculated as shown in Table 15.

Table 15: Travel times for different modes of transportation

Modes of transportation	Morning peak			Evening peak		
	Average speed (Km/h)	T _p (minutes)	T _q (minutes)	Average speed (Km/h)	T _p (minutes)	T _q (minutes)
Taxi	12.85	33.2	26.7	11.0	39.4	27.1
Car				14.6	38.9	35.4
Bus	9.5	60.7	48.1	8.7	66.4	48.1

According to the above data, the total cost of traffic congestion in Beijing's transportation system in 2010 is the sum of the costs of different travel modes, which is 37, 890, 524, 750 CNY (RMB). That's about 4489.24 million euros (adopt the 2010 exchange rate).

3.4.4.2 The Negative Externalities of Air Pollution

The annual variation of air pollution index related to motor vehicle emission in Beijing urban area from 2005 to 2010 is shown in Table 16. Studies have shown that the average health risk of nitrogen dioxide is 22.11 times that of sulfur dioxide and the risk of inhalable particulate matter is 29.33 times that of sulfur dioxide in all age groups in different regions. According to this, Zong Gang et al. carried out weighted average of inhalable particles and the effects of nitrogen dioxide and sulfur dioxide on human health, and obtained that the weighted average of inhalable particles in Beijing in 2010 was 165.1 micrograms/cubic meter (Zong, G., 2014).

Table 16: Inter annual variation of air pollution index related to vehicle emission in Beijing urban area - Unit: $\mu\text{g}/\text{m}^3$

Year	2005	2006	2007	2008	2009	2010
NO ₂	0.066	0.066	0.066	0.049	0.053	0.057
SO ₂	0.050	0.053	0.047	0.036	0.034	0.032
Inhalable particulate matter	0.142	0.161	0.148	0.122	0.121	0.121

Data source: Beijing Environmental Protection Bureau

According to the energy intensity of different transportation modes recommended by the National Development and Reform Commission (Table 17) as well as passenger and freight turnover of each transportation mode, the author calculated the energy consumption of each transportation mode as shown in Table 18.

Table 17: Energy intensity of different transportation modes - Unit: Kg standard coal / 1000 people (tons) km

	railway	highway	waterway	civil aviation	pipeline
freight	7.46	56.7	9.4	341.0	7.8
passenger	8.04	11.37	9.4	48.9	0

Data source: NDRC (National Development and Reform Commission)

Table 18: Energy consumption of various modes of transportation - Unit: Ten thousand tons of standard coal

	railway	highway	waterway	civil aviation	pipeline
Passenger and cargo transportation	26.63	74.08	0	471.47	8.30

According to the ratio of energy consumption of each transportation mode to the total energy consumption (Beijing's total energy consumption in 2010 was 69,545,500 tons of standard coal), the air pollution share rate of Beijing's transportation system is 8.35%. At the same time, the death rate and disease incidence of Chinese residents (per millions of people) related to air pollution were obtained from “Branch of foreign medical geography” (Table 19); The willingness of all health effect terminals to pay was obtained from the world bank report "clear water and blue sky: a vision of China's environment in the 21st century"(Table 20); The concentration limit of PM₁₀ was obtained from environmental air quality standard (GB3095-1996) (Table 21).

Table 19: Air pollution-related deaths and illnesses per million Chinese residents

Health effects	Number of people(person)
The number of air pollution deaths per million people	463
The number of cases of chronic bronchitis per million people	639
Number of cases of acute bronchitis per million people	21 450
The number of respiratory hospitalizations per million people	161
The number of cardiovascular hospitalizations per million people	81
Number of internal medicine clinics per million people	11 084
Number of pediatric clinics per million people	1170
Number of asthma attacks per million people under the age of 15	4851
Number of asthma attacks per million people over the age of 15	224
The number of people aged 20 and over with limited mobility per million people	282 000

Data source: Branch of foreign medical geography.

Table 20: The willingness to pay of various health effect terminals

Health effect terminal	Willingness to pay (CNY)
Death rate (person)	501 060

Outpatient rate of respiratory diseases (case)	2372
Days with limited activity (days)	19
Asthma in children	109
Asthma	33
Chronic bronchitis	66 808

Data source: "Clear water and blue sky: A vision of China's environment in the 21st century" by the World Bank.

Table 21: The concentration limit of PM₁₀

	Time range	Primary standard	Secondary standard	Tertiary standard
PM ₁₀ concentration (µg/m ³)	The annual average	40	100	150
	The average daily	50	150	250

Data source: The Environmental Air Quality Standard (GB3095-1996).

In Table 21, the primary standard is the implementation standard of nature reserves, scenic spots and other areas requiring special protection; the secondary standard is the implementation standard of residential area, commercial, traffic and residential mixed area, cultural area, general industrial area and agricultural and forestry area; The tertiary standard is the implementation standard of special industrial zone. For the consumer price index, if the CPI in 1995 was 100, it was 142.7 in 2010. According to the above data and formula (2), it is calculated that the air pollution cost of Beijing's transportation system in 2010 is RMB 5,489,959,869.

3.4.4.3 The Negative Externalities of Traffic Accidents

According to the composition of negative externality of traffic accidents, the direct economic loss, the loss of labor value of casualties, the mental loss of casualties and the loss of social service institutions in 2010 are calculated respectively.

(1) Direct economic loss

According to the statistical yearbook of the Beijing municipal commission of transport, the direct economic loss from traffic accidents in Beijing in 2010 was 23.416 million CNY.

(2) Loss of labor value of casualties

According to the 2010 annual report of road traffic accident statistics, the number and rate of deaths of all ages in China's road transport sector can be found. Due to the lack of region-level statistical data and considering the similarity of a large number of random traffic accidents, the proportion of Beijing traffic accidents in the whole country was used to estimate the death toll and proportion of Beijing traffic accidents. According to this, we can calculate the loss of labour value of casualties in highway traffic department and the loss of average death of one person.

In 2010, there were 4,161 traffic accidents in Beijing, 4,703 people were injured and 974 people died. According to the GDP of Beijing in 2010 (1,377.79 billion CNY) and the resident population data of Beijing (196.19 million people) obtained from the sixth national census, the per capita GDP of Beijing in 2010 is calculated to be 702.51 million CNY. According to the above data, the loss of social labour value of traffic accident victims in 2010 was calculated, as shown in Table 22.

Table 22: Loss of social labor value of traffic accident victims in Beijing in 2010

Age group	Traffic death toll	Proportion	Total loss of labor capacity value (CNY)	Partial loss of labor capacity value (CNY)	Loss of output by one death in each age group (CNY)	Average loss by one death (CNY)
0~6	25	2.82%	3 091 044	263 441	94 596	1 566 117
7~9	9	0.90%	3 091 044	263 441	30 190	
10~12	6	0.63%	3 091 044	263 441	21 133	
13~15	12	1.17%	3 091 044	263 441	39 247	
16~20	51	5.22%	2 950 542	263 441	167 770	
21~25	80	8.19%	2 599 287	263 441	234 457	
26~30	76	7.82%	2 248 032	263 441	196 397	
31~35	89	9.11%	1 896 777	263 441	196 796	
36~40	108	11.04%	1 545 522	263 441	199 710	
41~45	114	11.69%	1 194 267	263 441	170 406	
46~50	91	9.33%	843 012	263 441	103 232	
51~55	79	8.07%	491 757	263 441	60 944	
56~60	74	7.54%	140 502	263 441	30 457	
61~65	50	5.14%	0	210 753	10 833	
≥65	110	11.33%	0	87 814	9949	

According to the average loss by one death and the number of traffic accident deaths, the total loss of traffic accident deaths in Beijing in 2010 was 1, 525, 397, 958 CNY.

(3) The emotional loss of the relatives of the casualties

The Beijing municipal government has the compensation standard for the mental loss of traffic accidents. Beijing's courts usually determine damages based on disability levels, the court divided 10 disability levels, with the minimum amount of compensation being 5,000 CNY and the maximum not exceeding 100,000 CNY. The calculation results show that the total cost of mental loss caused by traffic accident casualties in Beijing in 2010 is 223 882 510 CNY.

(4) The loss of social service institutions

According to the data of insurance company in 2010, the claim expense of each traffic accident is 400 CNY on average. According to the five departments of first aid, fire protection, public security inspection and insurance, each department takes a social organization to deal with the loss expense of each traffic accident is 400 CNY. It can be concluded that in 2010, the average loss cost of social institutions in each traffic accident was 2000 CNY. The total cost of the loss was 8,322,000 CNY.

Based on the calculation of the above four parts, it can be concluded that the total external cost of traffic accidents in Beijing in 2010 is 178,01,846.8 billion CNY.

3.4.4.4 The Negative Externalities of Noise Pollution

According to formula (3), the author collates the total noise cost and average cost of European transportation from the external cost of transportation published by the German Institute for Transport Policy and the Swiss INFRAS Research Institute (Table 23).

Table 23: Total noise cost and average cost of transport in Europe in 2010

		highway		railway		aviation	
		passenger	freight	passenger	freight	passenger	freight
2010	total cost (Million euros/year)	27 800	14 900	1480	1030	3190	362
	average cost (Euros/1000 people (tons) km)	5.8	6.8	4.1	4.4	2.4	13.0

In 2010, the average exchange rate of RMB against Euro was 8.9725, the population density of EU was 115.8 people/square kilometres, and the per capita GDP was 31 747.13 US dollars. Beijing had a population density of 1,195 people per square kilometre and a per capita GDP of \$10,800, so $\alpha_{pop}=10.32$, $\alpha_{GDP}=0.34$. According to the above data and formula (3), the average cost of noise pollution in Beijing's traffic system in 2010 was calculated as shown in Table 24.

Moreover, the passenger and freight turnover of different transportation modes was obtained from the 2011 Beijing statistical yearbook. According to this, the cost of noise pollution for each transportation mode in 2010 is equal to the product of average noise cost and passenger-freight turnover. The calculated result is shown in Table 25. Thus, the total cost of noise pollution in Beijing's transportation system is equal to the sum of the costs of five transportation modes, and the result is 11 702 271 516 CNY.

Table 24: The average cost of noise pollution in Beijing's traffic system in 2010 - Unit: CNY/person (ton) Km

	railway	highway	waterway	aviation	pipeline
freight	0.1291	0.2141	0	0.4093	0
passenger	0.1385	0.1826	0	0.0756	0

Table 25: The cost of noise pollution in Beijing's transportation system in 2010 - Unit: CNY

	railway	highway	aviation	Total
Passenger and freight	4 608 965 405	2 797 415 613	4 295 890 498	11 702 271 516

Note: The cost of noise pollution for waterway and pipeline is 0 in Beijing and is not shown.

3.4.4.5 The Negative Externalities of Greenhouse Effect

According to the calculation of calorific value, the emission factor of one ton of standard coal is 2.7725 tons. In 2010, the energy consumption of Beijing's transportation system was 11,048,400 tons of standard coal, among which the aviation allocation was 1,971,300 tons, which was converted into 5,465,400 tons of CO₂. Other types of transportation were 9,077,100 tons, and the folded CO₂ was 25.166,200 tons. According to formula (4) and the above data, the total cost of greenhouse effect is equal to 541,455,000 CNY.

In 2010, the negative externality of Beijing's transportation system is the sum of the above five costs, which is 57,405,229,603 CNY, accounting for 4.17% of Beijing's GDP in that year. The specific composition is shown in Table 26.

Table 26: The composition of negative externalities in Beijing traffic system in 2010 - Unit: 100 million CNY

	traffic con- gestion	air pollution	traffic acci- dent	noise pollu- tion	greenhouse effect	Total
External costs	378.91	54.90	17.81	117.02	5.41	574.05
As a percentage of GDP	2.75%	0.40%	0.13%	0.85%	0.04%	4.17%
As a percentage of to- tal cost	66.01%	9.56%	3.10%	20.38%	0.94%	100%

3.4.5 CONCLUSIONS

The case study shows that traffic congestion is the main source of negative externalities in Beijing's traffic system, which accounts for 66.01% of the total external costs. The second is noise pollution, whose negative externalities account for 20.38% of the total external costs. The third is air pollution, whose negative externalities account for 9.56% of the total external costs. The negative externalities of the above three factors account for 95.95% of the external costs of Beijing's traffic system, so they are the key areas of negative externalities governance in Beijing's traffic system. In particular, high priority in negative externality governance should be given to traffic congestion alleviation, which will make a major contribution to reducing the negative externality of Beijing's traffic system.

3.5 EUROPEAN CASE STUDY: ROAD CONGESTION COSTS IN ROME

3.5.1 INTRODUCTION

Congestion can be defined as a situation in which, given a certain infrastructure capacity, the traffic density is such to undermine the smooth circulation of vehicles and therefore, among the various effects it produces, it basically determines an increase in travel times for users.

The assessment of congestion costs, associates to the acknowledgment that cities are increasingly facing problems caused by traffic jam, has therefore gained the status of being a common challenge for all major cities in Europe. Estimates, though, are extremely uncertain and subjected to a wide range of evaluations. For example, congestion in the EU is estimated to reach costs nearly EUR 100 billion, or 1 % of the EU's GDP, annually⁴.

On the other hand, evaluations from the database INRIX (2016) across 19 countries in Europe, showed a total economic impact of the traffic hotspots identified in about £183.2 billion (€211 billion) over the next decade. Due to the significant presence of very large and highly dense cities, the UK faced the greatest cost (£61.8 billion) followed by Germany (£41.9 billion).

The causes of an increase in travel times and therefore in the level of congestion can be considered of heterogenic nature. Basically, the causes can be divided into two categories: occasional and recurring. The former category (strikes, extreme weather events, etc.) is not considered in the analysis of the external costs of congestion because of the unpredictability of the key components.

On the other hand, the latter category is of interest in the context of the assessment of congestion costs, because their components determine situations of recurring and systematic traffic congestion episodes, as bottlenecks at given junctions due to excess of traffic flows.

In this case study, the focus is on congestion costs arising from road transport, in which there is in principle a free-entrance of additional vehicles imposing costs to the others. Congestion costs in other transport modes (e.g. air and rail), in which scheduled services prevent others to add transport services, are not considered. In such a case, more than congestion costs we are facing scarcity costs, in which there are opportunity costs for service providers due to the non-availability of slots.

In general, the impacts of congestion can be grouped into five main classes:

1. impacts on journey times, including waiting and access times;
2. impacts on the safety level of the infrastructure (the degree of saturation determines the average speed, other than the general degree of infrastructure security);
3. effects on the environment (higher emissions of pollutants attributable to driving conditions defined as “stop and go”);
4. effects on the operating costs of means of transport;
5. effects on users in terms of psycho-physical stress, which are nevertheless difficult to monetize.

Not all the above five classes of impacts are considered in this case study.

- The classes of impacts 2 and 3 concern respectively with safety and environmental implications from road congestion. In both cases, the evaluations are uncertain; reduction of congestion, increasing the average speed, may increase traffic casualties, which, according to

⁴ https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en

some estimates, appears to offset 5-10% of congestion reduction benefits (Litman, 2019). Concerning environmental impacts, depending on the speed-fuel efficiency curves adopted, the relationships between fuel consumption and speed may lead to higher or lower emissions.

- The class 4, the effects of road congestion on vehicle operating costs, such as higher deterioration, can be considered as internal to the user's decision to use the road infrastructure and therefore not included in the congestion external costs.
- The class 5 on the user's psycho-physical distress due to congestion, is not easy to quantify and literature on the matter is not consolidated.

In conclusion, the most relevant class of impact is the class 1, which includes the impacts on journey times, affecting both passenger and freight sector. In terms of IPA description, Figure XI depicts with red arrows the resulting causal-effects relationships examined in this case study.

The transport activity to be considered is the increase of traffic flows resulting from the individual user's decision to use car/road public transport/road freight haulage, in order to serve its mobility needs. These decisions collectively change the speed-flow functions on specific routes and more in general affecting the urban area mobility. The negative externality addressed is a reduction in the average journeys travel times.

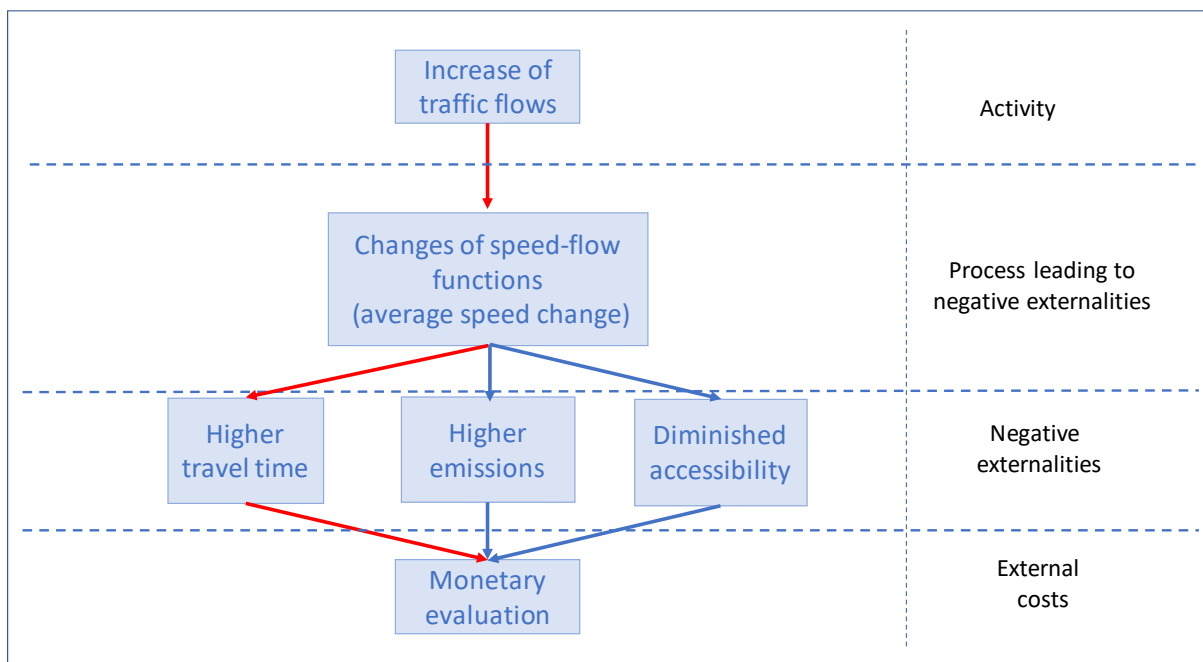


Figure XI: The impact pathway of road congestion costs in Rome

The next sections consider the prevailing approaches for measuring the impacts in monetary terms and the corresponding results.

3.5.2 METHODS FOR THE ASSESSMENT OF CONGESTION COSTS

In order to measure road congestion costs, two approaches are available: delay cost and deadweight loss (CE DELFT, 2019). Though further differences in data requirement and evaluation tools may be found depending on the analysis by urban size or spatial scope (urban or inter-urban areas), focussing on the two approaches allows to stress different interpretations of the evaluation of congestion costs, as far as basic assumptions and usability of results are concerned.

Figure XII shows a useful diagram to understand the rationale of the two approaches. Concerning the **delay cost** approach, the cost of travel is equal to p_0 in which traffic situation is characterised by free-flow condition (until q_0 , in the point F). After that, in presence of a major flow, the speed starts reducing, travel time increases, and consequently the average travel cost borne by the road users increases according to the shape of the private cost function (q), until it meets the demand curve of usage of the road link (q) in the point A⁵. The delay cost approach defines the road congestion cost as the value of the travel time lost relative to a free-flow situation. In the below figure, the delay cost corresponds to the rectangle p_0EAp_1 .

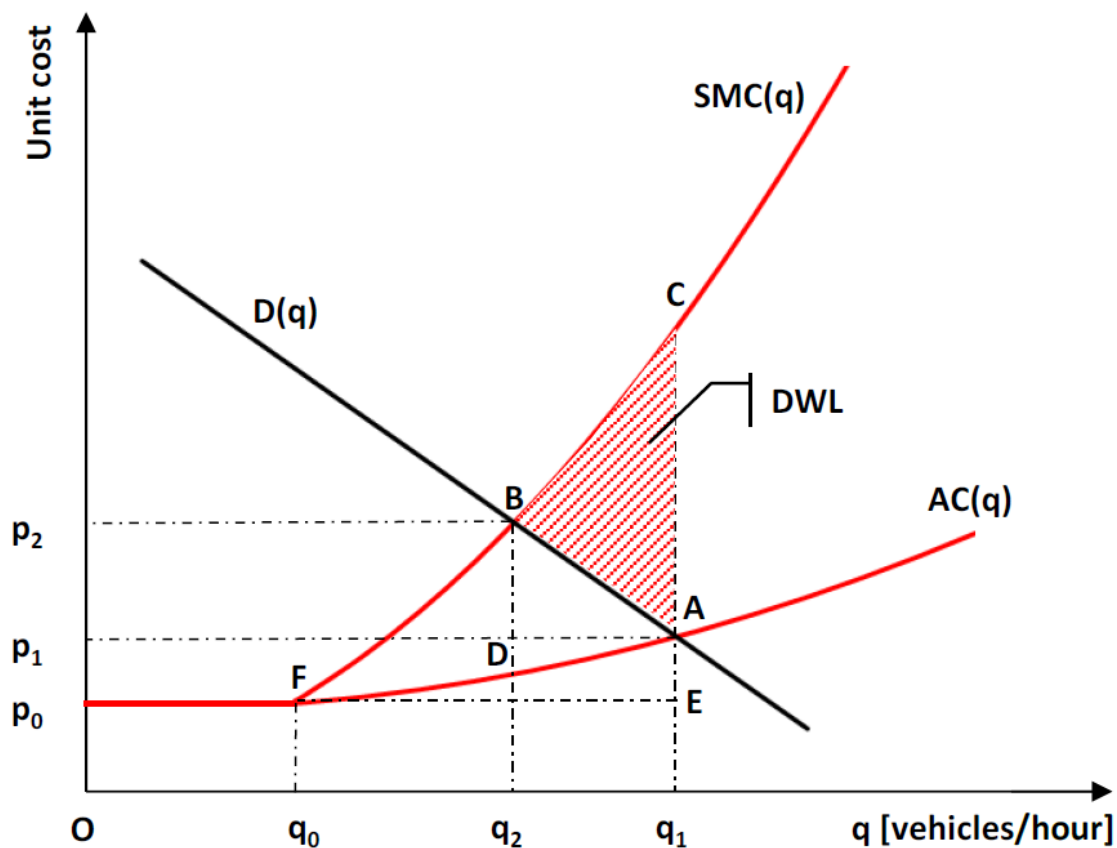


Figure XII: Conceptualisation of road congestion costs – delay cost and deadweight loss -

Concerning the **deadweight loss** approach, Figure XII shows the function $SM(q)$, which represents the social marginal cost function, that is equal to the average travel cost borne by the road users $AC(q)$,

⁵ The demand curve is estimated using demand elasticity parameters, e.g. a measure of the relationship between a change in the transport demand (i.e. the number of trips by car) and a change in the related cost (in this case the private cost per trip). As an example, a value of the elasticity parameter of -0.5 means that an increase of cost by 20% is reflected in a decrease of transport demand by -10%.

from the point F, as soon as traffic flows start to cause delays, plus the cost of the additional travel time, generated by the marginal vehicle that reduces the speed of all the other vehicles.

In such a way, the deadweight loss approach enables to determine the economically optimal solution (i.e., the point *B* where the demand function and the social marginal cost function meet). According to this approach, the external cost of congestion is given by the demand in excess with respect to q_2 and the triangle *ABC* is the so-called 'deadweight loss' (i.e., DWL).

The conceptualisation of the two approaches, i.e. the delay costs based on total congestion costs and the deadweight loss approach based on the social congestion costs, makes clear why the latter approach can be used in the specific perspective of transport pricing; to the extent that it takes into account of the impacts on delays caused by an additional vehicle entering in the traffic.

The next two sections better specify the assumptions behind the two approaches.

3.5.2.1 The delay cost approach

As seen in Figure XII, the meaning of the private cost curve $AC(q)$ is to reflect the monetary cost of driving time, namely the travel time under average conditions. The time cost of driving increases as the average speed falls, i.e. as the traffic flow increases. The private cost curve is shaped as a non-linear speed-flow function, of which the key components are the following:

$$T = T_0 \cdot (1 + ParA \cdot r^{ParB})$$

Where:

- T is the actual travel time;
- T_0 is the travel time in free flow conditions;
- r is the flow/capacity ratio;
- $ParA$ and $ParB$ are parameters of the function.

From engineering studies, different speed-flow functions have been implemented in order to differentiate between the road types (i.e., trunk urban road, other urban road, motorway and other non-urban roads).

Traffic engineers describe free flow or speed limits also as level-of-service (LOS) in terms of vehicle per hour that a specific road is able to carry. As traffic speeds increase so does the space required between vehicles for a given level of driver effort and safety. For example, main trunk urban roads capacity tends to peak at 50-60 vkm/hour, in other urban road at 30-40 vkm/hour.

In general, the specific composition of road types in a given urban area, i.e. the share of trunk roads, may lead to the determination of a representative (average) flow/capacity ratio, and therefore the specific average speed under free-flow conditions.

3.5.2.2 The deadweight loss approach

Figure XII shows that the deadweight loss (the DWL area) can be calculated as the difference between the private cost curve (q) and the social cost curve ($S(q)$). In terms of economic meaning, the function (q) represents the social marginal cost function, in which the private cost $AC(q)$ is added to the cost of the additional travel time generated by the marginal vehicle that reduces the speed of all the other vehicles.

It is important to stress that in order to calculate social cost curve ($S(q)$), the overall transport activity (a mix of several vehicles with different demand and elasticities) should be taken into account.

The value of time per vehicle is highly variable across vehicle types because of different occupancy (e.g. a car vs. a coach) and because the value of time of passengers and goods is different. Therefore, the curve representing the marginal social costs can only be a sort of average, which will be hardly representative of any real user.

Additionally, for the sake of consistency, the estimation of the deadweight loss should be based on the same cost curves used to estimate the marginal social cost. Then, also a demand curve would be needed. If the curve of the marginal social cost is a sort of average, also the demand curve should be a sort of average. However, again, different vehicle types have different demand curves because they have different elasticities. So, again, the representativeness of an average demand curve would be limited.

Having stressed the limitation in calculating a realistic social cost curve ($S(q)$), its components are the following:

$$dSCdq = AC(q) + q \cdot dAC(q) dq$$

Where, the first term is the 'private cost' of a single vehicle, while the second term is the external cost borne by the other users already in the flow due to the additional vehicle.

Including this external cost element, which is not considered by the single user, the social marginal cost curve is the relevant decision base, in particular for charging purposes. The point B (q_2 ; p_2), in Figure XII, is where the functions (q) and ($S(q)$) meet, representing the optimal solution. Indeed, beyond that point, any additional vehicle generates a social cost higher than the social benefit.

3.5.2.3 The approach adopted in this case study

Considering the complexities in calculating congestion curves under the deadweight loss approach, this case study adopts the delay cost approach, which allows the estimation of congestion costs considering the traffic as a whole, and so using average curves.

Besides, under the delay cost approach, the case study considers who incurs in congestion rather than who generates congestion. This approach allows to take into account differences in values of time (and elasticity of demand). These differences explain why costs are different across vehicle types, even if there is no any reference to the effect of a given type to social costs. Furthermore, this approach does not need to compute 'average' cost demand curves representing all different vehicle types.

3.5.3 MEASUREMENT OF CONGESTION COSTS

Data requirements and key variables for the estimation of congestion costs according to a simplified application of the delay cost approach are shown in Figure XIII.

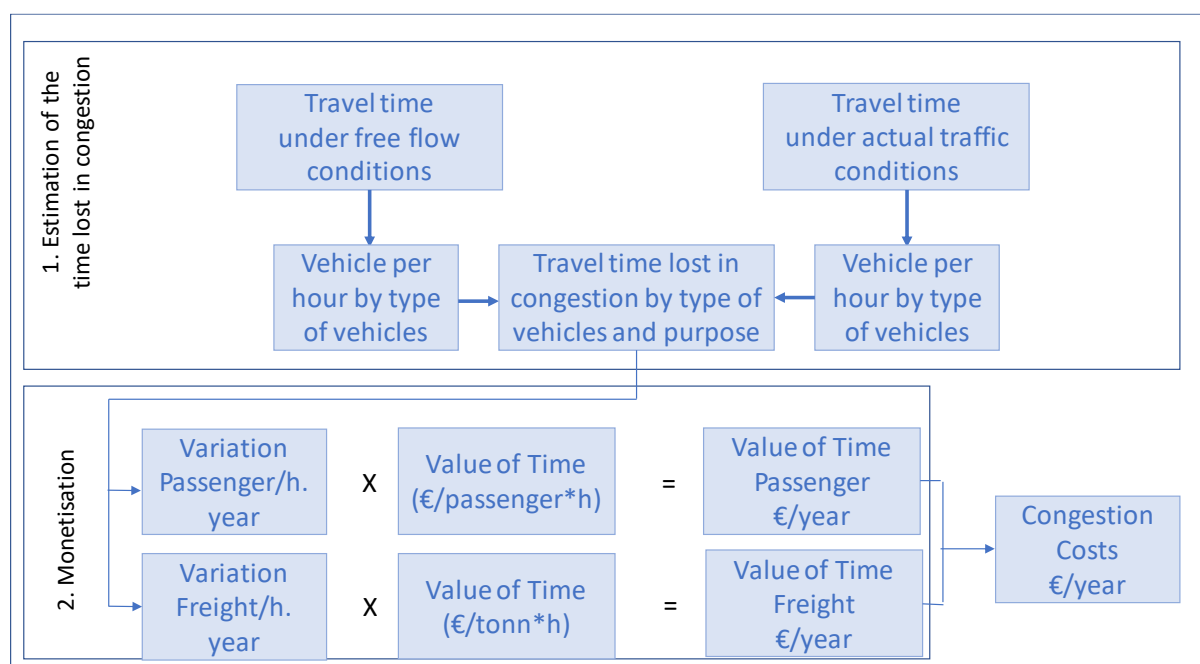


Figure XIII: Main steps in the calculation of congestion costs – delay cost approach -

The calculation implies two stages:

1. The estimation of travel time lost in congestion;
2. The monetization of time costs for passenger and freight sectors.

1. Estimation of the travel time lost in congestion

The first stage in estimating congestion costs concerns with the global assessment of travel times lost in congestion for the main categories of users involved, e.g. passengers and freight operators. This estimate may come from an assessment of the time lost due to congestion resulting from surveys at local or regional levels involving transport users during peak times, or from the generalization at urban level of time lost from traffic monitoring of key bottlenecks. In any case, the assessment should allow to evaluate:

- for each road transport mode (private, public), the travel times lost, inclusive of any congestion cause, with respect to free or scheduled outflow times;
- the type of traffic affected by delays, specified as follows:
 - passenger traffic for work reasons (passengers / year);
 - passenger traffic for commuting reasons (passengers / year);
 - leisure passenger traffic (passengers / year);
 - goods traffic (light and heavy (> 3.5 ton.) vehicles (/ year).

If such a disaggregation would not be available, it is possible to use the results of studies carried out at European level with particular reference to classification by trip purpose (leisure, working and others). For example, the European research project UNITE (UNITE, 2001) estimated the following subdivision passenger trip purpose by mode of transport.

	Car	Train
Business	18%	6%
Commuting	33%	71%
Other (Leisure)	49%	23%

In general, as already mentioned, traffic situation and the relative travel times lost in congestion can be analysed both at link level / node of the network, by origin-destination relationships, or estimated at urban level through surveys.

The final result compares average travel time under free flow condition, i.e. before congestion episodes happen, and average travel time “after” congestion. The resulting time lost, per vehicle (passenger or freight) can be expressed in minutes or hours per annum.

2. Monetization of time costs for passenger and freight sectors

The monetization of travel times in the second stage is carried out by multiplying the expected variations in time lost (passengers * hour or tons * hour or vehicles * hour comparing travel times before and after congestion), as estimated in the first stage of the calculation, by the following parameters, all concerning with Value of Time (VOT) evaluations. Namely:

1. value of working time;
2. leisure;
3. value of commuter time;
4. value of the time of goods.

Value of working time (or production loss). It means the working time in the strict sense, or rather the actual working activity, therefore excluding the time used for moving from the home to the workplace (and the other way around). As a parameter used for monetisation of time value, it is considered appropriate to consider the *average industrial cost of labour*, measuring in that the marginal productivity of work, or, in other words, its cost opportunity.

Value of free time (leisure). Travel times time spent in queues and traffic jams in activities not connected to work, obviously do not affect production, but, with reference to the management and enjoyment of time available for leisure, they may cause a loss of well-being, at least equal to the value attributable to free time. As a proxy of the monetary value of leisure, or the loss of well-being (and the willingness to pay for a decrease in congestion during own activities of leisure time) it can be considered the national *per capita consumption value*, expressed in hour.

Commuter time value. Congestion episodes in daily transfers to and from work and study sites, do not directly affect production level, which must be anyway guaranteed by the worker in the course of working time. However, they can have repercussions on work activity either regarding productivity during working hours, which could be affected by the stress suffered during the transfer, and because

it can generate distortions in the supply of work force. The presence of congestion episodes can in fact affect the willingness to offer work performance under certain conditions. It is believed that the willingness to pay for the one-hour reduction in travel time to and from the workplace is therefore greater than that relating to leisure and that its monetary value can be compared to one hour of work. For these reasons, it is considered that a proxy of the monetary value of the time for travel to or from the workplace, can be monetized using the *national average hourly wages*.

Examples of the variables used in the VOT assessment with reference to the Italian national statistics (year 2005) are the following:

Table 27: Monetisation of VOT in the Rome case study

Variable	Unit of measure	Value
Population	n.	58729130
Labour costs (gross value)	€mil	578238
Salary labour costs (net value)	€mil	279717
National consumption	€mil	1121633
Per capita consumption	€	19908
Number of employees	thousands	17213
Working days per year	n.	225
Working hours per day	n.	8
Working hours per year	n.	1800
Non-working hours per year (workers)	n.	4040
Non-working hours per year (non-workers)	n.	5840
Share workers/non workers	%	41.4
Leisure time available (per capita)	n.	5094
Average industrial cost of labour	€	18,6
National average hourly wages	€	9,03
Per capita consumption value	€	3,75

Source: Ministero delle Infrastrutture, Quaderni del PON, 2005

Time value of goods. Concerning the freight sector, the VOT evaluation is based on the results prepared by the studies carried out at European and Community level. The methodologies analysed for the monetization of the value of time for goods, in the case of road vehicles, consider a total hourly cost per vehicle, including the value of the goods and the driver's salary, between 37 and 43 euros. In particular, UNITE uses 47.0 Euros for light goods vehicles (LGV, total weight at full load <12 t) and 50.52 Euro for heavy (HGV, total weight at full load > 12 t), with an average of 48.76 Euro (values shown at 2005 prices).

From the methodological point of view, it is important to stress that national VOT can be used to transfer evaluations in different contexts, as a long tradition of EU studies testifies. For example, data for UK (ARUP, 2015). have been used to estimate values for the other countries based on GDP per capita (PPP adjusted) by country. Values of time for coach passengers have been found about 48% lower than the value of time of long-distance car passengers. For coaches, the VOT of the driver has been considered on the basis of the data available from Comité National Routier (2016) by country.

More specifically, the values for road modes have been used (tonne per hour), assuming the average load factor by country for heavy duty vehicles (e.g. about 13.6 tonnes per vehicle for HGV on average in EU28 countries and 0.7 tonnes per vehicle for LCV) and the VOT of the driver has been added to the estimation in order to measure the VOT per vehicle. For LCV it has been assumed that the VOT of the driver is lower than for HGV, assuming a lower cost of labour due to lower skills requested. The GDP deflator has been applied to update all the values to Euro 2016.

3.5.3.1 Application of the methodology in the case of Rome

This section shows the application of the methodology for the measurement of congestion costs in the city of Rome. With 2.8 million of inhabitants and the higher number of circulating vehicles per inhabitants in Italy (81 circulating vehicles per 100 inhabitants, year 2018⁶), the assessment of congestion costs is of particular interest and socio-economic relevance.

The procedure of assessment is based on the methodology illustrated in Figure XIII, distinguishing two stages: 1) assessment of the time spent in congestion and 2) monetisation of the delays.

The estimation of the time lost in congestion requires the following information:

- Average of travel time by purpose of the journey;
- Allocation of travel time by type of vehicle;
- Assessment of the time spent due to congestion episodes;
- Allocation of the time spent in congestion by purpose of the journey.

The average travel time by purpose of the journey can be derived from national statistics and surveys, carried out at local or regional/national level. In case local surveys were not available, information collected in different contexts can be assumed. In Italy, for example, the analysis of the average travel time in urban areas higher than 50,000 inhabitants, provides the following results (average travel time in minutes by purpose of journey (work-study or leisure) per passenger:

Work/study	45 min.
Other	80 min.
Total	125 min.

The allocation of travel time by type of vehicle is directly correlated with the traffic volume (in passenger * km) attributable to each type of vehicle. In the city of Rome, the following information have been assumed:

	Number of Vehicles	Average km/day	Passenger per vehicle	Volume (vkm)
Car (1)	1.759.601	10	1,7	17.596.010
Motorcycle	394.871	5	1	1.974.355
Bus (2)	2.653	61	70	162.500

⁶ Automobile Club Italia, <http://www.opv.aci.it/WEBDMCircolante/> 2018)

	Number of Vehicles	Average km/day	Passenger per vehicle	Volume (vkm)
Freight (3)	141.165	10	1,5	1.411.650
Total	2.298.290			21.144.515

(1) ACI, 2019

(2) Circulating bus, ATAC, La mobilità a Roma, 2016

(3) Data includes HGV (High Duty Vehicles) > 3.5 ton. and LCV (Light Commercial Vehicles), lower than 3.5 ton. The average composition has been estimated in Rome as 43% HGV and 57% LCV, from Comune di Roma, Piano Urbano Mobilità Sostenibile, 2019

In terms of contribution to congestion, the impacts of motorcycles has been considered equal to 0 and the contribution of car, bus and freight vehicles has been assumed multiplying the total vkms by the Passenger Car Equivalent coefficient (PCEs) of each vehicle type: car equal to 1, 2 for HGV and bus, 1.5 for light freight vehicles.

In total, the contribution of cars to congestion is equal to 86.5%, bus of 1,6%, HGV 6% and LCV of 5.9%.

The assessment of time spent due to congestion by transport mode is based on a national survey regularly carried out by ISFORT (2018). According to the survey the perceived average speed of transport modes in urban areas is 26 km/h for car and 14,7 km/h for bus. Assuming the average speed of 20,3 km/h and comparing this perceived average speed with the free-flow average speed of 25 km/h, we can assume that 18,6% of time spent in travelling ($25-20,3/25$) is spent during congestion.

According to these estimates, the per capita annual hours spent during congestion in Rome in 2018 were equal to **127,9**.

The second stage of the methodology is the monetization of travel time. Reference data are shown in Table 27, with reference to year 2005. Using the GDP deflator to update data to Euro 2018, the following unitary (per hour) VOT can be considered:

Value Of Time	€/h per ton/passenger 2018
VOT Freight (HGV)	63,2
VOT Freight (LCV)	58,8
VOT working time (production loss)	23,3
VOT commuting	11,3
VOT leisure	4,7

Applying the VOT monetary evaluation to the total average hours lost in congestion and the share of transport mode contribution to congestion, result in the following table. It is worthwhile to stress the important role of freight distribution (in particular light commercial vehicles) as source of congestion in Rome.

Table 28: Congestion costs in Rome

Transport mode	€ M 2018
----------------	----------

Car	2.504,562
Bus	59,669
LCV	1.273,821
HGV	0,345
Total	3.838,398

The comparison of these results with other studies focused on congestion costs may be useful to stress the extreme uncertainties underpinning the evaluations and to provide some insights on the order of magnitude of the external costs of congestion.

Table 29: Congestion costs in Rome: comparison of recent studies

	Congestion Costs € billion	Hours lost per annum million
2007 (1)	1,4	n.a
2009 (2)	10,3	n.a
2009 (3)	1,5	135
2009 (4)	n.a	252
2012 (5)	2,3	249
2018	3,8	365

- (1) AAVV, Città mobile, Rapporto Cittalia, 2007
- (2) G. Citterelli, F.Grillo, Vision & Value, Obiettivo: città senza auto. La misurazione del problema e l'idea del flexible congestion charge
- (3) Comune di Roma, Piano Strategico Mobilità Sostenibile, 2009
- (4) ACI, 2009
- (5) Fondazione Caracciolo, elaborations based on TomTom dataset, 2012

Table 29 shows that, despite the different methodologies underpinning the studies, the emerging key trend is the progressive worsening of hours lost in congestion in the city of Rome over the past 10 years.

3.5.1 CONCLUSIONS

The Rome case study shows limits and potentiality in using simplified approaches in the assessment of external costs of congestion.

We have seen that the assessment of congestion costs requires a great amount of information as well as complex elaborations, in particular if the deadweight loss approach is considered, both in terms of calculation (i.e., iterative transport modelling processes, demand curves for each type of vehicles and users) and interpretation of results (i.e. the determination of the cost -charge- necessary to reach the social optimum equilibrium).

The adoption of less demanding approaches (as the delay costs) may be undertaken at costs of diminishing expectations in terms of interpretation of results. Indeed, congestion costs according to the delay approach, as those estimated in the present case study, consider the total (or average) costs imposed on the drivers and passengers of the vehicles, i.e. it is an estimation of the costs to those incurred in congestion episodes, rather than the costs imposed to the others generated by the additional vehicle entering in the traffic. This last type of congestion cost is estimated in the deadweight loss approach, which can therefore be considered as a proper estimation of the external marginal congestion costs.

On the other hand, considering the traffic as a whole and using average delay costs, make the generalisation and transferability of results less problematic.

In such a case, the major sources of uncertainty in the proposed methodologies relies in the relative value of congested or crowded time as opposed to the "normal" travel time, which is not known. Therefore, a sensitivity test concerning the value of time is required.

This case study shows that the value transfer approach may be used for the transferability of VOT, given that proper conversion factors are used, e.g. GDP deflator or valued adjusted for Purchasing Power Parity in case of transferability among countries of different geographical areas.

4 COMPARING THE CHINESE AND EUROPEAN EXPERIENCES: RECOMMENDATIONS FOR THE UPTAKE OF SCBA IN URBAN PLANNING AND GOVERNANCE

The comparison of IPAs in OECD/EU and China reflects the different degree of development of SCBA applied to urbanisation activities, leading, in the Chinese cases, to a general undersized provision of monetary evaluations.

Besides, in the OECD/EU experience, IPAs tend to address overarching land use policies as the development of urban forms (sprawled vs compacted) or the implications of land take and loss of arable land (loss of ecosystem services). The identification of the key drivers leading to externalities is associated with the quantification of the negative external effects and the affected end points, paving the way to the internalisation of such effects in urban planning and land management policies.

On the other hand, the Chinese experience focuses on specific aspects of urbanisation activities, in particular the side-effects from rapid urbanisation growth on the quality of life of residents in urban areas (traffic congestion and air pollution, public services provision). Strategic policy options, such as urbanisation and rural-urban relationships and implications of the Chinese version of urban sprawl (urban fragmentation, unbalanced growth of urban land in peri-urban areas) are generally not supported by SCBA evaluations.

As already stressed, the analysis of Chinese examples of IPAs has pointed out the lack of quantifications of external effects. The conversion of side-effects to monetary evaluations is not available and therefore the IPA reaches in general the stage of the identification of the process (the cause) and the effects (negative externalities and end-points), without the monetary evaluations of external effects.

However, the provision of indicators quantifying the impacts of external effects (e.g. soil organic and mineral losses, outbreak of pathogenic bacteria in water, animal migration, invasion of alien species, etc.) makes the economic quantification potentially viable, provided that scientific advancements and the developments of evaluations guidelines are made available. From this point of view, the insights from the OECD/EU more consolidated tradition may be of help, with particular reference to the methodology for the monetary evaluation of ecosystem services.

The comparison of OECD/EU and Chinese externalities from transportation activities allows to depict a different picture, indicating the potential contribution that methods and guidelines developed in the OECD/EU tradition can provide to the application of SCBA in urban management and planning in China.

The case studies on the evaluation of congestion costs in Rome and Beijing indeed, show similarities in the underlying methodologies, as indicated in Table 30. The table shows a similar approach concerning the identification of the key components of the road congestion costs formula: time spent in congestion and monetization of the value of time. However, in the case of Rome, the inclusion of the freight sector contribution to congestion and a more complex composition of the factors determining the value of time represent the key methodological differences.

Incidentally, the inclusion of freight sector and a different assessment of VOT may explain the wide difference in per capita values of congestion costs: €1650 in the case of Rome and €260 in the case of Beijing (values at €2010)⁷.

Table 30: Comparison of methodological approaches in the quantification of congestion costs in Rome and Beijing

Methodology	Rome	Beijing
Congestion costs assessment formula (simplified approach)	$C_{\text{congestion}} = \text{Var}_{t(p/f)} \times V_{t(p/f)}$ where $\text{Var}_{t(p/f)}$ is estimation of travel time lost in congestion and $V_{t(p/f)}$ is monetization of time costs for passenger and freight sectors.	$C_{\text{congestion}} = (T_p - T_q) \times V_t \times L \times \epsilon$ where $(T_p - T_q)$ represents the maximum travel time that can be tolerated and T_p represents the average travel time of a particular mode of travel and V_t is the traveler's unit time value. L is the average daily travel volume; ϵ is a parameter equal to 1.
Quantification of time spent in congestion	Local survey in Beijing	National survey
Monetisation of time (Value Of Time)	Hourly Per capita average industrial cost of labour, wages and leisure time, depending on the component used for the VOT monetisation (production loss, commuter time, and free time). Per ton average value of goods by vehicle type (light and heavy good vehicle).	Per capita hourly GDP unit in Beijing.

The Chinese case study also allows to elicit insights on the potential of cross-referencing OECD-EU methodologies (transferability) for the evaluation of external costs of transport.

- Concerning the quantification of climate change costs, the Chinese methodology assumes as shadow price of CO₂ emissions the carbon tax, against the EU approach of using the avoidance cost approach, based on the target agreed in the Paris Agreement. Pondering over pros and cons of the two approaches could lead to different quantifications and toward a better assessment of climate change costs.
- Concerning the quantification of noise costs, the application of the benefit transfer approach (unit value transfer, adjusted for differences in income levels between the two sites -using GDP per capita- and/or differences in the costs of living -using Purchase Power Parity indices-), has been used for the calculation of noise costs. The formula $C_{\text{Beijing-ij}} = C_{\text{EU-ij}} \times \alpha_{\text{pop}} \times \alpha_{\text{GDP}}$, $C_{\text{EU-ij}}$ is based on the average noise cost in Europe $C_{\text{EU-ij}}$; α_{pop} is the population-adjusted factor ratio, which is equal to the ratio of population density of Beijing and EU; α_{GDP} is the adjusted ratio of GDP per capita, which is equal to the ratio of Beijing's per capita GDP and EU's per capita GDP.

⁷ For instance, the different methodologies in the evaluation of VOT lead to an average VOT of €/hour 13.1 for the passenger sector and €/hour 61 for the freight sector, against €/hour 2.5 in the case of Beijing, assuming no conversion for PPP)

The transition to socially integrative cities, whose concept has been defined in the TRANS-URBAN-EU-CHINA D3.1, may be supported through the exploitation of the potential for transferability of OECD/EU SCBA methods and tools in the Chinese urbanisation practices.

Table 31 specifies which and why of the 12 priorities defining socially integrative cities characteristics may benefit from the utilisation of SCBA contributions. The analysis distinguishes direct contributions, i.e. for which the SCBA insights are relevant, and indirect contributions, for which SCBA insights may need accompanying policies and initiatives to be fully effective. It is worthwhile to note that there are priorities for which SCBA contribution is limited, if not null.

Table 31: The contribution of SCBA to the transition to socially integrative cities in EU and China

Characteristics and priorities of the socially integrative cities	Contribution of the SCBA insights applied to urbanisation activities
Collaborative urban planning and design	
4. Reducing urban sprawl and promoting well-balanced land conversion from “rural” to “urban” and appropriate access to urban land.	Direct. The internalisation of externalities, e.g. natural resource management, environmental protection and regional transportation, would ultimately lead to a more efficient use of land, raising its price and compensations to farmers. The increased values of land could limit conversion from “rural” to “urban” in particular around urban fringes, reducing urban sprawl.
5. Involving the different stakeholders in collaborative and participative planning and design processes on the different politico-administrative levels.	Indirect. SCBA applied to the evaluation of eco-systems may need new approaches in decision making processes, reflecting views and values of multiple stakeholders. The evaluation of biodiversity, landscape beauty, cultural heritages imply evaluation methods which can address specific contexts at local level, indirectly paving the way to the involvement of local stakeholder preferences in land use and urban planning decisions.
Urban environment and living conditions	
6. Improving the environment and living conditions in urban areas	Direct. Externalities caused by the interaction between transportation activities and the environment, human capital and other non-renewable resources represent a key factor in affecting living conditions in urban areas. The application of SCBA in the assessment of the costs of accidents, noise and air pollution emissions, congestion and greenhouse effects may provide a direct contribution to the design of sustainable transport policies.
4. Upgrading the physical environment in distressed areas	Indirect. SCBA methodologies may provide an indirect contribution to improving built environment in distressed urban areas, for example through the evaluation of citizens preferences and willingness to pay for green spaces and infrastructure.
5. Promoting efficient and affordable urban transport	Direct. SCBA insights on the relationships between urban transport costs variability and urban configuration, e.g. urban sprawl vs compacted cities, represent a knowledge base with a direct contribution to major efficiency and affordability of urban transport services.

Characteristics and priorities of the socially integrative cities	Contribution of the SCBA insights applied to urbanisation activities
6. Assuring equal access to municipal services	Indirect. Urban forms affect the provision (in quality and quantity) of public services; in particular those for which density represents an important factor influencing service costs and performances (e.g. waste management). SCBA applied to the analysis of the performance of public services in different urban areas may provide an indirect contribution to improve accessibility.
Local economy and labour market	
7. Strengthening the local economy and labour market	Limited. Minor and uncertain impacts are expected with reference to labour market and local economy in presence of application of SCBA to urbanisation activities.
8. Strengthening (technical and social) innovation in cities and neighbourhoods opening up new possibilities for the local population.	Limited. As for the impacts on local economy, it's difficult to elicit likely impacts of SCBA on technical or social innovation in neighbourhoods.
Socio-cultural development and social capital	
10. Fostering proactive education and training policies for children and young people in disadvantaged neighbourhoods	Limited. Impacts of SCBA on training policies for disadvantaged people in urban areas are limited and of difficult evaluations.
10. Preserving cultural heritage and fostering the identity of neighbourhoods and their inhabitants	Direct. One of the fields of application of SCBA methodologies and tools concerns with the evaluation of eco-systems. Therefore, direct contributions to the evaluation and preservation of cultural heritage may derive from methodologies of evaluation that involve local stakeholder preferences and attitudes.
11. Fostering social capital and engagement of local stakeholders	Indirect. Fostering social capital in terms of empowering of local communities' identity and values may found an indirect contribution from the application of SCBA methodology in the evaluation of eco-systems assets.
Institutional development and urban finance	
13. Supporting adequate institutional and financial conditions and mechanisms	Indirect. To the extent to which SCBA leads to raising land price in urban fringe, indirect contributions towards changes of the public finance system could be expected. In particular, changes in land value may support the reduction of the dependency of local governments on land conversation and land auctioning as a major local tax base.

In sum, the application of SCBA to urban planning and management turns out to be relevant in favouring collaborative urban planning and in improving urban environment and quality of life. Due the implications on land value, SCBA may have indirect impacts on urban finance as well.

5 OUTLOOK AND FURTHER STEPS

In chapter 2, literature review concerning OECD/EU case studies and contributions on SCBA applied to urbanisation activities has shown a vivid knowledge base of heterogenic applications, addressing by the others urban forms and transportation activities, eco-systems and quality of life. Questioning what type of contributions and methodologies could be better amenable to be used in terms of cross-fertilisation between EU and China, ensuring generalisation and transferability of results, the answer has indicated those contributions developed in form of Handbooks and guidelines, as the EU Handbook for the calculation of external costs of transport.

Using the analytical framework of the impact pathways approach, in chapter 3 the analysis of Chinese and OECD/EU applications of SCBA to urbanisation activities has shown that there are still many deficiencies in the analysis and quantification of negative externalities from transport in China, despite notable exceptions discussed in the Chinese case study, and that, as consequence, this can be considered as a key area that needs to be strengthened in further research.

In order to test the potential of cross-fertilisation between EU and China methodologies, an interaction with local stakeholders can be developed within the framework of next Urban Living Labs (ULLs).

To this end, the ULL feedback to the following three questions could be of particular interest:

- Methodology and indicators for the evaluation of external costs of transport – potential for knowledge transfer - (question 1)
- What the implications for data collection (question 2)
- Which institutions can better preside over SCBA assessment (question 3)?

For each question, the next boxes show a brief introduction and the indication of the key category of stakeholders potentially involved in the ULLs.

Question 1: Methodology and indicators for the evaluation of external costs of transport – potential for knowledge transfer.

In China, transportation is becoming one of the main areas where externalities (especially negative externalities) occur. Air pollution and congestion are posing a challenge for urban areas in China.

The analysis of SCBA in OECD countries shows the following seven application fields, for which examples of indicators and methodologies are available, even if at different degrees of exhaustiveness:

1. **Air pollution**, e.g. emission rates, health impacts on human being, material and building damages, biodiversity loss, monetary evaluation of impacts, concentration-response functions, etc.;
2. **Accidents**, e.g. material costs (e.g. damages to vehicles, administrative costs and medical costs) and immaterial costs (e.g. shorter lifetimes, suffering, pain and sorrow, etc.;
3. **Noise**; e.g. physical or psychological harm to humans, health endpoints, noises during day, evening and night times, etc.;
4. **Climate change**. e.g. damage and avoidance costs, greenhouse gases composition: CO₂, N₂O and CH₄ (methane), assumptions and GHG emissions per vehicle category, etc.;
5. **Costs of well-to-tank emissions**, e.g. energy production ('pre-combustion') processes: extraction, processing, transport and transmission, etc.

6. **Congestion**, e.g. value of time (VOT), speed-flow relationships, contribution to congestion by vehicle types, time spent in congestion, etc.

7. **Other external costs**. Separation costs in urban areas, Land use and ecosystem damage for upstream processes, infrastructure set-up.

“Looking at the above types and indicators of external costs of transport, can you indicate and describe which field of application would be more important and why?”

Type of stakeholders involved:

-Policy makers: Local government and Urban planners

-Research: Academia, research organisation

Question 2: Barriers in data requirement.

The application of SCBA, independently from the specific field of application, implies a significant activity of data collection, both quantitative, e.g. number of vehicles, population affected, square meters of land, etc, and qualitative, e.g. surveys on social preferences, willingness to pay for reducing harmful effects, etc.

“Can you indicate which type of data collection would be more problematic in China and why?”

Type of stakeholders involved

- Research: Academia, research organisation

Question 3: The role of institutions.

Apart from the maturity of OECD countries knowledge base in SCBA, the urbanisation processes and priorities in China may urge the need to transfer knowledge in specific fields of intervention.

“Can you indicate which institutional and operational requirements for inter-sectoral cooperation towards integrated SCBAs in China would be more appropriate? Improving coordination between academia and policy making, etc.

Type of stakeholders involved

- Policy makers: Local government and Urban planners

- Research: Academia, research organisation

6 ANNEX I: LITERATURE REVIEW

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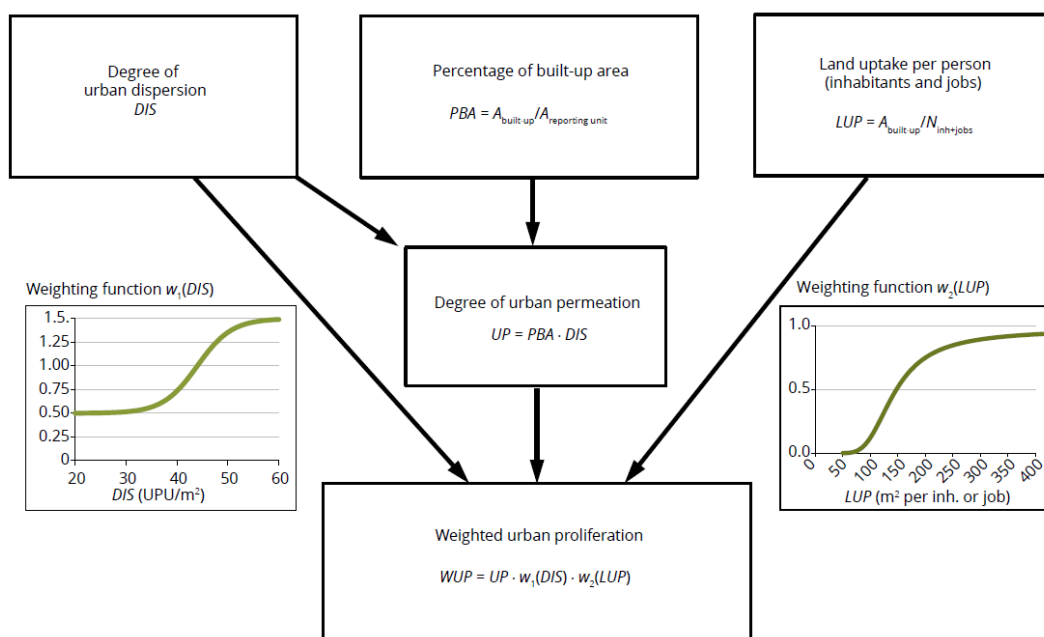
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7 ANNEX II: CONTRIBUTION TO THE INTERNALISATION OF URBAN SPRAWL COSTS IN URBAN PLANNING: THE WUP METHOD

This annex briefly outlines the WUP methodology. For a more extensive description, refer to the EEA report (EA, 2016), which provides sources and methodological details. The WUP (Weighted Urban Proliferation) method acts as a useful tool to measure the degree of urban sprawl. It is composed of the following components or dimensions considered of fundamental importance for the definition of urban sprawl: these dimensions are (1) the percentage of built-up area (PBA), (2) the dispersion of built-up area DIS and (3) the land uptake per person (inhabitant or job) LUP. A brief description of the three dimensions follows:

- The PBA measures the size of the built-up area (as a percentage of the landscape or reporting unit). Values for landscapes of differing sizes can be directly compared because the PBA value does not depend on the size of the particular area of landscape (i.e. it is an intensive metric).
- The dispersion of built-up area DIS concerns with the settlement pattern from a geometric perspective and is based on the distances between any two points within built-up areas (up to a maximum distance called the horizon of perception (HP)).
- The LUP describes the use of a built-up area by people that work and/or live in that area. Built-up areas with many inhabitants and employees are considered to be better used and, accordingly, are less sprawled. Alternatively, the intensity of use of a built-up area can be described by the reciprocal of LUP, that is by considering the utilization density (UD).

The following figure shows the relationships between the WUP dimensions.



Note: The DIS , PBA and $UD (= 1/LUP)$ are intensive metrics. $A_{reporting\ unit}$ area of the reporting unit (the landscape studied); $A_{built-up}$ size of built-up area in the reporting unit; $N_{inh+jobs}$ number of inhabitants and jobs in the built-up area of the reporting unit. The shapes of the weighting functions are shown in the boxes as indicated.

Source: EEA (2016)

The higher the value of WUP, the more sprawled the landscape investigated. The following table shows the metric used for measuring the WUP. The table can be useful in view of possible application of the methodology,

Acronym of the metric	Name of the metric	Unit	Range of low values (at NUTS-2 level)	Range of high values (at NUTS-2 level)
<i>WUP</i>	Weighted urban proliferation	UPU per m ² of landscape	< 2 UPU/m ²	> 4 UPU/m ²
<i>PBA</i>	Percentage of built-up area	%	< 3 %	> 10 %
<i>DIS</i>	Dispersion of built-up areas	UPU per m ² of built-up area	< 42.5 UPU/m ²	> 45.5 UPU/m ²
<i>LUP</i>	Land uptake per person (per inhabitant or job)	m ² per inhabitant or job	< 111 m ² per inhabitant or job	> 222 m ² per inhabitant or job
<i>UD</i>	Utilisation density	Inhabitants and jobs per km ² of built-up area	< 4 500 inhabitants and jobs per km ²	> 9 000 inhabitants and jobs per km ²
<i>UP</i>	Urban permeation	UPU per m ² of landscape	< 2 UPU/m ²	> 4 UPU/m ²

Source: EEA (2016)

Ultimately, the WUP method is able to encompass all types of settlement through the combination of its three components, that is it measures a rather complex phenomenon in a relatively simple way. The presentation of its three components as separate indicators is also useful for the understanding and interpretation of the values of WUP.

It is important to stress that the WUP methodology has been actually used in Switzerland as a tool for the internalisation of urban sprawl in land use decisions. For instance, The Alternative Bank of Switzerland used the WUP method for the evaluation of specific construction projects according to social and environmental criteria (including sprawl), in addition to economic criteria (Alternative Bank of Switzerland, 2012).

In principle, the application of the WUP methodology could allow existing and potential new buildings to be evaluated with regard to their contribution to urban sprawl, which could be used as a basis for decisions regarding the granting of mortgages. Such evaluations can also be the basis for awarding energy labels: the WUP indicator could be part of a new assessment system for sustainable construction in Switzerland (SNBS) which aims to reduce the negative impacts of new constructions on society, the economy and the environment. The WUP method could also serve as an indicator for the assessment of the loss of soils, effects on biodiversity and landscape consumption.

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