Politecnico
di Torino

RESULT OF THE MASTER THESIS
MAKING CITIES AND THE BUILT ENVIRONMENT MORE
SUSTAINABLE AND CIRCULAR (CIRCULAR CITIES AND SOCIETY)

GUIDANCE & RECOMMENDATIONS

FOR URBAN ACTORS AND FUTURE RESEARCHERS ON SELECTION OF METHODOLOGY FOR USE IN ENVIRONMENTAL IMPACT ASSESSMENT

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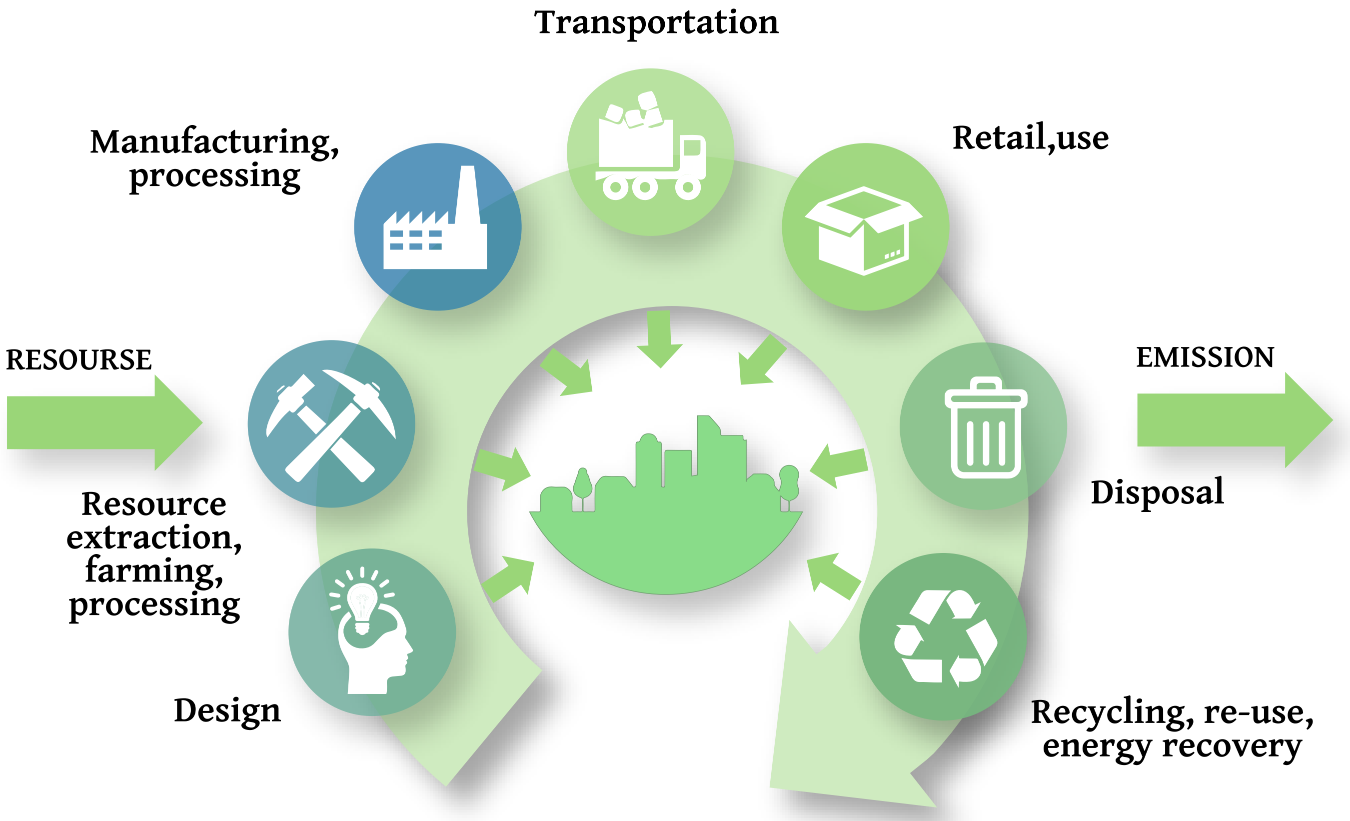
01 METHODOLOGIES USED IN URBAN STUDY

Urban environmental assessments are becoming more and more popular and nowadays there are numerous approaches available for evaluating the environmental impacts of the cities. It is known that holistic accounting of urban environmental impacts is still immature. Few quantitative and qualitative metrics exist to evaluate and improve the sustainability of cities from an environmental point of view.

MAKING CITIES AND THE BUILT ENVIRONMENT MORE SUSTAINABLE AND CIRCULAR



METHODOLOGIES USED IN URBAN STUDY

FOOTPRINT METHODOLOGY

Footprints methods are the most reliable, comparable, and verifiable way to improve environmental performance and help achieve a truly clean and circular economy of the cities. To avoid the chaos of the plenitude of indicators, the two most prevalent environmental footprints – i.e., Ecological footprint and Carbon

LIFE CYCLE ASSESSMENT METHODOLOGY

Life-cycle assessment (LCA) method is used to give a cradle-to-grave accounting of the direct, indirect, and supply chain effects of resource transformation and usage. The associated environmental effects of extraction and final disposal can also be considered in LCA

URBAN METABOLISM METHODOLOGY

Urban Metabolism is a concept typically uses a top-down approach and provides insight in the local reality through the inventory of the flows into and out of the city.Material flow analysis (MFA) reports stocks and flows of resources in terms of mass, which included application to cities.

HYBRID METHODOLOGY

Hybrid methodologies combines principles from the Urban Metabolism/ Material Flow Analysis, LCA and Footprint. Linking the UM/ MFA and LCA methodologies provide a 'sufficiently accurate' environmental impacts account when no further data is available

02 FOOTPRINT METHODOLOGY

Ecological Footprint is a methodology broadly used for assessing the environmental impact of human activities, expressed as the amount of land required to sustain their use of natural resources. Carbon Footprint, as an indicator of climate performance, help identify major GHG emission sources and potential areas of improvement

	ECOLOGICAL FOOTPRINT	CARBON FOOTPRINT
ORGANISATION	Global Footprint Network 2009 (Global Footprint Network)	
MAJOR CHARACTERISTICS	Measures renewable and non-renewable resourses used	Measures CO2 generated by activities
MAJOR VIEWPOINTS	• Quantative method • Consumption-based or input-output analysis (IOA) • Top down method • Bottom-up method • Combination of : • "low tech"data (statistics,literature) • "high tech data "(detailed GIS data)	
METRIC	Global hectares(gha)	(tCO2)

TOP-DOWN APPROACH (COMPOUND): uses national aggregate input data on production, trade flows (import and export data), and consumption to calculate a nation's Footprint or actual materials and energy flows

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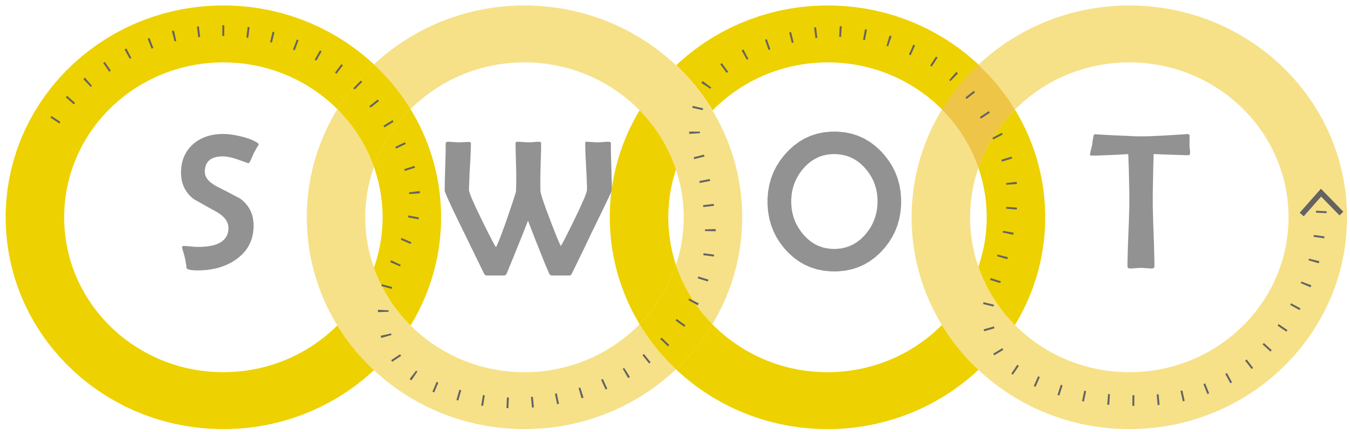
BOTTOM-UP APPROACH (COMPONENT): directly uses city-level data either local monetary input-output data or physical flows of materials and energy collected by the industry to calculate the city Footprint value



STRENGTHS	WEAKNESSES
• Highlights the problem areas • Hazard warning indicator • Snapshot of the current situation • Support for decision makers • Quantifies inputs and outputs • Broadly applicable • Easy to implement • Make forecast for future • Applied at different scale	• Express relative sustainability • Not comprehensive, incomplete quantitative assessment • Lack of transparency • Data intensity and availability • Not a dynamic indicator • Land can only have one function • Less reliable at the local/regional level • Uncertainty in calculation of methodologies
OPPORTUNITIES	**THREATS**
• Regulating its flows smartly and circularly • Actual impacts on the environment or human health • Guide to other projects • Free methods and database	• Assessment less reproducible, credible, and transparent • Data scarcity • Does not consider economic and social aspects •Difficult to build the complicated project

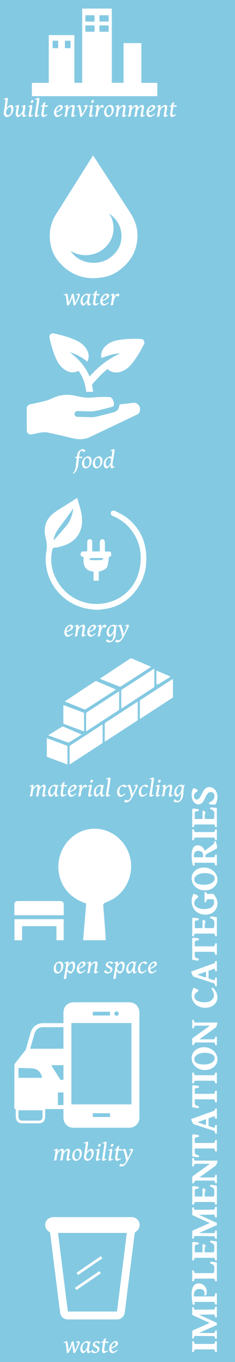
Overview of the main urban level Ecological Footprint application conducted as of today

Country	City	Methodology	Reference
Australia	Sydney	Top-down	(Lenzen, 2008)
Brazil	Curitiba	Top-down	(Global Footprint Network, 2010)
Canada	Calgary	Top-down	(Wilson and Anielski, 2005)
	Calgary	Bottom-up	(Global Footprint Network, 2007)
	Edmonton	Top-down	(Wilson and Anielski, 2005)
	Edmonton	Top-down	(Anielski, 2010)
	Québec City	Top-down	(Wilson and Anielski, 2005)
	Toronto	Top-down	(Wilson and Anielski, 2005)
	Vancouver	Bottom-up	(Moore et al., 2013)
	Vancouver	Top-down	(Wilson and Anielski, 2005)
China	Chongqing	Top-down	(WWF, 2012)
	Hong Kong	Top-down	(Global Footprint Network and WWF, 2013)
	Shanghai	Top-down	(WWF, 2012)
	Shenyang	Bottom-up	(Geng et al., 2014)
	Taiwan	Top-down	(Wang and Chou, 2012)
	Tianjin	Top-down	(WWF, 2012)
Ecuador	Quito	Top-down	(Moore and Stechbart, 2010)
Iran	Isfahan	Bottom-up	(Shayesteh et al., 2015)
	Tehran	Bottom-up	(Tavallai and Sasanpour, 2009)
Israel	Beer-Sheva	Bottom-up	(Zeev et al., 2014)
	Ra'anana	Bottom-up	(Kissinger and Haim, 2008)
Italy	Piacenza	Bottom-up	(Scotti et al., 2009)
	Siena (and its Province)	Bottom-up	(Bagliani et al., 2008)
	Turin	Bottom-up	(Genta et al., 2021)
	Turin	Bottom-up	(Genta et al., 2019)
Japan	Kawasaki	Bottom-up	(Geng et al., 2014)
Norway	Oslo	Bottom-up	(Aall and Norland, 2002)
Philippines	Manila	Top-down	(Global Footprint Network and Laguna Lake Development Authority, 2013)
Spain	Madrid	Top-down	(Zubelzu et al., 2015)
United Kingdom	Birmingham	Top-down	(Calcott and Bull, 2007)
	Cardiff	Top-down	(Collins et al., 2006)
	Edinburgh	Top-down	(Calcott and Bull, 2007)
	Glasgow	Top-down	(Birch et al., 2005)
	Greater Nottingham	Bottom-up	(Calcott and Bull, 2007)
	York	Top-down	(Barrett et al., 2002)
USA	San Francisco	Bottom-up	(Moore, 2011)
OAE	Qatar	Bottom-up	(Alhorr et al., 2014)
UK	Guernsey	Top-down	(Barrett, 2001)
South Africa	Cape Town	Top-down	(Swilling, 2006)
China	Hong Kong	Top-down	(Warren-Rhodes and Koenig, 2001)

03

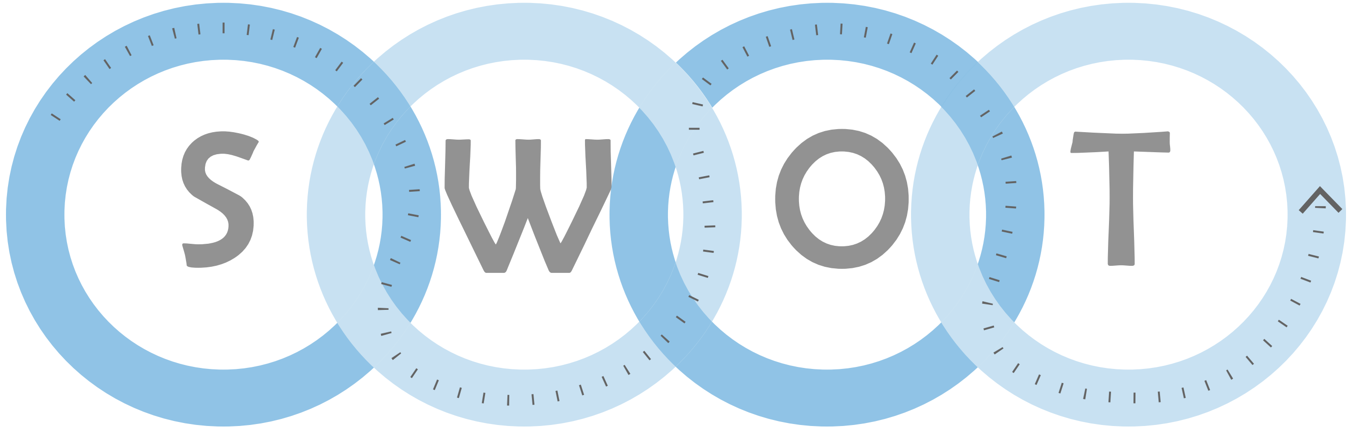
LIFE CYCLE ASSESSMENT METHODOLOGY

The Life-cycle assessment (LCA) method is used to give a cradle-to-grave accounting of the direct, indirect, and supply chain effects of resource transformation and usage. The associated environmental effects of extraction and final disposal can also be considered in LCA. (Chester, 2010; Solli, Reenaas, Stromman, & Hertwich, 2009). In order to analyze the movement of materials through the urban system, LCA analysis incorporates the inventorying part of materials flows analysis to detect the indirect and direct supply chain impacts of cities outside their borders



LIFE CYCLE ASSESSMENT

ORGANISATION	ISO 14001
MAJOR CHARACTERISTICS	Analysing the impact of material goods on their environment
MAJOR VIEWPOINTS	• Qualitative and Quantative method • Bottom up’ approach • Stock Agregation method • Cradle to grave approach
METRIC	kg CO2-equiv



STRENGTHS

- Support for decision makers
- Compare and select the products that impact less
- Cradle to grave concept
- Support for sustainable city management
- Widely recogised
- Data credability
- Point out the degradation of resources
- Holistic view on the environmental impacts
- Assessment of policies and projects for the micro-urban scale

WEAKNESSES

- Implementation strategies is relevant
- Not comprehensive indicator
- Research limitations, poor availability, reliability of data
- The constantly updating data
- Complex and large systems to analyze
- Lack of original data
- Not comprehensive indicator
- No applications at the entire urban scale
- Difficult to build the complicated project

OPPORTUNITIES

- Enhance the boundary problem research
- Data transparency
- Significant value and influence
- Actual impacts on the environment or human health

THREATS

- Assessment less reproducible, credible, and transparent
- Data scarcity
- Does not consider economic and social aspects
- Difficult to build a complicated project

LCA case studies		
Impact category	Country	Reference
Built environment	Different countries	(Mastrucci et al., 2017b)
Energy system	Turkey	(Atilgan B, Azapagic A., 2015)
Energy system	Switzerland	(Moret et al., 2016)
Energy system	China	(Chen et al., 2014)
Energy system	China	(Su et al., 2016)
Energy system	Germany	(Ripa et al., 2017)
Energy system	Italy	(Bonamente et al., 2015)
Water	Norway	(Slagstad and Bratteb, 2014)
Water	Australia	(Lane et al., 2015).
Water	Israel	(Opher and Friedler, 2016)
Water	Romania	(Barjoveanu et al., 2014)
Water	Romania	(Teodosiu et al., 2016)
Water	Egypt	(Mahgoub et al., 2010)
Water	Spain	(Pintilie et al., 2016)
Water	China	(Liu et al., 2016)
Water	U.S	(Jeong et al., 2015)
Water	Spain	(Uchea et al.2013)
Water	USA	(Risch et al.,2015)
Water	France	(Loubet et al.,2016)
Water	China	(Cai et al.,2016)
Waste	Asian countries	(Othman et al. 2013)
Waste	USA	(Coventry et al.,2016)
Waste	Romania	(Ghinea et al.,2012)
Waste	China	Chi et al. (2015)
Waste	Turkey	Erses Yay (2015)
Waste	Indonesia	Gunamantha and Sarto (2012)
Waste	Italy	Grosso et al. (2012)
Waste	Chile	Bezama et al. (2013)
Waste	Greece	Koroneos and Nanaki (2012)
Waste	Brazil	Reichert and Mendes (2014)
Waste	China	(Lam et al. 2016
Waste	Portugal	Teixeira et al. (2014)
Waste	Canada	Cleary's (2013)
Waste	Norway	(Slagstad and Bratteb 2012)
Transportation	France	François et al. (2017)
Transportation	Spain	Vedrenne et al. (2014)
Transportation	Hungary	Simon et al. (2010)
Transportation	USA	Liu et al. (2016)
Transportation	USA	Nichols and Kockelman (2015)
Transportation	USA	Fraser and Chester (2016)
Transportation	USA	Shahraeeni et al. (2015)
Consumption patterns	Different countries	Ivanova et al. (2016)
Consumption patterns	Finland	Heinonen et al. (2013a, b)
Consumption patterns	Denmark	Kalbar et al. (2016)
Urban green	Netherlands	Elmqvist et al. 2013)
Urban green	USA	Spatari et al. (2011)
Urban green	Australia	Rothwell et al. (2015)

04
URBAN METABOLISM METHODOLOGY

The concept of the Urban Metabolism is a concept typically uses a top-down approach and provides insight in the local reality through the inventory of the flows into and out of the city. Material flow analysis (MFA) reports stocks and flows of resources in terms of mass, which included application to cities. MFA alone cannot accurately calculate the environmental impacts of the system, although it can measure the flows in and out of the system

water

food

energy

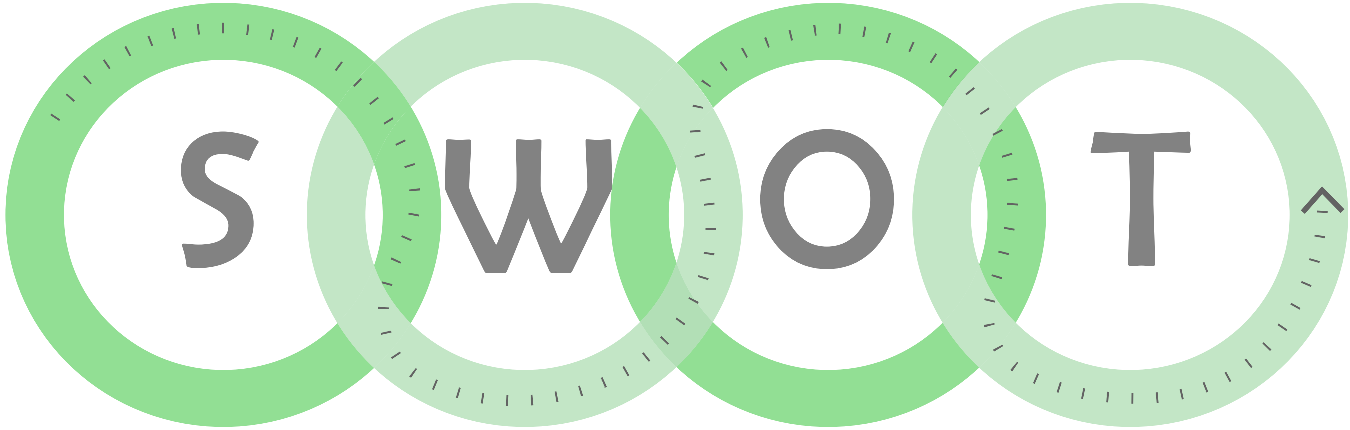
material cycling

waste

IMPLEMENTATION CATEGORIES

URBAN METABOLISM

ORGANISATION	European Commission 2010
MAJOR CHARACTERISTICS	UM is largerly an accounting tool measuring inputs and waste flows
MAJOR VIEWPOINTS	• Quantative method (quantifying energy flows) • Top-down method • Bottom-up method • Material flow analysis(e.g. mass flow) • Input/Output Approach
METRIC	kg,t/cap



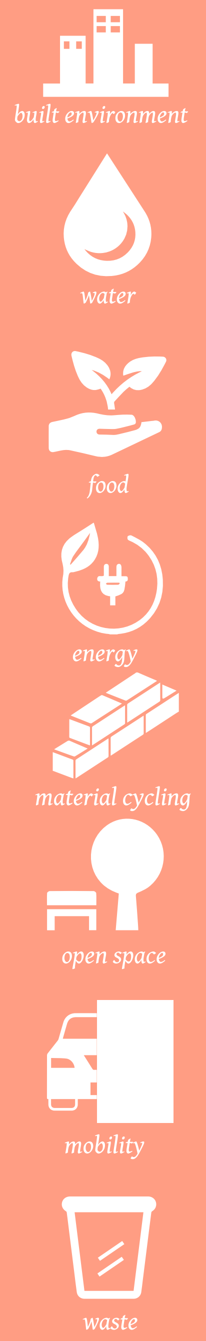
STRENGTHS	WEAKNESSES
• Support for decision makers • Quantifies inputs and outputs • Urban metabolism quantifies inputs and outputs of numerous commodities • Provide a snapshot of resource or energy use • Broadly applicable, relevant methodology	• Uncertainty in calculation of methodologies • Subjective system boundaries and threshold • Uncertainty in data • Lack of data, research limitations, poor availability • Lack of a standartisation • Difficult to addentify the product flow • Difficult to identify urban criteria, threshold criteria • Not allowing a specific assessment for the micro-urban scale
OPPORTUNITIES	**THREATS**
• Data sources are more available • Comprehensive systematic methodology • Actual impacts on the environment or human health	• Inability to identify the economic,social and political sectors • Understanding of the origin and destination of flows

Chronological review of urban metabolism studies. Flow analysis method used in UM studies

Notes/contribution	Country/City	Reference
Material Flow Analysis (MFA)	Berlin, Germany	(Baccini and Brunner, 2012)
Nitrogen (N) mass balance	Phoenix, USA	(Baker et al., 2001)
Material Flow Analysis (MFA)	Dalian, China	(Bao, 2010)
Material Flow Analysis (MFA)	Paris, France	(Barles, 2009, 2007a)
Materials	York, UK	(Barrett et al., 2002)
Measures product and waste flows	Paris, France	(Billen et al., 2009)
Critiqued metabolism perspective for food		(Bohle, 1994)
Material Flow Analysis (MFA)	Irish city-region, Ireland	(Browne et al., 2011, 2009, 2005)
Nitrogen & Phosphorus	Stockholm, Sweden	(Burstrom et al.,2003)
Assessment of total urban metabolism	Toronto, Canada	(Codoban and Kennedy, 2008)
Assesment of metal flow	Stockholm, Sweden	(Cui et al., 2009)
Relationship between metabolism and city surface		(Deilmann, 2009)
Energy use data for Barcelona and other cities	Prague, Czech	(European Environment Agency, 1995)
Urban nutrient balance	Bangkok, Thailand	(Færge et al., 2001)
Energy metabolism	Prague, Czech	(Fikar, 2009)
Nitrogen balance for the urban food metabolism	Toronto, Canada	(Forkes, 2007)
Water		(Gandy, 2004)
Assessment of total urban metabolism	Prague, Czech	(Garcia et al., 2009)
Recognized link to sustainable development of cities		(Girardet, 1992)
Material Flow Analysis (MFA)	Hamburg, Germany	(Hammer et al., 2003)
Assesment of heavy metals	Stockholm, Sweden	(Hedbrant, 2001)
Water		(Hermanowicz and Asano, 1999)
Assessment of the impacts of transportation	Toronto, Canada	(Kennedy, 2002)
Energy metabolism or energy flow	Austria	(Krausmann and Haberl, 2002)
Socio-metabolic transition	Czech,Slovakia	(Kuskova et al., 2008)
Mass balance for wastewater	Phoenix, USA	(Lauver and Baker, 2000)
State of the Environment report		(Lennox and Turner, 2004)
Assessment materials and energy flow, case study	Curitiba,Brazil	(Conke and Ferreira, 2015)
MFA applied for the case study	Jinchang, China	(Li et al., 2016)
MFA of inputs and outputs	Chinese Cities	(Liang and Zhang, 2011)
Assessesment water flows	Lisbon, Portugal	(Marteleira et al., 2014)
Assessment of urban metabolism	Australia	(Newman, 1999)
Flow of phosphorus	Lisbon, Portugal	(Nilsson, 1995)
MFA applied for the case study	Viena, Austria	(Niza et al., 2016, 2009)
Metal	Gävle, Sweden	(Obernosterer and Brunner, 2001)
Urban hydrology	Munich, Germany	(Pauleit and Duhme, 2000)
MFA applied for the case study	Lisbon, Portugal	(Rosado et al., 2016, 2014)
Assessment of urban metabolism	Toronto, Canada	(Sahely et al., 2003)
MFA applied for the case study	Singapore, Singapore	(Schulz, 2007)
Socio-economic metabolism	Trinket Island, India	(Singh et al., 2001)
Heavy metals	Stockholm, Sweden	(Sörme et al.,2001)
Urban metabolism to quality of life	Brisbane & Southeast Queensland, Australia	(Stimson et al., 1999)
Mercury	Stockholm, Sweden	(Svidén and Jonsson, 2001)
Water	Greater Moncton, Canada	(Thériault and Laroche, 2009)
MFA applied for the case study	Beijing, China	(Zhang et al., 2014, 2013)
Energy flow applied for the case study	Xiamen, China	(Zhao, 2012)

05 HYBRID METHODOLOGY

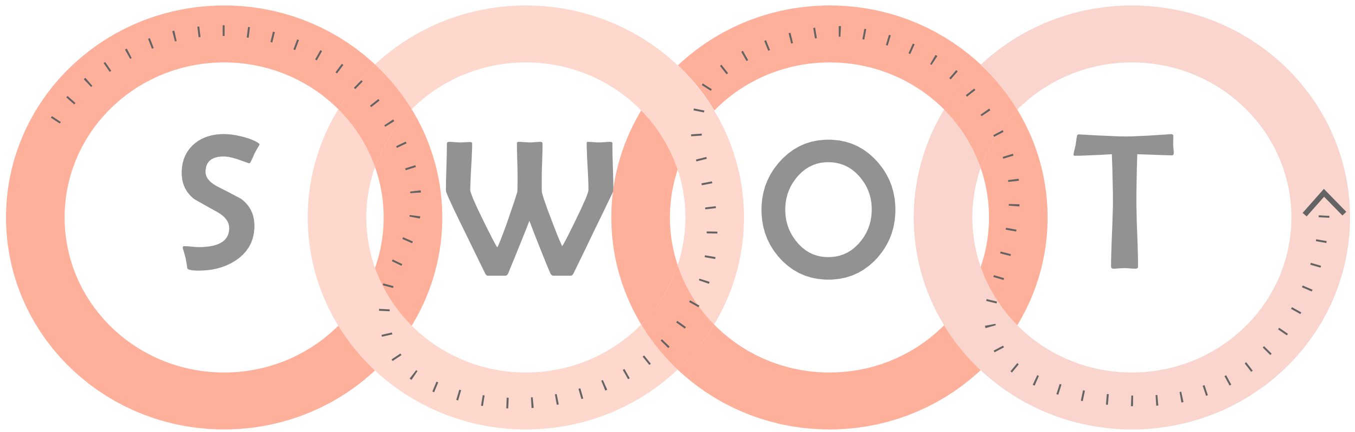
Hybrid methodology assesses the environmental impact in urban areas. It combines principles from the Urban Metabolism/ Material Flow Analysis (UM/ MFA), The Life Cycle Assessment (LCA) and Footprint. Linking the UM/ MFA and LCA methodologies provide a 'sufficiently accurate' environmental impacts account when no further data is available. The combination of LCA with top-down UM methods have still not been applied to the entire urban system. The proposed UM-LCA converts the city's input-output flows into environmental impacts. Integration of Urban Metabolism and Ecological Footprint allows identification of major loads and potential points of intervention for reducing urban impacts



IMPLEMENTATION CATEGORIES

HYBRID METHODOLOGY

CONCEPT	FT & LCA	LCA & UM	UM & FT
ORGANISATION	Global Footprint Network ISO 14001	ISO 14001	European Commission, 2010 Global Footprint
MAJOR CHARACTERISTICS	Comprehensive urban environmental assessment of energy and material use in cities	Comprehensive urban environmental assessment of energy and material use in cities	Quantify and assess urban environmental loads
MAJOR VIEWPOINTS	• Qualitative and Quantative method • Input-output approaches(sub-approaches) • Combines Top-down and Bottom up methods • Combination of "low tech"data "high tech data "	• Qualitative & Quantative method • Material flow analysis (MFA) tool & Bottom-up approach(process-based LCA method)	• Qualitative & Quantative method • Direct component analysis • Bottom up methods • Both use material flow analysis
METRIC	kg CO2-equiv gha per capita	kg CO2-equiv kg,t / capita	kg,t / cap gha per capita

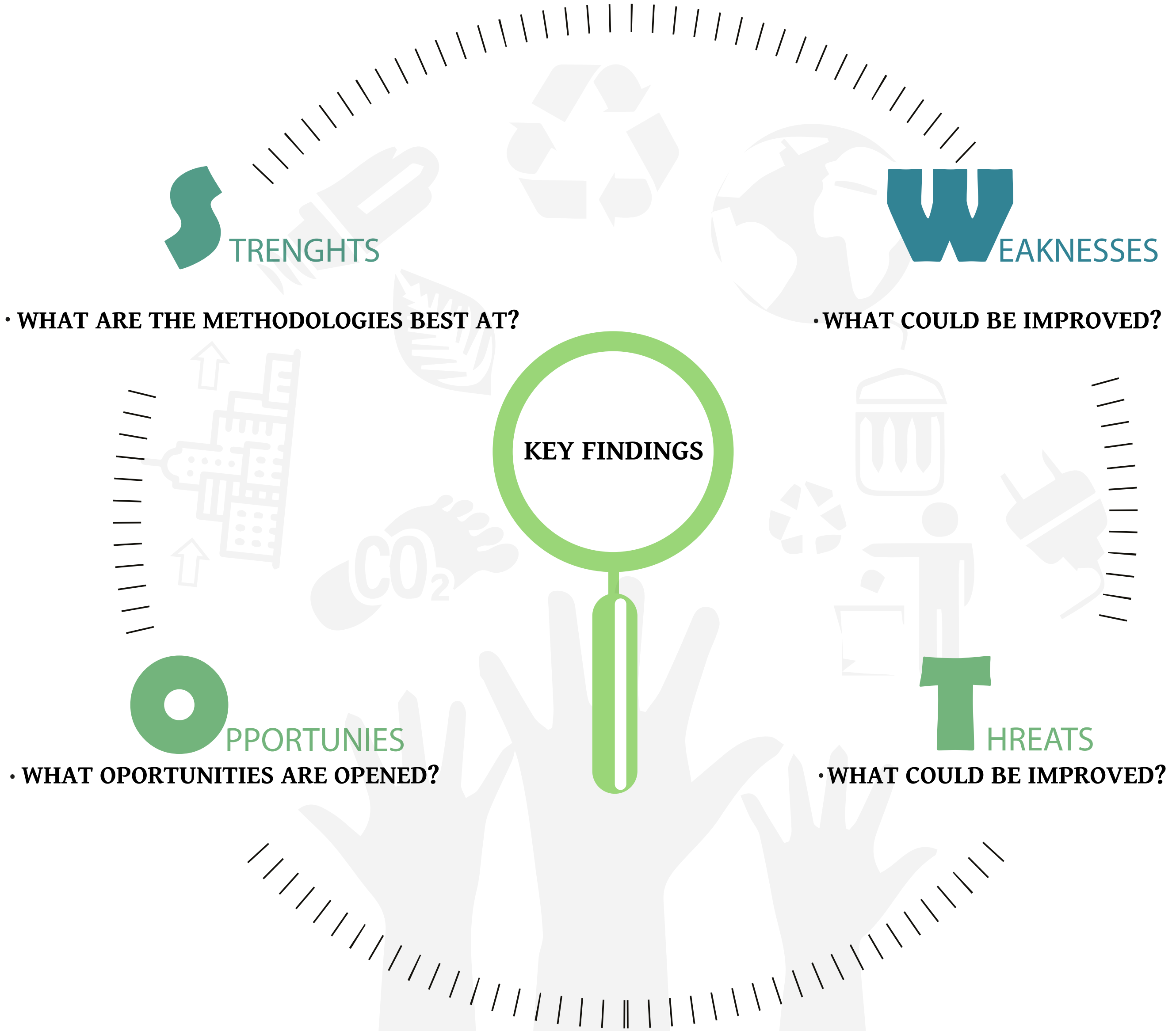


STRENGTHS	WEAKNESSES
• Support for decision makers • Cradle to grave concept • The quantification and communicability of model results • Comprehensive evaluation • Considering all the flows of a city • Sufficiently accurate environmental impacts account	• Subjective system boundaries and threshold • Research limitations, poor availability • Remains immature • Another limitation is the lack of spatiality
OPPORTUNITIES	**THREATS**
• Significant value and influence • Actual impacts on the environment or human health • Provide a more complete measurement • Fill the gap	• Not applied at the entire urban system

Integrated (combination of the previous methods)		
Impact category	Country	Reference
Top-down and Bottom-up	Toronto,Canada	(Harvey, 1993)
EF and LCA	Denver,US	(Hillman and Ramaswami, 2010)
MFA and Emergy Index	Taipei, Taiwan	(Huang and Hsu, 2003)
Industrial and Energy Structure Optimization, Energy Saving, Circular Economy	Shangai, China	(Lu et al., 2016)
Energy Flow Accounting, LCA and Energy Footprint	Barcelona,Spain	(Oliver-Sol a et al., 2007)
Economic Cost Analysis and Emergy Index	Uppsala, Sweden	(Russo et al., 2014)
(LMDI) methods and Emergy Index	Stockholm,Sweden	(Shahrokni et al., 2015)
Input-Output (MRIO) and Ecological Network Analysis	Shenyang,China	(Sun et al., 2016)
DEA method and Window Analysis	Beijing,China	(Zheng et al., 2016)
GIS and LCA	Taipei City, Lienchiang County Taiwan	(Yang et al., 2016)
UM and LCA	Different countries	(Junjie et al.,2021)
UM and EF	Beijing,China	(Goldstein et al.,2013)
	Cape Town, South Africa. Hong Kong,China London,UK Toronto, Canada Vancouver, Canada	(Moore,2013)

06 COMPARISON AND KEY FINDINGS

Comparison and key findings highlight and compare the feasibility of some of the proposals and the potential of each methodology. The key questions are compiled for each category, namely Strength, Weaknesses, Opportunities, Threats



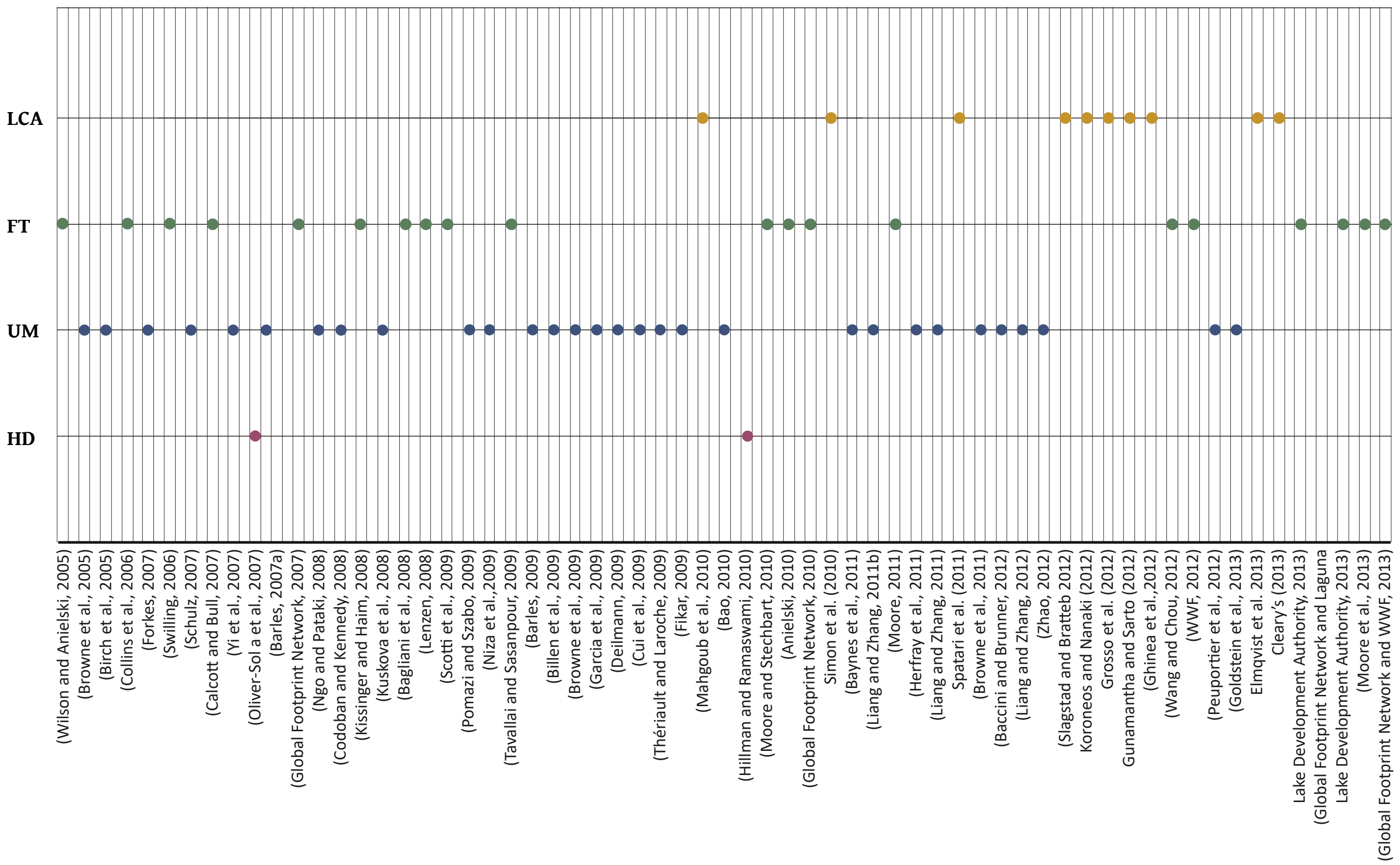
STRENGTHS WHAT ARE THE METHODOLOGIES BEST AT?	FOOTPRINT	LIFE CYCLE ASSESSMENT	URBAN METABOLISM	HYBRID
Support for decision makers	✓	✓	✓	✓
Compare and select the products that impact less	✗	✓	✗	✓
Cradle-to-grave evaluation	✗	✓	✗	✓
Quantifies inputs and outputs of commodities	✓	✓	✓	✓
Provide support for sustainable city management	✓	✓	✓	✓
Broadly applicable	✓	✓	✓	✓
Easy to implement	✓	✗	✗	✗
Point out the degradation of resources	✗	✓	✗	✓
Assessment of policies and projects for the	✓	✓	✗	✓
Comprehensive environmental strategy	✗	✗	✗	✓
'Sufficiently accurate' environmental impacts	✗	✗	✗	✓
Data credabilty	✗	✓	✗	✗

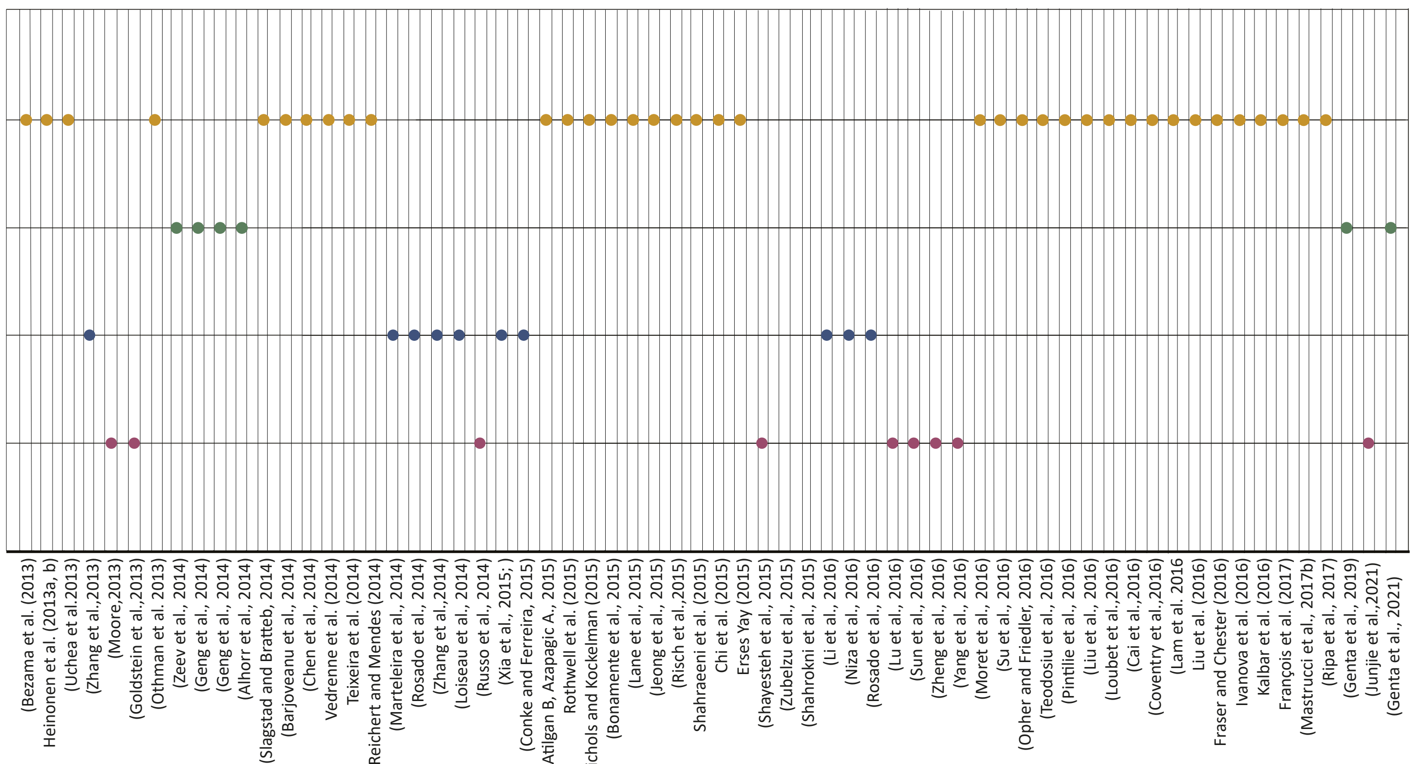
OPPORTUNITIES WHAT OPORTUNITIES ARE OPENED?	FOOTPRINT	LIFE CYCLE ASSESSMENT	URBAN METABOLISM	HYBRID
Significant value and influence	✓	✓	✓	✓
Regulating its flows smartly and circularly	✓	✓	✓	✓
CO2 emission reduction	✓	✓	✓	✓
Free methods and databases	✓	✓	✓	✓
Actual impacts on the environment or human	✓	✓	✓	✓
Guide to other projects	✓	✓	✓	✓
Regulating flows smartly and circularly	✗	✗	✗	✓

WEAKNESSES WHAT COULD BE IMPROVED?	FOOTPRINT	LIFE CYCLE ASSESSMENT	URBAN METABOLISM	HYBRID
Uncertainty in calculation of methodologies	✓	✓	✓	✗
Subjective system boundaries and threshold	✓	✓	✓	✓
Not comprehensive indicators	✓	✓	✓	✗
Research limitations, poor availability of data	✓	✓	✓	✓
Implementation of strateges is relevant	✓	✓	✓	✓
Complex and large systems to analyze	✗	✓	✓	✓
Not allowing an assessment for the micro-urban scale	✗	✗	✓	✗
Not widely evaluated by practitioners	✗	✗	✗	✓
Express relative sustainability	✓	✓	✓	✓
Incompact and incomplete quantitative assessment	✓	✓	✓	✗
Difficult to build the complicated projectaccount	✓	✓	✓	✓
Lacks of standardization	✓	✓	✗	✗

THREAT WHAT THREAT COULD HARM?	FOOTPRINT	LIFE CYCLE ASSESSMENT	URBAN METABOLISM	HYBRID
Diversity of evaluations	✓	✓	✓	✓
Assessment less reproducible, credible and transparent	✓	✓	✓	✗
Hidden environmental impacts	✗	✓	✗	✓
Limited funding	✓	✓	✓	✓
Not easy to communicate the results	✗	✓	✓	✓
Hard interpretation of flows	✗	✗	✓	✗
Does not consoder economic and social aspects	✓	✓	✓	✓

REVIEW OF PAPERS





07 RECOMMENDATIONS

FOR URBAN ACTORS AND FUTURE RESEARCHERS

Recommendations address the need to provide valuable information on how to better integrate and implement different environmental assessment methodologies in order to support urban actors and future researchers in reducing the environmental impact of cities.

01 USE THE ECOLOGICAL FOOTPRINT ANALYSIS WITH THE URBAN METABOLISM FRAMEWORK TO TACKLE A WIDE RANGE OF SUSTAINABILITY ISSUES AT A METROPOLITAN, REGIONAL SCALE

02 USE INTEGRATED METHODOLOGY (UM-LCA) FOR COMPREHENSIVE AND SUFFICIENTLY ACCURATE ENVIRONMENTAL IMPACT ANALYSIS

03 USE THE LCA METHOD TO OBTAIN REPRODUCIBLE, CREDIBLE AND TRANSPARENT ASSESSMENT

04 INTEGRATE DIFFERENT METHODOLOGIES TO ACCELERATE THE LEARNING PROCESS OF THE URBAN SUSTAINABILITY ASSESSMENT AND HELP IN THE IMPROVEMENT OF BOTH THEORY AND PRACTICE

05 USE THE FOOTPRINT INDICATOR TO PROVIDE URBAN ACTORS/FUTURE RESEARCHERS WITH A SIMPLER AND EASIER INDICATOR TO APPLY AT DIFFERENT STAGES OF THE DECISION-MAKING PROCESSES

06 CONSIDER A NEW METHOD WITH RESPECT TO SOCIAL OR ECONOMIC DIMENSIONS OF SUSTAINABILITY

Based on the SWOT analysis identified, the recommendations suggest a pragmatic shift in the focus of urban sustainability assessment from theory development to more of application. Recommendations may also be applicable to other projects at the EU level and on a broader scale. They are aimed at involving European and local urban actors in the use of these recommendations, thereby allowing them to contribute their experience and perspectives to the future project.

USE THE ECOLOGICAL FOOTPRINT ANALYSIS WITH THE URBAN METABOLISM FRAMEWORK TO TACKLE A WIDE RANGE OF SUSTAINABILITY ISSUES AT A METROPOLITAN, REGIONAL SCALE

Scale of Applicability: Metropolitan/Regional scale
Linkage with SDGs:

Background and justification:
Since LCA is indicator which is very difficult to apply to the entire city or regional scale, the integration of UM and EF is solution while applying for wider scale. Effective measures taken at sub-national level could assist us in addressing global environmental challenges at the global scale (Bulkeley and Betsill, 2005; Wilbanks and Kates, 1999). The application of a bottom-up ecological footprint analysis using an urban metabolism framework at a metropolitan, regional scale can be more effective in addressing urban actors concerns and interests.

Description:
Urban actors/Future researchers should use the Urban Metabolism framework and The Ecological Footprint study to address a variety of sustainability issues at a metropolitan and regional level. The use of a bottom-up ecological footprint study within an urban metabolism framework at a metropolitan, regional scale can be an effective tool to quantify flows consumed by cities.

Examples and/or references:
Moore et al. (2013) introduce a detailed, bottom-up urban metabolism and ecological footprint analysis for a North American metropolitan region. It aims to demonstrate the application of a bottom-up ecological footprint analysis using an urban metabolism framework at a regional scale. The authors show why and how the methodological approach for subnational ecological footprint research is based on economy-wide input-output estimates, which is standard in Europe.

USE INTEGRATED METHODOLOGY (UM-LCA) FOR COMPREHENSIVE AND SUFFICIENTLY ACCURATE ENVIRONMENTAL IMPACT ANALYSIS

Scale of Applicability: Local/Neighborhood
Linkage with SDGs:

Background and justification:
The application of LCA at the urban scale is not yet a reality. Its current application is limited in scope (e. g. Only the urban waste management sector is investigated) and applied to only a geographical part of the city (e. g. Neighborhood scale). Therefore, an incomplete environmental impact assessment will lead to the fact that the project will be associated with a higher risk of negative impact. Without the introduction of a proper environmental assessment tool that could provide a holistic perspective, the environment and people could be at risk. Thus, LCA requires assessment of a wide range of impacts, and its application with UM will expand the assessment of urban sustainability from its current focus on flows of energy, water, materials, nutrients, and waste (including greenhouse gas emissions, GHGs) to resource depletion, damage to human health and damage to ecosystem quality. By incorporating a wide range of impacts, urban actors can take more comprehensive measures to ensure urban resilience, and unforeseen consequences can be better avoided (Chester et al., 2012).

Description:
Using Integrated methodology (UM-LCA) by urban actors/future researchers for comprehensive and sufficiently accurate environmental impacts analysis. Both methods can ensure the sustainability of cities through intelligent and circular harmonization of flows.

Examples and/or references:
Some studies were already developed the UM-LCA model in the past. For example, UM–LCA model was applied to five case cities: Beijing, Cape Town, Hong Kong, London, and Toronto. Findings report that the considered flows, in combination with the UM-LCA methodology, provide a “sufficiently accurate” environmental impacts account when no further data is available. (Goldstein et al.,2013).

03 USE THE LCA METHOD TO OBTAIN REPRODUCIBLE, CREDIBLE AND TRANSPARENT ASSESSMENT

Scale of Applicability: Urban scale
Linkage with SDGs:

Background and justification:
As more and more regulations emerge to combat greenwashing, the credible environmental data to make products being sustainable is needed. The evaluation of the current urban methodologies remains methodologically immature and continues to limit accurate accounting of urban flows of cities. Taking them into account there are significant barriers and weaknesses such as a lack of data, omitted/hidden upstream flows, uncertainty regarding the appropriate scale of analysis. A certain lack of transparency in the calculations in development of the ecological footprint can lead to inaccurate result and false information. However, the use of the environmental data based on the LCA study can make the life cycle of a product truly sustainable (Kennedy et al., 2011).

Description:
Despite the fact that most assessment methodologies are currently immature, the use of a LCA method can be used to obtain reproducible and transparent assessment. The use of accurate data based on the LCA study not only confirms and strengthens sustainability of the cities, but it also enhances credibility.

Examples and/or references:
Currently, there are many studies devoted to the LCA method that provide a reliable result of data evaluation. For example, Loubet et al. (2016) developed framework and an associated modeling tool to perform LCA for urban water system. The model WaLA applied to a real-world case study, the urban water system of the Paris suburbs (France). The innovative and comprehensive strategy is supported by credible primary and secondary data (measurement flow meter, calculation from an external model or mass balance result).

04 INTEGRATE DIFFERENT METHODOLOGIES TO ACCELERATE THE LEARNING PROCESS OF THE URBAN SUSTAINABILITY ASSESSMENT AND HELP IN THE IMPROVEMENT OF BOTH THEORY AND PRACTICE

Scale of Applicability: , Regional
Linkage with SDGs:

Background and justification:
There is still a significant gap between assessment theories and assessment practices. Cooper (1997; 1999) refers to this fact and argues that the practice of assessment lags well behind development of methodological theories. New assessment approaches are still mostly experimental, with limited practical uses. A simple example of this is the current scenario in which most widely used assessment methods fail to make evaluations that sufficiently address most challenges underlying the sustainable urban development process. (Adinyira et al., 2007). To improve the current situation, it is necessary to identify those aspects of urban activities and challenges at various geographical scales that are poorly covered by existing evaluation methods. Based on identified gaps, urban actors should integrate main assessment methods to develop hybrid one which may be able of addressing most of urban sustainability issues at different scale.

Description:
By combining different methodologies that currently exist it will be possible to develop methods that will capture most if not all urban activities and spatial scales, accelerate the learning process of the urban sustainability assessment and aid in the improvement of both theory and practice.

Examples and/or references:
Currently, there are several hybrid proposals for quantifying environmental impacts. For example: 1) the integration of LCA and EF; 2) UM, MFA and LCA; 3) UM and EF. Such combinations of hybrid results in a more precise and detailed modelling allow for a clearer identification of hotspot and opportunities for efficient environmental performance of cities. Combining UMA with EFA can enhance strengths of both methods (Curry et al., 2011). The EFA, based on the UMA framework, adds an additional layer of insight to the already robust analysis of energy and material flows in a city (Mirabella et al., 2018).

05 USE THE FOOTPRINT INDICATOR TO PROVIDE URBAN ACTORS/FUTURE RESEARCHERS WITH A SIMPLER AND EASIER INDICATOR TO APPLY AT DIFFERENT STAGES OF THE DECISION-MAKING PROCESSES

Scale of Applicability: At all scale
Linkage with SDGs:

Background and justification:
Taking into account that LCA is too professional, complex and large tool to analyze, thus requiring urban actors to have professional knowledge to help them make decisions; footprint is simpler indicator to use and calculate, making it a usable indication for non-scientists. If indicators are too technical and complicated, most urban practitioners and future researchers will continue to avoid them. Therefore, the environment assessment Indicator should provide them with a simpler and more intuitive model for decision-making. The Ecological Footprint can be applied at all scales, ranging from single products to humanity as a whole by providing a solid knowledge base and an easily applicable calculation method (Wackernagel et al., 2006). Not surprising the footprint is the only indicator that can communicate results to a wide audience (Thomas Wiedmann and John Barrett, 2010).

Description:
Urban actors/Future researchers when choosing an environment assessment indicator should consider the Footprint indicator since it is simpler and easier indicator to use and apply in different stages of the decision-making processes.

Examples and/or references:
There are a number of EF approaches now available, differing in the underlying methodology. “A Review of the Ecological Footprint Indicator“ by Thomas Widman (2010) provided a comprehensive overview of perceptions and practices regarding the Ecological Footprint. That review is based on a survey of more than 50 international EF stakeholders and a review of more than 150 original papers on EF methods supporting the idea of the ease of using the Footprint indicator (Thomas Wiedmann and John Barrett, 2010).

06 CONSIDER A NEW METHOD WITH RESPECT TO SOCIAL OR ECONOMIC DIMENSIONS OF SUSTAINABILITY

Scale of Applicability: Urban/Neighborhood
Linkage with SDGs:

Background and justification:
The ability to address economic, social and environmental interdependencies within policies, plans, legislations and projects has become the basic requirement of all urban sustainability assessments methods. Most currently available methods still fail to demonstrate sufficient understanding of the interrelations of social, economic and environmental considerations. (Adinyira et al.,2007.) For example, Urban Metabolism does not consider the social and political impact and flows. Ecological Footprint does not count as well the social or economic dimensions of sustainability. To overcome these challenges, 'Social LCA’ method was suggested to be considered by one of the urban actors (from conducted interview) as an important and acknowledged framework for sustainability assessment. Taking these points into consideration, the importance of a new social and socio-economic assessment tool in moving towards sustainable development is undeniable. (Guideline for Social Life Cycle Assessment,2020).

Description:
Urban Actors/ Future Researchers should consider another recently growing quantitative tool for assessing the positive and negative impact of products and processes with respect to the social or economic dimensions. In this way it can support urban actors in improving their overall socio-economic performance and strategies to achieve sustainable urban growth.

Examples and/or references:
The Guidelines for Social Life Cycle Assessment (S-LCA) present a methodology to assess the social impact of products using a life cycle perspective. Moreover, it covers new methodological and provides a key and unique feature of Social-LCA practical developments. Therefore, that innovative methodology can be applied to calculate a social impact, social footprint, identify social hotspots (location or activity with high risk/impact), social handprinting, etc. (Guideline for Social Life Cycle Assessment,2020).

08 CONCLUSIONS

- This Guidance presents the assessment methodological approaches that have been used in previous studies to outline common strategies to evaluate the environmental impact of the cities.

- Results of the methodologies through a SWOT analysis give clear understanding which methodologies are the most advantageous/ disadvantageous in comparison with other methods.

- The recommendations for urban actors and future researchers were developed using the frameworks from the CESBA Med Commission (2019) and Restrepo Arias et al. (2020). They are focusing at promoting four assessment methodologies known in urban study and providing the advice on the use of a particular tool to decrease the environmental impact of the cities.

- Hopefully, the methodological options and development paths that Guidance& Recommendations propose will provide a solid foundation for future studies to harmonize data and analysis potential.

Politecnico di Torino

RESULT OF THE MASTER THESIS

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GUIDANCE & RECOMMENDATIONS

FOR URBAN ACTORS AND FUTURE RESEARCHERS ON SELECTION OF METHODOLOGY FOR USE IN ENVIRONMENTAL IMPACT ASSESSMENT