Development and Operationalisation of Local Sustainability Indicators - A Global South Perspective on Data Challenges and Opportunities for GIScience

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Abstract

Evaluating and monitoring the sustainable development of nations and cities requires sets of indicators. Such indicator sets should measure equity, health, environmental, or governmental progress or recess - among other sustainability aspects. In 2015 the United Nations ratified 17 Sustainable Development Goals (SDG) assessed through 231 indicators. However, other - local - sets of indicators have been developed too. In this paper we review geodata challenges that emerged when we developed four sustainability indicator sets in Chile. Faced challenges include (geo)data availability and data representativeness, among others. We analyse how GIScience knowledge has contributed to indicator development and outline three priority research topics: (i) updating indicators based on automated processes, while respecting representativeness, (ii) tools for planning scenario generation, and (iii) methods for short- and long-term forecasting.

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1 Introduction

In 2015 the United Nations adopted a new development agenda with the title "Transforming our world: the 2030 Agenda for Sustainable Development". In this agenda 17 Sustainable Development Goals (SDG) and 169 particular development targets are outlined that should be met until the year 2030. The first 4 sustainable development goals address people's basic demands: (1) no poverty, (2) zero hunger, (3) good health and wellbeing, and (4) quality education. Further important goals include gender equality, clean water, responsible consumption, as well as reduced inequalities. Given that today 54 percent of the global population lives in cities, Goal 11 has been targeted at cities. This goal has a focus on

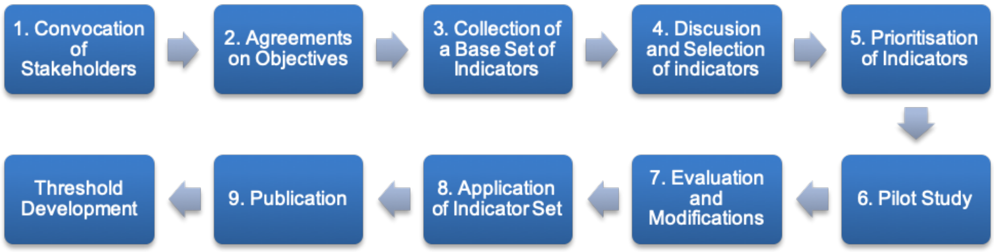

Figure 1 Typical process to develop a set of urban sustainability indicators.

"Make[ing] cities and human settlements inclusive, safe, resilient and sustainable". To evaluate progress towards reaching the development targets the SGDs are accompanied by a set of indicators, currently being 231. However, not only the UN has published indicators that measure coverage of people's basic needs, sustainability, and quality of life aspects. Other well-known globally applied indicator sets are for instance the Human Development Index and the Environmental Performance Index with a focus on assessing and comparing nations. But there are also indicator sets with a focus on cities, such the Happy Planet Index and the Global City Indicators (see [12]). For Chile, home country of the authors, several indicator sets have been developed as well. The authors directed and participated in the development of at least four sustainability indicator sets, including the CEDEUS Indicators (`http://indicadores.cedeus.cl`; [12]) and the SIEDU indicators published by the National Council for Urban Development (CNDU). Given these experiences on indicator development and operation, we wanted to review our work guided by the following question: "*What have been the difficulties during the operationalisation of urban indicators from a geoinformation perspective and how did GI experts contribute?*". To answer this question, we outline first the process to develop indicators (Section 2) and then summarize the (geo)data issues that we faced (Section 3). We then reflect on our experiences by looking at the geoinformation team contributions (Section 4) and further research needed to advance in our work (Section 5).

2 The development process of urban sustainability indicator sets

To better understand the context of difficulties that may be experienced during the development of indicators sets, we will outline the steps that may be used. We identified 9 steps that can be presented as consecutive steps (see Figure 1). However, in reality the development process often includes several iterations until consensus among the stakeholders may be reached. (1) The first step of the indicator development process usually addresses the convocation of stakeholders that may be interested in using the indicators later on. Stakeholders may include experts, including researchers, representatives from municipal and governmental administration, local civic organizations, and NGOs [1]. (2) The first meetings with these stakeholders have the objective to identify the purpose of the indicator set and finding a common language. (3) In the third step a base collection of indicators may be developed usually through an analysis of the literature with input from the stakeholders. Often the resulting base set consists of several hundred indicators. (4) In the following step the indicators of this base set are then analysed and discussed to select indicators that can meet the earlier defined objectives. (5) As the resulting set of indicators may still be large (e.g. around 100 indicators), a prioritisation exercise may be carried out. (6) Next step is a pilot study that operationalises the indicators that are considered as of high priority. The

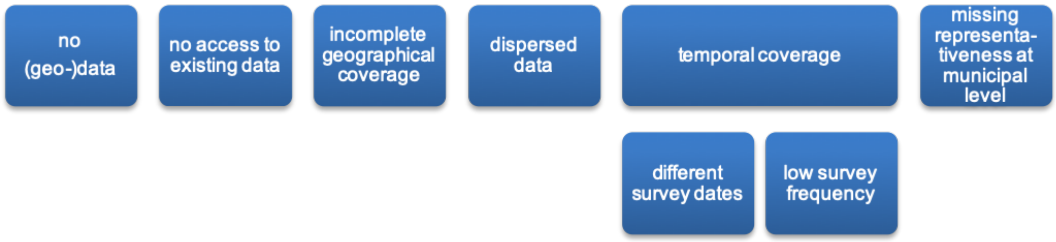

Figure 2 Data related challenges experienced during indicator development.

pilot study serves several purposes, including for instance the selection of indicator variables and analysis of the calculation results so as to confirm that the indicator variables are able to highlight differences and trends among study sites. This phase is often executed by a geo-information or statistics team consulting with domain experts. (7) The results of the pilot study are then presented to all stakeholders for further discussion, so as to identify if the selected indicators and variables are able to fulfil their purpose, being sufficiently sensitive and robust.(8) Given that all stakeholders agree on the indicators and variables, the indicators are calculated for all cities or region(s) of interest. (9) Finally, indicator results are to be published to inform the public. While these are the basic steps of indicator development, it is possible that these are followed by an additional process with the objective to develop sustainability (and quality of life) thresholds for each indicator.

3 Geodata challenges

Given our experiences, in general the processes of developing indicator sets face the problem of data availability when indicators are proposed. While this may perhaps not be a surprise, if one considers that our work has a focus on Chile, a country in South America, the very same issue of data availability has also been highlighted by the authors of the U.S. Sustainable Cities Report in their 2017 version [10]. Prakash and colleagues considered to calculate values for 49 indicators for the 150 most populous "cities" originally, but had to resort to analyse only the 100 most populous "U.S. Metropolitan Statistical Areas (MSA)" - out of a total of 382 MSAs - due to a lack of and problems with data [10]. Besides the in-existence of data, a range of difficulties related to (geo)data can be found (Figure 2). In some cases data may exist, but it may be difficult to obtain access to it. Reasons for access issues are for instance concerns and confidentiality classifications by public administration, such as tax and crime records in Chile, or because the data owner is actually a state-contracted survey company or a public service provider, such as a private electricity and water services provider. Whereas access to these locked-up data may not be impossible for the purpose of indicator calculation eventually, it still raises the issue of completeness, transparency, and reproducibility for users of the indicators. Further difficulties arise from the fact that responsibilities for (public) urban data are often distributed among different levels of government (ministries, regions, cities), and public & private service companies (see also [4]). Result of these dispersed responsibilities is that data may lack complete geographical coverage and are dispersed as well. This meant for some of the CEDEUS indicators that data had to be requested from 71 municipalities.

Not few times requested (tabular) data may come printed, on CD as pdf, via (snail) mail or email, since (Spatial) data infrastructures exist only in some ministerial divisions and a hand full of municipalities - mostly due to a lack of experts and high cost of such infrastructure. Even if a geodata infrastructure exists, access is often possible only for in-house users and access via data APIs are rare.

Completeness issues do not only concern geographical coverage of data. It includes also temporal coverage and statistical representativeness of survey data. Temporal coverage, i.e. survey frequency, turns out to be an issue when cities grow rapidly, as in many developing nations, when population census surveys are preformed only every 10 years. In this case evaluation and (city) planning is often based on outdated data and "monitoring" of change is complicated. Similarly, comparability among cities will be difficult if surveys are made in different seasons or years. These very same difficulties were already reported by Hoornweg et al. [5] 15 years ago (in 2007) for indicator projects at the World Bank, who found "a lack of reliable disaggregated data that are comparable across cities and over time." In the case of Chile, for instance, the origin-destination travel surveys used for mobility indicators are carried out only for mayor cities every 10 years, and surveyed in different years.

A lack of statistical representativeness of survey data for the municipal level has posed as well problems when we aimed at operationalising indicators. Some important surveys in Chile, such as the two-yearly socio-economic household survey CASEN, are carried out to obtain statistics at regional level only, and are therefore representative only at this level. However, city planning requires data at least at municipal level.

4 GIScience contributions

Changing the perspective from reviewing the encountered data challenges for indicator implementation to the perspective of how GIScience knowledge & technology can facilitate the process of indicator operationalisation, calculation, and communication, we identify three broader areas of contribution:

Expertise on geodata - The expert team that is usually in charge of gathering data and calculating the indicators often contain geographers and statisticians. Geographic information experts are able to contribute here with their expertise when searching for indicator base data and in the assessment of the suitability of candidate datasets. If no data could be found that fits indicator requirements, such as geographical coverage, yearly data updates, and geographical and socio-demographic representativeness [12], then GI experts can help to establish criteria for the collection of new data. This includes to identify at what geographic scale data is needed, and what data collection tools, methods, and sampling schemes may be used to ensure representativeness.

GI Systems & Standards - A second area of GIScience contributions to indicator development and operation concerns the utilization of GI technologies and standards. To mention here are technical developments and standards related to Spatial Data Infrastructures (SDIs) [8]. The Open GeoSpatial Consortiums' (OGC) standards for data description, cataloguing, and search help to identify suitable data sources for consecutive monitoring of urban conditions. Also other OGC standards, such as the OGC Simple Features specification implemented in spatial databases and the W*S specifications are essential to manage efficiently city or countrywide datasets. Finally, the OGC sensor web related standards permit updating sensor-based indicators that for instance assess environmental pollution or usage of transport modes. Other GI related tools have helped too: most prominently the scripting languages and processing frameworks that permit to automate data processing and analysis, such as Python and R.

The GI expert toolbox for indicator interpretation - There is a further area of expertise and opportunity for contribution that concerns the analysis of spatial data and a profound knowledge of the geostatistical analysis toolbox. Good indicator variables allow to identify differences and trends among cities or perhaps even neighborhoods. To assess a variables geographical sensitivity that permits to identify where a policy intervention may be necessary, it is necessary to assess a variables distribution function and employ (geo-)statistical tests to identify the significance of trends and differences. The geostatistical toolbox employed for identifying meaningful indicator variables can help as well to define sustainability thresholds for indicators. Geospatial visualization tools are further useful in producing maps or (carto-)diagrams, during indicator development and when interpreting results. Maps like visualizations allow to validate visually an indicator variable and its data for coherence (with expectations) as well as its geographical sensitivity. For instance, energy consumption patterns that reflect income segregation between city neighbourhoods [12]. Visualization of indicators through maps and urban dashboards supports communication of indicator results to the public and decision makers [6].

5 Three emerging research topics for GIScience

Considering our four indicator development experiences we analysed what challenges are ahead of us when maintaining and utilizing the indicator sets. We identified three broader challenges:

Indicator updates from Sensor Data – The first challenge concerns the ability to monitor urban change; be it as a result of changes in natural (e.g. climate) or political conditions (e.g. new policies). For most indicators it is sufficient to update data and indicators only once a year, however, for some indicators monthly or even daily updates are possible. The challenge is here to update data and indicators ideally in an automatic fashion, be it from sensor data or civil service registries. This requires (widespread) introduction of data APIs and the implementation of data processing chains. Implementing these becomes challenging if one considers that the data need to be collected, evaluated, cleaned, and processed for different cities and regions in a way that always ensures plausible and representative indicator results, even if sensors fail or received data contain somewhat obscure values. Similarly, scaling up of indicator results from neighborhoods to city and to regional levels requires to account for maximal permissible errors.

Planning Scenario Modelling - A further need that we see concerns the development of a toolbox that permits to generate and evaluate city planning scenarios, as shown for instance by the AURIN project and the Urban FootPrint platform [9, 7]. We imagine it to be somewhat like an online version of the computer game “Sim City”, but rather with a focus on city policy tools & models, than the provision of a city construction toolset. The scenarios that are created are then to be evaluated with indicator sets to assess the impact of policy changes [11]. Even more interesting could be to develop indicator-based scenarios via back-casting, i.e. defining what indicator values need to be obtained in the future and see what needs to be done to get there [2].

Short- and long-term forecasting - To evaluate how indicator values may develop in the future, spatial models need to be developed for forecasting. Of interest may be indicator forecasting for a few days only, similar to meteorological forecasting, and forecasting for the next year or the next five years. While it is safe to assume that policies do not change when forecasting for a few days or weeks, forecasting for one year may and for 5 years actually should be able to consider policy changes, so as to explore impacts of policy changes. The task is here to keep working on forecasting methods that explicitly allow to include spatial interdependencies among indicators (see for instance Fotheringham et al. [3]).

6 Conclusions

As we have outlined, a paramount challenge for the development of indicator sets for the assessment of urban sustainability is that often required data are either not existent or not accessible. This includes in particular data needed to evaluate the UN's 17 Sustainable Development Goals (SDGs). Work by Prakash et al. [10] and ours show that the lack of data is a global problem. Hence, the expertise of GIScientists and GI professionals is needed to identify and collect required (geo)data.

While being able to contribute with knowledge on data and tools to indicator development and monitoring, we think that GIScientists need to promote the (still new) spatio-temporal perspective - overcoming a statistical and national perspective. This will allow to develop geographical targeted indicators and policies that may be more suited for geographically diverse countries. Similarly, we think that GIScience needs to promote cost and resources effective governance and responsibility models concerning data. We believe that Europe's INSPIRE directive and the European Environment Agency can lead as an example that shows how Spatial Data Infrastructures (SDIs) can facilitate access to data.

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