On assessing governmental sustainable residential planning and its alignment with residents’ and estate investors’ objectives

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Abstract

There are three key actors in forming the sustainable spatial distribution of residency in an area, (local) government, the estate investor and the resident, each with its own objective. Most urban planning studies have mainly focused on the ex-post evaluation of residential development by considering the objective of each actor separately. This paper outlines a conceptual model where the three key actors and their unique objectives are integrated with the aim of providing an ex-ante evaluation of residential development for government to make policies operational on a micro level. The methodology is implemented on a Swedish city, where sustainable residential development is in high need due to the influx of immigrants. The case study demonstrates that the model can integrate the macro and micro actors well. The model can provide noteworthy insights for the government on where the objectives of sustainability, livability and profit can be met. A sensitivity check of the parameter settings shows that the implementation of the model is robust for replication in other cities.

Keywords: Sustainable urban development; CO₂ emissions; Multi-agent system model; Urban mobility

1. Introduction

Under the tide of sustainability and livability, governmental residential planning, estate investment and residential locations are gradually forming the spatial distribution of residency

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in a city. As Godschalk (2004) points out: “Land use planning faces both an opportunity and a threat. On the one hand, it is widely counted on and expected to deliver both sustainable development and livable communities. On the other hand, it must cope with serious conflicts in the values related to these two beguiling visions.” There are three key actors in forming the residential, spatial distribution, namely, (local) government, the estate investor and the resident, each with its own objective. One strand of the literature has focused on the actors’ objectives and their determinants, while another strand has discussed how a government may form policies for sustainable, residential development. However, to render such policies efficient on a micro level, the microscopic behavior of the other actors needs to be integrated into governmental policy. The aim of this paper is to develop such an integrated method for the identification of efficient, sustainable governmental policies.

In this paper, we set out to outline a conceptual model for the interaction of the three key actors in the forming of residential development – government, (residential) estate investors, and residents – each actor with their unique objective. Furthermore, we develop a methodology to ex-ante assess if, and where, the government’s sustainability objective may be in conflict with the objectives of the other market actors. The method is applied and demonstrated in a representative Swedish case study, the mid-sized city of Borlänge, which, similar to many other Swedish cities, is currently planning for massive residential development in response to population growth due to *inter alia* -the influx of immigrants.

In outlining the conceptual model, we define each actor’s objective (in utility terms), where we draw heavily on previous research that has scrutinized the actor’s objective separately. We regard the government as the macro actor in residential development, but purport that the government exerts the resident’s living preferences and the estate investor’s willingness to invest in its utility function. The objectives and behavior of the estate investor
and the resident are formulated on a micro level, meaning that our approach belongs to the tradition of microscopic models frequently applied in the transportation science when it comes to model the behavior of the market actors (Waddell, 2002; Iacono et al., 2008; Haase, and Schwarz, 2009).

The implementation of the methodology requires access to some key variables or proxy-variables thereof: (1) the spatial distribution of market value of residencies and the built-up cost, (2) road network and its traffic flow and the corresponding emissions (or other outputs giving rise to negative externalities), (3) availability of data on fractions of green land and water in the surrounding area, and (4) residents’ consumption. In the case study, we demonstrate how these variables can be obtained, measured or derived. The implementation of the methodology also requires a number of parameters to be set. To ensure that the results for the case study are robust for these settings, we conduct a sensitivity analysis where the most reasonable setting (default) is replaced by an aberrant setting.

Accordingly, the paper is structured as follows: Section 2 provides a review of the literature upon which our conceptual model that integrates the objectives of the three actors in residential development is based. In Section 3, we outline the conceptual model. Section 4 is devoted to the case study we use for demonstrating the implementation of the methodology for assessing if, and where, the government’s sustainability objective may be in conflict with the objectives of the other market actors. Section 5 concludes the paper.

2. A review of previous research

In residential development literature, the government is typically regarded as the macro actor, whilst the estate investor and the resident act on a micro level. The relationship between these two levels can be structured as illustrated in Figure 1 (cf Sun et al., 2014). The government possesses the power of approving a certain location for residential development. The (estate)
investors and residents behave in the market, based on the assessment of willingness to develop and willingness to live. This microscopic behavior may promote or hinder the fulfillment of the governmental objective.

Figure 1: The relationship between government planners, residents and investors in residential land planning (WTI = Willingness to invest, WTA = Willingness to approve, WTL = Willingness to live).

Campbell and Cocco (2007) point out that estates are risky assets with volatile prices and that it is therefore important for residents to assess carefully the estate's location with regard to accessibility (via transportations), its surrounding as well as its relation to the residents’ disposable income, and this, in turn, influences the strategy of the investor. Thus, on the estate market, the spatial distribution of market value and the built-up cost of estates are primary factors in influencing the decision of investors and residents. Given that residential development lies in a complex socio-ecological system (Cook, et al., 2012), the market value of estates is found to be dependent on the location (Alonso, 1964; Gelfand et al., 2004; Kiel and Zabel, 2008). As Kuethe (2012) states, “real estate is tied to a particular location, and as a result, many of its characteristics are shaped by the surrounding physical environment. This
notion has motivated a substantial body of research that addresses the price impact of various land use activities on neighboring properties.” For instance, Luttik (2000) found that natural elements, such as trees or water, increase property values. Moreover, transportation opportunities are also found influential in evaluating potential residences (Weisbrod, 1980; Srour, 2002; Chatman, 2009; Tillema, 2010)

Yiu and Tam (2004) conducted a review of empirical studies on property price gradients and identified two estimation methodologies and three assumptions on the spatial structure of an urban area that predominated. The two methods are: (1) the hedonic pricing model and (2) the repeat-sales model. In addition, the three assumptions on the spatial structure of an urban area are: (1) the monocentric assumption; (2) the non-monocentric/polycentric assumption; and (3) no a priori assumption about the urban spatial structure. Common to the literature, reviewed by Yiu and Tam (2004), is that the decision-making by one actor is unrelated to other actors’ decision-making, where the government as an actor is typically overlooked. For the government, sustainable development is a pillar in setting the macroplanning policy (Brugmann, 1996). This objective is usually evaluated by examining urban form strategies (Clark, 2001; Jabareen, 2006), or energy strategies (Dincer, 2000; Cooper et al., 2001; Lund 2007). In this strand of literature, it is almost taken for granted that the government and the market are incongruent in how residential development can achieve sustainability, livability and profit.

In another strand of the literature on residential development, however, a tie between the government and the other market actors is recognized. Bone et al. (2011) reviewed ‘top-down’ approaches like deterministic models, statistical models, and system dynamic models used for the purpose of identifying effective, governmental policies to achieve governments’ objective in residential development. There is also the ‘bottom-up’ approach, such as cellular
automata (CA), but Zhang et al. (2010) explained that these models have limitations in properly simulating the land use while integrating with the complex social, economic and human system of urban dynamics. Alternatively, Ferrand (1996) regarded the multi-agent system (MAS) model as a set of agents interacting in a common environment, but modifying themselves according to their objectives. Further, Parker et al. (2003) suggested that MAS models of land-use are well suited for representing complex spatial interactions under heterogeneous and dynamic conditions. Furthermore, Li and Liu (2007) proposed integrating MAS and CA to simulate residential development under different planning scenarios.

However, residents and investors often overlook the macroscopic policy constraints exerted by the government in the land use decision-making process (Bone et al. 2011). Most studies regard the government as a macro actor (we use actor and agent interchangeably in this paper), with exclusive power to set the general land-use development, and these studies do not, explicitly, consider the microscopic choice behavior of residents and investors (Huang et al., 2014; Zhang et al., 2015). The conceptual model we develop in the next section is strongly rooted in the MAS microscopic modelling tradition of considering investors’ investment strategy and residents’ choice behavior, but it also explicitly integrates governmental objectives that have been downplayed in MAS modelling so far. Moreover, it has conventionally focused on a single hotspot and thereby neglected the fact that a city has multiple hotspots that meet the multiple needs of the residents, and that most of the transportation arises because of residents’ travel between their residence and those hotspots (Zhao et al., 2016). The conceptual model developed allows for multiple hotspots.
3. A conceptual model of the interaction of government, estate investor, and resident and their objectives

As discussed in the previous section, Parker et al. (2003) suggested that multi agent (i.e. actor) system models of land-use are well-suited for representing complex spatial interactions under heterogeneous and dynamic conditions, while Li and Liu (2007) proposed integrating MAS and CA to simulate the residential development under different planning scenarios. Here, we purport that governmental residential planning plays a crucial role in shaping urban pattern, while the behavior of investors and residents plays an important role in promoting, or hindering, the fulfillment of the planning.

Governments are presumed to be careful in their planning to balance the environmental, political, personal and economic development, and integrate its plans with investors’ investment strategy and residents’ selection behavior of dwellings on a local level, bearing in mind the residents’ desire to access all hotspots in the city. In the outline of the conceptual model we present the objective of each actor, one at the time.

3.1. The government’s objective

In residential planning, governments are increasingly taking sustainable development as the primary objective to be balanced with personal, economic, political, cultural developments. Ultimately, governments are responsible for structuring residential locations to mitigate greenhouse gas (GHG), foremost CO₂ emissions. In what follows, we stipulate that the administrative area under governmental responsibility can be portioned in $H$ homogenous zones (or grids), indexed by $h$. Furthermore, we assume that the government is concerned about the negative externality generated by the CO₂ emission induced by intra-urban travel between the residential location $h$ and the hotspots, and we denote by $E$, the CO₂ emission quantity. The government is also concerned with several other factors that we simply collect and denote by $Q$. In maximizing the societal utility $U$, the government makes decisions in
maximizing the sub utility $\bar{U}$, by developing a location $h$ for residency based on mitigating the CO$_2$ emissions accordingly:

\[
\max_{E,Q} U = f(E, WTL, WTI, Q) \propto \max_{E} \bar{U} = \bar{f}(E, WTL, WTI)
\]

which implies that $E$ and $Q$ are independent factors, a necessary assumption. It should be noted that the objective of CO$_2$ emission mitigation could readily be replaced in the conceptual model by any other governmental objective, if so desired.

### 3.2 The resident’s decision rule for choosing residential location

In estimating the willingness of a resident to live at $h$, land-use type, land price, surrounding environment, accessibility, general public facilities, and education opportunities have been identified as important factors (Li and Liu, 2007, as well as others reviewed in Section 2). Note that the last three factors all can be combined and measured as a function of travel distance to the hotspots, implying that the WTL at a location $h$ will decrease with the travel distance to the hotspots.

Thus, with a natural extension that encompasses hotspots, Li and Liu (2007), the resident’s utility related to travel distance to hotspots from the location $h$ is expressed as:

\[
U_{\text{travel}}(h) = w_1 e^{-b_1 D_{\text{road}}} + w_2 e^{-b_2 D_{\text{highway}}} + w_3 e^{-b_3 D_{\text{hotspots}}}
\]

where $D_{\text{road}}$ and $D_{\text{highway}}$ are the Euclidian distances from $h$ to the nearest road and highway, respectively. $D_{\text{hotspots}}$ is the weighted network travel distance from $h$ to the hotspots, where the weights are determined by the frequency by which the hotspots are visited by the residents (see Zhao et al., 2016). $b_1$, $b_2$, and $b_3$ are decay coefficients and, $w_1$, $w_2$, and $w_3$ are the weights representing the resident’s utility of being subject to the three types of distances.
Another factor identified in the literature review that a resident considers in its utility function and, therefore, in the choice of residential location is the surrounding environment:

\[ U_{\text{env}}(h) = w_4 G(h) + w_5 W(h) \]

where \( G(h) \) and \( W(h) \) are the percentages of green land and water area at location \( h \), where, once more, the weights express the resident’s relative utility of green land and water area.

Constrained by income, price of the estate and the consumption of a composite of other goods are also factors influencing the preference of a residential location \( h \), in order to maximize the utility:

\[
\max_h U = w_P P(h) + w_z z + w_{\text{env}} U_{\text{env}}(h) + w_{\text{travel}} U_{\text{travel}}(h)
\]

\( w_P, w_z, w_{\text{env}} \) and \( w_{\text{travel}} \) are the weights that the resident assigns to each factor. \( P(h) \) is the estate price in location \( h \), while \( z \) denotes the consumption of a composite of other goods.

Piecing eq. (2-4) together, the willingness to live at location \( h \), rather than location \( h' \) of resident \( r \) can be formulated as (McFadden, 1978):

\[
WTL_r( h ) = \frac{\exp(U(r,h))}{\sum_{h' \in H} \exp(U(r,h'))}
\]

### 3.3 The estate investor’s decision on where to invest

Estate investors primarily consider the preferences of residents in home buying to set the investment strategies. The willingness of the investor to invest at location \( h \) is determined by the profit \( \pi \), where we abstract from uncertainty in the investment.

\[
\max_{d,h} \pi = dP(h) - C(d)
\]

where \( d \) is the development density, and \( C \) is the land and the construction cost in developing at location \( h \). The willingness for investor \( i \) to carry out an investment at location \( h \) is:
where an investment takes place at \( h \) if \( WTI_i(h) > \pi \), where \( \pi \) is the investor’s required return on capital.

4. Residential development in Borlänge as a demonstrating case study

The municipality of Borlänge lies 220 km northwest of the capital Stockholm, and its size is about 637 km\(^2\), with approximately 50,000 residents asymmetrically distributed in the area. According to Statistics Sweden\(^2\), 93% of the residents in Borlänge live in either a single-dwelling house, or an apartment in a multi-dwelling building, which, in total, amounts to 15,768 residencies\(^3\). In what follows, it is realistically assumed that all the residencies are tradable on the estate market, although a few residencies may be subject to restrictions for trading. Further, for the analysis, we assume that all the land in Borlänge has the potential to be developed or redeveloped into residential areas, and apply a 1 km\(^2\) grid to divide the municipality into 637 grids, where the centroid of each grid represents the location for possible development.

4.1 Variables needed to implement the methodology

The first variable that is needed to implement the methodology is the market value of an estate at location \( h \). To estimate the market value of the estates, we use the transaction data of single-dwelling houses and multiple-dwelling buildings from January 2013 to December 2016, as reported on Hemnet\(^4\). There were 2209 transactions during that time period, and for the 347 estates that were transacted multiple times, we have used the average price.

\[
WTI_i(h) = \frac{P(h)d}{C(d)}
\]

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1 Data and the source code in R and ArcGIS are freely available upon the request to the first author of this paper.


3 Provided by Construction and Plan Office, Borlänge Municipality

2(a) shows the distribution of all current single-dwelling houses and the multi-dwelling buildings in the municipality. Figure 2(b) illustrates the estates that have been transacted from 2013-2016.

Looking at Figures 2(a) and 2(b), simultaneously, the transacted estates are, as expected, distributed in a pattern similar to all the residential locations in Borlänge. To estimate the market value of the non-transacted residential locations, we have spatially interpolated the market value of the nearest transacted estate. In doing so, 90% of the non-transacted residential locations are within one kilometer of the nearest transacted estate. In some of the grids, there is no estate at all. For those grids, we have estimated the market value in the grid to be the market value at the adjoining grid with a market value.

As for the construction and land cost variable, we impose it to be uniform in Borlänge, based on the historical land selling price in the municipality (an approximation that may not apply elsewhere). However, the cost of construction may differ between investors, where we assume a variation in the cost between investors to be quantifiable by a random term $\varepsilon \sim N(0, \delta^2)$, as
the market for housing construction is unlikely to be perfectly competitive. Operationally, we set the difference to amount to 5%, such that the construction and land cost $C$ is on average 97.5% of the revenue with a standard deviation $\delta$ of 1.25% of $C$. Furthermore, we require at least one investor to be willing to invest at location $h$ for the location to be of interest to investors.

The second variable that is needed to implement the methodology is the traffic flow on the road network. To estimate the decay coefficients $b_1$, $b_2$ and $b_3$, we follow Li and Liu (2007):

$$ b_1/b_2 = f_{\text{highway}}/f_{\text{road}} $$

$$ b_1/b_3 = (z_1 f_{\text{road}} + z_2 f_{\text{highway}})/f_{\text{road}} $$

where $f_{\text{highway}}$ and $f_{\text{road}}$ are the average traffic densities (number of vehicles per time unit by road length). In Li and Liu (2007), $z_1$ and $z_2$ are assumed to be the number of roads and highways connected to the city center. Here, we take a more elaborated approach by acknowledging that travels to multiple hotspots are required for fulfilling the needs of a resident. Zhao et al. (2016) found that 51 hotspots attracted more than 90% of the residents’ movements in Borlänge. Therefore, to estimate $z_1$ and $z_2$, we compute the weighted average number of roads and highways that connect to the 51 hotspots. From this estimation procedure, the decay coefficients of $b_1$, $b_2$ and $b_3$ are set to 0.001, 0.0005 and 0.00025, respectively.

The third variable that is needed to implement the methodology is the percentage of green area and water area around location $h$. In each grid, the percentage of green land$^5$ and water area$^6$ was calculated. The fourth variable that is needed to implement the methodology is the

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$^5$ Based on SLU Forest Map, Dept. of Forest Resource Management, Swedish University of Agricultural Sciences.

$^6$ Provided by Construction and Plan Office, Borlänge Municipality
CO$_2$ emissions induced by travelling from location $h$ to the hotspots. We applied the network of induced emissions derived by Zhao et al. (2016), and calculated the CO$_2$ emission from each potential residence to each hotspot.

With the needed variables at hand, we can compute (emission) $E$, (willingness to live) $WTL$, and (willingness to invest) $WTI$ for each location $h$, and check the utility for each of the three actors, compared to a threshold value of residential development at the location $h$. Zhao et al. (2016) found in Borlänge that the current, average CO$_2$ emission induced by the residents’ trips by car to the hotspots was 1.94 kg. Residential locations that would induce CO$_2$ emission of less than 1.94 kg improve the governmental utility, and this value, therefore, serves as a natural threshold value for the local government in the city council.

The $WTL(h)$ is an index variable expressing the residents willingness (or unwillingness) to live at location $h$. We have set a location $h$ to be attractive to residents if it exceeds the 3$^{rd}$ quartile of the distribution of $WTL$ in Borlänge. Setting a low threshold value for this index would imply that almost all the locations in the municipality would be liked by the residents and, thereby, they would not exercise any influence on the regional development, which is unrealistic. Setting a high threshold value highlights the areas in Borlänge that are highly attractive to the residents, and the 3$^{rd}$ quartile is fairly high threshold value. As a threshold for the investors’ willingness to invest, we use the return (0.63%) on buying a 10-year Swedish government bond.

Figure 3(a) shows the preference of the three actors for residential development in the 637 locations (grids) in Borlänge municipality. Locations that meet the governmental objective of lowering CO$_2$ emission, while at the same time appealing to the residents and the investors, are marked by the color green. White areas are those locations that are unattractive to all the three actors, or, in a few locations, only attractive to the investors and therefore unlikely to be
developed. However, the locations marked with red color are attractive to both residents and investors, while undesirable for the government and, therefore, subject to tension between market forces and the government. Finally, yellow marked locations are ambiguous in that they appeal to investors and the government, but are not very appealing to the residents.

Figure 3: (a) The market’s alignment with sustainable residential development in Borlänge (b) Planned residential developments in Borlänge and their estimated induced CO₂ emissions.

So are market forces in Borlänge in alignment with the governmental objective of sustainable residential development, specifically with regard to CO₂ emissions? We are inclined to say yes. For most parts of the municipality, either the three actors have a common interest, or a common disinterest in residential development, with the exceptions being the north-western area and the east-most area of Borlänge, which appeal to residents and investors only. To get an insight into how the city council in Borlänge manages market forces jointly with the sustainability objective, Figure 3(b) depicts the presently existing 50 planned residential areas to be developed in Borlänge by the symbol of a house. A green, yellow and red colored house symbol indicates whether the induced CO₂ emissions would be below, on, or above the threshold value of 1.94 kg per trip, respectively. Green, planned residential developments
amount to 95% of all future houses to reside in, meaning that the sustainability objective is being effectively fulfilled. However, as is also evident from Figure 3(b), the city council also compromises with the market forces, as there are some locations under development which are in conflict with the sustainability objective.

4.2 Sensitivity check

Apart from the variables needed to implement the methodology, some parameters also need to be set to make the methodology operational. Figure 3(a) was derived by applying a set of default values for these parameters. The proper choice of values is hard to nail down and to check the sensitivity of the results presented in the previous sub-section. We have re-done the analysis applying alternative settings, as listed in Table 1.

Table 1: Sensitivity check of the default parameters settings in the implementation of the conceptual model.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Default</th>
<th>Alternative setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$b_1 = 0.001, b_2 = 0.0005, b_3 = 0.00025$</td>
<td>$b_1 = 0.01, b_2 = 0.005, b_3 = 0.0025$</td>
</tr>
<tr>
<td>2</td>
<td>$w_1 = w_2 = w_3 = 1/3$</td>
<td>$w_1 = 1/4, w_2 = 1/2, w_3 = 1/4$</td>
</tr>
<tr>
<td>3</td>
<td>$w_4 = w_5 = 1/2$</td>
<td>$w_4 = 1/4, w_5 = 3/4$</td>
</tr>
<tr>
<td>4</td>
<td>G is estimated based on total volume of all types of tree</td>
<td>G is estimated based on total volume of Birch, Deciduous, Oak and Beech</td>
</tr>
<tr>
<td>5</td>
<td>$z$ is assumed identical for all residents</td>
<td>$Z$ is differentiated in 50,000, 100,000, 300,000 in equal shares</td>
</tr>
<tr>
<td>6</td>
<td>Swedish government bond 10-year, return rate 0.63%</td>
<td>Swedish real total stock return rate 6.1%</td>
</tr>
<tr>
<td>7</td>
<td>$w_p = w_{env} = w_{travel} = 1/3$</td>
<td>$w_p = 1/9, w_{env} = 4/9, w_{travel} = 4/9$</td>
</tr>
<tr>
<td>8</td>
<td>$C$ is assumed to be the cost of one house</td>
<td>$C$ is assumed to be the cost of density $d$ houses</td>
</tr>
</tbody>
</table>

In estimating the distance decay coefficients in equations (8-9), $b_1$ was normed to be 0.001, in line with Li and Liu (2007). We have also checked with $b_1$ set to 0.01 and 0.0001. Equal weights were set in equations (2-4) as default. As alternative settings, residents consider distance to highway more important than to normal roads and hotspots, value proximity to water more than green land, (as Kaplan and Kaplan (1989) have stressed: “Water is a highly prized element in the landscape”), and value surrounding environment and less travel more
than house price in their choice of residential location. As a default setting, the residents have a common consumption of other goods, while we have checked the alternative that the residents are divided in three groups (low, middle and high incomers/consumers). For the investors, the required return on capital has also been set to the real total stock return, as well as letting the cost of construction decrease with $d$. The alteration of the parameter settings exercised little influence on the results shown in, and discussed, in relation to Figure 3(a).

5. Conclusion

In most urban planning studies, the formation of residential development has considered the objectives of social planners, investors and residents individually. Those studies also mainly focus on the ex-post evaluation of residential development. This paper outlines a conceptual model where the three key actors – (local) government, estate investor, and resident – and their unique objective are integrated. The primary motivation for this contribution is to improve on governmental policies towards sustainable residential development.

The conceptual model developed draws heavily on previous modelling work in the literature that has had a more partial scope, and it is strongly rooted in the tradition of microscopic multi-agent system models. The conceptual model can be made operational to provide decision support for (local) governmental residential planning on a micro level.

As a demonstration of the conceptual model’s ability to be operational, we have examined the case of the Borlänge municipality where residential planning is in a highly active state, as a consequence of substantial population growth due to the influx of immigrants. The application of the methodology in Borlänge provides several noteworthy insights. The first is that a city like Borlänge has multiple hotspots and that therefore the assumption of polycentric cities is the most plausible in urban planning of residential locations (Yiu and Tam, 2004). The second insight is that the market actors’ behavior is, in general, aligned with the
governmental objective of sustainable, residential development. However, on considering the present residential plans of Borlänge, it seems that the local government is aware of the market forces and compromises between its sustainability objective and the market actors’ preference, in areas where the actors are not in alignment with the local government’s objective.

The implementation of the methodology requires access to some key variables and the setting of a number of parameters. In relation to the demonstrating case study, we provide a detailed listing of these variables and indicate from where they may be retrieved, so that the conceptual model may be implemented elsewhere. In a detailed sensitivity check of the parameter settings for the case study, we found that the choice of settings has little to no impact on the model output, and therefore dares to claim that the implementation of the conceptual model is insensitive to the parameter settings, although this needs to be checked whenever the model is used in a specific case.

References


