Spatial Structures & Dynamics for Planning Sustainable City-Regions

Modelling and measuring the food and waste management systems using an urban analytics approach

Phd(c). Jonathan Cohen

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1 Introduction

1.1 Context

Urbanization is one of the most transformative trends of the 21st century. Although, urban areas only occupy 2% of the world's surface, by 2050, the percentage of urban population is expected to reach 68% and to nearly double in size. Virtually, all future population growth will be absorbed by cities. Human activity in urban areas consume 75% of global energy and are the place where 80% of the C02 emissions are produced [7]. In this context, it has never been more evident that

> The battle for sustainable development will be won or lost in cities [8].

At first glance, the fact that by focusing on solutions on cities to revert current trends, might seem an easy task to accomplish, but the truth is the complete opposite; there are hundreds if not thousands of caveats that undermine the task, makes it one of the challenges of our era. To begin with, our concept of what a city is might not be a unified vision. We might tend to believe that most humans live in world cities such as London, Paris or Berlin, but in fact the population distribution by city sizes shows that we live in a more heterogeneous world; (see 1).

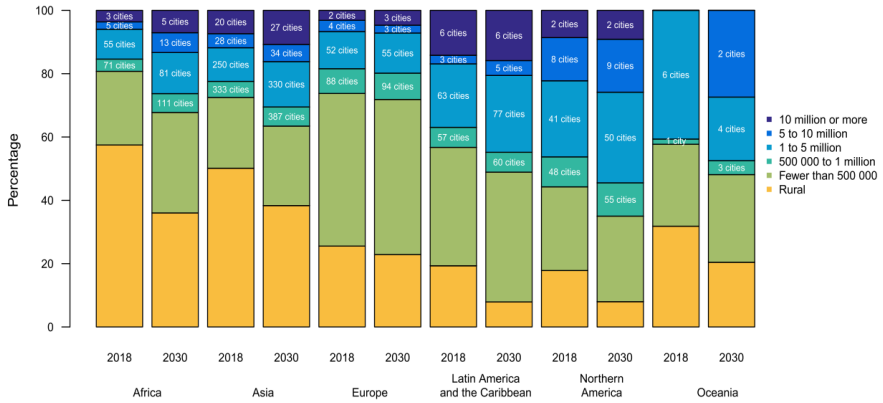


Figure 1: Population distribution by size class of settlement* and region, 2018 and 2030

Diversity in city sizes imply that there are other sources of heterogeneity such as context, socio-demographic characteristics, local capacities, and so forth. As can be obvserved in 1 there is a significant amount of citizens living in emerging cities. Consequently, it would be important for emerging cities to catch up with strategies and capacities of top-tier cities, to face global challenges. (Reinforce these concepts with proper citations).

In second place, there is no agreement or unified definition of what a city is. Throughout history, there has been significant efforts to understand and delimit the boundaries of cities. For certain, this is a highly contested arena with ongoing improvements and the definition of how an urban system is defined depends on what the focus of the study is. For instance, when dealing with municipal finances, research tends to use an administrative definition of the city; when analyzing job accessibility, the city is defined depending on the population the case of accessibility of jobs, the definition of what a city is depends on the population travel patterns; finally but not least, research done in urban expansion tend to look at the physical aspects and satellite images are used to delimit the city. At some point, we might come to realize that there is no single definition of a city; its a social construction, bounder less system, an object that will need to be defined in every work, depending on the study focus. In this sense, this work will deal with the concept of City-Regions, as a physical bounder less definition of human settlements. Concepts such as city, functional urban area (FUA) or urbanity will be used interchangeably in hat follows.

(Reinforce these concepts with proper citations)

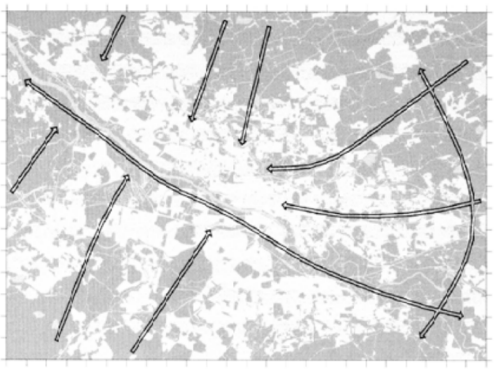


Figure 2: Hildebrand Frey. Designing the City. Towards a more Sustainable Urban Form. Page 161.]

Besides the fact that for the first time we are living in an urban world, it seems also important to highlight that we are living in a highly connected world. Since 2008, the number of devices connected to the internet has surpassed the number of humans on it. It is estimated that by 2020, 50 Billion devices will be actively connected to the web. In the context of city diversity, and lack of city boundaries, this fact becomes disruptive as there is an opportunity for sensing what is happening in human settlements disregards of the size, shape or boundary.

1.2 Motivation

Above all this Phd project is steered by the outcomes of the UN Sustainable Development Summit in 2015. The process initiated back in 2013 culminated in the adoption of the 2030 Agenda for Sustainable Development, with specific focus on 17 Sustainability Development Goals (SDGs).

Together with the 17 Goals, a set of sub-goals and 244 performance indicators were agreed upon [6]. As pointed out above, cities (of all sizes) are found to be important pieces in the sustainable development game. Its relevance has been detailed in the Sustainable Development Goals (i) 11: make cities and human settlements inclusive, safe, resilient and sustainable and (ii) 12: Ensure sustainable consumption and production patterns.

For instance, SDG 11 contains 7 sub-goals (plus 3) and its progress is being monitored by 15 Key Performance Indicators (KPIs). Sub-goal 11.6

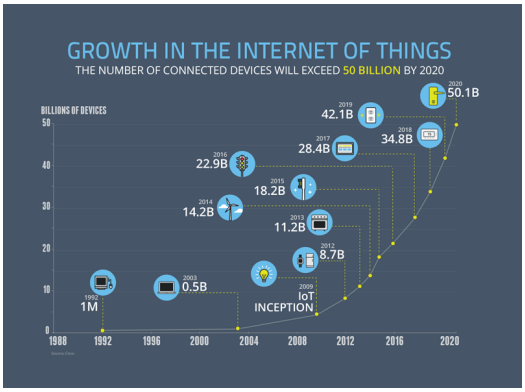


Figure 3: Connected devices. IoT by 2020
`https://www.ncta.com/whats-new/behind-the-numbers-growth-in-the-internet-of-things-2`

commits to reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management by 2030; and its evolution is being tracked by the KPI 11.6.1: The Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities. The structure of Goal, - Sub goal and KPI(s) is repeated for every SDG and they are self-defined by the UN as

> blueprint to achieve a better and more sustainable future for all.
> `https://www.un.org/sustainabledevelopment/sustainable-development-goals/`

Although its controversy in Business Management, the idea that 'one cannot manage, what is not measured' is now taken as granted. Significant amount research contributions have been trying to understand the importance of measuring performance in both, private and public institutions. There is a tradition that argues that metrics are negative and perceive

> Quantitative performance measurements-whether single, multiple, or composite-are seen to have undesirable consequences for over-all organizational performance. The complexity of large organizations requires better knowledge of organizational behavior (...) [3]

In another philosophical tone, the value of indicators is acknowledged, but understanding that 'performance measurement is not an end in itself' and

they could be used to (i) Learn what is working and what is not and (ii) Improve by identifying what would be done differently to improve [1]. In this project the value of the SDGs and KPIs is recognized as an important step towards building more sustainable and livable places. Setting goals and measuring them is one the first stages to improve performance, but to meet these targets another tool is needed. Planning (and execution) become crucial. P. Hall [2] define

> Planning as a general activity is the making of an orderly sequence of action that will lead to the achievement of a stated goal(s)' and motivates to question what the strategies and actions are needed to achieve the SDGs. More specifically, it is important to acknowledge that these events and activities happen somewhere in the territory which also need to be planned. (...)
>
> Planning with a spatial, or geographical, component, in which the general objective is to provide for a spatial structure of which in some way is better than the pattern that would exist without planning. Urban planning (or regional planning) is a special case of general planning, which does include the plan-making, or representational, component

1.3 Challenge

The importance of the SDGs and its KPIs is recognized as a step forward to meet the global sustainability. Yet the gap between indicators and how the planning of city-regions is done needs to be bridged. There is a challenge rised by the SDG11, to build better human settelemnts, and this mean dealing with the spatially planning of places. In order to plan better city-regions there is a need of spatializing, modelling and understanding how this information can be adequately incorporated into the different Planning Processes.

As described above, KPIs do not give information about the set of actions needed to create sustainable places or improve how resources can be used more efficiently. Studying and understanding the interaction between the indicators is crucial, but also where these events or actions happen (Space or Spatialization) is important and not trivial.

In order to meet the targets, it has never been clearer that spatial planning is necessary. In some urban domains such as transport, there has been long

tradition of exploring the relation between land use, mobility and socio-economic activities. As a result of data availability and it's natural proximity to geography, transport systems have been spatially planned for long time. New data sources and technological innovation can contribute to enhance the study of space in other urban domains.

2 General Problem

The problem of improving the quality of human settlements is complex and requires of a holistic approach to make effective contributions. There is a significant amount of interactions between the goals and in order to plan for a more sustainable places, these relationships need to be explored. By systematically looking at how these goals relate to each other, synergies can be enhanced, and tensions taken into consideration. Planning as a general practice will deal with evaluating and organizing what is the best course of action to meet a target.

Monitoring KPIs is an important activity, they provide information about the result of a process (or processes). By them self, they do not contain information about how a system works or is performing, but information about the working of a system are important for Planning purposes.

Figure 4: SDGs: Complex and Wicked Planning problems

Finally, but not least, it is important to recognize that these are not virtual or intangible processes, they occur in specific places in the space.

There is reason behind the geographical structure of these events which also deserves to be explored. By introducing the spatial dimension to the analysis, planning for better city-regions, becomes spatial planning.

For the purpose of this exposition, the idea that a city is works as a factory will be used to illustrate the general problem being faced here. Now, let's imagine that the owner of a factory wants to increase the amount produced, he would start to ask questions about how much is being currently produced and then start to monitor the amount of inputs requested. By solely looking at these variables, much planning cannot be done. Decisions about the amount and the combination inputs could help to enhance production, but soon more question about the processes behind production will arise. More information about the components of the factory will be requested, number of employees, salaries, energy consumption, machines used, and so forth. As more and more detailed KPIs about the production are being monitored, the processes of production will be revealed.

A city is not a a factory. besides many differences, in a factory the processes are linear. Inputs are transformed step by step in a linear process. One step is related to a previous one and so forth. Once a part moves forward in the production line, it never goes back and affects previous process. Social and Economic systems are complex and any performance indicator needs to take into account the complexity of these systems.

In Rittel and Webber's [4] words

> [large and interconnected network systems] In that structural framework it has become less apparent where problem centers lie, and less apparent where and how we should intervene even if we do happen to know what aims we seek.

Only after unpacking the systems interrelations, it would be possible to meet targets that are sustainable over time and minimize undesirable side effects.

Finally, but not least, space must be taken into consideration. Most of these are urban or regional processes occurring in specific locations. Spatial planning, then becomes the tool to help to define the specific set of actions in the space to affect performance.

To sum up, to modify the performance of a complex system it is needed to:

1. Understand the processes within the system

2. Understand how that system interacts with other systems

3. Understand the spatial-temporal properties

3 Research Project

3.1 Specific Problem

More specifically, the UN declares that the SDGs 'are a blueprint to achieve a better and more sustainable future', but the fact is that they a are just a monitor not a guide to achieve those goals. In order to meet the SDGs, we need to take a holistic approach and unpack the complexity of the different systems.

More specifically, to produce sustainable City-Regions, Urban and Regional Planning requires comprehension not only about: (i) the interactions within the components of a system and (ii) how different systems are interconnected, but also about the Role of Space and Structure.

Underneath, the running hypothesis of this research project is that location and the spatial structure matters. In order to plan sustainable city-regions the spatial distribution of human activities must be considered. Neglecting spatial patterns, is neglecting valuable information about how places work.

3.2 Research Aim of the Project

Given the specific challenge and problem detailed above, the aim of this study is to explore the relationship between performance, location and how events inter relate. In order to explore these relationships, the project goal will be to spatialize (capture the spatial structure) behind specific urban sub-systems.

By mapping the location of activities and events, it will be able to model and describe the specific properties of the systems will be studying.

By revealing the spatial dimension of urban systems, new and relevant information could be taken into consideration for Planning better City-Regions.

4 Theoretical Background

This research can be grounded to and will be benefited from developments in the following fields:

4.1 Urban and Regional Planning

- Compact cities
- Marshall
- Peter Hall
- Polycentric metropolis
- Designing the city
- Christaller
- The city is not a tree
- Arcaute
- Mejiers
- Vanoli
- Hilderbrand

4.2 Smart Cities, Analytics and Informatics

- Batty
- Ratti
- Townsend
- Kitchin
- Hollands
- Greenfield

4.3 Complex Systems

- Wilson
- Batty
- Betancourt

4.4 Urban Economics

- Urban Agglomerations
- Economics of Scale
- Bartholomy
- Industry clustters
- Bartholomy
- Jane Jacobs
- Von Thunen
- Alonso

4.5 Networks Science

- Cities are unbounded - Connected Cities
- Dupuy - Network of Buenos Aires
- To represent Cities with networks
- Castells
- Newman
- Barabasi
- Netto
- Hillier
- Taylor

5 Case Study: Waste MGMT & Food Sytems

Based on personal preferences, relevance for creating sustainable settlements (SDG11 & SDG12) and a potential knowledge gap in how space has been taken into account in the planning processes, two urban systems will be explored: Solid Waste Management and Food Systems are potential candidates to be explored as case studies for the present project.

In order to build a case towards the importance of spatialization and understanding the spatial characteristics of its this project will explore the food and waste management systems.

5.1 Waste MGMT System

According to the Director of Social, Urban, Rural and Resilience Global Practice, Ede Iljazs-Vasquez, Solid Waste Management (MSWM) is at the core of building sustainable and resilient city-regions. He specifies that this is not just a matter of providing technical solutions; how to make waste collection routes more efficient or how increase the waste-to-energy transformation ratio. Waste Management must consider other social and environmental systems.

In the countries of the European Union, in 2017 almost half of the waste generated was recycled (46.6 %) and on average, approximately 5% of the renewable energy is generated by municipal waste. In this sense, some countries such as the Netherlands show the highest percentage (almost 30%), evidencing the missed opportunity of understanding waste as a useful resource to generate energy.

5.2 Food System

Food system and the waste of it are one of the important pieces of the waste management puzzle. Estimations suggest that 1/3 of the total food production is being lost or wasted. This means that 1/3 or even more of the efforts allocated in producing food are also being missed. Consequently, research can help to reduce (i) food waste consumption at household level (ii) waste during the supply chain and/or (iii) the waste to energy processes inefficiencies.

5.3 Small note on the systems

A systematic literature review on both systems is needed. Urban metabolism, Resource efficiency, how space is taken into consideration to understand these systems and how Urban and Regional Planning has been dealing with this waste mgmt and food is important for the future of this project.

It has become clear that that the synergies between land, waste and food management need to be understood properly and information about location and relationship can provide valuable information.

6 Smart Cities & Urban Informatics

Urban Analytics and Informatics is a relatively new, multidisciplinary, and broad field of research that contributes to identify, describe and solve urban challenges. Its name indicates the conjunction of two disciplines. On one hand, brings specific knowledge from economics, sociology, or geography to address urban dynamics such as gentrification, segregation, lack of accessibility or housing informality. On the other hand, uses a quantitative approach to understand these dynamics. Urban analytics focuses on many domains but uses a specific toolbox to explore these topics.

Michael Batty, founder of the Center of Advanced Spatial Analytics (CASA) at UCL defines it as a

> fast emerging as the core set of tools employed to deal with problems of big data, urban simulation, and geodemographics

In another quote, Professor Emeritus of Geography at Santa Barbara University, Michael Goodchild, describes it as a

> New kind of urban research, one that exploits the vast new data resources that are becoming available from social media, crowd sourcing, and sensor networks (...)

[5].

During the last past years, a set of new forms of data and computational approaches have enabled a New Science of Cities to raise. But as the old KPIS, these new data sources do not produce insights on their own. Data needs to be stored, cleaned and combined with different sources to be used.

Urban Analytics is the disruptive approach that enables to handle big quantities of information to answer urban questions. Among the toolbox often employed we could list: (i) Modelling, (ii) Visualization, (iii) Data Capture, (iv) Data Science, (v) GIS and (vi) Simulations.

In order to illustrate what Urban Analytics and Informatics is capable of, a set of four projects are described below. Although, in each project different features of the toolkit are used, the strongest and most innovative resource was highlighted.

6.1 Data Science

In this example, Google Street View is used to create a perception index of how green a city is. In opposition to using satellite images or tree census, the objective of this project is to capture the amount of perceived green by the citizens of a settlement. Besides the innovative use of an already existing data source, the project is data intensive, as the images need to be processed and determine the amount of greenery. `http://senseable.mit.edu/treepedia`

6.2 New Data Sources

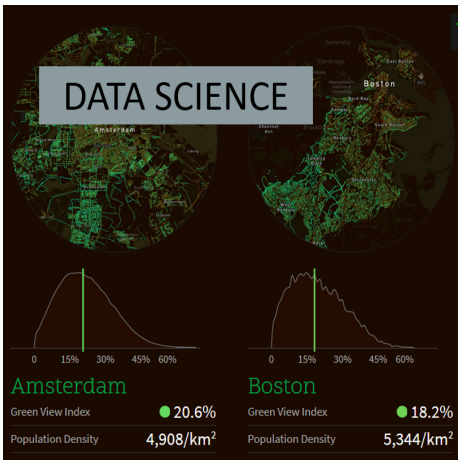
The second case tries to tackle one of the mayor data limitations faced by planners, politicians or any other stakeholder of the city. Using the data of a food service application the project managed to estimate the amount of people that lived in different cities in china. The results produced a more detailed dataset of the population (temporal and spatial) than what an official census can provide. `http://senseable.mit.edu/tasty-data/`

6.3 Data Capture

In some cases, Urban Analytics and Informatics can contribute to create a new data set. In this opportunity small trackable devices are embedded in objects to be thrown away. As a result, the, spatial-temporal trace of waste is generated. There is a completely new data set of where the waste is generated, where did it traveled and for how long and where it ended. `http://senseable.mit.edu/trashtrack/`

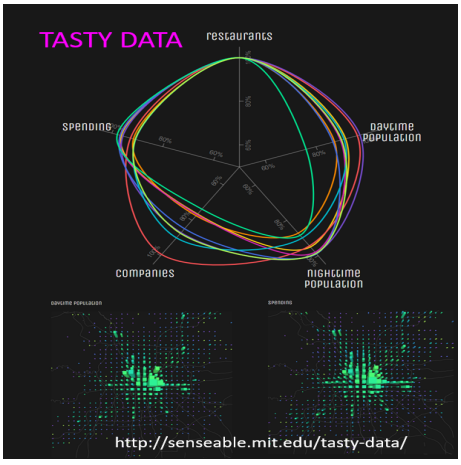
6.4 Visualizations

Another important component of Urban Analytics is to summarize the findings and highlights of big and complex data sets in a comprehensible way. Using an adequate visual strategy is important to make the results of the research understandable by a specific audience. In this opportunity GeoFluxus, was selected as an example as the project objective is to map and visualize the flow of waste. `http://geofluxus.com/#data`

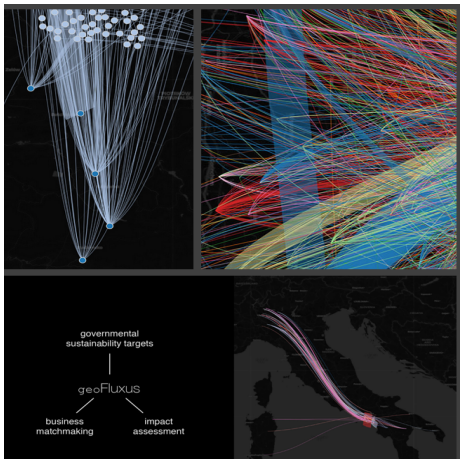


(a) Data Science

(c) Data Capture



(b) New Data Sources



(d) Visualization

Figure 5: Urban Analytics and Informatics toolkit

7 Tentative Lines of Research

7.1 Networks, Boundaries & Peformance

Short Project Description: Because of cultural, historical or natural reasons, Countries have the tendency to subdivide its territory in different administrative levels. On the other hand, the functional city-regions are difficult (if not impossible) to define. Transport, Education, Health and so forth cannot be bounded to territory as socio-economic activities happen in different locations. Regional, Provincial, Municipal jurisdictions are fictional boundaries created without taking into consideration urban functions.

This line of research will explore the consequences of spatial compartmentalization. By studying and understanding the spatial relations behind the waste MGMT system there is an opportunity to identify opportunities and threats of the system.

Hypothesis: Spatial administrative boundaries are fictional impositions that affect performance negatively.

Exploratory Research Questions:

- Should each municipality provide all the services related to waste MGMT or there is place for synergies?
- Under what circumstances the system might under perform and under which ones it will outperform?
- Is the service being provided equally across the territory or in border areas there is lower coverage due to shared responsibilities.

7.2 Urban Form, Land Use (Function) and Performance

Short Project Description: As any other systems, Waste MGMT and food production/distribution have their own set of KPIs to monitor the performance of the systems, fuel costs, time or emissions can be used to understand how well those systems are working. Yet, all these processes are happening somewhere in the City-Region and consequently mapping them and identifying how intensely they relate one to the other is important to improve some of the processes carried out by these systems. Land Use and how socio-economic activities are distributed across space, might have impact on the performance of these systems. The interrelationships between

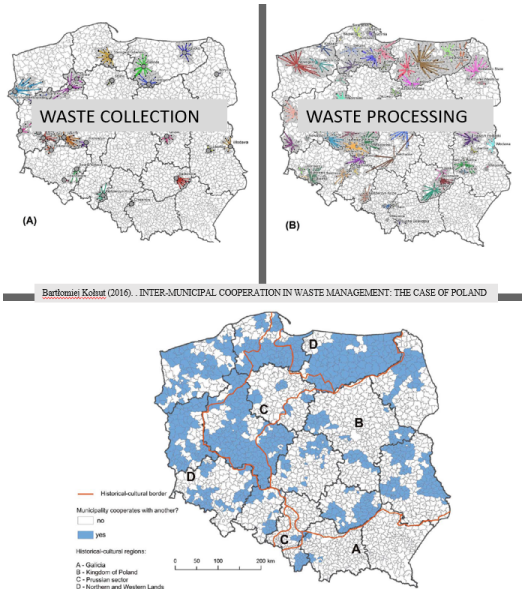


Figure 6: Research Lines 1

food generation, food disposal, food consumption, waste generation, waste treatment, waste collection and land use have not been explored as in depth as other systems; for instance, transport and land use.

Hypothesis: Urban and Regional Planning have not fully explored how the spatial distribution of socio-economic activities affect waste MGMT and food systems performance. By spatializing these activities, they would be more easily considerate in planning processes.

Exploratory Research Questions:

- Does each strategy perform differently under different urban form and land use scenarios?
- Which strategies are better given a specific urban form and function?

7.3 Network characteristics of food and waste MGMT

Short Project Description: After representing systems as networks, the structures of the relationships could be studied. Different systems have different properties. For instance, the road network is different from the train

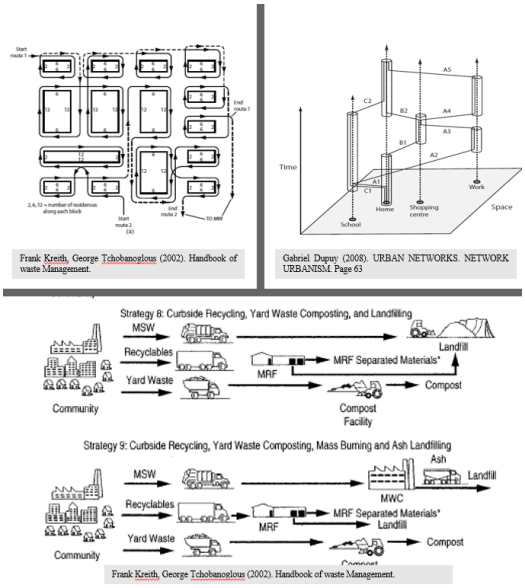


Figure 7: Research Lines 2

or flight networks. The network properties contain information about how a specific system is working.

Introducing the spatial dimension to life cycle assessments and urban metabolism concepts can contribute to rise important information about how these systems are performing. What might seem a single node or step in a Solid Waste Management Diagram, might not be clustered in space. Mapping, modelling and visualizing these steps might enhance our understanding of the system and eventually affect it's performance more accurately.

Hypothesis: There are structural characteristics of the relationships within a system.

Exploratory Research Questions:

- How does different waste MGMT systems relate to different network structures?
- Is there any connection between the structure and intensity of relationship and performance?
- By studying the structural properties of these systems, would it be possible to identify opportunities and threats?

- Can the spatial patterns help to identify waste MGMT or food system needs? Can they help us to predict illegal disposal sites?

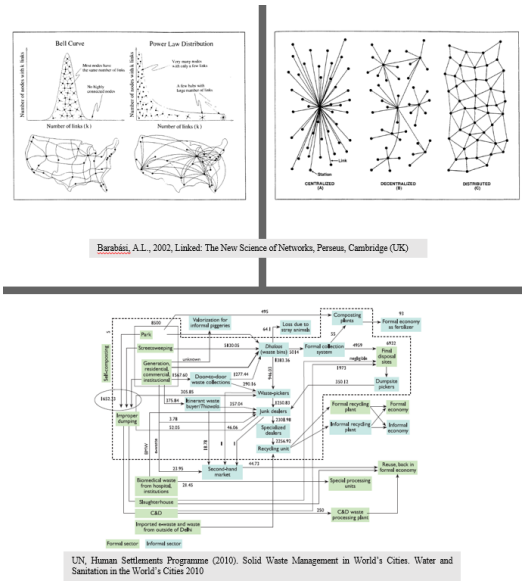


Figure 8: Research Lines 3

7.4 The Role of Location to enhance Circular Economy in the City-Region

Short Project Description: After revealing industry's needs, products and waste materials, it's important to understand their location. By mapping and modelling the spatial relationship of different industries or businesses opportunities for potential synergies can be detected. Moreover, previously unseen demands could be seen by looking at how activities are distributed in space.

Hypothesis: Circular Economy performance is space dependent and by modelling socio-economic activities is space, circularity can be enhanced.

Exploratory Research Questions:

- Model the system to identify potential opportunities and threats.
- How to integrate these into the planning process to improve these systems?

- Is the functioning of these systems affected by spatial planning?

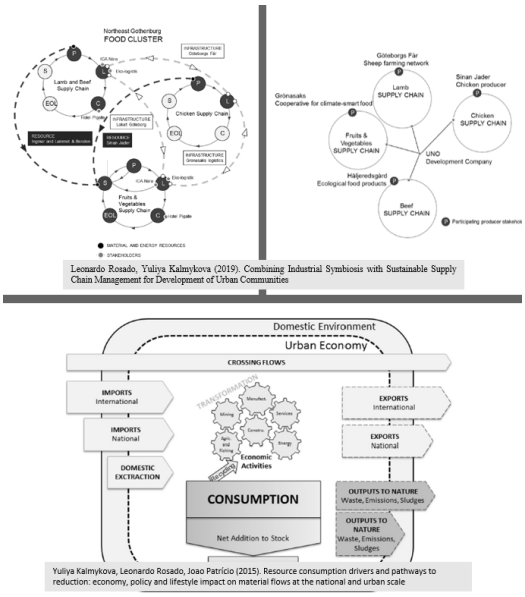


Figure 9: Research Lines 4

7.5 Integration between the food System and waste MGMT

Short Project Description: To some extent, waste MGMT and food system could be integrated into one system. Food waste could be used as compost or as energy, but the location of farms, warehouses and recycling facilities might contribute or undermine the synergies between these systems.

The mapping and analysis of these systems is not a straightforward task. There are multiple actors and they might be represented at different geographical and temporal scales. Aggregating and modelling these systems for a product will allow to understand how different actions or events can affect the overall performance of the system.

This project will track different components or subcomponents to reveal the spatial cycle as the move around the metabolic cycle of city-regions.

Hypothesis: Aggregating the relationships between different actors across different spatial-temporal scales will enable to plan better city-regions. The

spatial patterns hold valuable information for Planning processes. By revealing the flow of components, materials or inputs, it would be able to identify potential opportunities or threats of the system.

Exploratory Research Questions:

- How to (dis)aggregate and connect the different operators' levels?
- What is the effect of changes in the system?
- How does actions propagate across levels?

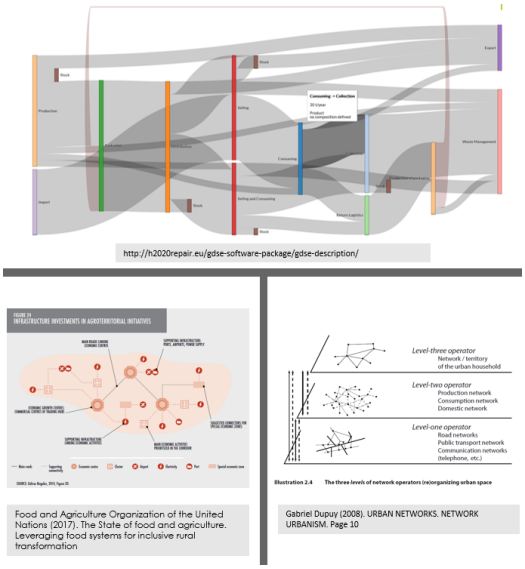


Figure 10: Research Lines 5

8 Future Steps

In order to successfully finish this research project, the following set of actions has been defined.

1. Engage with experts:
    - Food and Waste MGMT Systems

- Urban and Regional Planning

2. Continue expanding knowledge regarding Urban Metabolism and Regional Planning.
    - Explore how urban planning is taking into consideration solid waste MGMT and food necessities.
    - Understand the current state of integration between food and waste MGMT systems
    - To what extent there is a geographical gap in the waste MGMT and food system
3. Academic writing and publication:
    - BEYOND 2020: Towards a city congestion index: methodological explorations using Google's Distance Matrix API
    - 10% Report
    - Elasticity of Demand of the Buenos Aires Underground System
4. Start looking and exploring potential data sets to model and run experiments. Seek for potential data gaps or information systems to fill.
    - Test and decide about the specific toolbox to be used during the research project.

References

[1] Robert D Behn. Why_Measure_Performance_Stawa_En. (October), 2003.

[2] Peter Hall. *Urban & Regional Planning*. 1992.

[3] V. F. Ridgway. Dysfunctional Consequences of Performance Measurements. *Administrative Science Quarterly*, 1(2):240, sep 1956.

[4] H Rittel and M Webber. Rittel_and_Webber_1973_Planning_Problems_Are_Wicked_Problems.Pd 1973.

[5] Alex David Singleton, Seth Spielman, and David Folch. *Urban {{Analytics}}*. SAGE Publications Ltd, Los Angeles, first edit edition, 2018.

[6] UN. Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development (A/RES/71/313), Annex (6 July 2017). 11371(July):25, 2017.

[7] UN. The World 's Cities in 2018. *The World's Cities in 2018 - Data Booklet (ST/ESA/ SER.A/417)*, page 34, 2018.

[8] United Nations and The World Bank. Sustainable Development Goals Monitoring Human Settlements Indicators: Ashort guide to human settlement indicators 11+. 1(254 2):1–28.