A Systems Analysis for Air Quality in Urban Ecology

Gilbert Ahamer
https://orcid.org/0000-0003-2140-7654
Austrian Academy of Sciences, Austria

Ralf Aschemann
Graz University, Austria

Birgit Pilch
Graz University, Austria

1. INTRODUCTION

The linkage between *data science* and *systems analysis* is a very clear one: on the one hand, fine-tuned data facilitate modelling and thus yield more exact results, on the other hand, detected patterns in time-space can provide a direction in which key interactions between parameters can be detected (Antoniou et al., 2018, Bhardwaj et al., 2015; Gvishiani et al., 2016; Kazieva et al., 2020; Lei et al., 2015; Mondal, 2016; Salazar et al., 2017; Song et al., 2020; Steinwandter & Herwig, 2019; Tripakis, 2018; Weinand et al., 2021).

Moreover, the general architecture of any modelling task in systems analysis and systems dynamics requires understanding, which of the potentially contributing factors can actually exert substantial impact on the results of a model, and hence co-determine meaning of that (quantitatively described) world view (Bentur et al., 2021; Finelli & Narasimhan, 2020; Lee et al., 2020; Medford et al., 2018; Nannapaneni et al., 2015; Tedeschi, 2019; Yang et al., 2015).

A third argument for the relevance of systems dynamics is the need for suitable parametrisation of detected interactions: this needs sound basis drawn from data analysis (Bennett & Clark, 1994; Dominiczak & Khansa, 2018; Idreos & Kraska, 2019; Liebovitch et al., 2019; Parnell et al., 2021; Sheikh et al., 2021; Šoštarić et al., 2021; Wickramage, 2017; Zanin, et al., 2017).

Within systems science, the topic of *urban air quality* is among the most traditional themes because it allows clear systems borders when modelling, namely the city's borders. Within a city, the most dynamic contributing factors can easily be identified, and thus a quick list of remedies can be established – which will suitably lead to rapid decision making on the municipal level. Such a mathematical tool should be short, concise, transparent, easy to understand, quickly manoeuvrable and thus quickly gain sympathy of municipal policy makers such as a mayor and key clerks, who traditionally have a leaning to practical-minded operationalism.

Data scientists are invited to see that (i) a quick conceptual look (ii) based on modelling experience allows to demonstrate the usefulness of gathering data on the local levels.

As topical example after the aggressive war attack by Russia on Ukraine, even states of sustainable peace were modelled (Liebovitch et al., 2019), thus shedding light on the importance of peace and empathy for global conviviality.

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After this general justification of our theme's presence in this encyclopedia, we turn to the concrete theme: In the field of environmental protection and in any transdisciplinary education, it often becomes apparent that the effect of a certain action is not limited to the directly intended effect (Sterman, 2000; Coyle, 2000; Senge, 1990; Forrester, 1971; Aschemann, 2004; Ahamer and Kumpfmüller, 2013). Side effects can, via detours, spark a much greater dynamic in the overall system than direct effects. Such a characteristic occurs with closed control loops, which can build themselves up (positive feedback) or also stabilize (negative feedback).

For example, the relocation of residential areas into the unpolluted "green" on the outskirts triggers further traffic flows, which in turn cause additional traffic flows that further reduce the quality of life.

To support a clear thought organisation for the system "air pollution control in a city", the main descriptive variables should first be found out and then these should be related to each other.

2. THE DESCRIBING PARAMETERS

A uniform distribution of describing parameters across the entire subject area appears necessary for modelling the system dynamics. Their structure is as follows: the main thematic level consists of the four general themes (1) emitters, (2) the resulting so-called "emission" (i.e., concentration of air pollutants affecting the air quality) or effect on nature, (3) the effect on people and finally (4) the social boundary conditions regarding politics and economy.

Each such main level is divided into three intermediate levels, which can be seen in Table 1. For example, the emitters are divided into transport, energy / industry / trade and finally heat supply. Each of these intermediate levels is usually finally described by three indicators (= variables = parameters). A more detailed description of the individual indicators and units of measurement can be found in an early long version of this work (Pilch et al. 1988, 1992).

3. THE INTERACTIONS

In accordance with the widely differing types of variables from the areas of air chemistry, economics, sociology, etc., a semi-quantitative description of the strengths of interaction is preferred as follows: Effects from "very weak" to "very strong" correspond to the numbers 1 to 5, while positive or negative signs are possible (–5 … 0 … +5).

A harmonisation of all occurring strengths in horizontal and vertical direction as well as the restriction to the elementary steps of impacts led to the establishment of the matrix in Table 2. This matrix shows the strength of a parameter listed in a given row onto a parameter listed in a given column.

The most important of these 196 relationships are shown in Figure 1 "emission - transmission – resulting air quality and human health". The totality of all relationships is graphically portrayed in Figure 2.

In accordance with the cybernetic approach of the early Swiss pioneer Frederic Vester (Vester, 1980) and his colleagues, active and passive variables can already be described in this context in view of such a matrix: According to the definition, an active variable has an effect on many others, but itself is only slightly influenced. In the present case, these include the following variables: "Directives, institutions, norms and standards" (4.1.2), "State of technological development" (4.2.1), "Mindsets, models, and social behaviour" (3.3.1), "Land use and spatial planning" (4.3), "Material quality of life" (3.2.1), "Daily and annual concentration of air pollutants" (2.2.1), etc.

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