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Land Use Scenarios for Greater Copenhagen: Modelling the Impact of the Fingerplan

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ABSTRACT

Urban planning and development in Denmark can be characterised by a relatively strong planning framework. Land use scenarios based on empirically derived dynamics of urban growth are practically never applied. However, modelling approaches do offer a methodology to explore the pressures in an urban region, as well as an approach to understand urban development patterns outside the 'spatial masterplan'. In this context we will present the results of a modelling exercise addressing future land use change in the metropolitan area of Copenhagen, Denmark, and the impact of the current regional planning framework, the "Fingerplan 2007". We test three policy scenarios and analyse different effects on urban growth by using the Metronamica model from the Dutch-based Research Institute for Knowledge Systems (RIKS). We analyse the possibilities to elaborate a practical and useful outcome within a relatively short period of time. The set-up and the results were discussed with a few experts from the Danish Ministry of the Environment and its value as discussion input recognized. The approach offers a lot of possibilities to discuss urban growth and spatial planning policies, even in a country with a strong planning framework as in Denmark.

1. INTRODUCTION

Planning tasks are getting more complex and an increasing number of policy fields have to be taken into consideration. Modelling tools as well as other planning-support instruments are gaining momentum with this development [1] although many are still only used for basic activities as e.g. generating thematic maps [2]. In Denmark, urban planning and development can be characterised by a relatively strong planning framework. Projections of the future demand for urban development as well as decisions on how and where to accommodate this demand are part of the planning process and reflected in strategic and local development plans. Land use scenarios based on empirically derived dynamics of urban growth are practically never applied, however. This may be explained by the in-consistency between the logic of spatial master planning - and the organic or driver-dependent character of urban growth assumed by land use modelling approaches. However, modelling approaches do offer a methodology to explore the pressures in an urban region, as well as an approach to understand urban development patterns outside the 'spatial masterplan'.

In this paper we discuss a pilot project conducted to analyse the potential of such an approach. The purpose was to model future development of urban land uses in the area around Copenhagen, the capital of Denmark. Copenhagen has experienced considerable growth of urban areas in the last decades and its functional urban area is reaching up to 100 km from the city centre [3]. We used the land use modelling tool "Metronamica", developed by the Dutch-based Research Institute for Knowledge Systems (RIKS) to study the impact of the regional planning scheme "Fingerplan 2007" [4] on urban form in the next few decades under different policy scenarios. The main research question was if it is possible to evaluate the future impact of the Fingerplan with a modelling tool and to derive useful conclusions for planning practitioners.

The hypothesis regarding future urban growth in the region was that the Fingerplan would prevent urban growth considerably outside the Fingers and will support growth close to the suburban train stations. This cannot be answered by a pure forecast as it is hardly possible to account for the complex processes involved.

Land use modelling and simulation offers possibilities to explore scenarios and discuss alternative future impacts [5]. Epstein [6] names also other arguments for modelling including explanation or relationships, guidance of data collection, discovery of new questions, revealing the simple as complex and the complex as simple, training and educating users and the public as well as fuelling the dialogue.

In our project we focused on the general potential of modelling with Metronamica in the case area. The task was to get a reasonable, first simulation rather than developing a highly detailed model. This limitation is another issue which was discussed throughout the project: Does a small and quick modelling exercise makes sense or is more in-depth research indispensible? What are the technical and conceptual limits of such a quick approach? 'Quick' is meant relative, but it was clear from the beginning that we would not be able to use the model's full capacity and include a range of available extensions like a separate transport model or a regional migration model. We come back to that in the discussion section.

Before explaining our method and data in detail we will shortly introduce our case, the Fingerplan of Copenhagen.

1.1. The Copenhagen Fingerplan

The first Fingerplan was developed in 1947 [7]. It proposed a future urban development of the metropolitan area of Copenhagen along five suburban railroads. The areas between should be kept free of buildings, forming green wedges and supplying the urban population with recreational areas. Although the plan was only a report and never close by legally binding, it had a great influence on later regional plans and infrastructure development in the region [8].

The latest regional plan, Fingerplan 2007 [4], is referring directly to the original plan in an extended regional context. The plan is a national directive based on the current planning act and is therefore a legally binding document. However, it has been much discussed, and the wisdom of this steering tool has been questioned. Currently the ministry has opened for a debate on an adaptation of the plan which should result in a new directive in 2012.

The Fingerplan 2007 structures the region in 4 zones (fig. 1).

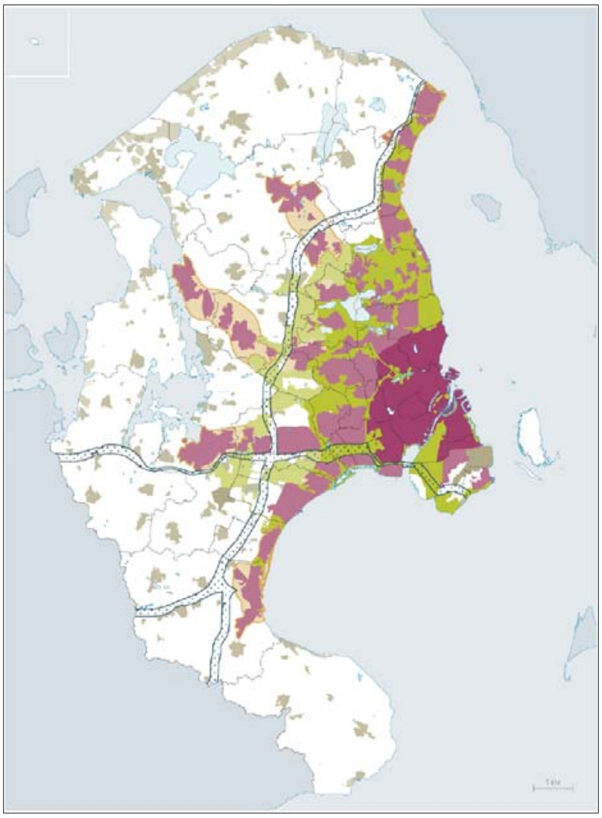

Figure 1. The Fingerplan 2007 [4].

The inner urban areas (palm of the hand), the outer urban area (fingers), the green wedges and the remaining area. The core principle is that only in the palm of the hand and the fingers urban development of regional importance is allowed. In the remaining metropolitan area only developments of local character are allowed, while the green wedges must be kept free from any development [9].

Furthermore, the principle of station-proximity was strengthened, enforcing functions causing a lot of person-traffic, such as e.g. big offices, to be located within 600 m from a railroad station, and minor ones within 1200 m. Another important principle of the Fingerplan is the ranking of urban development. That means e.g. that areas within station-proximity have to be built-up before areas outside can be. Not all these principles and rules can be implemented in the model – however, the overall guidelines regarding development along the fingers are included as outlined in the next section.

2. METHODOLOGY AND DATA

Land use modelling implies a number of steps and tasks. The parts most discussed are usually running scenarios and their evaluation. They require, however, a range of pre-steps which are usually invisible to outsiders, including spatial and statistical data ingestion, model set-up and calibration [10]. Besides these technical procedures a modelling exercise should also include relevant stakeholders as e.g. end-users. Otherwise the model might lack critical feedback and decreases its potential use for practical applications. In our case we decided to involve planning professionals from the Danish Ministry of the Environment – the responsible authority for the Fingerplan and a potential end-user. Together with them we discussed the modelling approach, input data quality, scenarios and finally the results at two informal meetings. There was positive feedback, but also several critiques were mentioned, especially regarding details on model inputs, model constraints and the scenario setup. It was concluded, that it is important to be clear about which questions can be asked and answered with such an approach, and which not. However, the general involvement of stakeholders was, due to the little resources of the project, rather limited.

2.1. Modelling with "Metronamica"

The modelling tool used for this project is Metronamica developed by RIKS [11]. It was used in a number of cases studies by RIKS and other institutions [12, 13, 14]. The modelling framework MOLAND, which is used by the EC's Joint Research Centre [15, 16], uses the same modelling framework as Metronamica which was originally developed by White, Engelen & Uljee [17].

Metronamica is based on a cellular automaton (CA). CA models combine elements of macro- and micro-simulation [18]. They consist of a regular grid of cells which change their status by a simple set of rules. In our case each cell is attributed with one type of land use. For each time step (one year) transition rules are applied to each cell and might result in a land use change.

Transition rules can include rules about attractiveness of other land use types in the neighbourhood, transport accessibility, suitability considerations and zoning. Furthermore a random perturbation is introduced to account for uncertain developments, producing small amounts of "noise" in the model. The different rules are multiplied with each other, resulting in a unique value of transition potential [11, p. 191]. All cells are ranked by their transition potential for each land use and are then filled starting with the cell with the highest potential until all demands are satisfied.

The core elements of each CA are transition rules based on neighbourhood characteristics. In Metronamica these are derived from distance-decay functions, illustrating the attractiveness of the neighbourhood of one land use to another. E.g. residential land use could be set to be attracted to be close to highways because of accessibility. Areas too close to the highway would however be repulsive because of noise and air pollution. A typical rule derived from calibration is that land uses are attracted to other cells with the same land use, i.e. residential /urban use is attracted to existing urban /residential cells.

The transition rules are derived from calibration. Before simulating future land use (Exploration), the model parameters and transition rules have to be calibrated by analyzing the past development, comparing the actual land use change between two points in time with the results of a simulation of the same period. The exploration of future land use is then based on the rules derived from the calibration. So for this project two models were set up: The calibration for the years 1990 – 2006 and the exploration of future land use based on scenarios for the years 2006 – 2040.

Calibration is an iterative process, shifting between the adaptation of the model characteristics, e.g. the adjustment of a certain neighbourhood function, and the validation of the simulation compared with the recorded land use changes. There are some recommendations on how to proceed through calibration.

However, due to the nature of a model based on a cellular automaton (CA), it is always necessary to go back and analyse issues which were calibrated earlier. Every introduction of a new rule demands more time for validation and adaptation. This is usually done by trial-and-error and by the modeller only although there are attempts to quantify these rules empirically [19, 20].

2.2. Scenario plots

Metronamica offers a range of options to introduce different aspects of scenarios including different growth assumptions, different infrastructure settings and different zoning, allowing the introduction of complex storylines. For this project we decided to focus on different spatial policy scenarios only, keeping growth assumptions and infrastructure settings the same across the scenarios.

After a meeting with experts from the Ministry we decided to run three policy scenarios which can be illustrated along an axis from stricter to weaker planning regulation (fig. 2).

The "Fingerplan" scenario includes the full implementation of Fingerplan 2007 with its different zones. Further it includes planning regulations on nature protection (Natura 2000, Danish nature areas and listed areas) and coastal protection.

In the "Green Wedges" scenario only the area designated for green wedges in the Fingerplan 2007 is implemented as well as nature protection, but excluding coastal area protection. The "Only Nature" scenario includes neither any regulation from the Fingerplan nor coastal protection. Only the strictest regulations on nature protection are implemented.

Figure 2. Three policy scenarios.

The Green Wedges and especially the Only Nature scenarios are hardly realistic, and neither is the full and strict implementation of the Fingerplan 2007. The model scenarios thus serve to illustrate various 'extreme' policy scenarios and accordingly the spatial consequences of such hypothetical scenarios.

2.3. Data

The most important data for a land use model is a land use map. For Copenhagen, only the CORINE data base [21] is providing data for more than one point in time (1990, 2000 & 2006), covering the region in 100 m cells resolution. Another land use classification covering Denmark is AIS (Areal Information System) provided by the Danish Ministry of the Environment. AIS is more detailed than CORINE – especially in urban areas –, but it exists so far only for 1998.

We reduced the original data to 14 land use classes as shown in Table 1. More detail was kept for urban classes while other classes, such as agriculture or natural areas, were heavily aggregated.

Table 1. Recorded (1990-2006) and assumed (2040) land use in the modelling area by class.

	Land use category	CORINE classes	Area in hectare (=100 m cells)			
			1990	2000	2006	2040
0	Agricultural areas	211-244	174,154	172,375	169,070	?
1	Forests	311-313	34,747	34,602	34,606	?
2	Semi natural areas	321-335	7,372	7,738	7,702	?
3	Continuous urban fabric	111	2,853	2,853	2,853	*3,051**
4	Discontinuous urban fabric	112	45,063	45,329	46,380	*49,601**
5	Industrial or commercial units	121	5,237	5,539	6,189	*8,000**
6	Mine, dump and construction sites	131-133	732	1,281	1,395	*1,800**
7	Green urban areas	141	5,896	5,860	5,965	*6,300**
8	Sport and leisure facilities	142	3,445	4,032	5,516	*7,000**
9	Summer houses		7,584	7,642	7,673	*7,800**
10	Transport units	122-124	4,239	4,338	4,433	4,433
11	Wetlands	411-423	4,683	4,637	4,532	4,532
12	Water bodies	511-512	8,086	8,178	8,177	8,177
13	Sea and ocean	521-523, 995	304,032	303,719	303,632	303,632
	Total		608,123	608,123	608,123	608,123
	Population		1,721,879	1,807,466	1,843,212	2,158,174

0-2 Vacant = passive land use; 3-9 Function = active land use; 10-13 Feature = unchangeable land use
* Assumed changes

The estimation of future land use needs is based on the population projection of Statistics Denmark [22] as well as on the previous development. The population projection shows a continuous population increase, reaching 2 158 000 inhabitants in 2040; 315 000 more than in 2006. To derive the amount of cells from population numbers we calculated the average land consumption of new population in the calibration period 1990-2006. In that period around 110m^2 of land were transformed into continuous /discontinuous urban fabric per each new inhabitant. The overall ratio in 2006 was 270 m^2 of continuous/discontinuous urban fabric per inhabitant. The growth in urban areas per inhabitant in the period was thus smaller than the ratio accumulated over the years. Densification and urban renewal policies up through the 1990'ies may have had a share in this. However, other urban land uses such as commercial area increased faster. But as we do not have any projections on the development of jobs or on other issues, we assumed a similar development as in the calibration period. An exception is "sport and leisure facilities", which mainly consists of golf course. Golf courses boomed in the recent decade, but due to the financial crises and a current saturation of consumer demands, it is very unlikely that any new course will be established until 2020. In total 5230 hectares of non-urban land are expected to change into urban land (land use classes 3-5 in table 1) until 2040. This number of hectares (or cells) is the basis for all three scenarios.

Besides land use data we introduced data on accessibility and zoning into the model. The model uses infrastructure to estimate the accessibility of cells by calculating the distance (with a decay effect) of each cell to a certain infrastructure, e.g. highway ramps or railroad stations. Infrastructures can be weighted differently for each land use. We included metro, s-train and other stations, highways, major roads and other roads. For the exploration of the scenarios we also included important planned transport infrastructure projects as the highway extension to Frederikssund or a new light rail in the Copenhagen suburbs.

Furthermore we introduced zoning maps from regional plans (Regionplan 1989, 1993, 2001, 2005) and from nature protection policies (Nature 2000, Danish Nature Protection Act, Listed Areas, and Coastal Protection Areas) for calibration. According to the zoning category a cell falls into, a factor for its transition potential is assigned. For the exploration, we introduced the zoning regulation of the Fingerplan 2007 adjusted to 7 zones:

- urban areas in palm of the hand and in fingers;
- other areas inside the fingers and urban areas in municipality centres outside fingers;
- summer house areas;
- other urban areas;
- rural areas;
- reserved Transport corridor and airports;
- green wedges.

These zones mainly influence new urban fabric or new industrial/commercial areas. Urban areas in the palm and the fingers are set to stimulate development, while development in the green wedges is restricted.

3. RESULTS AND DISCUSSION

3.1. Calibration results

Before presenting the results of the scenarios we shortly present the results of the calibration, which form the basis for the modelling of the scenarios. When modelling a complex system as land use in an urban region, it will never be possible to have a perfect calibration as there are too many uncertainties which cannot be accounted for. The aim is therefore not necessarily to model as close to the reality as possible, but to have a realistic model.

There are a wide range of methods to qualify and quantify the results including a simple visual inspection. A popular objective method for the local fit is the use of Kappa statistics. Kappa measures the agreement of two items – in this case the cells in two land use maps by class. The difference from a simple percentage calculation is that Kappa includes the agreement by chance, i.e. how much better is the model than a completely random map. A sub-variant also exists, called “Kappa Simulation” [23]. Here the random map is constrained as only newly changed cells are included in the comparison. Unchanged cells, which in a land use model usually are the vast majority, are not included. Kappa Simulation calculates a global measure of correspondence between -1 and +1. Values above zero mean that the simulation explains more than the random constraint map and therefore explains some land use change. There exist no other absolute thresholds for that measure and the results are obviously dependent on the level of complexity of the modelled system. The final calibration which was basis for the scenario simulation reached a value of 0.31.

The challenge with calibration in this particular case is to filter the “natural” logics of urban growth from influences of contemporary spatial plans, which have a strong influence on spatial development in Denmark. It is hard to find out by which combination a certain development is caused, or if some “natural” logics are even opposed to planning logics but are invisible due to the stronger influence of planning. Hence, the question: how would the region look like without any planning is a tricky one to answer. In our calibration, when excluding all regional plans and only keeping the strict nature protection zoning, we get a Kappa Simulation value of around 0.17. So the model still explains some land use change even without information on planning. However, Kappa Simulation alone cannot describe the model’s goodness of fit. Other parameters like e.g. patch size and form are important and were used during calibration but will not be discussed further here. Figure 3 shows the result of the calibration compared to the actual changes occurred. An issue is the focus of new urban area in the southern area of the region in the simulation, while in reality a considerable part of new urban areas appeared also in the northern part. This might be a result of the use of zoning data in the simulation, where no new areas for urban land were allocated in the northern part in the regional plans after 1993 because earlier allocated land seemed sufficient.

3.2. Scenario results

This modelling exercise focused on the transformation of non-urban land use into urban land use on the background of different policy scenarios. The growth assumptions, as described earlier, result in a total urban land use demand of 5230 ha until 2040. Table 2 summarizes the trends of major land use changes in each scenario related to issues of the Fingerplan including station proximity. The exact changes refer to one model run and are subject to some uncertainty as discussed earlier.

The first scenario illustrates urban growth in the region when the current Fingerplan as well as other zoning regulations are fully implemented and will be kept the same in the next decades. We can conclude that the assumed increase of urban land use can be accommodated in the areas assigned for urbanisation within the Fingers, filling only about one third of the available open space in the Fingers. Our growth assumptions are however only moderate.

In the “Fingerplan”-scenario a third of the development will happen within the 3 km coastal buffer zone.

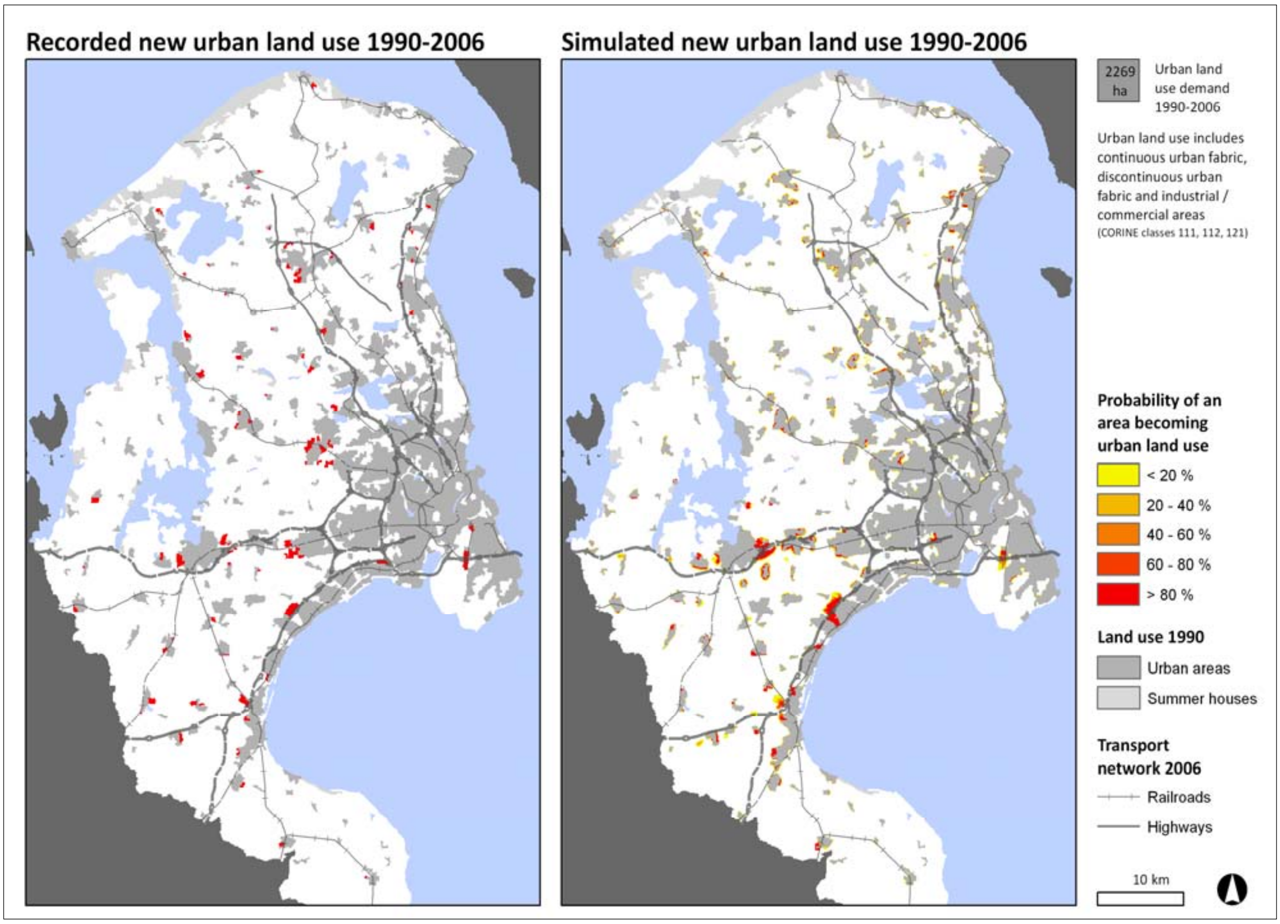

Figure 3. Urbanisation 1990-2006 – Recorded changes and model probability.

Table 2. New urban areas 2006-2040 by location and scenario.

Location of new urban areas	Fingerplan scenario	Green wedges scenario	Only nature scenario
Outside Fingers (rural areas, green wedges, small towns)	-46 ha	2347 ha (45 % of total increase)	2879 ha (55 %)
In rural areas	2 ha (0 %)	1841 ha (35 %)	1381 ha (26 %)
In green wedges	-50 ha	-38 ha	1070 ha (20 %)
In coastal buffer zone	1858 ha (36 %)	1721 ha (33 %)	1749 ha (33 %)
Within 600 m from station	578 ha (11 %)	362 ha (7 %)	422 ha (8 %)
600-1200 m from station	1222 ha (23 %)	654 ha (13 %)	781 ha (15 %)
Not within station proximity	3430 ha (60 %)	4204 ha (80 %)	4027 ha (77 %)

That is because the Fingerplan assigns urban land also in coastal areas; rural areas (as defined in the Fingerplan 2007) will be kept rural; and more new urban areas than in the other two scenarios (34 % vs. 20-23 %) will be within a 1200 m radius from a train station. In the "Green wedges" scenario the Fingerplan is reduced to the protection of the green structure; nature protection is enforced, coastal area protection is not. About half of the new urban areas occur outside the Fingers, most of it in rural areas. The protection of green wedges presses development towards the rural areas. Coastal buffer zones are slightly relieved as more areas are open for development compared to the Fingerplan. In this scenario the amount of new urban areas within station proximity is lowest as highly accessible areas in the green wedges are protected, but areas in the countryside, often remote to stations, are not.

The "Only nature" scenario only applies the strongest nature protection regulations. Coastal area or the green wedges are not specifically protected. Less rural areas than in the "Green wedges" scenario get urbanised due to the possibility of development in the green wedges close to Copenhagen, including areas close to the coast.

A considerable amount of new urban development happens within the existing green wedges protection zone, probably due to proximity of these areas to existing urban areas. 1070 ha (20 % of all new urban areas), or 3 % of the green wedges will be urbanised, and the scenario shows the fragile status of urban green structures if they are not protected.

Our hypothesis that the Fingerplan will prevent urban growth considerably outside the Fingers and will support growth close to the suburban train stations, could be verified. However, the results of the scenarios are also a result of the assumptions put into the model in the first place. So a proper verification is not possible. Although when comparing the three scenarios some conclusions can be drawn: The Fingerplan can accommodate the projected growth in the scenarios; protection of green wedges is necessary; and for the green wedges to be effectively protected we also need the rest of the Fingerplan – otherwise urban areas will spread into the countryside. Still, even this result has to be taken with caution, as this project was designed as a pilot and experimental project, limited in time and resources. We will discuss the limitations of this approach in the following section.

3.3. Discussion

A model is always a simplification of reality. Hence, several limitations apply which are important to consider when discussing the results of a modelling exercise. We can differentiate between two kinds of limitations: Limitations due to the structure of the modelling system, and limitations due to our own project setup. Some can be part of both. E.g. zoning regulations have to be simplified so that they can be translated into model parameters and some regulations cannot at all be illustrated in the model. But they are also simplified to limit the complexity of inputs and to distinguish effects more clearly. This limitation is caused by the modeller and not the model itself.

Grid representation and single cell status: The basis of the Metronamica modelling environment is a cellular automaton, which implies a cell grid space. The grid space simplifies the reality, but the more crucial limitation is that each cell can only contain one specific land use. It is not possible (so far) to combine more information in one cell, e.g. the share of different land uses or information on activities (for a possible approach see [24]). In reality, however, many cells are mixed to a certain degree. Such a cell status can only be introduced superficially – as a separate land use category – which would probably not come closer to reality. Especially the issue of urban renewal, which accounts in the Copenhagen region for the majority of all building activities and absorbs a lot of demand for new buildings, is not incorporated in the model, only in the sense that the absorption of a part of the urban growth is reflected in the gross amount of expected new urban land per inhabitant.

Neighbourhood effect smoothes cell allocation: Another issue is the allocation of new cells following a transition potential which is based on neighbourhood effects and distance decays. These rules foster the allocation of single new cells dispersed over various locations which have the highest potential. In reality however, e.g. new urban areas get established as bigger patches or clusters instead of single cells. This effect is currently hard to model.

Calibration as a mean for exploration studies: Besides the difficulties of modelling real changes, the way of using calibration to set up explorative studies can be seen as critical, as it assumes that e.g. land use change will follow the same rules in the future as it has done in the past. Van Vliet [25] points this issue out by writing that *"there is the implicit assumption that the behaviour of spatial actors (as expressed in model parameters) remains constant over time. This is certainly reasonable, over a limited period, but [...] over time, extrapolations become more uncertain (or speculative)."* However, for the typical simulation period of about 30 years this approach seems reasonable [25].

Resolution decisive to which dynamics can be modelled: The resolution is not an in-built model limitation, but a choice of the modeller. However, depending on the size of the modelling area, RIKS recommends cell resolutions between 50 and 500 m for an urban region model. Smaller resolution are more accurate but not necessarily useful to model on such a scale. On the other hand, at a resolution of 100 m like in this project, some dynamics become invisible, as e.g. the dispersed development of new houses in ex-urban or rural areas.

Model uncertainty: As the model has a random factor in-built to account for uncertain events, each model run deviates from another. This is even strengthened by the cellular automaton structure, which allows the system to react to small changes when reaching a tipping point.

In general this is a setup which is useful for learning. However, depending on the other model parameters, the results might deviate to a large extend between the runs. Figure 4 shows the difference in deviations between the three scenarios.

In the Fingerplan scenario the locations of new urban areas are more often the same in each run then in the other scenarios, accounting for the strict zoning regulation introduced in former.

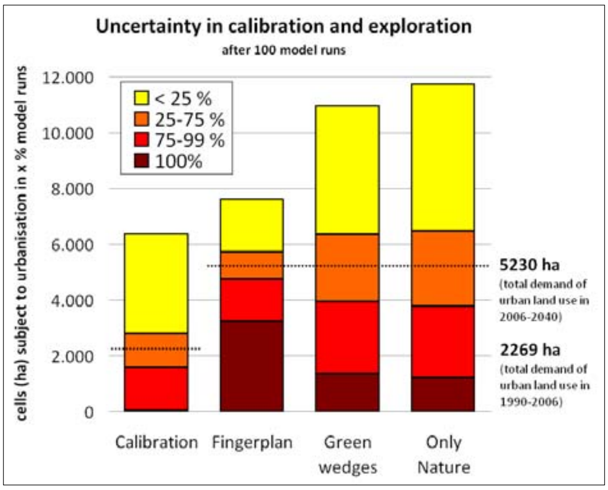

Figure 4. Model uncertainty in the scenarios.

The calibration itself also shows a relatively high deviation and surprisingly almost no cells which are always subject to urbanisation after 100 model runs. So the uncertainty in the calibration is relatively high.

This could be an indicator – together with one about the goodness of the calibration as e.g. Kappa Simulation – worth to improve in a follow-up study.

Simplification of zoning regulations: One element influencing the transition potential of cells in the model is zoning. Many of these regulations have to be simplified to be inserted in the model and some regulations might not even be possible to translate into model parameters. This is not only because of the given model structure, but also because of data availability. E.g. an important regulation in the Fingerplan 2007 is about the spatial location of person-traffic intensive functions such as big offices. The land use data used here (CORINE) does however not distinguish in that detail. All commercial and industrial land uses are merged in one category.

Another issue is the distinction of urban and rural areas in the Danish Planning Act (§§ 34-38). This regulation protects rural areas from getting built-up without proper planning permission from the municipal council or other authorities (ministries), including the possibility of an Environmental Impact Assessment procedure. In our case that means that even without the Fingerplan, rural areas would be protected to a certain degree. We did however not include this regulation in the model as it is applied locally and site-specific, making it hard to translate into a general regional zoning map.

Scenario plots: As written earlier, scenarios should usually be developed together with stakeholders, including an agreement on how they will be inserted in the model. Zoning regulations can be interpreted differently as can assumptions on growth. In this project we differentiated the scenarios only by different policies, without changing the growth assumptions. This facilitates the interpretation and discussion of the results, but is not accounting for the fact that variations of growth might be unrealistic. E.g. if there is no planning regulation at all, a much higher growth in the amount of urban area might be expected. Strict planning usually emphasises urban renewal and densification and hence decreases the amount of new urban land use demands.

For the projection of demands in the scenarios we referred to the official population projections from Statistics Denmark. Besides the inbuilt imprecision of such projections, it may be problematic to derive land use demands from population projections only, because even in times of economic crisis or population decrease, new land tends to be built-up. Furthermore, although using a relative conservative assumption on future land use demands with around 5230 ha within 34 years, the consumption in recent years with around 100 ha yearly is even below that. A more intense study of the region, including the future need of commercial and industrial areas, would be useful to have a sound basis for the scenarios.

Finally, this study only includes zoning on a regional level. Many planning regulations are however done on municipality level. Areas laid out by the municipalities for future urban land use as well as locally differentiated land use demands would be an issue to elaborate further on.

4. CONCLUSION & OUTLOOK

Despite the limitations discussed above, the project setup can be summarized in the following points:

- the pilot project demonstrated the potential of a modelling exercise set up in a relatively short period of time and only with little experience in the field;

- the application was kept simple because of limited resources, which limited its use for planning support;

- stakeholder involvement was very limited; other potential partners like a regional authority (Region Hovedstaden) or the representation of the municipalities (KL/KKR) were not included;

- understanding and capacity in modelling increased;

- calibration is time-intensive – some more time could have improved the results; but the limit was good in a sense that results were provided within a short time period;

- comprehensive material for further discussion was produced.

The crucial point is how to use the results and the material in the right way. After having set up a model, the temptation to use it for whatever question arising is very high. Practically this is possible, as the model is just an instrument which can be adapted in many ways. However, the model setup was done for a specific purpose: to model urbanisation in the case area to evaluate different zoning regulations. Using it for other purposes, e.g. deforestation or soil sealing is only possible to a limited extent as these processes work differently. Also, the results are not a general forecast of future land use change, but they are useful to discuss the overall performance of the Fingerplan and the general processes of urbanisation in the region. They are not an 'all-in-one solution', but an input for a wider debate. Furthermore, the visualisation of the scenarios also enables non-professionals to get engaged in the discussion.

The project has demonstrated the potential of such an approach and its use as input for a wider policy debate. Looking beyond the project's results, several possibilities for a further model development could be put forward including model refinement, more detailed analysis or different scenario plots. The approach would also be interesting to use in a different case study in Denmark. The conurbation in East Jutland would be an obvious case, with a strong growth of urban areas but lacking a common regional planning scheme. The impact of future urban growth management initiatives or transport infrastructure projects could be analysed. But also the Copenhagen case could be extended to the whole island of Zealand to look at changes going beyond the area covered by the Fingerplan. Finally also the Øresund Region would be an interesting case, adding issues around the development of a cross-border city-region.

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