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RAPPORT DE STAGE DE RECHERCHE

Application of evidence-based methods to the test of a multi-value evaluation framework for sustainable renovation

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NON CONFIDENTIEL

Département Humanités et Sciences Sociales
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Abstract

The integration of sustainability in architectural projects is a key issue for current research. That implies a robust definition of the notion of sustainibility which can not simply be reduced to single aspects in relation with it such as environmental performances or social impact. From a systemic point of view, sustainability is the ability of emerging properties of the system to satisfy on long time scales certain requirements. In that frame, the research project ReBo presented in THUVANDER & *al.*, 2011, aims to understand necessary variables to obtain sustainable refurbishment processes, with a focus on Swedish housing stocks.

We propose to apply evidence-based methods to strengthen the methodology and philosophy proposed by the framework of ReBo, especially for the need of horizontal and vertical integration. We first proceed to a short architectural and sociological review of concerned urban areas, what is essential as preliminary work for model construction. We then propose a quantitative top-down analysis with aim to understand deeper the planning of the districts and to propose indicators of urban quality. That allows us to build an integrated agent-based model at the scale of a district. On a double-scale economic basis, further aspects linked to social questions or quality of life are taken into account. After calibration on real data and partial validation through the reproduction of economical stylised facts, we are able to launch simulations on possible refurbishment scenarii. Finally, we propose an original evolutionnary algorithm for planning and design of a new district, in the spirit of a possible application on real case through the coupling with the agent-based model to analyse the influence of the construction of a new district near the old one.

Résumé

L'intégration du développement durable dans les projects architecturaux est une question clé pour la recherche actuelle. Cela implique une robuste définition de la notion de développement durable, qui ne peut pas être réduit à des simples problèmes le concernant, comme les performances environnementales ou l'impact social du projet. D'un point de vue systémique, le développement durable est la capacité des propriétés émergentes du système à satisfaire certains pré-requis sur de longues échelles temporelles. Dans ce cadre, le projet de recherche ReBo, présenté dans THUVANDER & *al.*, 2011, a pour but de comprendre les variables essentielles pour des projets de rénovation durables, en se concentrant sur le cas de la Suède.

Nous proposons d'appliquer des méthodes *evidence-based* pour renforcer la méthodologie et la philosophie proposées au sein du projet ReBo, particulièrement en ce qui concerne la nécessité d'une intégration horizontale et verticale. Nous procédons d'abord à une étude architecturale et sociologique des zones urbaines concernées, travail préliminaire à l'élaboration de modèles. Nous proposons ensuite une analyse quantitative *top-down* afin de mieux comprendre la conception de ces quartiers et de proposer des indicateurs de qualité urbaine. Cela nous permet de construire un modèle *agent-based* à l'échelle d'un quartier. A partir d'une base économique à deux échelles, d'autres aspects liés aux questions sociales ou à la qualité de vie sont pris en compte. Après calibrage et validation partielle par la reproduction de faits stylisés économiques, nous sommes en mesure de lancer des simulations sur différents scénarii de rénovation. Enfin, nous proposons un algorithme évolutionnaire original pour la planification d'un nouveau quartier, dans l'esprit d'une possible application à un cas réel par le couplage avec le précédent modèle, afin d'analyser l'influence de la construction du nouveau quartier sur l'ancien.

Foreword

This research work is the produce of a research internship conducted at Chalmers University of Technology, department of Architecture, in spring 2013.

The spirit behind the construction of the project is the establishment of a PhD subject in the field of urban system modeling, with aim to touch architecture, urbanism and complex system theory through a multi-scale approach. That's why that internship at the department of Architecture was a real chance. The elaboration of the project in link with a current research project allowed to work on actual research subject with a lot of available data, and also many people able to give advices.

The meeting between my formation in Complex Systems and the sociological approach of Architectural problems typical of the Swedish school led to a synergy in the definition of a various but globally coherent project. We managed to find four complementary fields of research, which gathering aims to bring an answer to our research question. That explains the structure of this documents : after the subject has been introduced, four independant thematic paper develop each theme. The order follows a global logic and the whole should be read in order for an exact apprehension of the issues, but each part was written to be read much independantly as possible. Appendices are more for technical purposes and are not essential at the first reading.

Acknowledgments

I would like to thank first of all Paula and Liane who welcomed me at the department of Architecture and found time to help me positionning my project in relation with the project ReBo. I also thank a lot Pål for giving me a place to work in his room and for his precious advices (unfortunately not so frequent because of the lack of time) regarding social aspects of urban problems.

I also thank people from School of Architecture at KTH that invited us to the research workshop, and all the participants of the workshop that was a great experience.

I thank my supervisor and teacher Karim Basbous for his amazing classes on Architecture and Urbanism and his advices before the internship, Kashayar Pakdaman and Arnaud Banos for having teached me the basis of research in complex systems during this year of master.

More undirectly but still essential, I thank organiser of the Complex Systems Summer School 2013 - all the lecturers brought me precious knowledge used here, and also participants, especially Claire and Chris for teaching me the reality of GIS, and Nico for his approbation on network algorithms.

I thank Raphaëlle for the correction of english mistakes, which unfortunately surely remain in great number because time for correction really lacked.

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Contents

Introduction

1 Setting the scene

This project can be situated at the intersection of multiples perspectives and approaches on architecture and urban design and follows therefore the actual trend of a more integrated and transversal way to practice architectural science. Indeed, the bottom-up systemic approach is quite recent in urban design (introduced for example by the architect Batty in the end of the 90s, recently sumed up in [1]), and more recent for architecture in itself (for exemple first papers on the use of computational design, as the work of Knight on shape grammars in [6], are not older than ten years), although earlier work already proposed implicitly top-down systemic for urban systems, for which the best example is the theory of Space Syntax introduced by Hillier in 1976 in [5]. More than the theorical already present, it is really the technical aspect of complex systems that is breaking nowadays into design and planning, as a consequence of the recent development of complexity analysis in link with new accessible and always more powerful computer simulation tools (see [3] to have an idea of the development of that disciplin).

The way to practice and to think architecture really depends of the cultural context. As an example, a friend studying nowadays in a school of architecture in France explained his vision of the disciplin : "there are three ways to do Architecture, the technical one [he meant construction technique], the artistic one and the social science one". Let take this as an unformal description, since we weren't able to find a similar description in the litterature, but that should reflect a "field" reality. Compared to that, the practice of research in Architecture in Sweden seems to be more oriented towards social science, and the systemic vision has its place as a branch of research in Architecture and Urban Planning ; in France, the field is not so developped and is studied by geographers. Our purpose is to claim that our study may be at the border of several disciplines and at the cross of points of views that may appear as opposed, but we bet on the fact that this originality could bring interessant ideas.

The implicit personal opinion behind the philosophy of this work is that the gap that could exist between the artistic aspect and the scientific aspect (that can be social science, technical aspect or complex systems science) has no strong justification and that it could be breached through epistemological, philosophical and technical work - a concrete example of such a try will be presented in the last paper composing this project, when we will propose an hybrid model based on scale integration. Therefore we will always try to keep a multidisciplinary point of view when posing the problematics and proposing solutions.

The general purpose of this work, as presented in the initial proposal (see [7], in appendice D), is to propose extensions of technical order to an existing research project lead at the departement of Architecture at Chalmers University of Technology, Göteborg, by applying in priority agent-based modeling, and more generally evidence-based methods. We use the theorical framework of the project (that we present in more details in the following) to build models which application is supposed to strengthen the ideas proposed by it.

2 Integrating sustainable processes : the project ReBo

General presentation The need of integrated processes has appeared as crucial for the sustainibility of the projects, and in that frame the consideration of refurbishment or requalification of buildings has totally its place. First the refurbishment in itself becomes sometimes necessary to fill ecological and societal constraints of sustainibility, but reciproquely a refurbishment can not be sustainable if its approach is not integrated. For example, strong cultural and architectural (in the sense of the subjective quality) components can become an issue, then an asset for sustainibility in a refurbishment process. These ideas have been first formulated by Stenberg & al. in [8], where they insist on the importance of taking into account societal aspects (will the refurbished district be "socially sustainable"?) and many other fields within the design of a refurbishment process. They point the fact that "Actually, it is not unusual that environmental projects in [...] areas are put forward as examples of holistic and good practice in urban development in general, without considering fundamental and negative social impacts", and therefore conclude to a huge need of transversal integration in the processes. The general transversal integration is shown on figure 1.

This has lead to the development of a research project called ReBo conducted since 2010 by Chalmers University of Technology in Göteborg, in which many other institutionnals stakeholders (komun, firms) are sometimes involved.

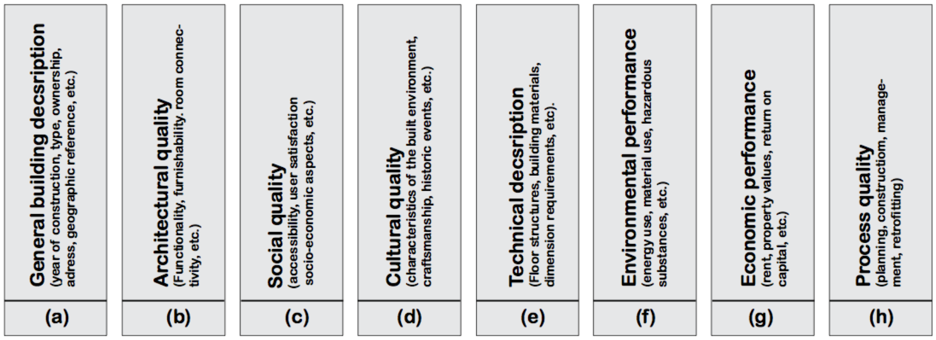

Figure 1: Multiples aspects taken into account in the evaluation by ReBo framework. (source [9])

The aim is to propose a multi-objective evaluation framework for sustainable refurbishment processes, that could be easily used by tenants and parts involved. In [9], Thuvander & al. describe the theorical framework, built from the concrete case of Swedish housing stocks from a particular type. They insist on the transversal integration (differents aspects taken into account as technical description, environmental performance, social aspects, cultural aspects, architectural legacy, etc.) but also on the vertical integration, by giving for each parameter what they call "parameter levels", that are the different scale levels for evaluation : the deepest is the local concrete observation of real proxys for the considered parameter, the highest the global notion around the parameter. The table 1 describes precisely the vertical and horizontal integration involved in ReBo framework.

Objectives and means We described the abstract aim of the project but didn't give any concrete objective. They seem to have appeared as consequences of the theoretical research, and one of the best example is the concrete establishment of rigourous framework and methods at all step of the refurbishment process. Therefore, a further step of the project was the holding of workshops with all types of stakeholders to identify the current practices and tools used for evaluation of refurbishment need and in the process itself. These workshops are described in [10]. More recently, a part of the work was aimed at understanding the expectations of inhabitants. A questionnaire was submitted to all residents of a given district. Currently, responses are analysed and mapped in order to understand social concepts behind the process of refurbishment.

Type of value (PL 1)	What does it mean? (PL 2)	How is it described or measured? (PL 3)
(a) General description	Cadastral information, evolution and changes, function, future property development	Ownership, tenure, location, dimensions and area, year of construction, value, property development plans (managers), land use planning (municipal)
(b) Architectural quality	Neighbourhood level (spatial planning, place-making characteristics, amenities, infrastructure, connectivity, safety, parks, landscape design) Building level (spatial organisation, openings and daylight, usability, materials and detailing)	Type of services, streets, pedestrian lines, greenery, proportions, variety of building typologies, dimensions, distribution of windows and doors, materials. Functionality and accessibility, furnishability, easy cleaning, room connectivity
(c) Social quality	Comfort, health, safety, user, image, occupant satisfaction, community interaction, demography	indoor air quality, emissions, accessibility, functionality, types of services, transport, tenure, socio-economic parameters
(d) Cultural quality	Cultural historical values, historic values, artistic values, building technology values, narratives	Significant characteristics of the built environment, urban landscape, user perspectives, craftsmanship, materials, historic events, traces of older society and lives
(e) Technical description	Type of structure, building components, building materials, dimensioning requirements	Floor structures, building materials, dimensioning requirements
(f) Technical performance	The building and its technical systems	Heat- and sound isolation, ventilation, indoor air quality, fire safety, accessibility, structure, wind-load, demands from building regulation, operation and maintenance qualities
(g) Functional performance	The building and its functions in terms of serviceability and adaptability to changing needs (management and user perspectives)	Spatial robustness, flexibility, layout qualities, structural and infrastructural possibilities and constraints
(h) Environmental performance	Life-cycle thinking, impact on the environment, resource efficiency, emissions and pollution, biodiversity	CO_2, energy use, water use, hazardous substances, material use
(i) Economic performance	Life-cycle thinking, development of cash-flow, market value	Book value, rent income, return on capital, LCC and other tools to assess investments, location, asset portfolio
(j) Renovation process quality	Renovation strategies, organisational capacities, client capacity,	Owner directives, decision making on renovation, maintenance plans, management team, knowledge and competence, routines

Table 1: Parameter list and vertical description (source [9])

3 The question of modeling

Since we want to propose formal models on which simulations can be launched and that could lead to evidence-based solutions to the problematics we face, and since a purely technical approach is not the purpose of our work, we were strongly confronted to the epistemological issue of the sense and the role of modeling.

Models in science The way of thinking science evolve with it and models have not always been seen as we do today. First the concept of level of complexity of models is quite recent. In [12], VARENNE sets the concept of complexity vector. Three values are needed to represent the complexity of a modeling process: complexity of the system, complexity of the model and complexity of the implementation. The implementation is what "we can touch", in the sense that the model is an abstract object which is different from the mathematical objects representing it (for example). Before POINCARRÉ and the formulation of the dynamical system of three corpses, science thought simple models were always associated with simple system, what is not the case at all, since that problem is the simpler example of chaotic dynamical system. The implicit definition of models by VARENNE is in resonance with the notion of perspectivism recently proposed by GIERE (see [4]), and it is in fact the most and most accepted vision of modeling as Brown confirms in [2]. Simply, a model is an abstract object that "someone uses to represent something". The fact of taking into account the object of modeling and the object that proceeds to modeling (the scientist in general) is the key of that perspectivist approach. That brings the notion of projection that we met during meta-modeling attempts. As VARENNE assumes, meta-modeling is in itself not possible. Let take the example of a meta-formulation of agent-based modeling. At the highest level, we can propose that the meta-model is composed of the abstract set of agents $\mathcal{A}$ and of an family of function $(f_{a,t})_{a\in\mathcal{A},t\in\mathbb{R}} \in \left(\mathcal{A}^{\mathcal{A}}\right)^{\mathbb{R}\times\mathcal{A}}$ describing evolutions. But still, that vision can not be formalised in the same way as a differential representation for example. And the vision of time is far from actual physics models, what reinforce the idea that a general meta-modeling process can't exist. Furthermore, trying to extend the modeling horizontally (i. e. in the number of objects "taken into account by the model"), we always reach a limit when we tend to real object. This limity is in fact the essence of modeling, it is the "projection" we saw before. That limitation in possible meta-modeling is in fact intrinsic to the concept of modeling. It is quite the same idea with informatic theory of languages, models and calculus: when formalising the formalisations themselves, a limit is also reached, first in the need of strong axioms and secondly in the fact that it proves that theories are not self-consistent (see GÖDEL theorem). That shows how modeling is in essence delicate, because it is in fact not really possible to proceed to modeling without thinking on what we are doing.

Modeling in our context In our context, the clear aim of modeling is to proceed to simulations. On that point, Varenne explains in [11] that the difference can be done between *simulation of models* and *models of simulations*. If one creates a model and then uses it for simulations, without having conceived the model in that particular aim, then the informatic code he writes for that will be in itself a model of the model, since translation and interpretation are needed. That leads to intrinsic complications and unwanted side effects. That is the simulation of model. On the contrary, if the model is directly created as a simulation, then the problem won't exist. We do in that case a model of simulation. Concretely, that means for us that the formalisation has to be rigourous and closest as possible to the implementation (what can be quite difficult in some cases). In our project, we will then use models as simulations, but also abstract models in themselves, as in the reflexion on the relation between art and science in the frame of evolutionnary design.

4 Description of the project

Research question The research question leading the project is: "How can we build models of complex systems to test different perspectives on refurbishment evaluation, especially to test the method of horizontal and vertical integration proposed by the project ReBo in the case of Swedish housing stocks?".

Overview The research project will by nature be composed of heterogeneous aspects. The question directly implies the understanding of the sociological context of the particular case, what brings a first decomposition between the technical part and a social science analysis. After that it appears quickly that the technical understanding of housing projects is also a prerequisite for the elaboration of any model concerning these districts. That work is still preliminary to model construction. Then the core part is the modeling in itself, that combines two approaches: agent-based modeling and evolutionnary design.

Plan of work In Paper A, we will proceed to architectural and sociological review of the urban areas that are the object of study in the next papers. We will focus on the understanding of the notion of "suburb", which has a particular meaning in the Swedish context.

In Paper B, we propose a technical understanding of Swedish urban planning. That brings to the construction of objective indicators of urban quality at the scale of a district. This is a top-down approach of the urban question. We are then able to apply these indicators to a comparison case study between a

Swedish and a French district, to test if some planning have globally better objective qualities than other.

In Paper C, we build an agent-based model to represent life in a district of Göteborg, Långängen. This is the core part of the project. The model is build to be applicable on real data and data collection and processing is part of the work. The aim is to have multiples aspects, beyond the economical one, to justify the multi-criteria approach done in ReBo. The question of calibration of the model is also well considered. One key result is the possibility of simulations on different refurbishment scenarii.

Finally, we propose in Paper D a reflexion on automatic design and planning through evolutionnary algorithms. A generative model for planning of a new district is described and implemented. The initial aim was to couple the model with the agent-based model built in Paper C, representing that way a new district that have just been built besides Långängen.

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Paper A
Architectural and sociological analysis of the Swedish peri-urban areas : past, present and perspectives

Abstract

We proceed to a description of the Swedish peri-urban areas, first from the historical point of view of their development and of their architectural description. Then we propose a sociological diagnosis around the existence of the Swedish "suburb", and finally we review some perspectives on the future of these areas.

Introduction

Understanding the nature of the area concerned by our research project appears as a necessity. In the first place the context is really particular, because history of Sweden led to unique urban configurations that can not directly be compared with analog configurations in other countries. Secondly, our object of study is inside Sweden of a particular type, on which prejudices are quite current. Therefore we need to sum up history of these peri-urban areas, and try to define what they are today.

1 Architectural history

1.1 People's Home : Modern architecture for social housing

Historical context

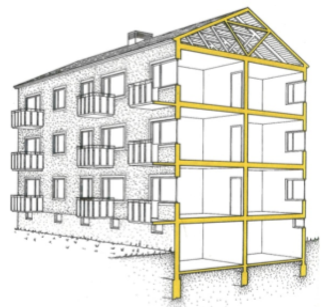
The People's Home (*Folkhemmet*) projects (or more the "notion" of People's Home, because it can be presented as a political ideal, a realization of the Welfare State) are well reviewed in [10]. A case study on a particular district made in [11] was also a keypoint to understand the ideas behind this description. Around 1930, Swedish state proceeded to an investigation on the qualities of housing all over the country, which conclusion was that there was a need to give to each citizen a decent home for a decent price. Concretly, advantageous loans were done for constructions of new buildings. Public housing companies formed a important part of the owners. This politic led to the apparition of areas of new type, mostly in peri-urban fields (in free spaces, since "housing politics were focused on the construction of new housing on virgin land").

Architecture of buildings

The main principle applied for the design of these new districts was functionalism. The aims were "resource efficiency, low-costs, and good housing quality". Tests on shapes of buildings were done to maximize sunlight in flats. Ideas of modern Architecture were applied to the design of the building : geometric shapes, undecorated facades, generous windows. However, the roof and the floor were considered in a "traditionnal" way. The idea was to built simple but functionnal and comfortable buildings with the technical means at disposition. Figure 1 illustrate that description, with building stocks of 1948 and 1953.

Urban planning of the areas

Concerning urban planning, the ideas used are also coming from modern Architecture. A huge place is let to open space and green space is necessary for a



(a) Section of a building

(b) Organisation in “Laminar houses” (1950s)

(c) Organisation in “Tower houses” (1940s)

Figure 1: Typical building design and organisation of “People’s Home” (source [10])

good urban quality. Buildings are locally placed to have most sunlight possible, in relation with their shapes. That gave repeated patterns on the masterplan and visually but not necessarly monotonous as we can constate on figure 2 for the plan of Kortedala, Göteborg. Figure 3 shows the district that is the object of our study in the core part of the project, which can be considered a bit more monotonous. The buildings are generally well accessible and daylight performances are judged optimal, what confirms the research of functionnality during the design of the district (although those points stay subjective and could be analysed in an objective way as we will do in paper B).

When it is possible (i. e. when implantation areas are initially composed of forest, fields and swamps on a quite hilly terrain), natural features are preserved by planning. Furthermore, they are taken as elements of the planning in order to offer better quality of life to inhabitants. That can be seen through the implantation plan of Kortedala, where relief (level curves on the map) is taken as an asset to place the buildings, giving more open space to some, creating discontinuities in the possible monotony.

Figure 2: Initial plan of Kortedala, Göteborg. Built around 1950 (Source [10])

1.2 Million Homes Program : the Welfare State at a greater scale

After 1960, began an other area in the implication of the State in building dwellings, since a strong lack of the global quantity of dwellings was constated. After the war, Sweden followed a quick urbanization process, but the infrastructure was not ready to face such an increase in demand. Therefore legal disposition were taken to proceed to the new constructions at an impressive rates. That was called later the "Million Homes Program" (Miljonprogrammet), and the building of a million new dwellings was really scheduled in ten years. According to Hall in [5], where a review of the program is done, the housing queues had became really problematic, as a symptom of the increasing demand against the small number of disponible houses. The law was adpoted by Swedish parliament in 1965, and high rates of construction were maintained until 1974, when the constatation of a housing surplus was done. We can see on figure 4 the consequent increase in production rate during the Million Program. The consequent loans were still there and particularly used during this period. In itself, Million Homes projects are included in People's home terminology. New technical means were availables, like cranes on rails or prefabricated materials, what facilitated the production.

The design of buildings were also derived from modern ideas ; flat roofs

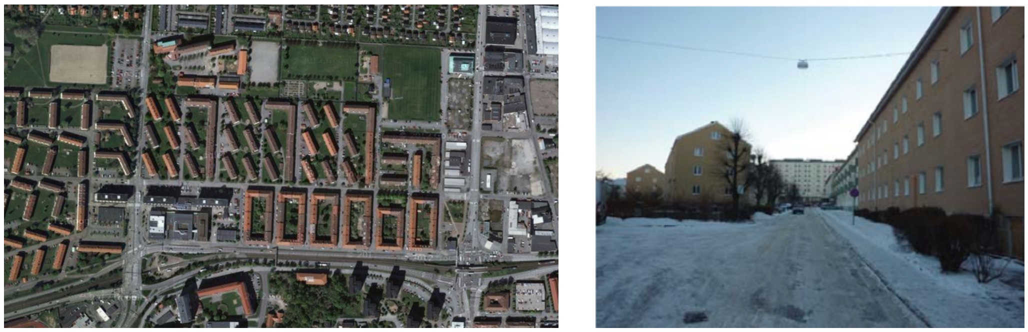


Figure 3: District Långängen, Göteborg

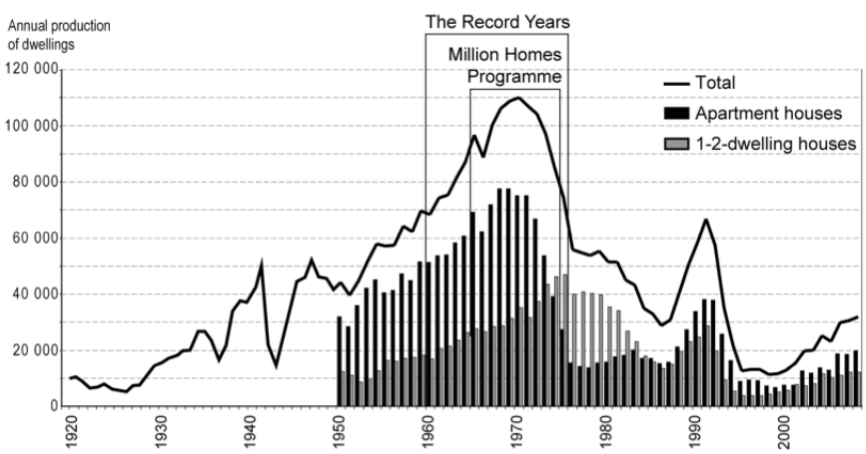


Figure 4: Construction of dwellings during the “record years” (1960-1974). (Source [4])

Figure 5: Million Home buildings, Bergsjön, Göteborg.
Left: Particular towers. Facade is covered with tiles, balconies have decorative patterns, roof has an original shape. Projects were often varied. Rymtorget.
Right: Common buildings. Komettorget.

were most frequent. If facades were mostly recovered of bricks, some tentatives of other materials existed, such as metallic facades for example. Standard for the apartments were higher than previous People's Home, with well furnished kitchen and bathroom and well-agenced interior. For individual houses (around 30% of the production), no particular external design was applied but living standard was also high.

Concerning urban planning, a strong guideline was "strict separation of traffic", what means the existence of a coherent network of bicycle and pedestrian paths. Collective buildings form pedestrian complexes including public open space. For Hall, environment was quite neglected during planning, by destruction of nature and creation of glaucous empty public spaces. However, all examples in the article are based on Stockholm outskirts, Malmö or smaller cities, but less on Göteborg (only one example of Bergsjön, Göteborg to show plan display for visitors). A field survey in number of Million Home projects around Göteborg (Bergsjön, Angered, Hammarkullen, Tolered, Biskopgården) shows that nature is quite preservated, in the sense that pieces of nature are inserted in part of the projects without modification. Of course the integration is not so precise as for older People's Home buildings, as the comparison between Kortedala and Bergsjön can show, but still nature seems to stay central in the project conception.

To sum up, areas we are interested in are mostly composed of collective dwellings projects (70%) and are located in peri-urban areas. Architectural features and planning characteristics are typical of modern ideas. We will then

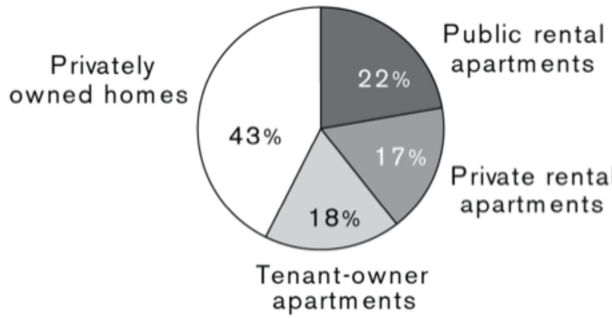


Figure 6: Proportions of types of tenure

study the sociological aspect of these areas that we then call call "suburbs".

2 "The myth of the Swedish suburb"

The consequences of the development of peri-urban areas during the 20th century include the birth of a particular type of "suburb" (notion that we have to redefine in that particular case). Castell proposes to explore that "myth" of the Swedish suburb in [4], trying to set the definition for the particular case of Sweden.

2.1 The suburb as rental housing area

Castell presents first the context of rental housing and the importance of munucipal housing companies. On figure 1 we can see the repartition between different types of tenure. It appears that almost a half of people rent their dwelling. That set the role of housing companies. The municipal companies (*allmännyttan*) had in the past privileges over private ones, such as loans with very low interest rate. That was part of the Swedish Welfare State, because these companies were considered as instruments to allow access to decent dwelling for everyone. Rents were strongly regulated, fixed according to standard for municipal companies and regulated to a close value for private companies. Although economic privilege for public housing companies disappeared 20 years ago, these companies have still an important place on the market, and the systems of regulation for rents has not changed. An important point is also that public companies are still the mean for local authorities to develop policies or try to implement solutions to social problems.

The name *allmännyttan* can also be translated as "social housing", but the notion has not the pejorative sense it can have in countries such as France :

social housing is conceived for everyone, not only for economically disadvantaged categories.

Taking into account the fact that most of peri-urban areas that we would like to define as suburbs are totally composed of rental housing, especially for collective housing areas, we can propose the approach that CASTELL gives implicitely in his work : the Swedish suburbs are peri-urban areas with a majority of rental housing. Included sub-areas of owned individual homes are considered as so, but some area with only individual houses are not (as the exemple of South-West of Göteborg).

2.2 Current representation against reality of the Swedish suburb

Environmental qualities In common representation, suburbs are associated with "large-scale housing areas" and therefore with high buildings creating monotonous landscape. That is not mostly not the case in Sweden : if that "environmental stigma" is justified in a few places, a major part of projects is composed of short-storey buildings, giving a more human scale to the area. Open space are appreciated by inhabitants. In fact, the physical layout of suburbs gives more positive considerations than negative ones.

Figure 7: Devil is in the details: benches where no one expected it. Bergsjön, Göteborg.

Functionally and culturaly rich areas The functionality of suburbs is also misjudged. The accessibility with public transportation is of high quality, since for example no peri-urban area of Göteborg is not directly connected with city center by a tramway line or a frequent bus line. For Stockholm, accessibility may be more discussed because of the remotness of some districts. However, they always have an access to commuter train for which the network is well developped and efficient. Concerning local functionality, services are of a high standard (supermarkets open every days until 22pm is the best example) and outskirts are agreable to live. Everything lies in small details, such as the benchs we see on figure 7 : on a random pedestrian path doing a connection between two parts of the district, the fact that the way is quite long and a tired would like to rest, or some other would like to sit and appreciate nature around, was considered and realized in that small action. The whole of details creates the character of an neighborhood as an emerging feature.

Figure 8: 37°/Suburbia, cultural performance at Rymdtorget, Bergsjön, Mai 2013. Inhabitants where involved voluntary in performances, attesting of the dynamic of local cultural life. (source website)

An other prejudice on suburbs is that they are unactive areas, with no cultural life for example. That is also not true, since most of projects include community centers, local libraries, etc. Suburbs have sometimes build their own cultural identity (see the musician Timbuktu for example). Recently, danse company of the Göteborgs Operan created a set of artistic performances together with residents of Rymdtorget, Bergsjön. People where able to share their culture by being part of the artistic performance. Religion was also well considered during planning, since places of worship for most present religions where built.

The question of segregation However, the negative aspect of segregation in different ways stays a reality associated to suburbs. Segregation can be defined as residential grouping of people sharing appartenance to the same "social status" (socio-economic segregation) or sharing the same culture (ethnic segregation). In mai 2013, riots broke in Husby in the outskirts of Stockholm. The trigger was an incident during a police intervention, but the real causes seem to be the bad economic situation of the neighborhood combined with ethnic segregation (see Newspaper articles about it[1]).

The measure of segregation can be subject to debate since many indicators can be defined. As an example, the dramatic situation of English suburban areas described by Simpson in [8] was nuanced by a response in [7]. Other statistical

[1] For example, The Local (http://www.thelocal.se/48006/20130520) or dn.se (http://www.dn.se/sthlm/upplopp-och-brander-i-husby/).

measures led to different results. There is also the question of the proxy variable used for measure ; socio-economic segregation is not always directly linked with ethnic segregation, although a complex relation between the two seems to exists.

However, as Castell points out, segregation has more and more became a reality in Swedish suburbs. In his essay "See you in the suburbs - if you dare!" in [6], Hammaren describes the common vision of north-east suburbs of Göteborg, that are seen as extremly segregated and dangerous to live. Altough the description appears as exagerated, it proves the increasing importance of that problem. Segregation seems to be the main future problematic for these neighborhoods.

3 Perspectives

We can now interrogate the possible perspectives for Swedish suburbs regarding some aspects we described.

3.1 Future of social housing

Around 1990, housing system was strongly reformed. Municipal companies lost their privileges and all kind of subsidies linked to the old housing system were stopped, all that in a context of merket opening. In [12], Turner and Whitehead take stock 10 years after these structurals reforms. Through a macro-economic analysis, they conclude that "significant modifications of the housing system" had emerged. Main features were augmentation of risk in the rental domain, an increase of inequalities and a reduction of demand in the construction of new buildings. That implies that poorer were disadvantaged by the reform. Social housing in Sweden may for this reasons be in strong crisis today.

In 2012, Göteborg Stad led a study ([9]) to find out the best alternatives to keep an efficient social housing in this context of market opening. Indeed, the mix of people with different incomes in a district ("mix of social classes") appears as a way to encourage social housing and to break segregation, but the market-ruled prices produce too high rents for low-income people. Therefore they analyse all social housing systems in Europe and come to the conclusion that the state should help local organisations to manage social housing, through construction of new buildings by non-lucrative organisms, in which municipality should have a strong role - in a way a compromise between old swedish system and french one for example. In all cases, future of social housing in Sweden stays totally unclear today.

3.2 Evolution of segregation

Andersson studies in [1] the consequence of policies taken to counter segregation (called "Metropolitan Development Initiative" and launched by the state in 1999) and concludes that the expected effects didn't appear. The reason for that seems to be that governement measures more amount to assist people than to structurally change the neighborhood. He argues that deep transformation of the concerned districts, with new constructions in order to obtain "socially mixed neighborhood". The results do not help to be optimistic regarding the evolution of segragation.

Concerning ethnic segregation, it seems harder to understand the phenomenon. Indeed, the authors of [3] argue that this segregation is reinforced by an ethnic housing segmentation, i. e. that immigrants are significantly "underrepresented in home ownership". They try to explain that fact by looking at people leaving rental housings for home ownership. By means of statistical regressions on data for the city of Uppsala, they express the relations between the two variables. The results are that the correlations are not enough so ethnic discrimination is not the explanation for the housing segmentation, what implies that discrimination has few chances to be at the origin of ethnic segregation. In the same way the work by Simpson didn't give clear answer on ethnic segregation, this one shows how that fact is complex to understand. Therefore we are not able to give precise answer about the evolution of ethnic segregation.

3.3 Possible actions

Many policies are proposed to counter problems suburbs are facing today. For Sweden, recent state initiatives appears as having failed as we saw before. However, local actors are involved in finding policies as the work of Göteborg Stad. Castell points the fact that environmental actions were totally ignored by the government recently and that maybe a requalification following a "resident-based" approach for neighborhood requalifications could be a great asset againt suburb deprivation. This is in fact the spirit of the project ReBo presented in introduction.

The bottom-up "resident-based" approach should be one of the great assets for the requalification of our cities. In France, that fact is confirmed by Badariotti in [2]. He analyses how we recently switch from the only morphological appraoch to a mixed point of view including local functional questions, taking into account especially the "interest of residents of the city".

Combined with the argument of Andersson on measures against segregation, that brings us to think that the most promising scenarii for urban renewal are bottom-up approaches with strong structural impact, such as integrated refurbishment or/and construction of new infrastructures.

Conclusion

We have seen that Swedish peri-urban areas have a strong historical and architectural identity, since they are mainly results of People's Home and Million Homes projects. This identity is associated to urban features that have led to a particular notion of suburb. Behind that the context of social housing and housing policies adds ambiguity in that. Even if these areas are now facing segregation problems, one must not forget the intrinsic quality of these places and consider perspectives for their preservation and requalification.

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Paper B
Architectural urbanity : between art and science, how Swedish urban planning can be considered as particularly performant and valuable

Abstract

We propose to study caracteristics of Swedish urban planning, especially for the districts built during the Million Homes program. First a qualitative analysis in general and case studies inform on the nature of these district and allow us to evoke the notion of "architectural urbanity". Then we consolidate the proposed ideas through objective quantitative case study by the construction of diverse indicators at the scale of a district and by applying them to the comparison between two suburbian districts.

Introduction

The city cannot be only composed of architectural exceptions, first of all for technical and pragmatic evident reasons, then maybe for more complicated internal structure effects. As Lynch has shown in [13], the distinction of landmarks and distinctive edges is essential in the personnal creation of the image of the city, so in its perception and appreciation, what can be considered as influencing the quality of urban life. The apparition of the suburbs in the second middle of the 20th century has directly followed that logic, taking it more dramatically as a general rule, which led to "aggregation of unperceptible and disagreable pieces, that we can difficultly consider as buildings" (subjective comment on suburbs heard from an urbanist). It would mean that some parts of urban areas, especially the suburbs, lack of architectural quality and therefore of life quality for their inhabitants.

However, such a vision stays at a small level of integration and forgets to take into account more global descriptors of the urban environment, since the local architectural or urban qualities of the built environment can be strongly different of more global properties evaluated at the scale of the district, the entire city or even within system of cities. Pumain ([19]) argued that this more global vision is necessary to understand, analyse, predict the performance of urban systems and therefore necessary for an optimal planning. That argument is also presented from an other point of view when Hillier propose ([9]) spatial and topological analysis of static urban systems in order to enlight some of their qualities or defaults.

Those arguments are to be developed in the following section, particularly the ideas developped by Lars Marcus in his thesis ([14]), when he focuses on the existence of these integrated qualities (what he calls the "functional performance") in a majority of districts.

1 Swedish Urban planning : subjective qualitative analysis

1.1 Architectural urbanity

1.1.1 Presentation

In his thesis, Marcus' aim is to show evidences of the existence of real performances for district planned during the 20th century. The background is a crisis of functionalism, since the expected emerging social aspects for district planned in a functionalist way do not appear today in an obvious way. Such criticism has raised particularly in Sweden, where the context for projects planned during the Million Homes program was this one. Looking at reviews on history of urban planning during the 20th century, a skepticism on possible accumulated knowledge in that field is quite present in mentalities today, and that is what Marcus wants to contest.

The first point of his response is the existence of "architectural urbanity", highlighted as a distinct part of urbanity : "within urban planning and design in the 20th century, one can distinguish a distinct category termed architectural urbanity". It is not really clear if that supposes a success of the top-down planning process behind most of urbanistic projects, or if this category is a consequence of commons local aspects, through the emergence of similar effects. Anyway, the purpose of this first part is not to explain the origin but to show the reality of this concept. Without going into details, the methods used to prove it are the application of spatial analysis methods (see [11] for further details on this theory and associated methods ; a written report of the workshop is in Appendice A). By extracting features of spatial configurations, we are able to classify the configurations according to quantifications of parameters of some features. The analogy between the organisation of a building through its architecture and the noticeable organisation in these patterns of features is the main argument for calling that class within planning "architectural urbanity". An example of the output of a spatial analysis calculation is shown in figure 1.

Going further in the second point, he brings proofs that architectural urbanity implies a minimal level of urban quality. Indeed "there are spatial preferences within [architectural urbanity] which is possible to link to certain functional performances". The built form has both consequences on its meaning and on its function. Therefore social aspects should be strongly influenced by urban form. The methods used are the same as for the first point, but only brought one step forward, since he sees these "quantitative methods as a scientific approach to the relationship between form and function".

Following this path, we will first try to get a rough feeling what this notion can mean. This theory will be applied in the second part with technical means, not exactly as Marcus does, because we will be more looking for a diversification in the approaches of the evaluation of performances.

Figure 1: Spatial configuration analysis of different district of Stockholm (source [24]).

1.1.2 Example

We can touch the notion of architectural urbanity by looking at a brief case study. The concrete example of the district Angered in Göteborg, which has been built during the Million Program and is typical of the criticals presented in Paper A, fits well for that study.

To set the global situation of that district, it is the most distant district from center. It is not accessible by walking (10km from center) and is isolated by natural and artificial obstacles such as hills, forest and industrial areas. Still, a direct tramway line links Angered to the center of Göteborg in approximatively 15 minutes. The part of occupied surface for collective buildings and individual houses is around 50% each, what means that a majority of the inhabitants live in the buildings.

Concerning the configuration and the local characteristics, we can analyse the detailed map shown on figure 2.

First of all, we note that the district is divided into four main parts (Centrum, Rannebergen, Lövgärdet, Gårdsten) wich are composed of cores of complexes of buildings, with satellites of individual houses systems. Each part is at the same distance of the Centrum, were the tramway line ended, so the transportation times are quite the same for all inhabitants and they are simply minimised. Local service is assured by bus but in worst case, the greatest walking distance to the station is 1,5 km. We can see that walking and bicycle paths (intermittent

Figure 2: Map of district Angered, Göteborg Kommun. Scale 1/10000. Source [17]

Figure 3: View of Gårdstensvägen, Angered. (street west of Gårdsten, view towards North).

black lines) are strictly separated from car traffic, for safety reasons (bridges and tunnels). All these simple points suggest a good performance regarding movements of individuals in the district and to the center of Göteborg. Furthermore, the tree structure of most satellites of individual houses is an other proof of optimisation of traffic distribution.

The well being of inhabitants is not forgotten in the planning : forest is always accessible and has been preserved all around the cores, to give a better living environment than only buildings everywhere around. An other interesting point is the accessibility of bathing places in the natural lakes. Swedish culture give a great place to the relation with nature and people know how to honor it, by appreciating and respecting it. When summer comes, bathing in natural lakes and going in the forest is a main activity. The planner have functionnaly optimised this access to nature, particularly to bathing places, since each part of the district has its own lake (in blue on the map) and the associated places, wich are very close by walking distance.

Last but not least, the core part of the district are each well self-organised. The building generally form a thin enveloppe surrounding public green spaces as parks and parts of forest, that are inside the core for the two convex parts, and partially inside for the third that is opened. The Centrum is different because compact, but its relative size allows easy access to surroundings green spaces even for buildings in the middle of it. If building shapes are globally the same and the architecture is also the same inside a part of the district, the monotony that could result and that is one of the main criticals evoked (see Paper A) is here broken through the non-monotonous aspect of the global masterplan ; for example just the small curvature of west front of Gårdsten is enough to entertain the walker by suggesting next buildings just showing a part behind (figure 3).

All these point are showing that district planning has intrinsic qualities, suggesting a certain level of "functionnal performance". They are not consequence of hazard but of small details in planning, in local and global organisation. That should be one proof of the reality of the "architectural urbanity". Of course the approach here was quite suggestive and not necessary justified, that's why we will apply to build in the second section a more objective analysis.

1.2 An implicit culture of performance ?

It is not clear wether all these aspects of planning were core elements of the planning directives at this time or they were implicit features that are part of Swedish culture in architecture and urban planning. Concerning traffic separation for example, it was clearly one of constraints in Million Program projects as it is explained in [8]. But other "softer" aspects are not generally mentionned in this review.

We explored briefly historical litterature to understand that point : in [16], that is a book published in the middle of the "record years" of Million program, the authors want to set standards for planning. It is interesting to note that some points may appear as contradictory : concerning the choice of building terrain, they recommand flat regions with less geographic constraints, as south of Sweden around Malmö. However, most of district built in that time (quasi totality for Göteborg, the same for Stockholm for South and North suburban areas, and these two cities gather majority of Million Program projects), were built on complicated hilly terrain, in contradiction with the directives for lower costs. The reason of these locations appears as an open question, in fact there may be no simple reason, the choice resulting of complex interactions of elements involved in the decision process.

But as we saw in the case of Angered, the disadvantaging geographic location becomes strong assets for performance of the project : the 4-core structure is suggested by topology, the natural lakes offer opportunities, etc. Therefore we can ask ourselves if the planners (consciously or inconsciously) did contradict the recommended rules in order to get more functionnal performance. That would suggest the presence of a culture of performance among planners, that express itself in an artistic way through the architectural urbanity of the district, confirming in an other way the importance of this notion.

2 Case study : quantitative comparison

2.1 Choice of the subjects

Proceeding to an evaluation of some evaluation criteria to a single district would have no sense at all, because if they are not normalised, reference values are necessarily needed. We propose in the following to built normalised criteria, but since it would be the purpose of an entiere study for each to determine the domain of validity and to assess of their pertinence, we will apply them to "reasonable cases", in the sense that cases must not be extreme cases for any aspect taken into account in the criteria. We also won't have clear ideas on the range of values taken by the indicators, so comparison will be binary and not quantitative. To proceed to quantitative comparison, a deeper study of indicators on a large range of cases would also be needed.

Concerning the scale of the subjects, it is not possible to find two districts exactly at the same size, especially in demographic and geographic size. Since our indicators are normalised, that point shouldn't matter. Still, following the hypothesis that scaling laws generally apply to urban systems as Pumain argues in [20], we are encouraged to think that the scale ratio between the studied element and its neighbors in the system of systems will have more influence on the properties of the subject than the absolute scale in itself. That allows to determine the set of comparable cases to a fixed subject.

Since we were interested in Swedish urban planning, and especially in Million Program projects, one of the subjects will be of that type. For practical reasons (thorough field surveys have been done), we will take the district of Bergsjön, in the East of Göteborg Kommun, Sweden (+57° 45' 21", +12° 4' 12"). For the second one, we will choose a french district also for practical reasons. The constraint of scale ratio in the system of systems of cities in the country imposes a district of the suburbs of Lyon, since Göteborg is the second city of Sweden. According to the choice of criteria, we need a district linked with town center with fast and frequent public transportation (if not, comparing the networks would have no sense). It is also coherent to choose a district built approximatively at the same period. Therefore the comparison case will be the district of Minguettes, Venissieux, France (+45° 41' 47", +4° 52' 16"), that fits perfectly all these needs.

2.2 Selected analysis criteria

On the variety and the arbitrary in the choice of evaluation criteria One could always argue, especially in social complex systems study, that the chosen evaluation criteria are the reason of the obtained results and that other criteria, even very close, would have led to totally opposed conclusions. It is obvious that we can build example where e. g. an arbitrary small change in the degree of an evaluation norm can lead to arbitrary big changes in the comparison results, however, we can suppose that there exists a sort of continuity in human systems and that the sensitivity of real systems stays small, in other terms that some near criteria are continuously linked.

The choice of evaluation criteria is at the heart of the multi-criteria decision analysis. An example can be seen in [30], where the authors try to propose an heuristic for systematic multi-criteria decision-making, and where the choice of indicators appears crucial but still arbitrary, show how ambiguous that problem can be. Although the construction of meta-methods for evaluation can be formally justified, as the use of aggregation functions proposed in that case, the initial problem of the human choice of evaluation space remains particular to each case. In that case, there are no strong geographic constraints, so criteria are mainly ecologic and economic ones. That is far from the choice of corridor for Highway A75 in France around the town of Millau, where lies nowadays the famous Viaduc de Millau : geotechnical constraints and direct impact on urbanization led to the choice of the "high solution" against the "low" - the choice of west against other option was made for ecological reasons and also consequences on urbanization. (source [6]).

Therefore we need to stay aware that our choice of indicators can arbitrary influence the results. We try to make it reasonnably regarding our problem, taking four aspects that appear important for the life quality in a district and for which the comparison across different countries will still have a sense. These are the spatial configuration, the repartition of landuse, the daylight qualities of buildings and the qualities of the transportation network. This diversification of aspects is suggested by the work of Ceccato in her thesis ([2]), notably when she insists on the fact that urban facts are understandable only through the conjunction of multiple characteristics and she proposes a simplified typology of possible fields of evaluation (what meets in background the ideas behind the ReBo project).

2.2.1 Spatial configuration

The spatial configuration of a district should have strong influence on its use by the inhabitants, so on social and economic aspects of the life in it. Studying the influence of spatial configuration on human parameters of the city was the original aim of the space syntax theory when it was first introduced in [9]. Since that, a lot of developments and other applications have been discovered in that context, creating a sort of informal sub-discipline of urban planning that we can call "spatial analysis". For example, recent work on the subject in Sweden is applied on linking attractability of green spaces with their accessibility, what allows to make proposals on the role of green spaces as in [24]. This work is a further exploration of the general investigation of public open space that Ståhle did in his thesis ([23]).

Of course this approach has received a lot of criticals, especially the analytical method used in most of studies, which is more based on topological analysis of the relation between subjective spaces of the configuration than on the real spatial configuration. In [22], it is shown that the abstract axial line extraction is really sensible to arbitrary small space changes, even with strong constraints such as fixing intersections points of lines. However, such a lack of robustness in that way shouldn't be a problem in our purpose, since we want to compare discrete values of an integrated indicator and we won't go deeper in the study of the local behaviour of the used function. Therefore we will adopt as a descriptor of spatial configuration the simplified local accessibility, following the generalised formula proposed in [25] (page 6) with an axial map as the representation of space and with no difference between individuals.

We extract a topological graph $G = (V, E)$ describing space through a representation of space Γ. Our representation is done through axial map construction at it is explained on figure 4 (we don't formalise exactly the function Γ since it would be quite heavy). With $i, j \in V$, we note d_{ij} the topological distance from i to j in G. For each node, the current method is to look at the mean distance to other nodes. Because sometimes it is more important to look at the maximal distance or at an intermediate value, we will use the normalised norm-p to integrate on the graph[1]. We also normalise by the maximal distance to obtain a scale-free index. With $p_l, p_g \in [1; +\infty[$, the spatial integration index is then defined as

$$I = \frac{1}{max_{i \neq j} d_{ij}} \cdot \left\| \left(\left\| (d_{ij})_{j \in V, j \neq i} \right\|_{p_l} \right)_{i \in V} \right\|_{p_g}$$

The figure 5 shows the implementation of this calculation on a concrete case (test on a Stockholm district).

2.2.2 Land use diversity

The diversity of landuse could have an increasing influence on "urban quality". To our knowledge, there exist no study in the litterature trying to confirm or invalidate that hypothesis or to explore the influence of local distribution of diversity on performances of the city. Some elaborated measures exist but they are more used by geographers to measure phenomena as urban sprawl or to quantify the morphologic structure of the urban form. Spatial correlation indexes are most of the time used, such as the Gini coefficient or the Moran index described in [29] and that appear to be necessary in [12] to characterise the urban form and try to link it to mobility through regression models. Other indexes are described in [28] in order to measure urban sprawl.

We will admit that the influence of diversity on urban quality is effectively increasing, knowing the limitations of such an hypothesis, since a too big diversity can obviously create negative drawbacks in the functionnality. In fact, the curve must have an absolute minimum which location depends on the particular case. But for real situations, it could be situated lower than the minimal diversity feasible in terms of technical means. All these points are interesting materials

[1] The normalised norm-p is defined as follows for vectors : for $p \in [1; +\infty[$ and for $x = (x_i)_{1 \leq i \leq N} \in \mathbb{R}^N, \|x\|_p = (\frac{1}{N} \cdot \sum_{i=1}^{N} |x_i|^p)^{1/p}$. It is particularly interesting, because for vectors with positive components (always the case here), the extreme cases give the mean of components ($p = 1$) and the maximum ($p = +\infty$), so the other values of p give a compromise between the two, more or less far from the two.

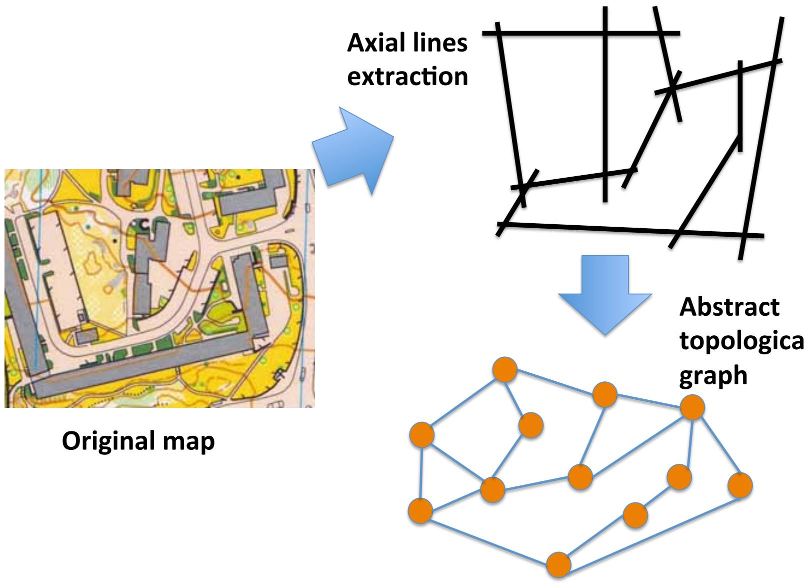


Figure 4: Topological graph extraction (source [11])

Figure 5: Implementation of spatial integration calculation (test on Sodermalm district, Stockholm)

for further studies. In most of recent planning projects, diversity of landuse is encouraged, what support us in our first hypothesis (see for example the new district Paris Rive Gauche conducted by PORTZAMPARC and administrated by the SEMAPA, or the new district Massy Atlantis, France, etc.).

If the world is composed of a set of patches P and that we can associate a type of landuse to each patch by the function $t : p \in P \mapsto t(p) \in [|1; N|]$, then our index is calculated as

$$d = \frac{N}{Card(P)} \cdot \frac{\sum_{p\in P} \sum_{p'\neq p} \frac{\mathbb{1}_{t(p)\neq t(p')}}{d(p,p')}}{\sum_{p\in P} \sum_{p'\neq p} \frac{1}{d(p,p')}}$$

The weighting by the inverse of the distance allows to translate diversity from a fixed patch : in a way, the "changes" of type of landuses are counted while going away from the patch. Then the integration on all patches gives the global diversity. The normalisation by $\frac{N}{Card(P)}$ puts the index between 0 and 1, because it is possible to show that the ratio of sum is lower than $\frac{Card(P)}{N}$.

2.2.3 Daylight performances

The role of light is essential in architecture, as Le Corbusier said in [4] in this famous quote : "Our eyes are made to see forms in light; light and shade reveal [...] forms", or as the work of Tadao Ando devotes to it in the Church of the Light (Ibaraki Kasugaoka Church in Japan). Daylight has therefore also a main place in the appreciation of the quality of a dwelling. In [18], PHILIPS confirms that "changing is the heart of daylighting, perception reacts to change".

It is possible to quantify the performance of a room towards daylighting by considerations on surface of windows, depth of the room, etc. Here, we don't consider the small scale of the flat or the building, but a more global level. We propose in appendice B a simplified model to calculate performance index of a hole district towards daylight. Such indicator doesn't exist in the litterature and seems to have never been used systematically during the conception of large scale urban projects. Of course the question has since long time been solved locally, e. g. the total renewal of Paris in the 19th century by BARON HAUSSMANN included in its guidelines the need of larger streets, with calculated ratio between height of buildings and recommended street width (as he describes in its memories, well summed up by CHOAY in her anthology [3]). But a global indicator depending on geographical position of the district (sun position in the sky depends strongly on it), topology (hills, differences of floor heights), natural obstacles (trees) and expriming a normalised value on a year can go further than simple height regulation rules.

The construction of the index was based on adaptation at a greater scale of of the basic layer of a daylight calculation model at the scale of the building proposed in [15]. In the following, since we take non necessarly linear aggregation functions (in fact the norms used are linear only in the case of the mean and for positive reals), the order of integration has a meaning, and it appeared more significant to first integrate on a day for each spatial point (daily performance of the point), then aggregate it on space (daily performance of district), and finally to evaluate it through a year.

Formal description Given a latitude L and a time in the year T, we suppose knowing the positions of the sun during a day by its spherical coordinates : $(\mathcal{S}_{L,T})_{L,T} = (t \in [0;24] \mapsto (\theta_{L,T}(t), \varphi_{L,T}(t)))_{L,T}$, the height function of the district $h(x,y)$ on a subset of $\mathbb{R}^2$ (we assume the projection has already been done), and the positions of all windows $((x_i^0, y_i^0, z_i^0))_{1\leq i\leq N}$. We can calculate for each window with these data the binaries enlightning functions (not detailed here) $s_i(L,T) : [0;24] \to \{0;1\}$. Finally, the successives aggregations as explained before give our index $S(L)$, with $p_s, p_Y \in [1;+\infty]$ parameters for the norms :

$$S(L) = \left\| \left(\left\| \left(\frac{\int_{t=0}^{24} s_i(L,d)[t]dt}{\int_{t=0}^{24} \mathbb{1}_{\theta_{L,T}(t)<\frac{\pi}{2}} dt} \right)_{1\leq i\leq N} \right\|_{p_s} \right)_{1\leq d\leq 365} \right\|_{p_Y}$$

The point particularly interesting in this indicator is that it exprimes the capacity of district to use the given daylight, thanks to the normalization by the lighting time in a day ; in winter in Sweden, enlighting times are short, but that does not mean that the district is not designed in an efficient way. This point raises the question of the validity field of the indicator : on latitudes close to huge North or South (just Kiruna in north Sweden could already pose a problem), it will become very sensitive to configuration because of the small values of enlightning time and won't have really a sense (it should be possible to build masterplans leading to strong bifurcation phenomena) - exploration of validity domain through linking to felt impressions and cultural expectations, and maybe diversification of its expression depending on human parameters, could be the object of further study. Still, we will use that here as an approximative indicator.

The figure 6 shows the implementation through sunbeams trajectory calculation.

2.2.4 Public transportation performances

The last criteria we chose was the performances of the public transportation network ; it is in an other field that the three we already have and appears also as crucial in the life of the city. Without getting into the debate of the structuring aspect of the transportation network or of its interactions with the other aspects of urban systems, we will admit the reasonable hypothesis that the relation between the quality of the transportation network (according to

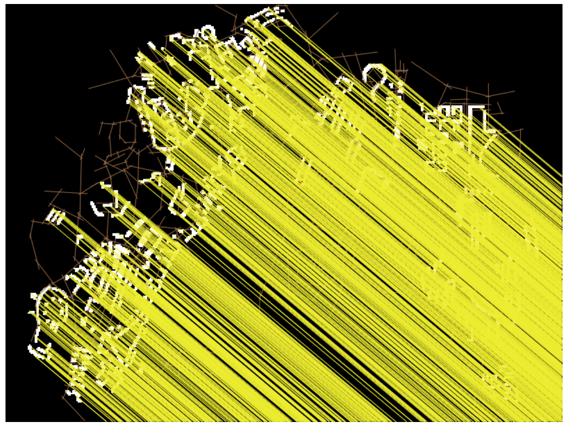


Figure 6: Implementation of daylight indicator

various criteria as robustness, connectivity, speed, etc) and the "quality" of the district (which is of course not really defined) is an increasing function.

The intermediate scale for which we give indicators is not appropriated for complex network analysis as centrality measures (see [5] on physical street network), clustering analysis (see [10] on named street network), or real robustness evaluation (see [26] on large scale road network weighted by real traffic), but the promising recent developments in complex networks theory (in particular by application of results on complex networks in physics to the study social networks) should invite us to find a way to consider networks at this smaller scale and try to apply these methods ; that could be the object of future work.

For our district evaluation, we will stay to very simple but essential indexes : transportation time and network relative speed. Formally, we suppose having the abstract representation of pedestrian network as an euclidian graph (V_p, E_p) with V finite part of the euclidian plane, and the same for the public transportation network (V_t, E_t). Each building will correspond to a node in V_p, so the buildings can be seen as $B \subset V_p$. Transportation network is accessible by foot, i. e. for all $v \in V_p$, there exists at least a path to a vertex $v' \in V_p \cap V_t$. Then we are able to define the shortest path to transportation for all $b \in B$, and the nearest station $s(b)$. To simplify, there exists a "target station" T in transportation network which is concretly the town center. We note $d_{v,v'}$ the length in networks between vertices v and v'. With mean speeds pedestrian speeds v_p and transportation speed v_t (we neglige waiting time, which can be integrated in speed if needed), we define our first indicator for the network (homogeneous to a time), with $p_t \in [1; +\infty[$:

$$\tau = \left\| \left(d_{b,s(b)} \cdot v_p + d_{s(b),T} \cdot v_t \right)_{b \in B} \right\|_{p_t}$$

The other network performance we propose is the relative "speed", i.e. the quantification of how the network is able to go directly to destination. It appears as an essential metric in real network studies as it is explained in [1]. With the same notations as previously, we will calculate it only on the pedestrian network, since at our scale the transportation network adapts itself to local constraints, quantifying its performance that way would have no sense. The undimensioned "relative speed" integrated on all travels is defined as follows, with $p_s \in [1; +\infty[$,

$$\sigma = \left\| \left(\frac{d_{b,s(b)}}{\sqrt{(x_b - x_{s(b)})^2 + (y_b - y_{s(b)})^2}} \right)_{b \in B} \right\|_{p_s}$$

2.3 Quantitative comparison

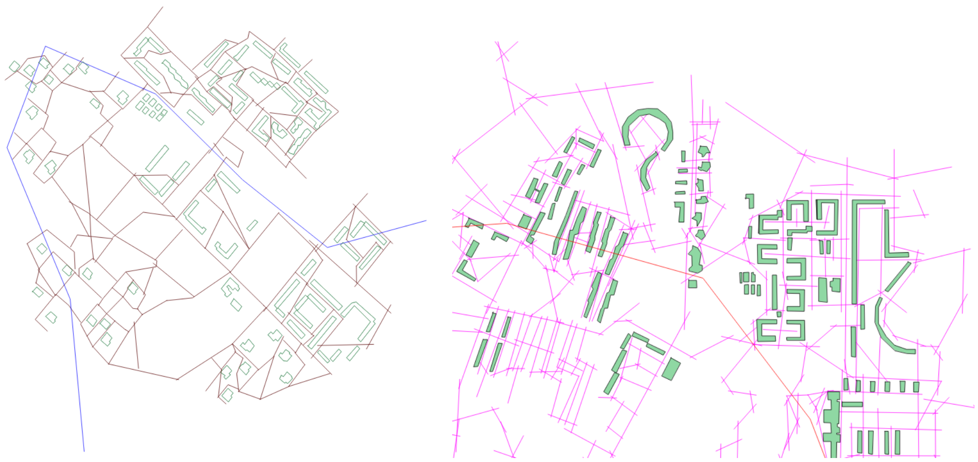
2.3.1 Extraction of data

The GIS data for building shapes of the Bergsjön district in Göteborg were available from internal database, but we didn't have adapted shapefiles for paths and roads (spatial analysis) or for the transportation network. Also for the french district it was totally impossible to get data simply (French geographic national institute, IGN, makes pay for it). That's why we proceeded to the data extraction by hand in a Desktop GIS Software ([21]), for all different layers : one layer for buildings used for landuse diversity, daylight performances calculation and public transportation performances (generation of origin/destination matrix), one for pedestrian paths for spatial configuration analysis and a third layer for public transportation (simplified to the tram lines, since the bus lines appeared not significant in both districts). Technically, an export to ESRI shapefile format made the analysis by the Netlogo handmade code possible. We can see in figure 7 the image of the used layers for both districts.

2.3.2 Results

For both districts we have calculated the indicators presented above for different values of the parameters for the p-norms. All results are summed up in table 1 for norms as means. The curves in figure 8 show comparison of results with different values for the parameters.

Interpretation and discussion First of all, we can say that we weren't expecting such results with quite balanced scores. The subjective impression after having lived a few time in one of the district (Bergsjön) and done consequent field survey in the other was that the Swedish district should be better on all points, what is not the case at all. That difference between subjective and objective analysis proves on the one hand that we must always be careful with subjective judgements, and on the other hand that it is not possible to translate in a few objective indicators the global feeling that one can have when appreciating an area.

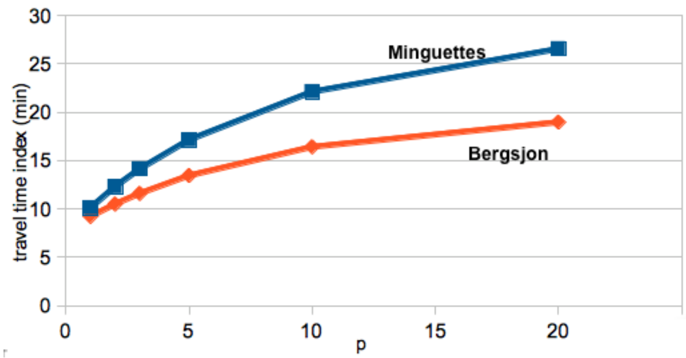


(a) Les Minguettes, Vénissieux, France (b) Bergsjön, Göteborg, Sweden

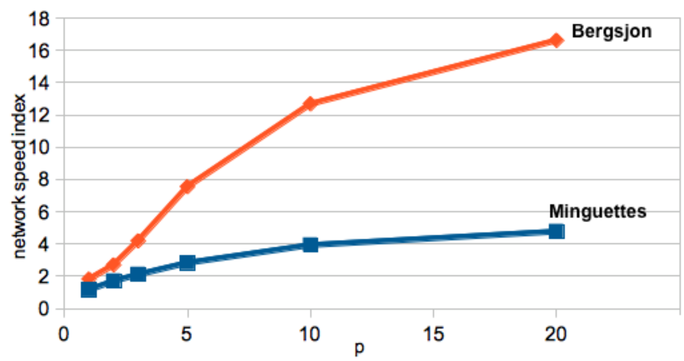
Figure 7: GIS Data used for district analysis

	Minguettes	Bergsjön
Mean travel time (T)	10,11	9,21
Mean network speed (1)	1,16	1,82
Mean spatial integration (1)	0,22	0,54
Diversity (1)	0.003	0,01
Sunlight index (1)	0.55	0,32

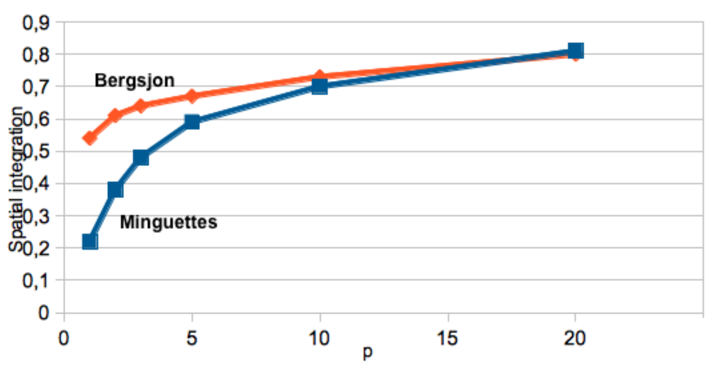
Table 1: Comparison of results for both districts (means are taken as norms).



(a) Travel time



(b) Network speed



(c) Spatial integration

Figure 8: Influence of norm parameter on indicators

Bergsjön is doing better on travel time, but not so much for the mean value, for which the time is almost the same (less than one minute). Looking at the curves, it is interesting that Bergsjon is more equalitarian, in the sense that duration of travel increases less quickly according to the rank among all travels.

Concerning network speed, Minguettes is better around the mean, but again with very small difference. The shape of the curves tell a lot about the structure of the network : because the curve for Minguettes is flat, the network should be regular all around the space, i. e. that we observe topological similarities but also that different parts of the network are used in the same way. In the contrary, the quickly increasing curve for Bergsjön shows strong irregularities in the network. That can be explained that there exists a lot of geographical obstacles that need to be avoided (cliffs), so on some parts of the networks huge detours were needed.

For spatial integration, the result is also quite logical when we know the districts, since Bergsjön is really fragmented by the pieces of forest whereas the Minguettes has a kind of spatial unity through a space really more open. That brings us to question the legitimity of the spatial integration index, because the fragmentation is not a problem for inhabitants, on the contrary it defines clear spaces that can be easier to appreciate. For the local travels, the tramway line is used, what breaks the fragmentation. In that case, our index has no strong sense.

The diversity index translates directly the more compact character of the french district. It joins the remark just before on the good influence of the fragmentation of space : more diversity between buildings, public open spaces, lakes and forest should be a good point.

Finally, the sunlight performance is better for the Minguettes, what is also a surprise because Swedish architecture is in general particularly demanding for daylight performance, because daylight is there in winter quite rare so it is better not to miss a single sunbeam. That could be a vice of implementation, because as a simplification the set of objective points was determined by discretisation of the union of the discontinuity curves of the height function, what is of course not true because there are walls without windows. In the french district, buildings of square shape with windows on every wall, are more frequent, so the error made during the calculation should be smaller.

More generally, going back to the question of the functional performance, the values taken stay abstract because we didn't do the tests on a greater number of district. But that suggest a method to give an evidence-based response to the thesis of architectural urbanity ; even in his applied work, Marcus doesn't generalise his methods to a representative set of districts, and some points stay at the state of assumption, since maybe no clear pattern of classification between districts would appear from a generalised analysis. That point also need to be explored in future work. An automation of the data collection is for that a crucial point, that can be solved through exploration of geographic database. Still, the problem of the difference between administrative definition of district and the boundaries of the concerned planning project remains, and the collection of the set of these boundaries would be important. After that, a projection of all projects in the criteria space should allow to proceed to clustering methods in order to search for possible patterns, and definitively confirm or invalidate the existence of the class called architectural urbanity. What could happen is that the projects form a continuum in the space, and that the clustering patterns bring out more cultural difference, or even nothing particular.

Conclusion

We were able to quantify by comparable indexes some aspects of what can be called the functionnal performances of parts of a city. The title of this paper, insisting on the quality of Swedish urban planning, is in fact just justified by the subjective analysis of the first part, since the objective analysis led to the conclusion that the Swedish district was not particularly better regarding the criteria we chose.

The question would need further development in both subjective and objective directions. We also touched a possible method for systematic classification of functional urban patterns. Linking it with recent classification methods of the urban shape (as mathematical morphology based methods developed in [7, 27]) would be a step further in the comprehension of the relation between form and function in urban systems.

That top-down approach for understanding characters of Swedish urban planning was in any cases a milestone of the global research project, especially as preliminary work for the third part, since the construction of agent-based models subtly depends on the overall context, and that a small misunderstanding or approximation can drastically change the internal mechanisms of the model.

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Paper C
Application of agent-based modeling to the consolidation of a multi-criteria evaluation framework for building refurbishment

Abstract

With aim to integrate sustainability in the more and more current refurbishment processes - especially in Swedish building stocks typicals of People's Home and Million Program projects, which are today beginning to decay, THUVANDER & *al.* describe in [15] the ReBo model, a conceptual framework for a multi-criteria evaluation of the need of refurbishment and of the possible ways to proceed to it. We propose here to consolidate this multi-criteria approach through agent-based modeling of the evolution of a district. We describe a formal economic model that we then extend to an heterogeneous model with aspects suggested by ReBo. Thanks to dedicated calibration process, we are able to launch simulations on real data and to explore possible refurbishment scenarii, what in a way reinforce the proposal by ReBo of a multi-criteria approach.

Introduction

As we explained in [12] (in Appendice D), the main part of our project on ReBo and Långängen case is the conception and implementation of an agent-based model at the scale of the district, which will take into account several aspects, from economic field to socio-cultural issues. That requires a heterogeneous model, which also need to be multi-scaled, since the concrete data we will use are themselves on different scales (macro scale for economic data such as unemployment, micro scale for the sociological data coming from individual questionnaires submitted recently to households of the district in the frame of an other part of the project). It is well known that, beyond epistemological issues that are also a great part of the problem according to [11], the technical aspect of building such models is a huge obstacle, so an appropriate methodology, proposed in [3], is to construct the model step by step, beginning with the essential in a simple way. Even following this, it appears that the first step is a great challenge in itself. We applied this methodology in consequence ; it appeared that the first aspect that was necessary to have a credible and working model was the economic one, what brought us to build a simple economic model to which we could add the other aspects later.

After a review of existing applications of Agent-based Modeling to urban questions, synthetized in [10, 1] , we saw that economic models of urban systems never were the purpose of pure economic research, since the economic field seems to have difficulties to accept the synergetics approach to their problems as it is argued in [4], but that there already exists promising economic agent-based models applied to geography. The SimPop model, developped for ten years by Sanders & *al.* , presented in [14], seemed to be the nearest of what we wanted to do, but at a greater scale, staying however adaptable at our smaller scale.

1 Background economic model

1.1 Scales and data

The real data we dispose of are of two types : macro yearly data such as unemployment rates at the scale of Gothenburg city or its part containing Långängen (Kvillbäcken), obtained from local statistic office, and micro data at the scale of the building or the household, for example the rent values obtained from the companies renting the buildings (annual reports), or incomes of households and subjective considerations about the quality of life from the questionnaires recently submitted.

That implies a double-scaled model : the evolution of agents and interactions between them will take place at the smallest level, which will be the flat and the household, with a small temporal scale as two weeks for example, whereas the district will also be considered from a global point of view to integrate the macro data, which will then be seen as exogeneous fixed time-series, on which the local behaviours will have no influence, but which the integration of local values will tend to reproduce in the better way. This hypothesis seems to be reasonable if the people work mainly outside the district, so a local perturbation of the economic configuration will have few impact on the unemployment (for example, if everybody works at the local supermarket and it burns, this hypothesis won't be true, whereas if the main part works outside, the fire won't have direct impact on unemployment - it will have of course on other aspect such as life quality).

1.2 Agents

For the basic model, the agents are households and flats. A household $h \in \mathcal{H}(t)$, with $\mathcal{H}(t)$ set of households at time t, is described by the number of people in it, the incomes status (with the convention that non-actives can't have income and unemployed have null income), the level of competence (approximately level of studies) of each active in it, the years of experience in the current job for each active, a consumption rate c_h which describes approximately the propensity to consume and the occupied flat $f \in \mathcal{F}(t)$ ($\mathcal{F}(t)$ set of flats), so he have for all $t \geq 0$,

$$\mathcal{H}(t) \subset [|1; p_{max}|] \times \bigcup_{k \leq p_{max}} ([0; I_{max}] \times [0; s_{max}] \times [0; e_{max}])^k \times [0;1] \times p_{\mathcal{F}\to\mathbb{N}}(\mathcal{F}(t))$$

where p_{max} is the maximal number of people in a household, I_{max} (resp. s_{max}, e_{max}) the maximal income in SEK (resp. level of studies in years, resp. experience in current work) for actives, and $p_{\mathcal{F}\to\mathbb{N}}$ a projection of $\mathcal{F}$ on $\mathbb{N}$ given by an arbitrary numerotation.

For the set of flats, we considere more simply the number of rooms and the rent, since the location is not of interest yet (the building fixes the rent per square meter, but it doesn't matter if we take the rent as given), and also the surface is in first approximation directly linearly linked with the number of rooms. That means that for all $t \geq 0$, $\mathcal{F}(t) \subset [|1; R_{max}|] \times]0; r_{max}]$, with R_{max} maximal number of rooms, r_{max} maximal rent.

1.3 Evolution and interactions

The economic situation of households evolves according to the global economic data and the evolution of flat rents, whereas the evolution of flat rents is function of themselves and the mean economic value of the district.

An iteration step of the model, corresponding to the small time step, is globally the following :

- Update work situation ; some people loose their jobs, other find one, in order to fit the current unemployment macro-value. Social help attribution and work experiences are also updated.
- Calculate economic balances for each houshold, taking into account all expenditures (rent, taxes, consumption).
- Households in great difficulty leave the district (seen as too expensive for them), whereas new inhabitants can come.
- Update rents for each building.

We describe the rules in details in the following.

1.3.1 Initialisation

The initialisation is done both at random and following external data. For example, the buildings follow their real GIS shapes. The exact way to initialize will not be described in detail here and can be seen in source code if needed. More explanations are given in the section concerning the integration of real data. The important point is the one of the internal coherence of the implementation, so the variables of households are initialized following the update rules explained in the following, in order to have no transitionnary state before the "real behaviour" of the model (that means that the model does directly what it should do and that there is no bord-effects due to wrong initialisation, it is as we followed a situation that already evolved before).

1.3.2 Update work situations

Employment For a household h, we can define by projection and counting the number u_h of people unemployed and the number a_h of actives in it, so the total number of unemployed is $U(t) = \sum_{h \in \mathcal{H}(t)} u_h$ and the unemployment rate is $u(t) = \frac{\sum_{h \in \mathcal{H}(t)} u_h}{\sum_{h \in \mathcal{H}(t)} a_h}$.

The global tendance of u should verify $< u(t_n) >= u_n$, where u_n is the fixed external time-serie. If $N_u(t_{n+1})$ is the number of people loosing their jobs and $N_e(t_{n+1})$ the number of people finding a job, we have approximatively $N_u(t_{n+1}) - N_e(t_{n+1}) = A(t_n) \cdot (u(t_{n+1}) - u(t_n))$ (taking the number of active $A(t)$ as constant at this time scale, that suppose that emigration and immigration rates are relatively small). New employed are directly linked to a global economic tendancy, that can be also represented by a time serie J_n (which represents the quantity of job opportunities), so it's possible to write $N_e(t_{n+1}) \sim \mathcal{N}(J_{n+1}, \sigma_J)$ (the variance is a fixed parameter), so we can then calculate the number of people loosing their jobs also as a random function (σ_u parameter) :

$$N_u(t_{n+1}) \sim \mathcal{N}(\mathcal{N}(J_{n+1}, \sigma_J) + A(t_n) \cdot (u_{n+1} - u(t_n)), \sigma_u)$$

That satisfies our constraint on the mean, we can see it by taking the mean on the above formula.[1]

A new employed person fixes his income such that $I_i(t_{n+1}) = max(I_{min}, \mathcal{N}(m_I - \sigma_I + k_I \cdot s_i \cdot \sigma_I, \sigma_I))$ where I_{min} is a minimal income, m_I a mean value, σ_I a standard deviation, k_I a parameter representing the importance of studies in income attribution (if $k_I = 1$, mean income will correspond to 1 year of studies. Such a relation is of course reducing but we will take that in first approximation).

Experience After that, for each household h, if $(e_i(t))$ are the experiences and $(I_i(t))$ the incomes, τ the value of the time step, we set $e_i(t_{n+1}) = \mathbb{1}_{I_i(t_{n+1})=0} \cdot e_i(t_n) + \tau$ and if the income has not already be defined through a new employment, $I_i(t_{n+1}) = \mathbb{1}_{e_i(t_{n+1}) \bmod \tau_{prom}=0} \cdot (I_(t_n) + I_{step})$ where τ_{prom} is the duration to be promoted (necessary multiple of τ) and I_{step} the corresponding income variation.

Social Help At each step, a given subset $\mathcal{S}(t)$ of $\mathcal{H}$ can benefit of social help. We define the primary reduced balance by $b_r(h) = (\sum I_i - r(f(h)))/p(h)$, with f the occupied flat, r its rent function and p the people number. Following a simple treshold criterium, the households in $\mathcal{S}$ are the S_{max} elements in $\{h \in \mathcal{H} | b_r(h) < t_S\}$ with the lowest b_r.

1.3.3 Economic balances

Then the global economic balance is calculated for each household. It is defined, taking $b_p(h) = (1 - t - c_h \cdot p_h) \sum I_i - r(f(h))$, by $b(h) = max(b_p(h), \mathbb{1}_{h \in \mathcal{S}} \cdot min(I_S^{max}, b_p(h) + I_S))$, with t global taxe rate (we take the taxe linear in a first approximation ; a tresholded function could be more appropriate), c_h the

[1] Note that to be correct, we should note $N_e(t_{n+1}) \sim_{law} \mathcal{N}(J_{n+1}, \sigma_J)$ and $N_u(t_{n+1}) \sim_{\text{cond. to } N_e = n_e} \mathcal{N}(n_e + A(t_n) \cdot (u_{n+1} - u(t_n)), \sigma_u)$, and the calculation of mean is done conditionally : $\mathbb{E}(N_u(t_{n+1})) = \mathbb{E}(\mathbb{E}(N_u(t_{n+1})|N_e)) = \mathbb{E}(N_e + A(t_n) \cdot (u_{n+1} - u(t_n))) = J_{n+1} + A(t_n) \cdot (u_{n+1} - u(t_n))$, what gives well $< u(t_{n+1}) >= u_{n+1}$.

propension to consume (per person) of the household, p_h the number of people, I_S the max amount of social help and I_S^{max} the maximal value of balance after getting social help

1.3.4 Population movements

According to the value of their economic balance, people can then leave the district if it has become too expensive for them. That is modeled simply by a treshold rule again, households with $b(h) < t_d$ are deleted from $\mathcal{H}$ at this step.

Then can immigrate new inhabitants, of mean income the current mean income, and with other parameters chosen following the current initialisation rule (can be at random or depending of u_n for unemployment for example). Their number is limited by the number of free flats $Card(\{f \in \mathcal{F} | \forall h \in \mathcal{H}, f(h) \neq f\})$ and a maximal number N_n.

1.3.5 Update rents values

It seems logical to propose that rents are updated according to the previous values and mean of rents (to have an auto-regulation) and to the global "economic value" of the district, which we can see as a direct function of incomes. Furthermore, a strong legal disposition particular to Sweden fixes a treshold that rents can not exceed to regulate the rents (recently set more flexible as we saw in Paper A). To follow these constraints, we propose a rent update for flat i of the form

$$\begin{aligned} r_i(t_{n+1}) \sim_{law} \mathcal{N}(min(r_{max} \cdot n_r(i) \cdot s_0, (1 + \tfrac{<b(h)>_{\mathcal{H}}(t) - b_{ref}}{b_{norm}}) \cdot r_i(t_n) \\ + K_r \cdot (< r_i >_{\mathcal{F}} (t) - r_i(t_n))), \sigma_r) \end{aligned}$$

where σ_r is the variance parameter, r_{max} the maximal rent per square meter fixed by the law, $n_r(i)$ the bumber of rooms in flat, s_0 the mean surface of a room (the random fluctuations are translated through the randomness of rent), b_{ref} and b_{norm} two parameters quantifying the influence of economic status on rents, K_r the auto-regulation coefficient.

The term of auto-regulation tends to create a uniform distribution of rents on long times, because it brings all rents to the mean value, so we will for long time executions set the parameter K_r to zero.

1.4 List of parameters

The right boundaries of descriptive variables for households and flats are parameters in themselves, but since we need to take them arbitrary big to always stay in the definition domain because they don't appear in formula, they have no influence on the model behaviour, so we don't consider them.

Follows the list of essential parameters.

- τ the time step corresponding to the real value of one iteration

- J_n, u_n the fixed time-series corresponding more to data than to parameters, and their corresponding sample time step τ_{ext}
- I_{min} the minimal income, m_I the mean income (that we could also take as a time serie later, to represent for example the external consequence of inflation on incomes), σ_I the corresponding deviation, k_I the coefficient determining the importance of competence level
- τ_{prom} the experience time to get promoted, I_{step} the corresponding income increasing
- S_{max} the maximal number of households that can get simulteanously social help, t_S the social help attribution treshold, I_S the maximal amount of money a household can get from social help, I_S^{max} the maximal final balance for people getting social help
- r_{max}, s_0, b_{ref}, b_{norm}, K_r the rent parameters
- t_d die treshold and N_n maximal number of immigrants per step

2 Integration of multiple aspects

The next step of the model construction process was to consider the first layer as validated, and to add new layers of agents and variables in order to create a heterogeneous integrated model. The validation step was made through model exploration and sensitivity analysis, that we describe further in the results section.

2.1 Choice of extending aspects

The main objective was to diversify the model in the direction of socio-cultural aspect, since the purpose of ReBo is to highlight the importance of these multiple aspects in the refurbishment process. The consideration of such problems is quite poor in the history of agent-based modeling of urban systems. In [2], Benenson explores the residential dynamics following first only economic rules, then "sociological" rules, using a cultural code for agents and the cultural dissonance, what is the distance between two codes, to define preferences of agents. It is like an evolved Schelling's segregation model, and the model was able to reproduce segregation patterns. Unfortunately, coupling between economic and sociological aspects is not explored in his work. The concept of sociodynamics introduced by Weidlich in [17] would be a sort of meta-method for modeling sociological dynamical phenomena. That way of modeling, deducing macro equations from local dynamics, was not really followed in the study of urban systems. More recently, the use of agent-based modeling appeared as a good tool for sociological studies, following other approaches of urbanism. For example, a operationnal framework based on multi-agent modeling with aim to explore policies against segregation was proposed by Feitosa & *al.* in [5] and explored in [6]. The core of the agent-based model is economic, but socio-demographic aspects are integrated through a feedback of experimental measures in the evolution of the model. We would like to add in our model more concrete influence of elements that could be considered as part of sociological aspects of the life of the district.

Within the ReBo project, recent work (forthcoming publications) was concentrated on the inhabitants of the district. As we described briefly in introduction, a questionnaire was submitted to all inhabitants of the district for which our model was designed (Lågängen), with a quite good rate of answer (around 75%). The questionnaire grid is available in appendice H. The purpose was to ask about all aspects of daily life, in the district (for example satisfaction with neighbourhood, dangerous places, accessibility, etc.), in the flats (satisfaction with rooms, storages, heating, bathroom, kitchen, etc.) and in buildings (common parts, stairs). The satisfaction about these points was asked, and then the point of view on the need of the renewal of each point during a refurbishment. Currently, data are processed, by mappings, statistical analysis, etc. A file with all answers was created, what is particularly practical for us for teh integration of questionnaire data in the model. For the choice of the aspects, fields concerned by the questionnaire were especially looked at.

We also chose the aspects that would allow to make simulations on different possible refurbishment scenarii and therefore the new aspects are at the intersection of these two characterictics. We used the preliminary work done in Paper B in order to understand what was really important. Finally, a discussion was led with main researcher involved in ReBo to extract from the shortlist a small number of aspects, which they judged as the closest to the spirit of the model.

The extending aspects are finally the following, they will be detailed in next subsection.

- Green space
- Public transportation
- Local services
- Energetic performances of buildings
- Living standard of flats

2.2 Description of the integration

Green spaces These new agents don't have direct influence on economic situation but there exists a feedback in the other sense: people will use green space according to their available time, what is a consequence of job situation. To simplify, green space are ponctuals, so it is more the symbolic action of going to a given green space than doing some things in it that will be taken into account.

The set of green spaces at a time is a subset $\mathcal{G} \subset \mathbb{R}^2 \times \mathbb{R} \times \mathbb{R}^{\mathcal{H}(t)}$, we note for $g \in \mathcal{G}$, $g = ((x, y), q, I^g_{\mathcal{H}(t)})$. That set can discontinuously evolve in time, especially in the case of a refurbishment: quality of existing green spaces can be improved or new one can be created. The first vectorial component is the position in the district, known from the geographical position in the GIS data. The second is a real parameter describing a "quality" of the green space. It is quite abstract and is supposed to aggregate diverse characteristics as surface, subjective quality (is it amazing to be in ?), capacity in number of people, opportunities of activities offered by it, opportunities of social contacts. The values are determined subjectively during the field survey we did on the area, and according to the mean results of the questionnaire concerning the feeling of people with the different spaces (section E.5 and E.6 of the questionnaire, see Appendice I). They are stored as attributes associated to the elements of the GIS file. The last component is a function associating to each household a coefficient of preference to this green space. In other word, for $h \in \mathcal{H}(t)$, we can describe the preference of individuals by sorting the set of coefficients $\{I^g_{\mathcal{H}(t)}(h) | g \in \mathcal{G}\}$. Concerning the time available for leisure, we will follow a simplification : at experience and level of studies both fixed, time is decreasing with income ; at same level of studies, available time is decreasing with experience (more responsabilities) ; at same experience, time is decreasing with level of studies (idem) ; so we propose the function, with I (resp. S, E) incomes (resp. studies, experiences) $T_h(I, S, E) = \frac{1}{8 \cdot Card(I)} \cdot \sum_{i \in I} max(0, 8 - K_T \cdot i \cdot s(i) \cdot e(i))$, where K_T is a constant allowing the second member to be a time of the good magnitude (fixed by experience). The normalisation is done in order to obtain a coefficient between 0 and 1. The value of the constant in the affine function correspond to reasonable remaining time in a day without incompressible tasks. We can also consider the distances from flats to green space in order to weigth by accessibility : for $f \in \mathcal{F}(t)$ and $g \in \mathcal{G}(t)$, $d(f, g)$ is the walking distance from f to g (calculated through shortest path routing in the pedestrian network, which is an euclidian network imported from GIS data), and by that defining an adimensioned coefficient of geographic accessibility $\tilde{d}(f, g) = {d(f,g)}/{max_{f' \in \mathcal{F}, g' \in \mathcal{G}} d(f', g')}$. With that, we can set the role of green spaces in the model by adding the output representing "satisfaction of people with green spaces", with $p_{gs} \in [1; +\infty[$,

$$S_{gs}(t) = \left\| \left(T_h \cdot \frac{1}{Card(\mathcal{G})} \cdot \sum_{g \in \mathcal{G}} \tilde{d}(f(h), g) \cdot q(g) \cdot I^g_{\mathcal{H}(t)}(h) \right)_{h \in \mathcal{H}(t)} \right\|_{p_{gs}}$$

Public transportation The public transportation network (tramway and bus lines) is modeled as an euclidian graph, which vertices (stations) are necessarly nodes of the pedestrian network. We can then define the satisfaction of people with public transportation by looking at the accessibility of stations through the pedestrian network, and then through mean time to get to city center. However, this point stays as a theoical one and is not implemented because the question of transportation infrastructure and gestion (change of bus lines, of timetables) is more the responsability of a company at the scale of the city (Västtraffik for Göteborg) and a local refurbishment of the district, led by local stakholders as the tenants of buildings, shouldn't influence these.

Local services The services are local shops, community centers, cultural spaces, etc. We won't distinguish the different types and consider that people always go to a certain number of services. The modeling is done exactly the same way as for green spaces, with the difference that available time is not taken into account as weight in the output function. So the set of services is $\mathcal{S}_e \subset \mathbb{R}^2 \times \mathbb{R} \times \mathbb{R}^{\mathcal{H}(t)}$, and we evaluate the global perceived quality of services the same way, with $p_s \in [1; +\infty[$, $S_s(t) = \left\| \left(\frac{1}{Card(\mathcal{S}_e)} \cdot \sum_{s \in \mathcal{S}_e} \tilde{d}(f(h), s) \cdot q(s) \cdot I^s_{\mathcal{H}(t)}(h) \right)_{h \in \mathcal{H}(t)} \right\|_{p_s}$. As for green spaces, that point is essential for the refurbishment simulations.

Energetic performances Each building has its own energetic performances, depending on isolation, heating materials, etc. Increasing in insulation capacity is for example one of targeted point during refurbishment processes (as it is explained in [16], "environmental goals" are systematically purchased in "decision-making process during preliminary investigation phase"). Therefore we extend the description of flats by setting a function $\varepsilon(t) : \mathcal{F}(t) \to \mathbb{R}$, and we change the economic balance by adding the price of energy consumption : the new balance is $\tilde{b}(h) = b(h) - \varepsilon(t)[f(h)] \cdot \pi_e$ where π_e is a constant representing the price of energy per time unit.

Living standard Living standard will also be added as a characteristic of flats, and will influence the initial rent (and not directly the evolution of rents ; this effect is indirectly expressed through the feedback of the incomes on rent). We will represent it as a function $\lambda(t) : \mathcal{F}(t) \to \mathbb{R}+$ and the new initialisation function for rents is, following notation of previous section, with $\bar{r}$ initial mean rent parameter, λ_{ref} such that maximal variations of the mean are of the same magnitude as the expected standard deviation and σ'_r a negligible value regarding σ_r, $r_i(t_0) \sim_{law} \mathcal{N}(min(r_{max} \cdot n_r(i) \cdot s_0, \bar{r} \cdot n_r(i) \cdot s_0 \cdot (1 + \frac{\lambda(0)[f_i]}{\lambda_{ref}}), \sigma'_r)$.

3 Concrete results : refurbishment simulation

3.1 Implementation and calibration

3.1.1 Implementation issues

The model was implemented with the NetLogo software ([18]), which is designed for agent-based modeling. Source code is available in appendice F. Automatic calibration process, setup procedures and different ways to run simulations (with or without refurbishment e. g., on different periods of time, etc...), as we can see on the interface of the model shown on figure 1. The visual representation is in itself not necessary for the model to run but help understanding the mechanisms. Graph are keypoints because they show some of the outputs. Other outputs are written in file, such as mean-square errors on time-series, for treatment in calculation softwares such as Scilab.

The formal description we did of agents and evolution equations was done with aim to limit all possible edge effect of the implementation. However, small points can become problematic if the user is not aware of them. To give an example, the handle of pedestrian network is not so simple. The shapefile of paths is imported through the GIS-extension of NetLogo, but the network composed of agents (nodes and links) has to be created in order to manage shortest path calculations. A quick but not deterministic clustering algorithm is used for that. The algorithm finishes with a connex network not far from the original if initial agents are ditributed under certain conditions, i. e. extremities of GIS paths that are supposed to be linked are close in space (distance under a certain threshold passed as parameter for the algorithm).

3.1.2 Calibration process

The aim of the model was to make predictions based on real data, so after having reduced the number of unknown (mostly because abstracts) parameters in the model, we designed a particular calibration process, in order to automatically find one of the best set of values for the parameters that makes the model "fit the reality" (according to some objective functions). The technical details of the elaboration process (which includes exploration and experiments) are developped in Appendice C, and we will just sum up here globally the method used.

The calibration has to be done on a small number of parameters. Indeed, with K parameters $(p_1, \dots, p_K) \in [p_1^{min}, p_1^{max}] \times ... \times [p_K^{min}, p_K^{max}]$ with precision steps $(p_1^{step}, \dots, p_K^{step})$, it is obvious that with $M = max_{1 \leq i \leq K}(\frac{p_i^{max} - p_i^{min}}{p_i^{step}})$, calibration time is a $O(M^K)$ (we have supposed number of replications as constant and maximal replication time fixed). That exponential becomes quickly impossible to manage with all possible needs. Therefore we follow the prerogative explained in [9] of finding as much proxies as possible for the parameters in order to decrease signifanctly the number of abstract parameters. Concretely, we will do that on not more than three parameters.

The method is single-objective based because the use of the gradient method through the simplex algorithm is efficient to minimize the objective function.

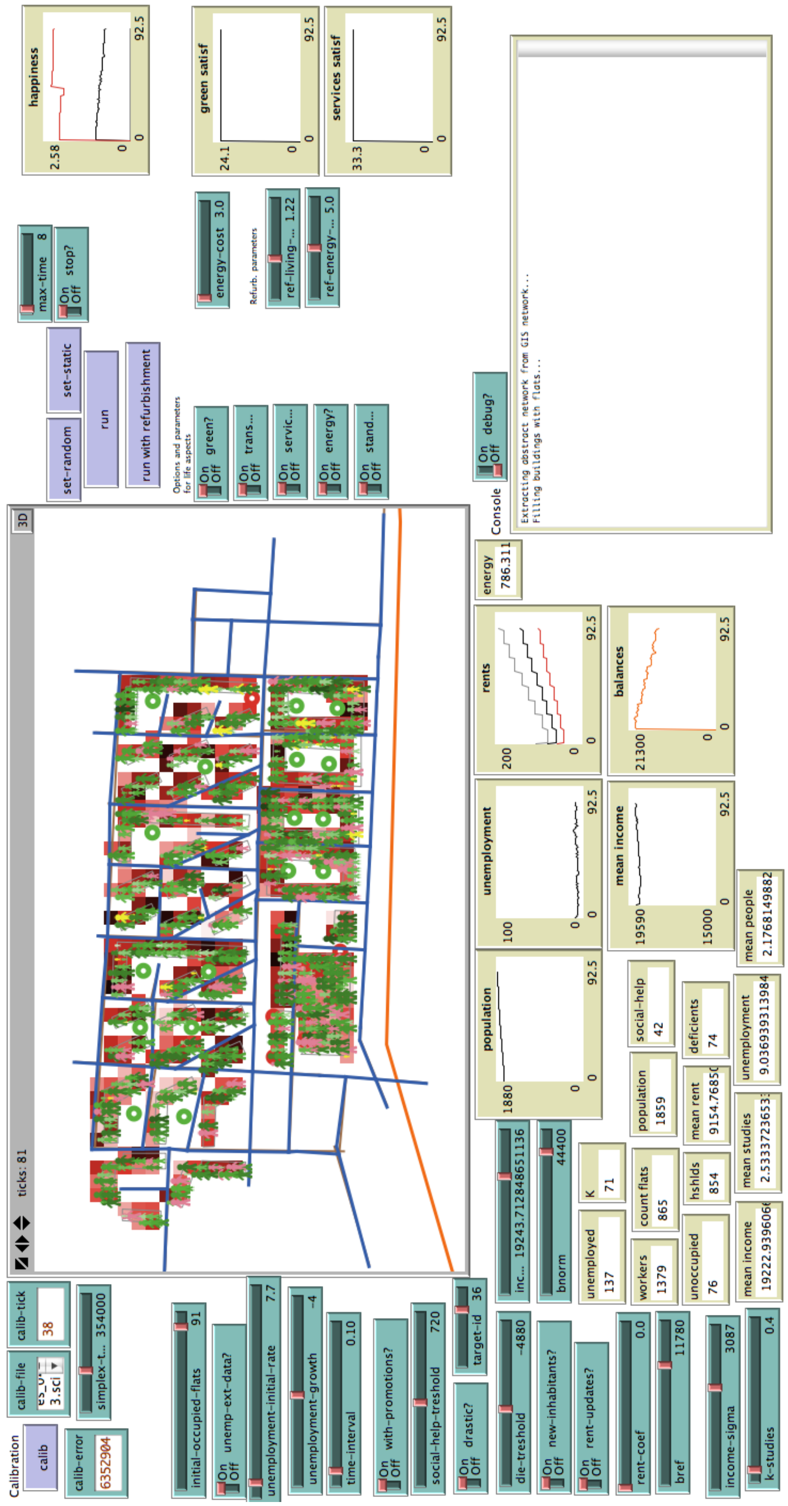
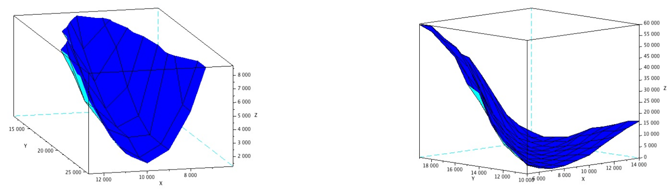


Figure 1: Interface of the model



(a) Along plane income-mean=cste

(b) Along plane bnorm=cste

Figure 2: Responses surfaces along given planes of parameters.

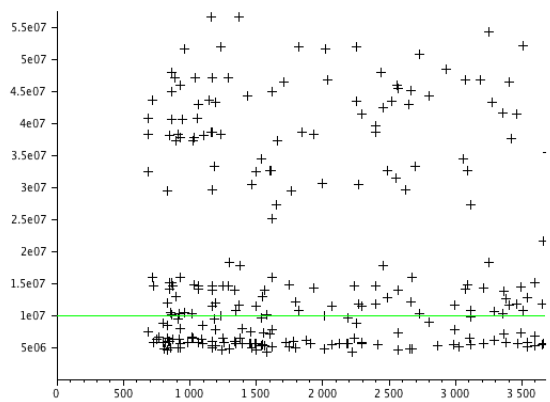


Figure 3: Projection of realizations in the plan of both mean-square errors. Green curve corresponds to the equation $\sum_i (\tau(i) - t_i)^2 + \sum_i (\sigma(i) - s_i)^2 = cste$, so the horizontal shape confirms the magnitude property is verified.

The experimental response surfaces of mean-square errors on objective time-serie (rents evolution) shown on figure 2 justify the use of that technique, since the surfaces appears as regular and convex.

Towards a multi-objective calibration, the possibility of using an evolutionnary algorithm, powerful way to proceed to automatic calibration as it is argued in [13] (calibration of the SimPop model), was considered but the structure of the model was not adapted. Instead we used a magnitude property verified by outputs. If $(t_i)_{1\leq i \leq n}$ and $(s_i)_{1\leq i \leq n}$ are objectives for discrete values of real-valued functions τ and σ such that for all realisations of τ, σ, $\sum_i (\tau(i) - t_i)^2 + \sum_i (\sigma(i) - s_i)^2 \approx \sum_i (\tau(i) - t_i)^2$, then minimizing $\sum_i (\tau(i) - t_i)^2 + \sum_i (\sigma(i) - s_i)^2$ will minimize both numbers of the sum. It appears in experiences that outputs for rents and incomes verify that property as we can see on figure 3, what allowed to proceed to the minimization of the aggregated mean-square errors on both time-series.

3.2 Case study : district Långängen

3.2.1 Data collection and integration

A consequent part of the parameters are representing reals variables, so their correct value has to be extracted from real data. Some are calculated once and for all and fixed in the code setup procedure, but other are loaded from external files during the setup, in order to bring more flexibility to the use of the model. All real data are sumed up in table 1.

Type of data The data are of four types :

- "Calibration" : these are the two time-series on which the mean-square error with the output of the model are used as aggregated objective for the calibration process.
- "Parameter" : can be a time-serie or constant parameter, these are parameter representing real variables.
- "Objective" : these data are not used yet in the current version of the model. They are supposed to be objective values for output corresponding to additional aspects, in order to proceed to additional calibration.
- "Structural data" : these are GIS data, allowing spatial dimension of the model. For the basic model they are not essential, since locations of flat don't have influence on evolutions and abstract buildings could be enough in the implementation. However, they are key features in the extended model because outputs are calculated taking into account walking distance from flats to services, green space and transportation stations.

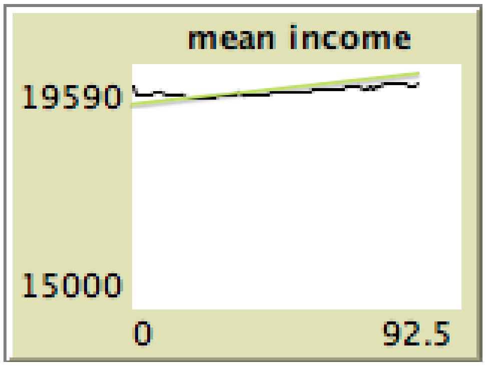
Origin of data and specificities in processing The data have multiple origin. The Statistic service of Göteborg city publishes every year reports with detailed values of economic, demographic, sociological, etc. variables ([8]). We use here the values of unemployment rate, taken as macro variable as explained in the formal description before. We also use the mean income and the variance in incomes (approximated through the given distributions of population) to create a virtual gaussian distribution of incomes and then attribute initial incomes to workers : response on economic status in the questionnaire are scaled on the left part of the distribution (hypothesis of a "modest" district), what allows to give an income randomly around the expected one.

Concerning the rents of flats, a data collection work had to be done because there exists no compiled database including these values. Therefore, we started with the assumption to take values for buildings owned by the municipal company Familje Bostader as proxy for all rents in the district, since they own approximatively 50% of the district and their data is easely available (using [7]).

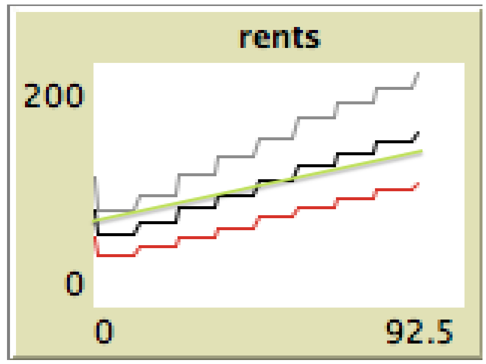
Origin of input data for Agent-based model for Langängen

Data	Type	Unit	Origin	Input procedure
Mean rent	Calibration	Kr/m^2/month	Familje Bostader annual reports	Annual mean for Familjebostader buildings taken as proxy for all buildings
Mean income	Calibration	Kr/month	Statistiks Göteborg/Questionnaire	Statistical distribution evaluated from mean/variance from Statistik Göteborgs, individual localization in distrib evaluated from economic vars in Questionnaire
Unemployment rate	Parameter	%	Statistiks Göteborg	Global unemployment, no local data found
Proxy of living-standard	Parameter	-	Questionnaire	Var satisfaction with standard
GIS Building Layer	Structural data	-	Drawn GIS data	
GIS « green spaces » layer	Structural data	-	Drawn GIS data/field survey	
GIS services layer	Structural data	-	Drawn GIS data/field survey	
GIS public transportation layer	Structural data	-	Drawn GIS data	
Individual satisfaction with green spaces	Objective	-	Questionnaire	Combination of variables from Questionnaire (accessibility, satisfaction)
Individual satisfaction with services	Objective	-	Questionnaire	idem
Individual satisfaction with living-standard in flats	Objective	-	Questionnaire	idem
Energy performances of buildings	Parameter	kWh/m^2/year	Energy deklarationner	For buildings without data, extrapolation from statistical distribution

Table 1: Origin and processing methods of the real data.



(a) Incomes (Kr/month).



(b) Rents (Kr/month/m2). Mean value is black curve.

Figure 4: Results on objective time-series (rents and incomes). Green lines are objective linear function.

Data from questionnaire are simply used, by taking response on satisfaction on subjects. For points concerning the neighbourhood, the satisfaction is weighted with the satisfaction with accessibility.

Finally, a file containing energy consumption declarations was linked to the attributes table of the shapefile of buildings to obtain energy consumption values for each flat. The file was obtain in the frame of ReBo from Göteborg Stad services and came from official energy comsumption declaration from tenants.

3.2.2 Running the basic model

Reproduction of real situation During calibration process and regular runs, number of repetitions was generally five, since more did not appeared as necessary because of the small magnitude of the random fluctuations (standard deviation are mostly around 1/10 of means for all random laws). After having fixed the objective time-series for rents and incomes and launched the calibration process, we are able to see a simple run of the model on a time period of about ten years. Figures 4 shows the outputs for the two objectives.

Exploration of stylised facts We are able to reproduce coherent economic facts what allows to go a step further in the validation of the model. The most remarquable is the reproduction of economical segregation. Increasing rents in a modest district (i. e. setting artificially during a run higher rents than expected according to the mean of incomes) leads to a quick significative increasing of incomes. The same way, augmenting the variance of the distribution of incomes and the importance of the level of studies gives automatically a socio-economic segregation as the curves on figure 5 sh

We can also simulate the consequences of an economic crisis or an energy crisis on the district. For the economical approach, just increasing the unemployment of 30% give interesting results: rents are going down as expected but less than a half of what would be needed to keep the district safe, what leads necessarily to economic segregation in the times following the crisis. The speed of variations depends on the threshold under which people leave, which is unfortunately a not so realistic parameter and which is difficult to estimate. That's why the typical time values observed may have no real signification. For an energy crisis, we observe in fact the same effects as a rent augmentation and not complex emerging behavior as for the economic crisis.

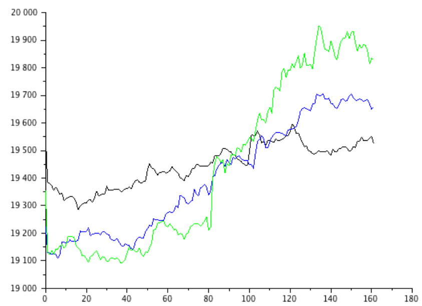


Figure 5: Economic segregation : black is normal situation, blue and green curves are with progressively increased income variance and studies value parameter. (incomes are in Kr/month)

3.3 Simulating possible refurbishment scenarii

We are able to explore many different refurbishment scenarii thanks to the implementation done in that way. The fact of not disposing of real values for costs, real impact on energetic performances, possibilities of changing green spaces or adding services, makes these simulation still abstract, but just a further work of data collection would be enough to give real prevision for scenarii.

Structural changes at the scale of the district By changing GIS layers of green spaces and services, we can explore the effects of modifications at the scale of the district. By plotting in a plane cost against advantages (i. e. increase in individuals satisfaction for example), we can search for best compromises. Giving an abstract cost does not change the result as soon as the cost is supposed to be linear, since it only induces a dilatation along one axis without changing the relative positions of the points. It appears that, as expected, resonnable ameliorations are the best compromise for structural changes. That should stay true in a domain around identity point. In the outside, saturation effects have not been taken into account in the model and should be added for an extension of the validity domain.

Changes in buildings We can also compare possible changes in energetic performances and living-standard. Comparisons of output curves are shown on figure 6. On marking point is that even people can on short term benefit of a better insulation thanks to less energy consumption, on the long term the final economic balances are quite close, supposing an augmentation of rents. This emerging effect of rent augmentation can be understandable, since housing companies will consider dwelling as of better quality and therefore (inconsciously maybe) impact it on rent.

Problem of outputs Our definition of individual satisfaction may not be scalable for direct comparison with real values and representation of the proxy of satisfactions by the output of the model. Further exploration would be needed to confirm and strengthen the sense of these outputs.

4 Discussion and perspectives

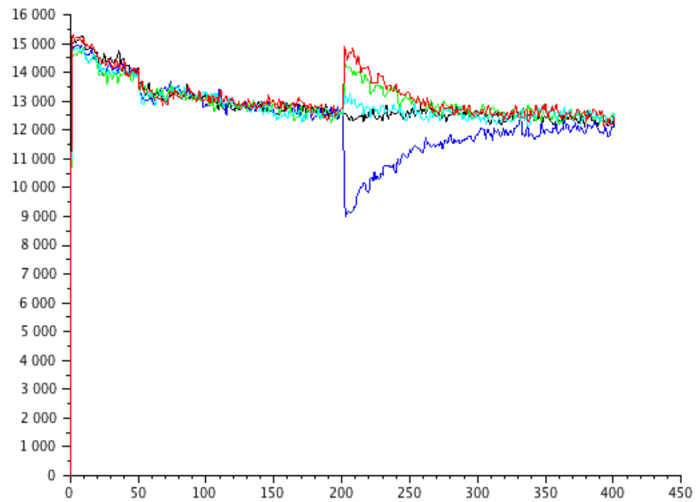
4.1 Obtained results

Concrete results Although the robustness of the model has not been proved and that sensitivity tests and explorations are still needed for the validation of an arbitral framework, we managed to obtain an self-consistent model. The precise calibration process gives accurate results on concerned outputs. Furthermore, the integration of heterogeneous aspects led to the possibility of testing scenarii for refurbishment. A lack of reference values let this point still abstract but it shows that evidence-based descision making thanks to simulations is possible.

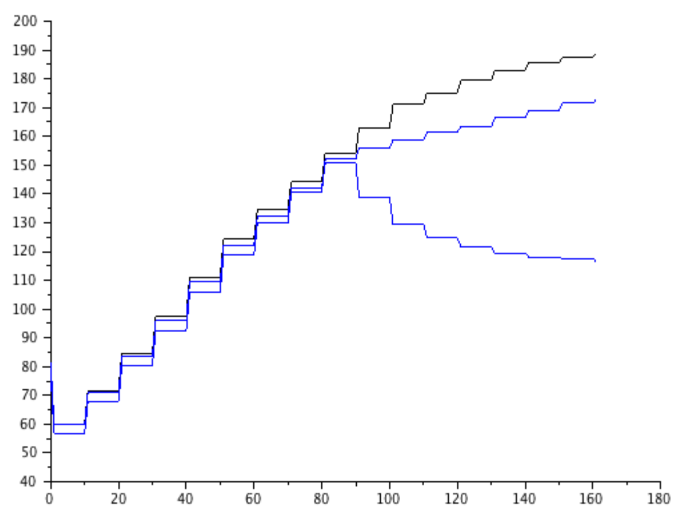
Consolidation of the original framework ? The way our work consolidate the original philosophy of ReBo is not really of pragmatic nature but more an epistemological question. Of course the possibilities offered by simulations can reinforce the project but that does not justify the global approach. What does is the fact of considering that our way of modeling was an analogy of the way ReBo framework was constructed. Through that idea, we can argue that the extension of the basic economic model brings more robustness, and therefore comes the need of horizontal integration. For the vertical integration, the structure of our model justifies it, since it was necessary to build a double-scale integration of data. For these reasons, we can argue that this work is equivalent to testing and approving the approach of the ReBo framework.

4.2 Limitations of agent-based modeling

We are not sure that horizontal integration of the model could go further. First for technical reasons because quantity of implementation is directly linked with quantity of side effect and it is possible sometimes that over a certain level of complexity, side effects becomes of greater magnitude that white noise of random functions, what gives an unvalidated model. The difficulty of formalizing some social aspects of urban life can also remind there are still limitations in social science simulations by agent-based modeling.



(a) Time-series of economic balances. Each curve is a different scenario of refurbishment (different energetic performance).



(b) Evolution of rents along different scenarii for living-standard.

Figure 6: Comparison of refurbishment scenarii.

Concerning the robustness of the model, as we already noted, further studies of sensibility are needed because that is a weakness of agent-based modeling. It is possible that an arbitrary small change in a parameter that is not considered in the calibration process because it is suppose to have a real proxy changes all behaviour and outputs of the model. Because of the high number of parameters, study of the response surfaces were done only for ones judged as most influent, but it there is still the possibility that chaotic behavior exists in some place of the space that has not been explored yet.

4.3 Perspectives of developments

Next steps in the project can be directed towards the application to other concrete case. The study of the generalisation to all People's Home, and then Million Homes projects should be the first step. The final point would to get a generic framework working on all possibles cases, with an easy integration of data. We also need to deeper validate and explore the model, as we already claim.

Conclusion

From the theorical point of view, we managed to propose a self-consistent agent-based model for the simulation of the life of a district. The integration of heterogeneous aspects and the construction of output functions was possible thanks to the work done in Paper B, whereas the understanding of how to represent refurbishment process in that particular case and the fact that the model is well adapted to the real context were made possible through the review of Paper A. We must insist that we managed to design a special calibration process which could be the object of further work, especially in a more accurate formalisation of the magnitude properties for a greater number of objectives. Finally, we can point out that we partially answered to the research question, since the process of agent-based modeling and the obtain results can be seen as a justification of ReBo proposals.

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Paper D
Local and global design of a new district through evolutionary algorithm

Abstract

The study of refurbishment of old building stocks through Agent-based Modeling in Paper C had voluntary occulted the background problem of a parallel building of a totally new district (Project Homes for Tomorrow, reviewed in [15]) which would have strong influence on the existing one. Although the design has already been done and the construction process is well advanced, we propose here to follow the thought experience of proposing a possible design from scratch through computational methods for this new district. We explore first the question of the role of computational design in architecture and the one of multi-objective optimisation in urban planning, and how it could be interesting to link them in order to construct an hybrid approach. We finally describe a simplified algorithm that we apply to our concrete problem to propose automatic design.

Introduction

In the case of a global project, the process of urban planning consists in exploring the space of possibilities under certain constraints and finding the best compromise in all evaluated solutions. It is the analog for the artistic creation during architectural design as we will see further. Going back to the problem of modeling the district, we can suppose that the new project has not been planned yet and propose an algorithm for optimal planning. The idea is to offer the possibility of a coupling with the agent-based model of Paper C. It could even be then possible to calibrate the algorithm to fit the real planning of the new district. We will in the following consider the question of computationnal methods and propose a formal evolutionnary algorithm for automatic planning and design.

1 Overall approach of the problem

1.1 From Artificial Art to Computational Design, applications in Architecture

The use of softwares and computers to produce Art, what we can call artificial art, has recently developped as a branch of practical applications of computational algorithms.

The designer Casey Reas is one of the pioneers in that field, and is still very active today. He formulates his vision on the use of software in design in [13], that can be considered as his manifest. As an interpretation of his ideas, we propose that imagination can be seen as a powerful method of exploration of the space of possibilities (which we paradoxaly present as the search space of the mind, but which is not rigourously defined in that case), so it appeared quickly as an application of artificial intelligence to simulate artifacts of the imagination, with its own advantages and issues. Typically, by using algorithms to create pieces of art or to design shapes, we just suggest new ideas to help the mind to create, but the process is still totally guided by the artist. The software is then only a new medium of expression and exploration of artistic possibilities.

Reas has explored figurative and abstract software painting, but also applications in design and architecture. One example of such work in architectural design can be seen in figure 1 .

The most recent researches in artificial art go towards use of artificial ants. In [12], the authors, that are specialists of solving complex optimisation problems using systems of artificial ants, present how these “ants” can be used to produce paintings or music. In a forthcoming work (presented at [11]), Monmarché proposes some applications to the design of real forms in three dimensions, first for everyday objects, but also for sculptures. Following local rules (as for the 2D systems) and global constraints (it is one of the limitations of the method that

Figure 1: Software for architectural design. Project Tour Signal, La Defense, France. (source [13])

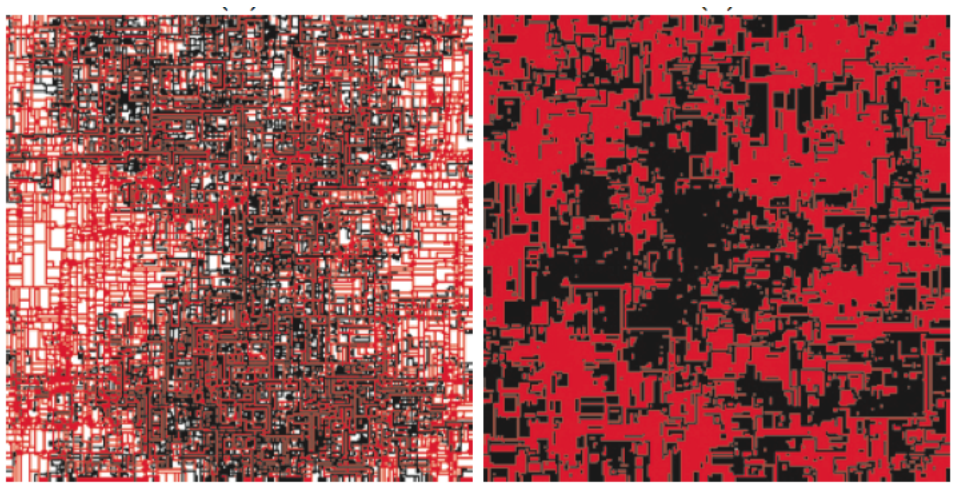


Figure 2: Ant Painting (source : [12])

still need to be overriden), the ants build objects and shapes in space. It could be easely applied to design of architectural shapes. An exemple of abstract art obtained by ants is shown on figure 2.

An other important aspect of mathematical methods applied to design is the use of shape grammars in computational design. T. Knight has recently proposed a theorization for the use of these methods ; in [8], which is more an essay than an aimed paper, he tries to characterize the ideas behind this type of art. He managed to make a link between a generative rule (the title of the paper, "either, or -> and") for computational algorithms with an implicit spirit of Bauhaus' artists like Kandinski or Klee. The rule is applied to many concepts of art philosophy in order to show that the Bauhaus artistic movement followed this abstract rule in many ways. Without going into details, one of the most interesting application (for our purpose) is the link between emergence and predictability, since it meets epistemological notions that are crucial in our work. At the heart of the study of complex system, emergence can be seen in a simplified way as the global properties of the system that come from the interaction of its local parts and that are by essence not predictable (it can be argued that this notion is really more subtle, as it is defined in different ways by Bedau in [2], but we will stay at this simple definition for our problem). Therefore, it is difficult to combine emergence and predictability, but still, these artists has sometimes managed that, and for Knight, "a good design requires both emergence and predictability". That is a real issue when dealing with shape grammars : one can create incredible shapes, but they have to follow given constraints (so to show predictability) to be applied to architectural problems. A concrete application of this theory is proposed in [7], where he shows examples of shape generation through the application of shape grammar (formally it is a

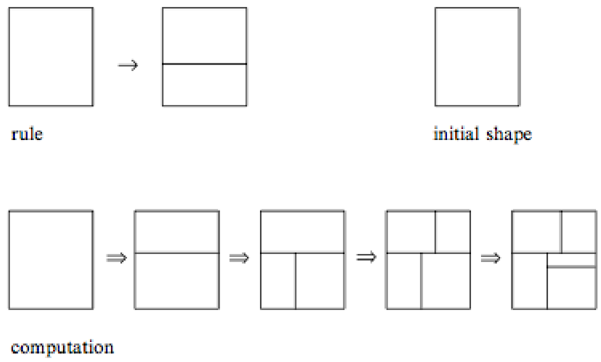


Figure 3: Principle of shape grammar. (source [7])

grammar which rule can evolve according to user constraints, which rules apply to subsets of the plan). Further developments have been proposed recently, as the application on curved shapes in [5], concretely implemented through Bezier's curves calculations in [6], allowing new designs including curves. The principles of shape grammars are shown in figure 3.

1.2 Evolutionary Algorithms for multi-objective Optimisation

On a greater scale, algorithms are also used to explore a space of possibilities, not for design purposes but to solve optimisation problems. Whereas simple objective optimisation can be easily solved by classic methods as the gradient descent as soon as some hypotheses on the function are met, the multi-objective optimisation problems present instrinsic difficulties to their resolution. In an analog way as combinatory problems on great cardinal sets, an exhaustive exploration of the definition set of the function is most of the times not possible with the current technical means, what imposes the need of performants exploration algorithms. The concept of *Evolutionnary Algorithm* is not older than 20 years and works with an analogy with the theory of evolution: as natural selection does, possible solution are crossed and can mutate, under external constraints. That proceeds to an exploration of the solution space quite efficient since only the best solutions are kept for further iterations. Different types of algorithms are reviewed in [1]. Further than multi-objective optimisation, evolutionnary algorithm are also used for multi-parameter calibration of models as it is done in [10] for hydrologic models which are particular since they have necessarly a lot of unknown parameters. Such algorithm can be associated with urban planning and the associated scale because solving a planning problem is nothing more than proceed to multi-objective optimisation. These methods or analog ones begin to be used in current practice, such as the work of Aeadas R&D (presented in [9], annexe A) for example.

1.3 Mixing the two approaches : heterogeneous modeling and design through scale integration

We propose here an approach to the problem of multi-scale urban planning and design that could be considered as a mix of the two techniques described in the preceding sections. Indeed, it appears that they may be not so far, and that the gap would just be a question of scale. To go further, we can try to make some hypotheses that of course would need deeper exploration and that offer strong potential for future works : maybe is the edge between architecture and urban design not so well defined, and just a change of point of view or scale can break this edge. Some evidences, as the existence of an "architectural urbanity" that we have presented in Paper B, or the parallel that we have just done between computational methods at different scales, can reinforce that vision.

Therefore we will try here to explore the possibilities offered by that point of view by building a scale-integrated model for automatic design : in a really simple way (we don't try to elaborate complicated model, the aim is more a beginning of exploration of the fundamental ideas), we will couple a macro-scale evolutionnary algorithm for the design of landuses and transportation network with a local shape-generation algorithm for the buildings. The main idea that we use for scale coupling will be more indirect feedback through sub-systems interactions inside the global system, as it was proposed for multi-scale cellular automata coupling in [4], than direct feedback on the variable and parameters at both scale as it is done between macro differential equation and micro agent-based model for evolution of individuals in the work of Duboz on marine ecology in his thesis ([3]).

2 Evolutionary algorithm for automatic design and planning

2.1 Formal description of the algorithm

The algorithm considers configurations and produce new ones from already explored configuration by crossing configurations and doing mutations. Following the idea of [14] in which the population is constinuously updated, we keep in a hashtable the description of the known configurations and their corresponding evaluation values.

2.1.1 Configurations

The space is discretised in a set of patches $\mathcal{P} = \{p_0, ..., p_n\}$. We will distinguish the description of landuses at the macro level, that, given a number of distincts landuses N, can be translated through a function $L : \mathcal{P} \to [|1; N|]^n$, and the micro description of the shapes of the buildings, that would be for a configuration a family of continuous parts of surfaces in space $(S_i)_{1 \leq i \leq K}$. We also suppose the existence of a transportation network, formalised as an euclidian graph $G = (V, E)$ with V finite subset of $\mathbb{R}^2$.

2.1.2 Optimisation objectives

The objective will be some of urban qualities used in Paper B for objective district comparison. We adapt each as follows:

- Landuse diversity: calculation done through the function L
- Sunlight index: formally calculable thanks distribution of buildings. However, the performances of the calculation make us not implement this objective
- Spatial configuration: not implemented since axial map extraction would have a huge algorithmic complexity in that case (would require calculation of Radon transform of height function)
- Network performances: with the positions of buildings (barycentres of S_i for example) and the network G we can calculate the network density and speed. The transportation time is not implemented because there is no destination for individuals. For that, we should set destination points outside the world.

2.1.3 Producing new configurations

We produce new configurations, evaluate them for the selected optimisation objectives and keep in memory their associated values after having projected objective point in objctive space (Pareto optimisation).

The heuristic to produce new configurations is the following:

Crossing Given two configurations (L_1, G_1, S_1) and (L_2, G_2, S_2), we cross them to obtain a new one. Let P a random subset of $\mathcal{P}$ such that P and ${}^cP$ form a coherent partition of space, in the sense that one of the two is composed of a reasonnable number of connex components and that the shape are quite regular (squares and ellipses). We define the new landuses L by setting $L = L_1 \cdot \mathbb{1}_P + L_2 \cdot \mathbb{1}_{{}^cP}$ (the property of partition allows L to be a function of the good form). For the network, we take as vertices the vertices of first network on P and of the other on the complementary. The edges with both ends in the same part are kept. Fot the others, the closest vertex to one end on the other side of the border is chosen to create a new edge. Finally, the remaining connex components are connected in order to keep a connex network. The new shapes of buildings are the same by keeping the shapes corresponding to the selected set of the partition. They can only change by mutations.

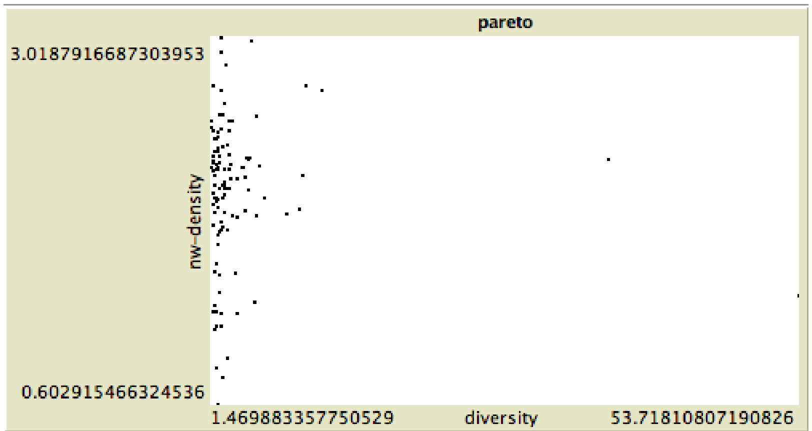


Figure 4: Projection of configurations in the plane diversity/nw-density

Mutations Mutation are the way to produce new shapes for buildings as the shape grammar does. Formally, we suppose having a random variable M which values are function within $\mathbb{R}^3$. A shape S_i mutates in shape $S_i' = M(\omega)[S_i]$ for one realisation $M(\omega)$ of the random variable. The functions are supposed to transform surfaces into surfaces, so an assumption of - at least - C^0-diffeomorphism seems honnest, although weaker hypotheses could surely work. That feature was not implemented and stays for now at the theorical state.

2.2 Exploration

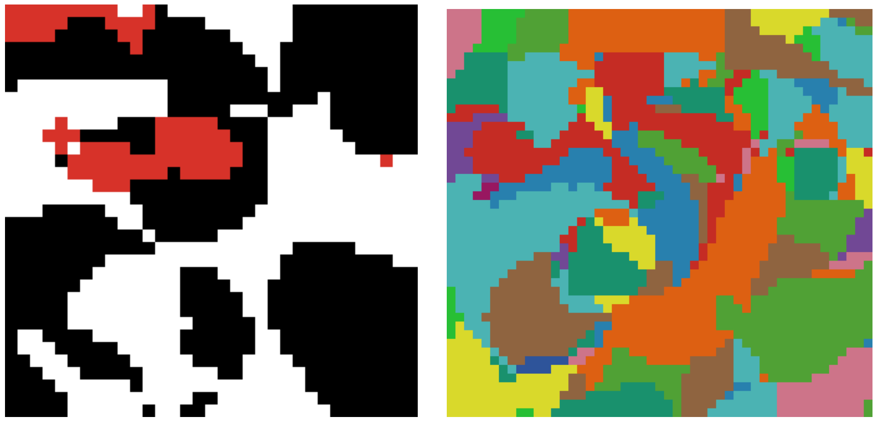
Core functions and selected features were implemented to have a first working program. Source code is available in Appendice G. The performances of the algorithm are quite promising: around 100 explored configurations in 5 minutes. We show here the obtained results. Figure 4 is the projection of all configurations in the Pareto plane of two objective.

2.2.1 Patterns for landuse

We obtain interesting patterns for landuse, shown on figure 5. Since the geometrical shapes can quickly become strange, maybe it should be needed to add an other optimisation objective representing the "regularity" of patterns.

2.2.2 Patterns for network

Concerning the network, there is no big surprise because of the connexification heuristic that always makes tree-structured networks. However, that heuristic appears as necessary as show the results obtained without it on figure 6. Further work would be possible in the exploration of heuristic for maintaining real



(a) 3 possible landuses (b) With 30 landuses

Figure 5: Patterns for landuse.

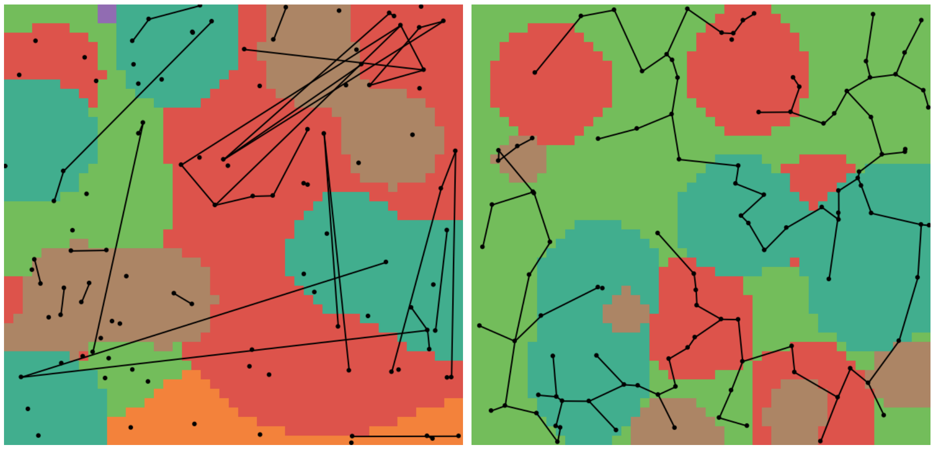
networks through the crossings. That is a complex point that could become a research subject in itself in complex network theory. Therefore we keep first that naive heuristic that allows still to get realistic networks.

3 Further developments

Better implementation We were not able to implement the micro scale, i. e. the design scale of our algorithm. That point is the priority in possible further developments in order to realise the scale coupling which is the essence of the algorithm. Now, the implemented program is only able to proceed to planning optimisation.

Application on real cases We need to test the results given by the algorithm on real cases and adapt the heuristic to obtain realistic situations. For example, the current network crossing heuristic produces non-realistic tree-like networks. Also for landuse repartition, a work has to be done on the intermediate function, in order to have an optimal value for landuse diversity. Without that, the algorithm diverges towards arbitrary mixed situation that are also non-realistic.

Coupling with agent-based model After being able to produce realistic configurations, the last development is the use of the planning algorithm to simulate influence of the new district on the old one in Långägen through the coupling with the agent-based model. For that, we would need to attribute activities to the buildings, to set a system for rents and to add individuals.



(a) Failure, without connexification procedure. (b) Tree-structured network

Figure 6: Networks obtained

Since the district is supposed to be new, the rents may be stable during the length of the simulation, but the question of their determination remains. In fact, doing the coupling would imply creating an agent-based model for the new planned district and finding consistent outputs that can be taken as influencing parameters in the old model.

Conclusion

After having reviewed the existing techniques in automatic design at the small scale and planning optimisation (multi-objective optimisation) at the macro scale, we have proposed a simple evolutionary algorithm with aim both to propose optimal planning solution and original design patterns. We began to explore the solutions given by the algorithm. Finally, we reviewed the work still left, remembering especially the initial motive that was the design of the new district and coupling with agent-based model.

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Conclusion

Taking a step back on the global project, we can better understand how the different parts are complementary to answer our research question. The top-down analysis approach was the key for the construction of indicators we used for some as outputs of the heterogeneous agent-based model and for others as objectives for the multi-objective optimisation in the evolutionary algorithm. The architectural and sociological review was required for a contextual construction of a local agent-based model, but was also necessary for the understanding of the concept of suburbs specific to Sweden and knowing which type of area on which we could build the indicators of second part. The failure on meta-modeling attempt was essential to go further in the understanding of the concept of modeling. Although some points were not developped so much as expected and although the preliminary results for simulations obtained through the model of simulation for Långägen were not strongly validated, we produced through the synthesis of the whole new theorical and practical knowledge and answered partly our research question with the proposed methods.

We must insist on the importance of the cultural context of Sweden on the quality of that work. The way to practice architecture and urban planning there is really specific and research exchanges are all the richer. Generally, urban questions cannot be solved from an unique perspective despite the fact that they are strongly linked with the local cultural context, what strengthen the delicate character of this type of complex systems modeling. Nevertheless we showed here that heterogeneous approaches mixing top-down and bottom-up modeling, architectural and urbanistic considerations, sociological and technical analysis were possible and promising.

We also opened in that work a lot of research questions some of which can lead to interesting developments. As an example, the problem of trying to find patterns of classification of the projection of urban parts in the indicator space may be a path toward a new approach of the relation between morphology and functionality in urban systems. The issue of the choice of surfaces of integration suggest of trying on a subset of convex subparts of the plane, what would imply the knowledge of function on this set and what makes think of a mathematical transformation. The integration of complicated submodels in complex models of complex systems is often unpopular since it goes against the popular methodology "Keep It Simple". However, it seems possible to use some wisely, as brownian motion can find its place in traffic simulation models or pedestrian flows prediction. The diversity of questions opened encourages to go further on some points which will surely be prosperous research subjects.

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Appendice A

Written report of the research Workshop

“Architectural Morphology

Investigative modeling and spatial analysis”

KTH, May 14th 2013

Architectural Morphology
Investigative modeling and spatial analysis

Public Research Workshop
Stockholm, KTH School of Architecture
May 14th, 2013

Abstract

The development of new theorical and technical means, particularly in the field of computer science and its direct applications, leads more and more to a renewal of the approach on design and architecture. The increasing place of modeling and calculations in the architectural process confirms that Architecture lays on the interface, in this case ambiguous, between art and science. This workshop aims to be a presentation of the state of the art of actual research in the field of spatial analysis applied to urban design, urban planning and architecture.

Speakers

John Peponis
Professor, Associate Chair Advanced Studies and Research
GeorgiaTech School of Architecture

Sophia Psarra
Reader of Architecture and Spatial Design
The Bartlett School of Graduate Studies, Editor, Journal of Space Syntax

Ermal Shpuza
Associate Professor
Department of Architecture, Southern Polytechnic State University

Meta Berghauser Pont
Chair Urban Design – Theory and Methods
TU Delft Faculty of Architecture

Ulrika Karlsson
Visiting Professor School of Architecture, KTH; servo stockholm

Christian Deri
Head of AEDAS Architects R&D
Visiting Professor, Technical University of Munich

Åsmund Izaki
AEDAS Architects R&D

Daniel Koch
Researcher, Director of Research Studies
KTH School of Architecture

Pablo Miranda Carranza
Researcher
KTH School of Architecture

Introduction

This workshop was presented as follows :

The Research Workshop Architectural Morphology: Investigative modeling and spatial analysis is meant as a beginning or a point of departure, in research and for coming events revolving around modeling and spatial analysis in architecture. With speakers of considerable repute within the field commonly referred to as Space Syntax, as well as in other Architectural fields, it is meant to communicate cutting edge analytical, configurative modeling as well as explore relations to other modeling and analytical traditions in architectural research. Furthermore, through the participation of AEDAS R&D and the experience of many of the speakers, the relation between modeling and analysis in research and practice will be highlighted and discussed.

JOHN PEPONIS, GeorgiaTech School of Architecture Concrete applications of Space Syntax

We unfortunately missed the begining of this first presentation.

That presented direct application of spatial integration calculations on Atlanta districts.

The theory of space syntax was introduced by HILLIER in 1976 in [4]. Its aim is to study the influence of spatial configuration on human aspects of urban life. One current implementation is the axial map extraction : we extract the axial map of a place by considering linear spaces, in the sense of one feels belonging to that space when evolving in it (it's globally what one can see, that's why that leads to an axial map in the context of street network analysis). Then we can built the topological graph corresponding to the axial maps, and can calculate what we call "spatial integration" on it : with N places and d_{ij} the topological distance from place i to j, the mean accessibility to other places : $I_S = \frac{2}{N \cdot (N-1)} \cdot \sum_{i<j} d_{ij}$, and the integration is the mean of all accessibilities on the graph.

The figure 1 shows that process of topological graph extraction.

Concerning the concrete applications, it is possible for example, by distinguishing pedestrian and car axial maps, to show evidences of "bad" designed district in the sense that they are not liveable for a pedestrian, what is no more possible nowadays. Such designs present a strong lack of flexibility.

Such errors could have been avoided by the use of analytic methods like spatial analysis, and we need today to switch from an exclusive descriptive approach of architecture to a normative point of view ; we need more normative, evidence-based practice. For example, back to the Atlanta districts, it can be showed through investigative modeling that a greater building flexibility could have been permitted thanks to a non equivalent distribution of block size ; that can be put in parallel with the need for local activity diversification.

Of course spatial analysis will never be the direct answer to the difficult question of what is an ideal city, but the motivation of space syntax has always been a normative aim through a better understanding of urban systems.

Question *Should not the designer adapt the used methods to the real situation, in the sense that the normative means won't be the same depending on the neighborhood?*

Yes of course. Here it is the ideas behind the methods that are important, not the concrete implementation themselves. The "normative" is more a systematic application of calculation and modeling in general than a specific method of furmula.

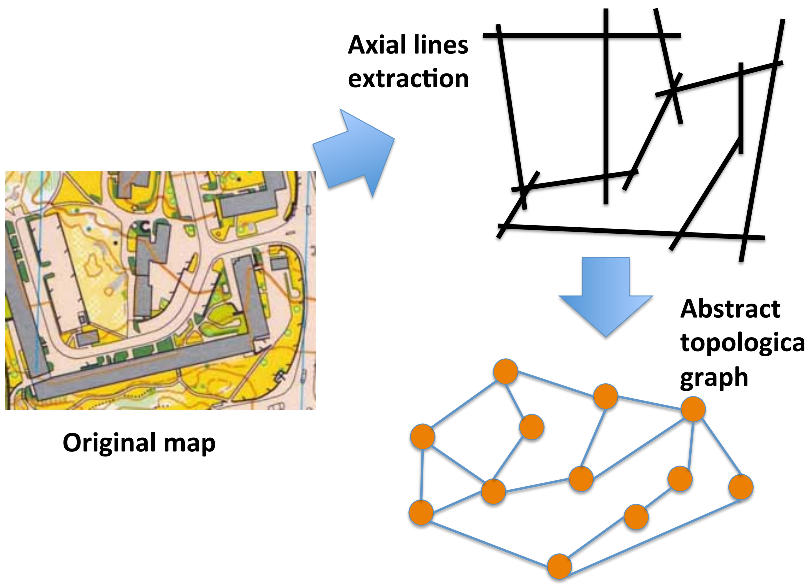


Figure 1: Topological graph extraction

Question *If Space Syntax would have existed 100 years ago, would it have solved the problems of modern urban planning and changed the vision of Le Corbusier for example?*

A theory is created within a particular context, but if it is consistent and powerful then it can be applied to other situations and fields. Therefore, because of the success of this theory today, it should have worked the same in the past.

Sophia Psarra, UCL

The Venice variations : Interactions between generation and explanation

1 Role of spatial analysis considerations in Design and Architectural Knowledge

Architecture and its narrative approach are direct consequences of the geometric spatial configuration and an embodied experience, which can be approximated through a topological description of space. That's why geometry and topology play both key roles in architectural analysis ; they have in fact a strong relationship which form determine most aspects of the architectural experience.

As a consequence, a useful tool of investigative modeling can be the try of different geometric shapes associated with the same topology. In that case, whereas the spatial integration stays the same (since we define it in the classic way, as done in the first lecture) because it depends only of the topological configuration, the visual integration differs and is interesting to consider as a design criteria. The visual integration can be defined as follows : the architectural structure can be considered as a subset $A \subset P \subset \mathbb{R}^2$, where P is the part of the space we work in. Then the visual integration of a point is the measure of the visually accessible subset taking into account the architectural obstacles (walls). For $M \in P$, it is defined as

$$I_v(M) = \int\limits_{M' \in P \setminus S} \mathbb{1}_{\{M + t\vec{MM'} | t \in [0,1]\} \cap S = \emptyset} dS$$

Such a criteria can also be generalised in 3 dimensions, by discrete superposition of floor layers, or by an analog continuous definition.

Its use can then play role in the development of architectural knowledge. In [3], Calvino explains that imagination can be in fact considered as *Ars combinatoria*, that means finding one good configuration among all possibles. In other words, creating is exploring the plurality of words. The knowledge can be classified in 4 types : dialectic knowledge (empirical), encyclopedic knowledge (to make predictions), analytic knowledge (calculations) and creative knowledge (imagination) ; and design is in particular the combination of the last two : it joins these two different types of knowledge through functionnal aspect and the use of imagination.

To go further in the role of computation in design, we can consider the work of Smithson in the 70s, and the concept of "Mat-building" developped particularly in [7]. The important ideas are that architecture and urbanism are closely linked to the notion of emergence, and that an only top-down approach is not sufficient, a bottom-up approach is also needed, by considerations of evolutionnary fields and local relations.

That importance of computers in design was later in the 90s confirmed by the apparition of evolutionnal design, e. g. design through genetic algorithm that use given rules of the genetic languages to compute new designs. That is again a bottom-up approach for which the unpredictability of the emerging properties is inherent to the system and its self-organisation.

2 Evolution and Urban form : case Venice

Venice can be seen as an archipel lago of monuments and open spaces. It is interesting to study relations between spatial and visual integration in it. The single consideration of pedestrian network is not enough to understand the patterns in urban form.

That lead to the idea of proceeding to a network coupling between pedestrian network and water network, since the canals are in Venice as important as the streets, and they can be considered as streets themselves. The coupling is done throug the locations of step access, that allow to bank with boats.

The important results of that study is that the urban form were strongly influenced by both networks, and that modelings taking into account only one lead to weak correlations. To sum up, the evolution of Venice was strongly determined by the coupling of its two networks.

3 Comparison to the project of hospital by Le Corbusier

One major project by Le Corbusier at the end of his life was a porject of huge modern hospital for Venice, that we can see on figure 2.

For Sarkis in [6], the spirit of the project is closely linked to the Mat-building. The hospital is like a city in itself, and without going too far, we can make a parallel between the coupling of the visibility network and the accessibility network in the hospital and the street/water networks in the city of Venice. Le Corbusier would have unconsciously understood the essence of the city and built a project corresponding exactly to it, reproducing the structure of Venice ?

The building follows scaling laws and the flexibility of the design suggests a sort of functionnal optimisation. It has also both good spatial and visual integrations.

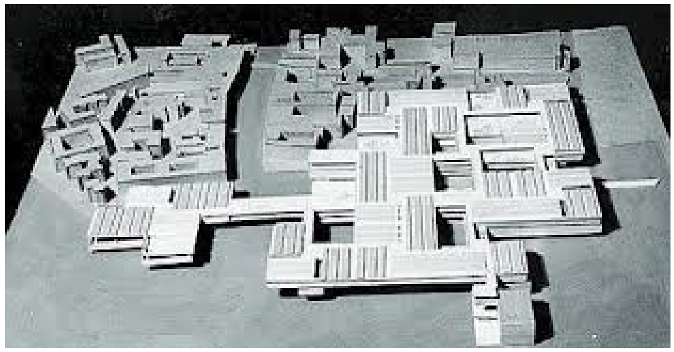


Figure 2: Project for Venice hospital by le Corbusier

The analysis of the project by analytical methods shows us hidden aspects and leads to a better understanding of its internal mechanisms.

Conclusion

After having presented new applications and implementations of space syntax theory, and having linked them to architectural history and the sense of architectural knowledge, we have seen the rich opportunites these methods offered both in urban planning analyis and architectural project understanding.

Daniel Koch, KTH
Architectural Interfaces & Resilience

Introduction

Architecture can be seen as the interface between the one and other : it has a strong impact on the social relations. Whereas socio-cultural identification can explain differences in housings, on the opposite how is architecture communicating with these socio-cultural considerations?

Characterization of interfaces

We first need to characterize the interface we are responding to. Without going into details, a study of the influence of typical architectural objects on our presence and our movement, by a projection in a evaluation plane for these two functions, emphasises the importance of open space. People are connected through space, and maybe that's why we are studying these connections. As a consequence the resilience would be the way social statuts are defined regarding our vision of space.

The question is therefore to study how architecture relates to exterior, but also how it interfaces with people inside. Architecture is in itself in a way teh interface between arrangment of objects and movement of people. The link between visual interface and physical accessibility is in that frame interesting to look at ; the projection of configurations in the plane visibility/accessibility gives a measure of assymetry. These concrete calculations on existing buildings strengthen our knowledge of this internal interface.

The role of the relation between interior and exterior has to be considered since it has consequences on the calculation of the measures. A concrete example is the existence of an external path that changes the accessibility measures inside the building. Without the exterior, we are able to explain better the relations and interfaces inside the building. In that way, visibility measures explain better how the building is internally built. An interesting result of investigative modeling through visibility measures is the fact that fusion of spaces ("open space") in a building of offices strongly increases the social segregation (whereas the common idea is that it would help proximity and decrease it).

Consequences for the resilience of the built environment

Taking for definition of resilience the relations through space of social agents in the built environment has strong consequences on the results obtained through investigative modeling. Indeed, we need to explore the sensitivity of interfaces regarding system parameters, and to make tests of continuity of the response proxys before validating these output functions. We need to compare the different measures and look for the existence of strong discontinuities at given points, since these discontinuities can bring conclusions to non-sense.

We might change the classification of configuration by defining the continuity not on a measure of "similarity" [*that appears to be classic distance between geometric patterns through sums of distances along local homeomorphisms and discrete adding/deletion of shape parts*] but more a measure of "seamness", that would be defined the reciprocal way, by declare as close in seamness configuration close in resilience. Then the continuity will not be a problem anymore. A path to explore in future work is the question of the existence of an algorithm using discretization and reduction of configurations, that could lead from geometrical similarity to this "seamness", i. e. a class reduction algorithm that would not calculate explicitly the quotienting function but find directly the class only through spatial discretisation and simple geometrical reductions, since the calculation of the function can in some cases be arbitrary sensitive and lead to wrong results because of bord-effects of the implementation. The existence of such an algorithm has no direct reason to be true, and it is still an intuition now. But its proof would deeply change calculation heuristics and results on the resilience of the built environment.

Pablo Miranda Carranza, KTH

Tools used nowadays in advanced spatial analysis

Generalities

In the previous presentation some results of spatial analysis were presented but not in details the tools behind the calculations. We show here example of these tools.

Examples The following list is not exhaustive and is just to give an idea of the diversity of analytical methods used in spatial analysis.

- Random walk : for blind building or city exploration, Brownian motion can be interesting to explore virtual public open space.
- Graph analysis : for combinatorial problems, for example for generating a configuration, the use of graph exploration and complex graph theory can be a way to obtain efficient calculations.
- Space syntax : the original space syntax through axial map is used in our studies to understand the way we perceive space.
- Tree clustering : By successively clustering the tree of spatial relations in an office, we try to understand the social logic of space through the position of sitting places of workers. The main issue is to divide space into "logical" boxes. The following shows us an other way to do it for other applications.

Analysis of bunker architecture through convex decomposition of space

We can define an algorithm for extracting the convex decomposition of an internal space, by associating a point to the closest walls. That is equivalent to make lines parallels to the walls to go progressively away from the walls until the space is totally filled. The vertexes and the edges of the decomposition are point equidistants from several walls. We can show that the convexity limits are maximal convex shapes in the building. We must be aware that the decomposition and the results depend on the definition of convexity wa have, for example the described algorithm is not applicable with the definition of strict convexity, but only large. The strict convex decomposition doesn't exist in general in real building plans.

This method was applied to the analysis of bunker architecture. an interesting application is to link that with the location of the emergency exits and with the potential flows of people in the different spaces. The particular case of bunker is one of quasi only functional architecture, so the study of relation between shape and function is more relevant, and the method we described here lead in that case to concluding results.

Meta Berghauser Pont, TU Delft
Density, Architecture and the City

Why study density?

Through history, density of cities has always have a great importance. As a concrete example, there is evidence of the link between a high density of population and health problems in Ansterdam, Jordean at the end of the 19th century. At the same time, regulations to constraint the height of buildings according to the street width were taken all over the world (see Paris of Haussman for example). The promoters of the Garden City took the aspect of a healthier city as a main argument. In the late 50s, Jacobs proposed ([5]) in opposition to these idealisms a return to a more natural and by consequence a more dense city.

Today, density can still be an issue. Back to the example of Amsterdam, the global density is too low, as a consequence of an explosion of the urban footprint, and of different relative growths of land uses (the proportion of dwellings went bigger).

We could try to give an answer to the question of arguments for or against densification, but there are very much pertinent arguments on both side, so the really important aspect that appears is the study of density in itself, the fact that it has good or bad consequences on some aspects of the urban system is in fact an other problem, depending most of the time on the particular concrete situation we are in.

Measuring density

There exists in the litterature several way of measuring density, and each is particular to the specific defintion given to density and the field of application of the results. For example, the physical density is different from the perceived density, or the demographic density.

One important issue of the classic measure is that they don't manage to capture in a single way the urban from and other aspects of urban life. For example, the floor space index, the ground space index or the open space ratio are currently used measures with their advantages as qualifying in a way the perceived space. But still, the urban form is not captured, and the size of the elements is not included, as we can see on concrete example (same density for radically different forms).

By considering the network density, in a way the streets per area, we believe being able to define density in a new way that would capture urban form. This hypothesis of coupling network analysis with spatial considerations is our current research work which will lead we hope to a new way of considering density

Performance of density

An other important aspect in the study of density is the measure of the performance of density ; it is also the object of furhter development in our research to try to express simplified relations between density function and several qualities of the urban life, for example the parking performance of a street (available places to park the car) or the daylight performances of the buildings.

We need to mix several aspects in the expression of the performance of density. One issue would be to understand the relation between physical density and perceived density in another way space syntax does it. Indeed, the determination of perception of different performances should be quite simple in relation to cultural aspects, so if our quantification of performance of density is sufficiently consistent, we would undirectly make that link through that quantification.

Note : Implicitly this presentation gives the impression that a strong link exists between space syntax theory and that vision of density, the top-down approach proposed here seems to exploit the same internal mechanisms that the bottom-up calculation of spatial analysis to reveal relations between shape and function in cities. Need to explore that.

Ermal Shpuza, Southern Polytechnic State University

Interaction between boundary shape and circulation structure in the built environment

Recent research work has been oriented towards the study of the mutual effect of rules and constraints, in the sense of the relations between the building shape and the social organization occupying it. These two elements have totally different time longevity, so we can ask if it could lead to contradictions between the functionnal aim of an architecture and its effective use.

That lead to the study of two aspects and the links they have : the boudary shape of the building and the contained circulation. Circulation system is directly linked to a level of movement, and can be taken as a local description of floorplates, whereas the boundaries are more a global description. Such a study can also be done at the urban scale, by searching the impacts of an imposed shape on internal circulations.

We will see here first the pure shape aspect, then the influence of circulation on shape, and finally the inverse relation.

1 Unique shape approach

It can be useful to first describe the boundary shape in itself, since we will interest us later on clustering of shapes.

Given a boundary shape, it is possible to extract a polygonal approximation (which can be exact in the case of a polygonal shape, what is the most used case for the following studies), and then classify it through the classification of the polygon. It has been shown ([Missing reference]) that a polygonal shape can be quite uniquely put in correspondance with 6 sets of reals numbers, that are, if we note, with S summits of the polygons, $A_i(s)$ the set of depth i adjacent summits to summit s, $S_i^j = \{d(k,a)^j | k \in S, a \in A_i(k)\}$, the particular sets S_1^1, S_2^1, S_3^1, S_1^2, S_2^2 and S_3^2. Such a classification of polygonal shapes is the starting point of the following work, since we will work on unscaled polygonal shapes, i.e. with $\mathcal{P}$ set of polygonal shape and the equivalence relation on it : $\mathcal{R} : P_1 \mathcal{R} P_2 \iff (\exists \alpha \in \mathbb{R}^*, S_i^j(P_1) = \alpha S_i^j(P_2), i = 1,2,3, j = 1,2)$, on the quotient set ${}^{\mathcal{P}}/_{\mathcal{R}}$. On the following, when we consider polygonal shapes, it will always be on that set.

2 From circulation to shape : the inside-out approach

This approach is a modular approach, in the sense that it goes from inside to outside. The internal space influences the boundary shape. A shape can be seen as the result of an equilibrium of constraints, external and internal forces. That approach is the consideration of the internal forces only, to understand the influence of internal constraints (for us the internal circulation) on the boundary shapes. To do that, we concretely consider measures for these two parameters of the built environment and we plot different classes of polygonal shapes in the plan among these two measures, in order to try to bring out clustering patterns between the shapes. The measures are metric inertia, i. e. compactness and kinetic inertia, i. e. fragmentation coefficient of the space. [*Note : measures not clearly defined*]

Plotting simple polygonal shapes shows some strong clustering in the plane, and some shapes appears to be optimal towards both measures. Adding constraints on the shapes, as holes in polygonal shapes, shows also strongly localised clustering, what suggest the relevance of the measures.

We can also study the correlation between the two measures by plotting mazes generated by precise rules on the internal circulation. Seeing the consequence of these rules on the relation compactness/circulation gives an idea of the correlation.

Finally, one application is plotting on the same graph real configurations at different scales : building shapes, cities plans, etc. , to classify the real shapes regarding the clustering already done. No concluding result have been found yet but this concrete application is our next goal in the research process.

3 Influence of shape on circulation

This process is quite the same as the previous one but the measure are different, we plot here the real shapes according to the real connectivity and the perceived connectivity (calculated through visual integration). At a greater scale, this is quite equivalent as studying the relation between urban shape and street networks. This work is also still in process, and should lead to a reciprocal confirmation of the results obtained with the previous approach.

Ulrika Karlsson, KTH
Biotic interferences

This presentation is more on research in pure design than in spatial analysis, but is closely linked to it because of the underlying systemic approach in the design process. It presents a work of integrated design lead by a multi-disciplinary team at servo Stockholm and KTH, including researchers from several disciplines such as Design, Architecture, Ecology of biodiversity, Composition of built materials. The project was called hydrophile, in relation to its particular aspects that we will see in the following.

Presentation

To define the project in itself, which name is "biotic interference", we need to come back to the initial definition of these words : biotic means related with living organism, and interference should be taken here as the emergence from sharing by agents of a system. Here the abstract aim of the project is to create such positives interferences within a biotic system. It lays on the line of relationship between technical design (mathematical aspects) and architecture.

An ubiquitous idea is the overreaching presence of nature, almost a symbiosis between all the dirts of nature and human being, as it can be feeled in the introduction sequence of the swedish film *Melancholia*, or in the artwork *Partially Buried Woodshed* by Robert Smithson.

In the 70s, Banham built in Los Angeles the first green roof building, in a exceptionaly innovative way, through the elegant combination of glass walls with the turf roof. He was one of the first to propose ecology-oriented analysis of urban systems and environmental designed architectural projects. He wrote theorical explanations in [2]. One ambitious aim of the project is to reinvent, to rethink that concept of green roof, in a innovative approach called the hydrodynamic green roof.

An overview of the project can be seen on figure 3.

Particular aspects

Biotope A focus was done on the place of biological species in the design of the project. A biotope map was created (figure 4), including all animal and vegetal species (as frogs, hooks, conifers, etc) and simulations on the influence of the project on these species was conducted. The main goal was to preserve and further encourage biodiversity.

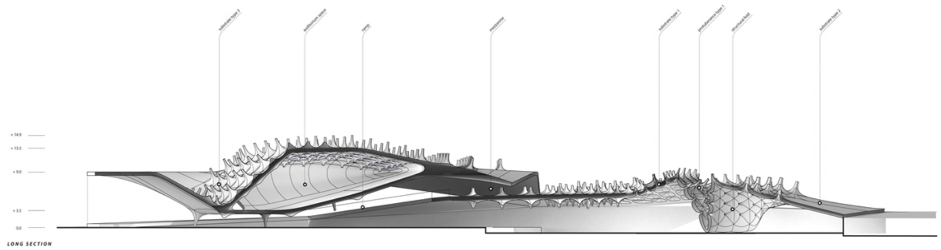


Figure 3: Global view of the hydrophile

Technical aspects for the roof Since vegetals are implanted on the roof, the thickness of the substrate, its nature, and the material of the hard roof should have influence on their development. Several tests around these parameters were done. One important is the shape of the ground on which the substrate lies, and therefore real tests were done on miniature versions of the roof.

Rainfall Hydrodynamic studies were needed to predict from the map of rainfall the move of water on the roof. Hydrophobic and hydrophile surface are used to redirect places to wanted places. The protuberances are used for irrigation and natural light inside the building.

Conclusion

The spirit of the project is to integrate biotic processes in archtitecture, and to have a system globally adaptative to local disturbances, so it should be integrated vertically and horizontally.

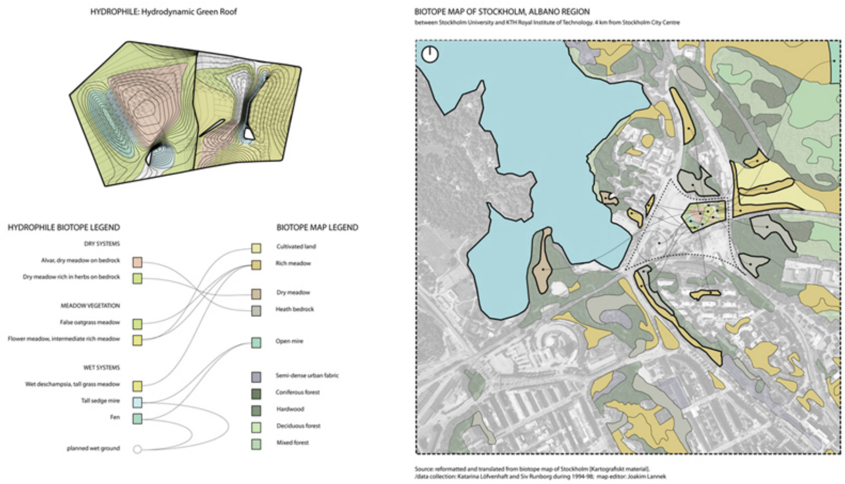


Figure 4: Biotope map

Christian Derix, AEDAS Architects R&D Computationnal Design and Advanced Spatial Modeling

1 Context of the work of Aedas R&D

The company proposes to its client powerful applications of computational design and advanced spatial modeling to design problems, oriented towards sustainable solutions.

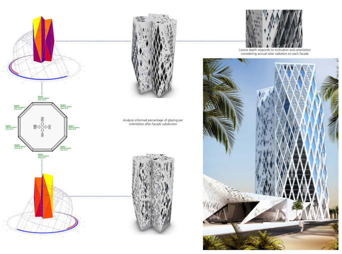
The models that are created can be at several different space scales, but also include people and their interactions between them and with their environment ; that can be seen as the switch from original space syntax to computational models for social logic [*Note : In fact, Aedas does in that case nothing more than complex social system modeling and analysis, but according to their client profile that are architects and designers, they market it as an evolution of space syntax*].

Examples of outlines of different projects are shown on figure 5 (source [1]).

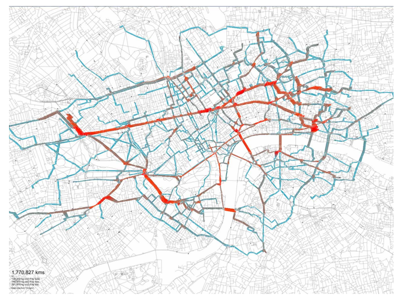
2 Examples of recent research projects

Study for masterplan

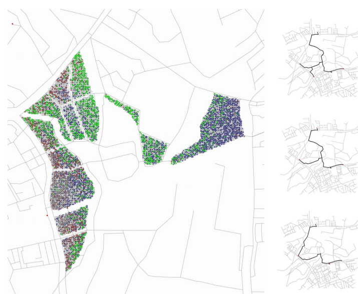
It is possible to apply directly syntax to help design ; this example of project shows how a proposal of masterplan is done and how the designer can move pieces of



(a) Modeling of solar repartition for towers in Abu-Dhabi



(b) Mapping of cycling flows



(c) Global spatial planning solutions

Figure 5: Results of Aedas projects

it to see the consequences through the self-organisation of the rest of the plan. The modification can be done at different scales, from furnitures sometimes to the overall floor.

Note : The techniques used are called "agent-based aggregation", what seems to be a computational design of possible configuration (not more precisions since it appears to be confidential for the company).

The figure 6 shows the final result for the Hong Kong polytechnic University, after the created masterplan has been integrated to the other sections.

Distribution of densities

For the planning of a new business district in China, there was the need to decide the local densities of activities (in order to then directly apply it to the local design of buildings). For that, a tool was created, that allowed the designer to fix some points at a given density and observe the generated global field of density that resulted from these imposed values.

Figure 6: Hong-Kong southern Polytechnic University

The method used to extract the interpolating field seems to be not far from non-parametric estimation (see [8]) : with n given points $(M_1, ..., M_n)$ in space and the expected values $(y_1, ..., y_n)$, the problem is to find a function f such that for all i, $f(M_i) = y_i$. That can be done for example by kernel estimation aggregation.

Visibility study

The construction of the new huge tower on the right bank of the Tamise in London has raised interrogations about its impact on the visual landscape of the city. The aim of that project was to model the visual impacts of that new landmark.

To do that, it is possible to calculate by ray-tracing if the tower is visible from a given point, what was done for a big part of the city for which the 3D data of building shapes were available. Then for each point, we can judge if the visible impact is significant, and also see the total proportion of places for which it has a real impact.

Pedestrian traffic analysis

For the construction of a new railway station, the locations of entries for pedestrians had to be decided and a pedestrian flow simulation model was created.

Concretely, it is an easely parametrizable model, for which test could be done on localization of "source" and "sink" points for pedestrian flows. From an external points of view, it is quite similar to the problem of distribution of densities, although here the interest is more on the flow quantities resulting from fixed potential points. But the method to solve the problem is exactly at the opposite, since for densities it was solved by a top-down calculation, by global mathematical calculations, and here the model used is a bottom-up approach, since it simulates the flows through individuals agents that are the pedestrian themselves.

Mapping architectural controversies

Urban studies are also sociological studies, as this project testify. Through newspaper articles analysis, it was possible to proceed to "social mapping", and identify trending subjects and social clustering around these key subjects.

What is really interesting is to make the parallel between the social system and the architectural system analysis.

Questions

Question *Do a global comparative knowledge emerge from all these research projects?*

Yes but not formally, in the sense that no exhaustive list of knowledge was created in the company. But still, it contributes to the spread of such knowledge and methods.

Question *Was network self-generation already considered in one of the projects?*

Not at all ; but that seems interesting to consider. Self-generation following local rules can be a way to proceed to global optimisation on some propoerties of the network, as nature does in some cases.

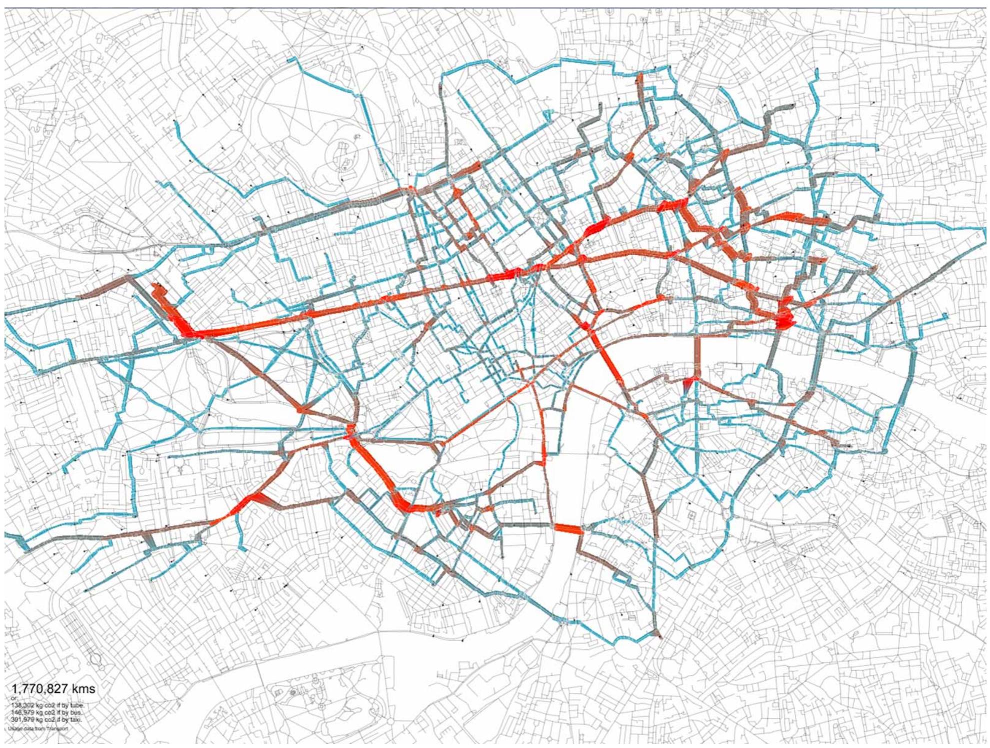


Figure 7: Project of bicycles flows modeling for prediction of future position of rented bicycles in London (more detailed view).

ÅSMUND IZAKI, AEDAS Architects R&D
Algorithmic aspects of spatial analysis

That last presentation is a short overview of computer science issues that occur when doing spatial analysis and investigative modeling.

Complexity of algorithms

When doing computations, the speed depends on the machine on which they are done, but what is really important is the intrinsic complexity of the used algorithm. For example, there exists many ways to sort a set of number, and the best ones (quick sort or fusion) will have a mean complexity in $O(n \cdot ln(n))$, what can be assimilated to a linear time as a function of the size of the set, whereas bad ones will execute in $O(n^2)$, what is quadratic and can quickly lead to impossible calculation times on big data.

This aspect is particularly important in spatial analysis because of the size of the data and the natural complexity of graph exploration problems, that's why finding "good" algorithms for spatial analysis is necessary.

Difficulty of problems

When dealing with spatial generation algorithm, some technical problems appear, as the question of the calculation of visibilities, to obtain the integration of spatial visibility. It is usually done through ray-tracing, but that suppose to test for small spatial discretization if there are edges and if they are open, what can become slow if it is not done the good way (dynamic programming can help to make the process quickier).

Examples of applications

We propose concrete applications that are tools for the architect or the designer. For example, you have an interactive model calculating spatial and visual integration, in which you can open/close doors, add new ones or deleting others. It is a sort of "design in direct", you directly see the consequence of your choices on the properties of the building. An other example is a 3 dimensionnal configuration for a building (a school), where you can also modify pieces and see consequences on internal flows.

Note : main part of the presentation was after that the demonstration of these softwares.

Conclusion

The architectural solution for a project is a particular response to the context of the project, a local proposal in space and time, but it is also a proposition for architecture in general. Architectural theory builds itself from concrete responses to concrete cases.

What is important to understand is that we need to learn from all these applications, and from itself the theory should become more robust. Investigative modeling is still at the beginning but should become more and more present in architectural projects and in urban planning tomorrow.

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Appendice B
Description of model for daylight calculation

Basic model for daylight exposition calculation with objective of urban contexts comparison

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Abstract

In the frame of a research of objective indicators of different types in order to compare qualities of given urban contexts, it appeared that the direct exposition of building windows to daylight (sunbeams) was quite important for the life quality, since we wanted to apply our model to districts without particular architectural programs, current residentials districts. We propose therefore here a simplified but directly and quickly implementable model for such comparisons, the aim being more to have an approximate idea if great differences exists than very precise calculations, because it will be used in a more general context.

Introduction

The importance of daylight on the perception of architectural objects, so therefore of their quality, but also on direct life quality (health issues, natural need of daylight) are described in [4], and that's why we would like to consider it as an evaluation criteria for urban districts. We place ourselves in the framework of investigative modeling that is today strongly developing in architecture (see [3]) : we want to use objective calculations and investigations on the studied objects.

If we consider buildings in themselves, it is possible to estimate subjectively and objectively the performance of the architecture regarding daylight treatment, but it is an evaluation of the individual architecture. More globally, we would like to evaluate the performance of an urban configuration in that context, that means not if the buildings see daylight (they always see it of course), but how the sunbeams come on building facades and the effect of shadows consequences of the district configuration. A simplified example is if the designer creates line buildings oriented North-South, it will be significantly more efficient to get sunbeams on facades than if it was oriented East-West. Further, there are also the shadows effects between buildings and natural elements of the site.

In [2], the authors study an elaborated model of daylight calculations, and we have based ourselves on the same ideas for sunbeam calculations. In the following, we describe the theorical framework of the model and briefly give clues for quick concrete implementation.

Model Description

Input Data

Sun course

We want to apply our model to districts located in different places, but also integrate on short and long time periods, so the input description of the sun course will depend of the location L (location on earth, for which only latitude will be influent) and of the time in the year T (in days).

The space is parametrized in spherical coordinates (adapted to the calculations), a point in the sky is defined by (r, θ, φ). It is natural to make the assumption that the sun is located at $r = +\infty$ and that its relative position to every point in the district is the same, given by the angles (θ, φ). (it stays true as long as the studied zone remains "small", although we didn't quantify this size, it appears as normal that it is the case for a city district).

The course of the sun will by consequent be represented by a family of functions

$$(\mathcal{S}_{L,T})_{L,T} = (t \mapsto (\theta_{L,T}(t), \varphi_{L,T}(t)))_{L,T}$$

that we will in input roughly approximate by regulars samplings (like every hour for example) $\mathcal{S}_{L,T}^{(d)} = ((\theta_{i,L,T}, \varphi_{i,L,T}))_{1 \leq i \leq K}$ ($K = 12$ for 2 hour sampling for example).

District configuration

We need to know the configuration of the buildings, but also their elevation (shadow effects). A simple way to represent it is just to give the height function of the position in the district $h(x, y)$, with $(x, y) \in P \subset \mathbb{R}^2$ coordinate within district bounds relative to an arbitrary origin. We can even by that mean represent hills or trees (roughly simplified of course). Concretely, the input data is spatially discretised, and can be for example a GIS raster data.

Set of objective points (windows)

An other part of the architecture that is needed is the positions of windows in buildings, that we will consider as a set of N "objective points" : $((x_i^0, y_i^0, z_i^0))_{1 \leq i \leq N}$, supposed to be compatible with the descriptive function h (the windows need to be on the wall, so on vertical discontinuities of h). Of course the real windows are more than points but we will assume the simplification that the windows is enlightened if its center is (which is the objective point), what shouldn't be a problem because of the small size of a window compared to a all building.

Calculation of indicators

Given this simple description of the district configuration, we are able to calculate indicators of the quantity of direct daylight exposition.

With $\vec{u}_r(\theta,\varphi)$ the radial unit vector corresponding to angles (θ,φ), the approximation that sunbeams come parallel on all points of our study zone gives directly the equivalence that $M(x,y,z)$ *is enlightened at time t of day T in L* $\iff$ $\theta_{L,T}(t) > 0$ and $M+\mathbb{R}_+\cdot\vec{u}_r(\theta_{L,T}(t),\varphi_{L,T}(t))\cap\bigcup_{(x,y)\in P}[(x,y,0)(x,y,h(x,y))] = \emptyset$.

Concretely, the test shouldn't be done on all P but on the projection of the line for better performance, and the intersection tests can be done by discretising the segments. It is in fact necessary, since in 3 dimensions it will be easy to have very close but not intersecting lines, which intersects in reality, that's why the discretisation is necessary (if we test among the projection, it will be on its discretisation, and the given vertical segments will never exactly intersect the line since we have float values).

Then it is possible to compute the "enlightening" functions for each point :

$$s_i(L,T) : t \mapsto \begin{cases} 1 & \text{if } (x_i^0, y_i^0, z_i^0) \text{ is enlightened at time } t \\ 0 & \qquad\qquad\qquad \textit{otherwise} \end{cases}$$

so their integration on the day gives the enlightening time $\tau_i(L,T) = \int_{t=0}^{24} s_i(L,T)[t]dt$, measure that we need to normalise if we want to be coherent (compare absolute enlightening times would have no sense because it depends directly of T and L). In that way we define the normalized enlightening time $\tilde{\tau}_i(L,T)$ by

$$\tilde{\tau}_i(L,T) = \frac{\tau_i(L,T)}{\int_{t=0}^{24} \mathbb{1}_{\theta_{L,T}(t)<\frac{\pi}{2}}\,dt}$$

Then we integrate on the all district by taking the normalized p-norm of the vector of these values : with $p_d \in [1;+\infty[$, we define $\tilde{\tau}(L,T) = \left\|(\tau_i(\tilde{L},T))_{1\leq i\leq N}\right\|_{p_d}$ (with $p_d = 1$ it gives the mean and $p_d = +\infty$ the max).

To conclude, we just need to consider it on a hole year. With $p_Y \in [1;+\infty[$, the indicator that we will use to approximate and compare the global daylight expositions is

$$S(L) = \|(\tilde{\tau}(L,d))_{1\leq d\leq 365}\|_{p_Y}$$

Since that indicator is normalized by the relative day lengths and integrated on all district and all year, it should be a good candidate to represent the "performance" of the urban district regarding the daylight exposition, independently of its location : that tells if the buildings are agenced to profit at maximum of the light that is given.

Note that we normalized by an approximation of the length of the day and not by the global enlightening time, because first it would be quite complicated to have it as a data, and then it would make not real sense because the builder can not change anything to that through design, the geometric configuration of the district has only interaction with the geometry of the sun course, not with the fact that it is hidden or not.

Implementation

We are currently doing test to implement that model quickly and integrate it in a more global project. Follows important aspects related to the implementation.

Software Because we place ourselves in a project which main part consists of Agent-Based Modeling, we choose the plateform NetLogo ([5]) for compatibility reasons. In fact it appears to be particularly ergonomic for that case, because of the efficient GIS extension, and the system of the world divised in patches that are already the spatial discretisation we wanted.

Input data Concerning the sun course, as explained before we can take samples of the position each hour, and the same on the year (each two weeks for example), so the input can be a simple list of couples.

For the height configuration, we can use GIS raster data as input. Data can be available from precise Lidar data, a mean to get precise mappings that have become more popular and efficient quite recently (see [1] for example), and in some countries extended coverage has been proceded, at least in great cities (for Sweden we have available data). These height data are very precise (50cm) and are particularly adapted to our problem.

Finally, for the windows position, we could input the exact configuration, but that would require field survey. Instead, we can simplify by approximating a given number of windows per square meter on facades (will depend on architecture of course, but we can consider a mean on the district), then extract hypothetic position from facades shapes (what are themselves calculated by searching the vertical discontinuities of the height function), so we don't need more input by doing that way.

Conclusion

Although a lot of approximations are done in the model, the approximated output values can be used for comparison purposes, and that gives us an objective criteria to evaluate performance of a district regarding enlightening, that we can integrate in a global comparison of different districts among criteria of various types.

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Appendice C
Elaboration of the calibration process

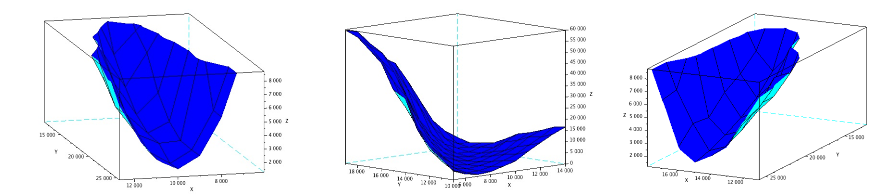
Basic model calibration

Experience plan

The experience plan for model calibration will be a regular grid within an hypercube in the parameter space. Since we proceed first to a single objective calibration, for which the objective function is the mean square error between the simulated values of a given time-serie and their real values according to the data we dispose, and since the theorical description of the model is not easily projectable in a space on which cross-mutations dicted by evolutionnary algorithms are possible, we choose to proceed to a brutal calibration through an exploration of the hypercube.

Exploration domain If we need to calibrate the model on K parameters $(p_1, \ldots, p_K) \in [p_1^{min}, p_1^{max}] \times \ldots \times [p_K^{min}, p_K^{max}]$ with corresponding precision steps $(p_1^{step}, \ldots, p_K^{step})$, a minimal replication number τ_K for which the output value are considered as acceptable, that depends on parameters and on given trust intervals on the output values (empirically we will fix that number according to first experienced outputs, since the sensitivity of output variances regarding to the parameters seems to be relatively small), and a maximal execution time for one replication T_{max} (also empirically fixed by experiences), then the necessary calculation time will be bounded by $\left\lfloor \frac{p_1^{max}-p_1^{min}}{p_1^{step}} \right\rfloor \times \ldots \times \left\lfloor \frac{p_K^{max}-p_K^{min}}{p_K^{step}} \right\rfloor \cdot \tau_K \cdot T_{max}$ which is, with $M = max_{1 \leq i \leq K}(\frac{p_i^{max}-p_i^{min}}{p_i^{step}})$, unfortunately a $O(M^K)$: the brutal exploration time increase exponentially on the number of parameters, which leads us to try to fix the most possible number of parameters value by evaluating a real world approximation, what is possible only for parameters that are precise proxies.

Gradient descent optimisation After having minimized the size of the exploration domain, we will proceed to the optimization of the mean-square error on that remaining domain. If the function is quite regular, a direct application of a gradient-descent method on the multi-variable function should be a huge gain of time and lead to a quick model calibration. However, if there exists chaotic behaviours and a lot of local minima, the optimization can in worst case be as costly as the hole exploration of the grid within the hypercube. In that case, we will not be able to calibrate on more than 3 or 4 parameters on reasonable calculation times (let say one day). Furthermore, it is not yet possible to say if



(a) Along plane income-mean=cste (b) Along plane bnorm=cste (c) Along plane bref=cste

Figure 1: Responses surfaces along given planes

the gradient method will efficiently be applicable, because we have no idea of the response surface before doing some tests. The first empirical results will guide the following calibration process.

Concrete calibration

Exploration of parameters space with low number of parameters

We were able to fix reasonably all parameters but 3 which were intrinsic coefficient in the discrete differential equation that couldn't be approximate by their real world values since they didn't mean anything concrete. For these, we explored totally a regular grid of dimension 3, in order to have an idea of the response surface of the objective function. Staying in single objective calibration, the function to minimize was the mean square error on an output time-serie of the model (concretely the time-serie representing the mean rent). We show in figure 1 representations of the response surface along vertical and horizontal planes, for the 3 possible combinations of 2 parameters.

The quite regular shape of the reponse surfaces, for all possibilities, suggests that the use of a gradient descent could be helpful to converge towards a possible global minimum.

Tests for a multi-objective calibration

However, it appeared in first tests of the model that the single objective calibration could led to bad result regarding the reproduction of the real situation : the model was then quite precise to reproduce the rent evolution, but the mean income of actives was in the supposed best situation showing unrealistic values. That's why a multi-objective calibration on several outputs of the model (at least two) was necessary.

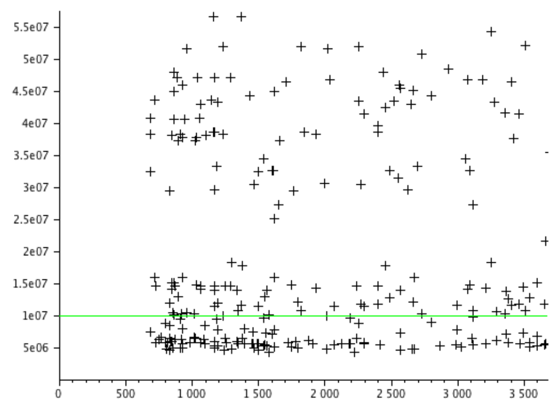


Figure 2: Projection of realizations in the plan of both mean-square errors. Green curve corresponds to the equation $MSE_1 + MSE_2 = cste$, so the horizontal shape confirms the magnitude property is verified.

In that case, the simple but expensive method is the total exploration of the grid as we did for the initial tests. The calculation time (1 day) makes it not possible to use in a simple run of the model, what we would like to have (several cases of real values for the other parameters may be tested, so we want to have a immediate calibration before running the model, according to the values of the pther parameters). Furthermore, the use of evolutionnary algorithm is also not possible as we explained in introduction.

The only solution left is the use of an aggregated error function and a gradient descent on that function. Fortunately, the magnitude of the two main errors functions were quite different, as the tests have shown it. We can verify on figure 2 that property on experimentals outputs of the model.

To conclude, the method finally used is a gradient descent on the aggregated mean-square errors on the two objective time-series.

Appendice D
Description of research project

Application of evidence-based methods to the test of a multi-value evaluation framework for sustainable renovation

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April 14th, 2013

Presentation of research project under the direction of

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Abstract

We present here in details the planned project for our research internship, that will be based on the same theorical basis that we presented in the first draft of the project ([20]), but will take place in a particular context regarding the objective and concrete applications : indeed, we will work in the frame of a recent research project called ReBo conducted by Chalmers' Department of Architecture, which aim is to show the necessity of considering several fields in the process of sustainable refurbishment of housing stocks and to propose a framework usable by the different involved stakholders to take all these aspects into account.

1 Objectives of the project

1.1 Global description

1.1.1 Context

The swedish historical context in politics lead to specific practices in Architecture and Urban Design, particularly from 1950 to 1970. The People's Home project (Folkhemmet in swedish), which aim was access for everybody of good life standards for reasonnable price, resulted in the construction of about 100,000 new flats per year between 1965 and 1974 and by consequence in the planning of hole new districts in the neighborhoods of big swedish cities. Lot of these buildings begin to need renovation, but according to the philosophy of the ReBo project, it is not possible to assume a sustainable renovation by considering only economic aspects (costs) or direct environmentals apsects (energetic performance). As it is formalised by THUVANDER & *al.* in [27], both material and immaterial aspects has to be taken into account in the process of sustainable renovation, in order not to destroy inherent qualities such as social or cultural ones. In short, sustainable refurbishment has to be conducted regarding many fields through a multi-value evaluation process. Concrete description of these fields and of the parameters that have to be integrated at each scaled are presented in [24].

1.1.2 Objectives

We would like to support the proposal of the ReBo project by a concrete urban system modeling, showing by evidence-based methods the relevance of this multi-value evaluation. Since a lot of data have been gathered for a given district of Göteborg built in 1950-53 called Långängen (see fig. 1), especially in [26] and also in more recent work with direct questionnaires on the population, we will direct our modeling work towards this particular case. We will try to build a model with strong theorical basis, but which will be able to fit the real data and to reproduce in the best way the real situation of the district. We will also consider annex but important problems, such as the influence of the building of a totally new district in the neighborhood. These complex systems modeling will then allow an evidence-based justification of the ReBo point of view, but also to make predictions on the future evolution of the district and to propose multi-objective optimisation for different possible renovation scenarii.

The following sections of this part show the progressive objectives of our project and will therefore constitute a plan of work.

1.2 Study of the Swedish "suburb"

1.2.1 Philosophy of Folkhemmet Project

In order to really understand what are the issues raised by the ReBo project and to build our models in consequence, it will be necessary to have a good knowledge

(a) Housing stock

(b) Map

Figure 1: Langängen district

of the historical and geographical context ; that means an understanding of the philosophy of Folkhemmet project, by studying recent litterature as the review did for the elaboration of ReBo in [25], but also documents of that time such as [19], and also an concrete architectural study of some of these district today. In fact, many questions that can have consequences in the conception of our models can be raised through that study, as e. g. the real existence or not of "segregated suburbs" in Sweden that Castell questionned in [6].

1.2.2 Comparative study

The swedish suburbs seem, despite all the critics that they can receive, to present very strong qualities of urban environment and of standard of living. For example, the integration in nature is most of the time impressively well done, what offers exceptionnal places to live ; but also the role of public transportation is in the center of the planning. These two examples are directly translated in the map of the district Bergsjön of Göteborg (fig. 2).

In order to show these qualities, we will proceed to a case comparative study of this district (for example) with a comparable one located in France, considering subjective evaluation (perception, construction of an image according to [15]) of the district but also objective evaluation criteria.

1.3 Agent-based modeling of the life of district Langängen

1.3.1 Presentation

After having well situated the frame of our studies by the analysis of the swedish suburbs, we will apply to create an agent-based model to simulate the life and the evolution of the Langängen district.

Because we want to consider totally different aspects such as the social, the cultural or the economic ones, we will need a very flexible theorical framework. Only a few works that consider social or cultural aspects exist in litterature, e.g.

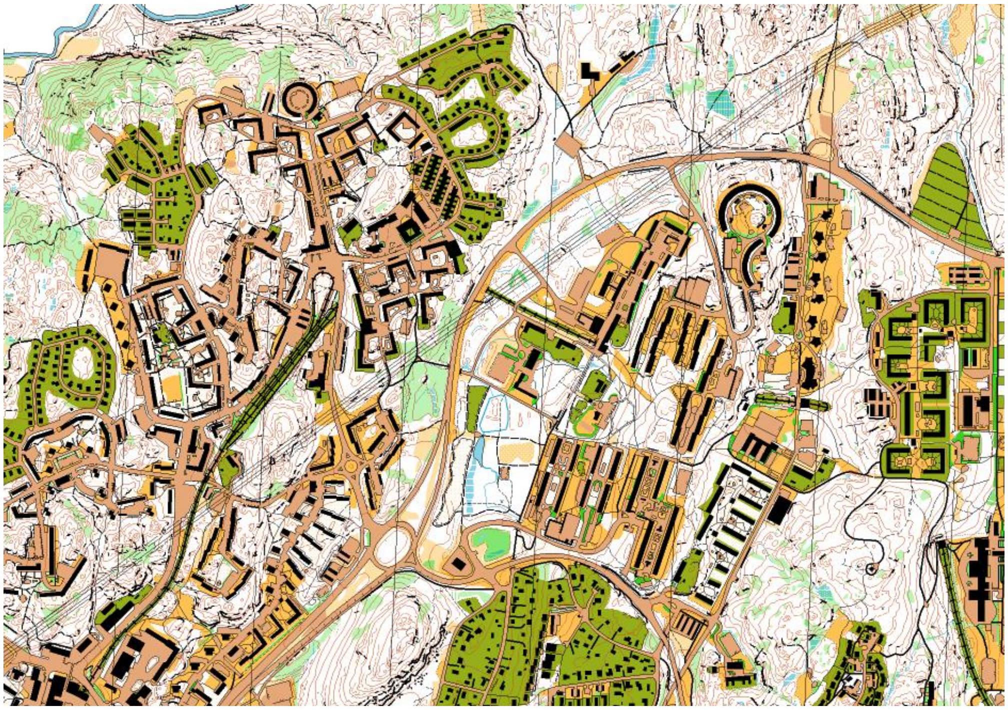

Figure 2: Map of district Bergsjön. The housing stocks are smartly distributed through nature and topography, the global shape of the district is in direct echo with the tramcar line.

a modeling of urban development through application of sociodynamics in [29], or of the role of cultural influence in population clustering in [4], and they don't try to integrate different type of variable. The integration of these social or cultural aspects in our model will be an interesting issue, as the recent reviewes in [17, 3] on agent-based modeling show that it's still an inexplorated path.

We also need a model in which we can choose which variables are taken into consideration, in order to show that the reality is better reproduced considering a large range of fields as ReBo proposes. That's why we will orientate the modeling towards an abstract space in which abstract agents interact, then different uses will be possible through the choices of different projections of the interaction functions and of the real agents from our world to the abstract space. This choice is pertinent regarding the precedent issue (socio-cultural considerations), because it brings back the representation problem to the determination of the projector, so a impossibility or an imprecision at this stade won't block the entire project.

1.3.2 Expected results

This step is the most important in the hole project because the expected results will be the most significant. They are the followings :

- Comparison of simulations fitness to the reality considering different range of fields : approbation or not of the ReBo philosophy through evidence-based methods

- Prediction of future evolution of the district thanks to the calibration on past and present data
- Multi-objective optimisation on different possible renovation scenarii

1.4 Coupling with an evolutive model for the new district

We also keep in mind our initial proposal of project which was the design of a tool to propose automatic shape design through multi-criteria optimisation for the building of a new district from scratch. Depending on the time we have left and on the qualities of the results of the precedent parts, we will try to construct this tool and adapt it to the new district that will be soon built beside Langängen. It will be more probably an evolutive Cellular Automaton model, as we used in [21] on the basis of classical works such as [2, 5, 18].

After that, we will try to operate a heterogeneous model coupling with the first model, in order to represent the influence of the construction of that new district aside Langängen. It may have huge consequences, as we can imagine that for example, a rich population linked to a high rent standard in the new district will certainly mutate the neighborhood and lead to a rent increase in Langängen, what could be not desirable for the stability of the district considering the actual social profile of its inhabitants. That justifies the interest of modeling the interactions between the two districts.

The expected results of this last part of the project are also quite important :

- Multi-objective optimisation on possible building configurations for the new district alone
- Multi-objective optimisation of the consequences on Lagängen on possible configurations for the new district
- Shape designing framework interesting in itself (initial project)

2 Main issues and points of particular interest

We present here quickly the main issues that could appear during the development of the project. The approaches and answers that we will give to them will be almost as important as the results. The list is of course not exhaustive, since the real ones appear all along the development work and can only be seen through a stepping back on the project after it is finished.

2.1 Philosophical issues

2.1.1 For a better understanding of "sustainable"

In the common sense, there is a misunderstanding of the notion of "sustainable", since it is mostly directly associated with "good environmental performances".

That is surely part of it but it must not hide the other aspects such as social sustainibility, cultural conservation, economic sustainibility. The sustainibility of a complex system is closely linked to his resilience and is therefore an emerging property that cannot be deduced from a single variable of the system. The philosophy of the ReBo project follows exactly this idea, and one of its aim is to aware of that fact all the common stakeholders involved in the renovation processes, or more generally in all the planning or building processes.

2.1.2 On the notion of "suburb"

The perception of the "suburbs" and of the segregation of ethnic groups that could be associated can be strongly controversial. In [6], the swedish suburbs are questioned, and policies are proposed to counter the increasing segregation. But this notion of segregation can in itself be discussed, as e. g. the authors of [13] contradict the results on segregation in London's suburbs proposed in [22]. The signification of the notion of "suburb" and the associated problems is an interesting issue that we will touch.

2.1.3 Objective modeling of subjective aspects?

The precedent problem raises the question of definition and measures of subjective phenomena, which is globally recurrent in social sciences.

It is the same for the evaluation of the quality of life which will be central in our modeling. As the question of the definition of utility in economy, we need to find objective criteria which the aggregation (in the better case) or the common consideration will represent a proxy of the quality of life of an individual. A quite exhaustive review of such techniques is done in [7], and we can begin by overlapping them with the concrete needs of our modeling.

We may also try to integrate the architecture as an agent, so the subjective relations of other agents to it could be complicated to model.

2.2 Issues for Urban systems modeling

2.2.1 Choice of indicators and measures

A current issue in Urban design is the "good" choice of measures and indicators for an urban configuration, and that's not always the most elaborated that are the most appropriate.

For example, the Moran indice, proposed in [14] to measure the regularity of the spatial distribution of the city, is not adapted to the spatial intercorrelation of more than one field, so it is in that case needed to simplify it for a working generalisation.

Also concerning the morphological properties of an urban shape, we need most of the time to extract the real enveloppe of the city to calculate pertinent measures, and that is a complicated problem that has just recently have had solutions, through distorsions techniques proposed in [10, 23].

Plenty of indicators are proposed in [28] to measure urban sprawl, and it is not evident which one are pertinent. That shows that the choice of indicators is also a real issue here.

2.2.2 On the need of diversification

The preliminary researches for the comparative study of swedish suburb district against a french one lead to the question of local diversification of activities.

The spatial diversification of the urban space and the local diversification of activities seems to be positive according to most of actual architectes and planners. But in a logical way there exists an inferior limit to this diversification since the size of the urban components decrease as a function of the diversification level, and there is a limit size for the functionnality of this components. We can then make the conjuncture that an urban system would have an "optimal" level of diversification (for each fixed set of other parameters of the urban system). The search in litterature about that problem gave no results although that appears to be an important issue, so we may give us time to search around this question by qualitative analysis and simple model building.

2.2.3 Level of complexity of the models

Most of existing complex models of urban systems concern each time particular aspects and not so much take into account a diversity in type of parameters and variables. One issue will be to test the coherence of putting together multiple type of variables, and to which level we can increase the complexity of the model without making it disconnected from the reality. We hope that the abstraction explained precendently will help to consider the largest number of variables and parameters.

2.3 Technical issues

2.3.1 Scale and heterogeneous model coupling

Integrated multi-scale model The ABM for Langangen district will need to consider at least two scales, because of the type of the data that have been collected, which are sometimes at the scale of all the district himself, sometimes at a more local scale (building or people themselves for the questionnaires). The ideal situation for the model we want to create would to obtain an integrated multi-scale model, containing at least these two distincts scales in order to have the best inclusion for all available data. However, multi-scale models are often hard to construct, so that should be an interesting issue. A proposition of integration is described in [12], where the scale coupling is realised through a system coupling of all subsystems that can then be seen as agents for the global system.

Heterogeneous model coupling An other technical problem that can occur in the last part of the project is the coupling between the two models. In fact, the differente nature of the two models will raise difficulties in finding the way to connect the outputs with the inputs, and at which level the connections are done. We could need to proceed to an abstract formulation of the coupling process, since a lot of litterature have been developped on the subject, as the DEV formalism presented in [9].

2.3.2 Model calibration

Once the model is constructed and implemented, a huge problem is its calibration, that means finding the values of parameters that lead to the best fitting of the results obtained to reality. This process has no simple solution in general and often takes a lot of time because of the large calculation it needs. We will have to find the more efficient approximate solution for our problem and proceed it in a reasonnable time. This problem occurs in quite different fields such as hydrologic models ([11, 16]) or applied economics ([30]), but is in fact always the same and working solutions are proposed in this specialized litterature, our problem will be to adapt them to our field.

2.3.3 Multi-objective optimisation through Evolutionnary Algorithms

The Pareto-front approach for multi-criteria optimisation works well when the set of configurations stays discrete and of small cardinal, since the complexity of a brutal domination-test algorithm is in $O(d \cdot n^2)$ where n is the number of points and d the dimension of the criteria space. But as we tend to continuous distribution of configuration, that can't work anymore and specific multi-objective optimisation algorithms are needed. The most common family of such algorithms today is the Evolutionnary Algorithms, also known as genetic algorithms. They allow the determination of a continous Pareto-front, which can be interesting for the decision-maker if the optimised function is a homeomorphism (otherwise the solutions could have no sense), because he can then choose along a continuous set of propositions. Such algorithms are described and compared in [31, 1, 8], and it appears that the choice of the exact method will depend on the situation we are dealing with.

Depending on the size of the set of configurations we will work and on several tests we will proceed around these techniques, we may use a non-parametric estimation of the functions representing the criteria and then extract the continuous Pareto-front instead of a discrete one which may not be sufficient.

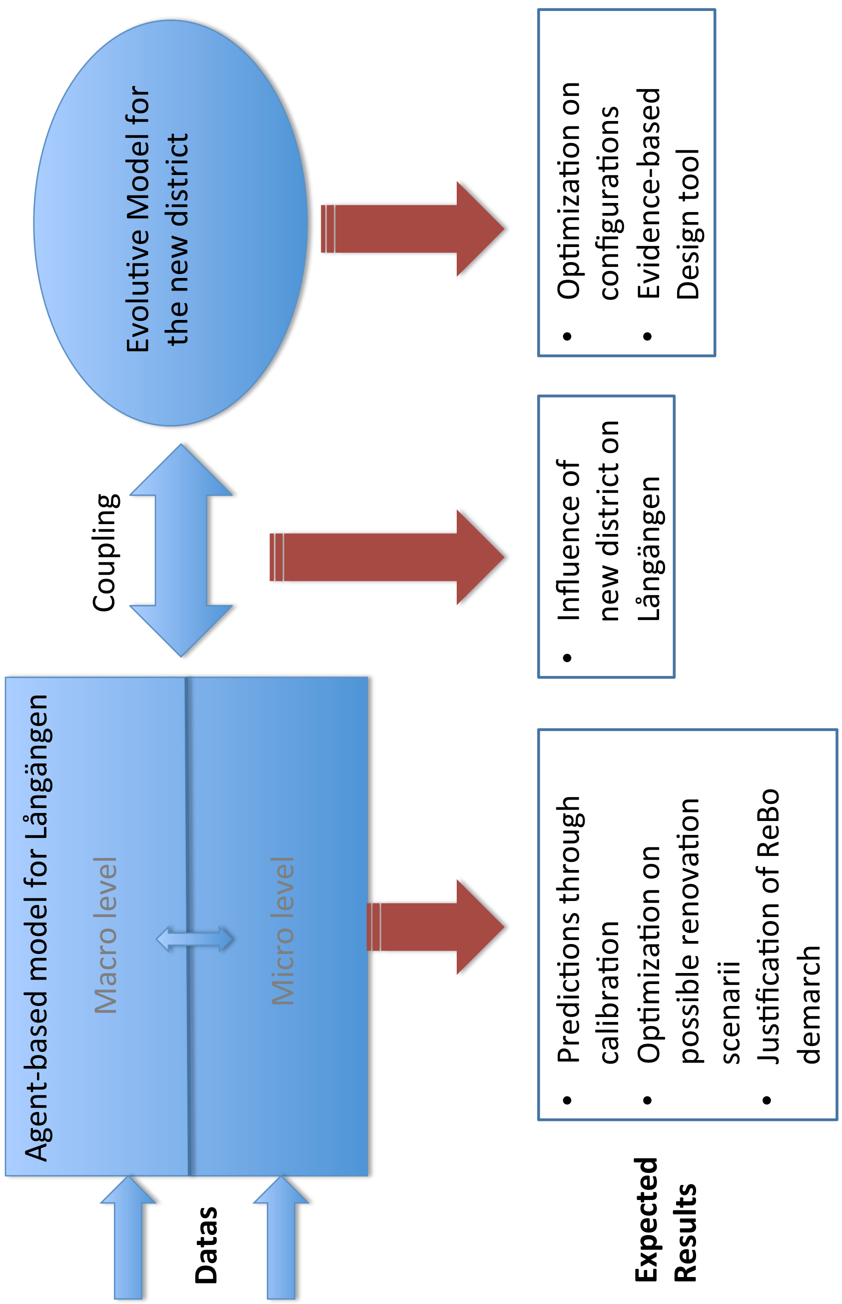

Figure 3: Explicative scheme of the overall project

Conclusion

We have presented the global framework for our project and its objectives, the most important is the translation of the philosophy of the ReBo project in Urban Models in order to show its relevance and efficiency. The other objectives are also important since they can lead to real proposition of architectural and planning choices for the decision makers. We can see on Fig. 3 a recapitulative scheme of the overall project, that shows the working plan and the expected results. We will always work carefully keeping in mind the global context of the Swedish suburb, and the preliminary historical and architectural study will help us for that. Some challenges may not be solved and we may adapt our working plan in consequence ; that is not a problem but more an advantage, because it is the nature of research in itself.

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Appendice E
Source code for static district analysis model

Main file

```
extensions [gis nw]

__includes [
   "[...]/LinkUtilities.nls"
   "[...]/ListUtilities.nls"
   "[...]/NetworkUtilities.nls"
   "[...]/EuclidianDistancesUtilities.nls"
   "[...]/FileUtilities.nls"
  "daylight.nls"
  "indicatorsVars.nls"
]

globals [
  ;;scale factor
  ;;value in meters of 1 step in NL world
  scale-factor

  ;;network
  paths-layer-data
  buildings-layer-data
  tram-layer-data

  remaining-links
  remaining-vertices

  ;;speed
  target-station

  ;;landuse
  landuse-diversity
  patches-count

  ;;daylight
  ;;list of successives theta angles
  theta
  ;;list of successives phi angles
  phi
  ;;time interval to change angle (first line of txt file)
  angle-time-interval
  sunlight-index
]


breed [vertices vertex]

breed [abstract-gis-paths abstract-gis-path]

abstract-gis-paths-own [
 gis-feature
 vertices-list
]

breed [stations station]

breed [buildings building]

undirected-link-breed [paths path]
undirected-link-breed [rails rail]

paths-own[path-length]
rails-own [rail-length]

vertices-own[
```

```
 d
 ;;simplified as mean distance to other vertices
 spatial-integration
]

buildings-own[
 gis-shape
 distance-to-nearest-station
 nearest-station
 transportation-time
 transportation-speed
]

patches-own [
  ;;daylight
  height
  neighb

  ;;diversity
  use
      ]

to load-and-draw-data
  ca
  resize-world 0 400 0 300
  set-patch-size 2
  set scale-factor real-world-width / world-width
  ask patches [set height 0]
  set paths-layer-data gis:load-dataset path-data
  set buildings-layer-data gis:load-dataset building-data
  set tram-layer-data gis:load-dataset tram-data
  gis:set-world-envelope gis:envelope-union-of
     gis:envelope-union-of (gis:envelope-of paths-layer-data)
    (gis:envelope-of buildings-layer-data) (gis:envelope-of tram-layer-data)
  gis:set-drawing-color brown
  gis:draw paths-layer-data 2

  ;;create abstract buildings
  foreach gis:feature-list-of buildings-layer-data [
    create-buildings 1 [
      let pos gis:location-of gis:centroid-of ?
          set gis-shape ?
      set distance-to-nearest-station 0 set hidden? true
      setxy first pos first but-first pos
    ]
  ]
end

to import-tram
 ask stations [die] ask rails [die]
  let current-station nobody
  foreach gis:feature-list-of tram-layer-data [
    foreach gis:vertex-lists-of ? [
      foreach ? [
      let loc gis:location-of ?
      create-stations 1 [
        setxy first loc first but-first loc
                set shape "circle"
                set color red set size 1
        ifelse current-station != nobody [
                create-rail-with current-station [
                  set thickness 0.4 set color red]
                ][set target-station self]
        set current-station self
      ]
    ]
```

```
  ]
 ]
end
```

Indicators calculation

```
to set-indicators-vars
  output-print "Calculating speeds from buildings..."
;calculate-nw-buildings
  output-print "Calculating landuse diversity..."
  ;calculate-landuse-diversity
  output-print "Calculating sunlight distribution..."
  ;calculate-sunlight-index
   calculate-spatial-integration
end

to calculate-spatial-integration
  nw:set-snapshot vertices paths
  let n count vertices
  ask vertices [
   ;;!!topological distance !
     let tot 0 ask other vertices [
                 let dis nw:distance-to myself if dis != false [set tot tot + dis]]
     set spatial-integration tot / n   ]
end

to calculate-nw-buildings
  ;;make in one time both nw indicators calculation
  ;;done in building-distance-to-transportation for speed
     ask paths [set color blue set thickness 0.3 let di 0 ask end1 [
                 set di distance [end2] of myself] set path-length di]
  ask rails [ let di 0 ask end1 [
                 set di distance [end2] of myself] set rail-length di]
  ask buildings [set distance-to-nearest-station building-distance-to-transportation]
  nw:set-snapshot stations rails
  ask buildings [let di 0 ask nearest-station [
        set di nw:weighted-distance-to target-station "rail-length"]
        set transportation-time scale-factor * 60 / 1000 *
                        ((distance-to-nearest-station / pedestrian-speed) +
                        (di / (tram-speed)))]
  let mi min [transportation-time] of buildings
  let ma max [transportation-time] of buildings
  ask buildings[
      gis:set-drawing-color scale-color yellow  (- transportation-time) (- ma ) (- mi)
      gis:fill gis-shape 1
  ]
end

to-report building-distance-to-transportation
  let res 0
  let v1 first sort-on [distance myself] vertices
  ;show v1
  nw:set-snapshot vertices paths
  let n-station nobody
  let target nobody
  ask v1 [
    set n-station first sort-on [from-station myself] stations
```

```
      set target first sort-on [distance n-station] vertices
      set res nw:weighted-distance-to target "path-length"
      let l nw:weighted-path-to target "path-length"
     let t nw:turtles-on-weighted-path-to target "path-length"
    foreach l [ask ? [set color green set hidden? false]]
    foreach t [ask ? [set color green set hidden? false]]
  ]
      ;;set the "speed" to that station
  if res = false [set res 0] ;;ok, just not counted!
  set transportation-speed res / (distance target)
      set nearest-station n-station
  ;show res
  report res
end

to-report from-station [target-vertex]
  let res 0
  let s first sort-on [distance myself] vertices
  ask target-vertex[set res nw:weighted-distance-to s "path-length"]
  ifelse res != false [report res] [
    report sqrt (world-width ^ 2 + world-height ^ 2)]
end

to calculate-landuse-diversity
  ask patches [set use landuse]
  set landuse-diversity diversity
end

to-report diversity
   let W 0
   let r 0
   let echantillon n-of round (0.3 * count patches) patches
   ask echantillon [let x pxcor let y pycor let t use
      ask other echantillon[
      if use != t [ set r r + (1 / distancexy x y)] set W W + (1 / distancexy x y)]
     set patches-count patches-count + 1]
   report 3 / 2 * r / W ;;normalisation since we have 3 landuse here
end

;;patch procedure reporting landuse in that particular case
to-report landuse
  if count buildings-here > 0 [report 0]
  if count stations-here > 0 [report 1]
  report 2
end
```

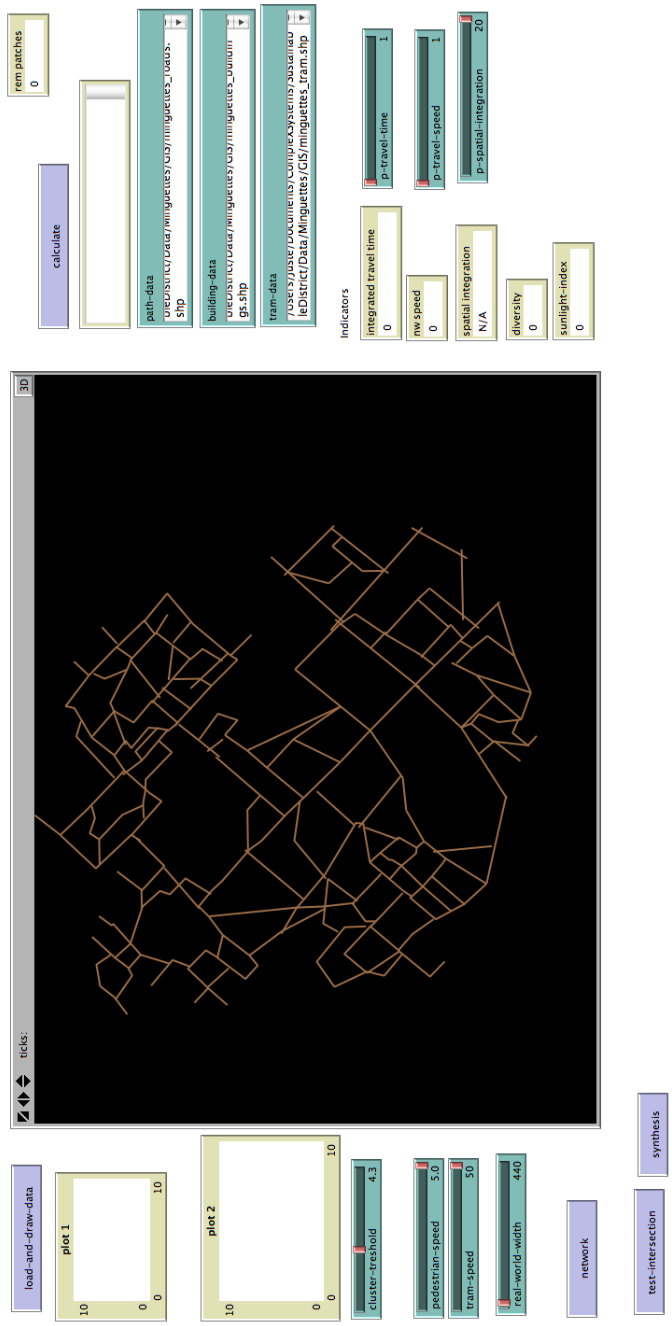
Sunlight index calculation

```
;;patches need owned-variable height
;;import from raster data? first directly from layer
;;patches are spatial discretisation (not more, so need to be precise)

to calculate-sunlight-index
  ;;set heights of buildings
  ;;simplified : all same height, would need attribute file
  set-heights

```

```
    ;;set sun positions
  set-sun-positions

    ;;angle interval will be tick time
  set angle-time-interval round ((length theta) / 24)
     let objectives objective-points

    ;;more simple to first integrate on space then in time,
  ;;so we take p=1 in the norm so no interversion pb

 let tot 0 let s 0
  repeat round (24 / angle-time-interval) [
     if first theta > 0 [
       clear-drawing
       gis:draw paths-layer-data 1
       output-print word "Hour " ((tot * angle-time-interval) + 1)
       set s s + daylight-value list (first theta) (first phi) objectives
       set tot tot + 1
     ]
     set theta but-first theta
     set phi but-first phi
  ]
  set sunlight-index s / tot

end

;;reporter for a given sun position
;;position as a couple (theta,phi)
to-report daylight-value [sun-position points]
  let enl 0
 foreach points [
     set enl enl + local-daylight-value sun-position ?
  ]
  report enl / length points
end

to-report local-daylight-value [sun-position point]
  ;;implementation : a turtle goes in theta direction
  ;;checks at each step (1?) if l*sin(theta) > local-height
  ;;in a way, turtle is one photon !
  let photon nobody let light? true let l 0 let th first sun-position
  create-turtles 1 [
        setxy first point last point
        set heading last sun-position
        set photon self set color yellow pen-down
  ]
  ask photon [
     while [can-move? 1][
       if l > 0 [set light?
                (light? and (l * scale-factor * tan th ) > [height] of patch-here) ]
       set l l + 1
       fd 1
     ]
     die
  ]
  ifelse light? [report 1][report 0]
end

to set-heights
  ask patches [set pcolor black set height 0]
;  ask buildings [
;     let env gis:envelope-of gis-shape
;     let xmin first env let xmax first but-first env
;     let ymin first but-first but-first env
;     let ymax first but-first but-first but-first env
;     let i 0 let j 0
```

```
;     repeat (xmax - xmin) [repeat (ymax - ymin)[
;        let p patch (xmin + i) (ymin + j) if p != nobody [
;                if gis:contains? gis-shape p or gis:intersects?
;                        gis-shape p [ask p [set height 30]]] set j j + 1] set i i + 1 set j 0]
;   ]
;  show "ok"
  ask buildings [ask patches with [
        gis:intersects? [gis-shape] of myself self
                or gis:contains? [gis-shape] of myself self]
                [set height 30 set pcolor white]]
end

to set-sun-positions
  ;;read from file
  ;;values of angles every hour
  set theta map read-from-string read-file "thetaSW.txt"
  set phi map read-from-string read-file "phiSW.txt"
end

to-report objective-points
   let res []
     ask patches [
    ask neighbors4[
       if height - [height] of myself != 0 [
                set res lput list (([pxcor] of myself + pxcor) / 2)
                                (([pycor] of myself + pycor) / 2) res]
    ]
  ]
  report res
end
```

Interface of the model



Appendice E
Source code for Agent-based model

Main code

```
extensions[gis test profiler nw numanal]

__includes[
         "[...]/EuclidianDistancesUtilities.nls"
         "[...]/StringUtilities.nls"
         "[...]/SortingUtilities.nls"
         "[...]/ListUtilities.nls"
         "[...]/TypesUtilities.nls"
         "[...]/FileUtilities.nls"
         "[...]/LinkUtilities.nls"
         "[...]/NetworkUtilities.nls"
     "[...]/GISUtilities.nls"
         "setup.nls"
         "calibration.nls"
         "refscenarii.nls"
]

globals [
  ;;utils variables
  building-layer-data
  transport-layer-data
  green-layer-data
  services-layer-data

  ;;network include vars
  paths-layer-data
  remaining-links
  remaining-vertexes
  cluster-treshold

  flats-list-by-rooms

  ;coefficient before the derivative in mean unemployment equa diff
  unemployment-diff

  ;stop?
  tst

  ;;real variables
  ;;considered as a macro variable,
  ;;may evolve in long time series,
  ;;according to external data?
  ;unemployment-rate

  ;basically considered as linear function
  ;of income ; no taxes if get social help
  taxes-proportion

  ;very important : closely linked to the time scale, if small time step
  ;as 2 weeks, must be small ! to reproduce real situations with a lot of steps,
  ;such small step is needed
  job-opportunities-per-year

  ;time-serie to match
  unemployment-data
  unemployment-data-time-scale

  ;max proportion of population that can get social help
  ;social help is attributed to the people with negative balance
  ;first approx bring balance to zero
  ;social-help-rate

  ;approximate cost of a person per month (food etc)
```

```
  person-cost

  ;time for each tick, in years
  ;time-interval

  ;treshold under which you can get social help
  ;expressed in Kr/person (including children) -> allocs
  ;social help
  ;social-help-treshold

  ;max fraction of the population which can get social help
  social-help-max-recipient-proportion
  ; max amount perceived from social help
  social-help-max-amount

  ;;rent update
  ;law regulation
  max-rent-per-square-meter
  ; normalisation coef for the influence of balances on rents
  ;bnorm
  ;bref

  ;params for immigrants
  max-immigrant-number-per-year

  ;;globals for random config
  couple-proba
  children-mean
  ;income-mean
  ;income-sigma
  rent-mean
  rent-sigma

  ;;;;;;;;;;;;
  ;;globals for extended aspects
  ;;;;;;;;;;;;

  ;;external agents satisfaction
  green-space-satisfaction-individual-norm-factor
  services-satisfaction-individual-norm-factor

  ;;influence parameters
  ;;can move according to global economic situation
  standard-influence-on-rent
  ;energy-cost
  ;;data from questionnaire : list of listes
  questionnaire-data

  ;;calibration variables
  ;;oblective for calibration
  rents-obj
  incomes-obj
  ;;output file
  ;calib-file
  ;calib-tick

  ;;;;;;
  ;;Globals for refurbishment description : parameters, new layers
  ;;;;;;
  ;ref-living-standard-change-factor
  ;ref-energy-change-factor
  additional-green-spaces-layer
  additional-services-layer
]
```

```
;;Basic breeds

breed [flats flat]

breed [buildings building]

breed [households household]

;;new breeds
breed [services service]

breed [transports transport]

breed [green-spaces green-space]

;;;;;;;;;;;;;;;;;;;;;;;
;;network include breeds
;;;;;;;;;;;;;;;;;;;;;;;
breed [vertexes vertex]

breed [abstract-gis-paths abstract-gis-path]

abstract-gis-paths-own [
  gis-feature
  vertexes-list
]

undirected-link-breed [paths path]

paths-own [path-length]

;;;;;;;;;;;;;;;;;;;;;;;;;;;;


;;;;;;;;;;;;;;;;;;;;;;
;; Owned variables
;;;;;;;;;;;;;;;;;;;;;;

buildings-own [
  ;corresponding gis VectorFeature
  gis-shape

  ;list of flats contained in the building
  in-flats

  ;numeric value of rents in the building
  rent-per-square-meter

  ;;energy perf
  ;initial value, a refurbishment changes this value
  building-energetic-performance
]

households-own[
  ;list of incomes
  incomes
  total-income

  ;for each people, level of studies in years.
  ;shows potentiality to find a job (children have 0 for example)
  ;studies

  ;years of experience in job
  experiences

  social-help?
```

```
  ;economic bilan of the last period
  global-balance

  ;number of people in the household
  people-number

  ;quite constant, shows the tendancy to consum
  consumption-rate

  ;pointer to the occuped flat
  occupied-flat

  ;;life quality aspects
  green-space-satisfaction
  services-satisfaction
]

flats-own[
  ;number of rooms
  rooms
  ;surface, directly linked to number of rooms.
  surface

  rent

  ;pointer to the occuping household
  occupant

  ;;living conditions variables
  living-standard

 ;;% of total rent
  energetic-performance

  ;;caches lists for distances
  ;index corresponds to place in the sorted list of green by who (avoids a hashmap)
  distances-to-green-spaces
  distances-to-services
]

green-spaces-own[
 ;what can evolve through strong modification of district situation or refurbishment
 quality
]

services-own[quality ;idem as for green-spaces ]

to new-household [income]
  ;;set people
  let r random-float 1
  ifelse r >= couple-proba [set people-number 1]
     [set people-number 2 + (random 2 * children-mean)]
     ;;set studies !! BEFORE incomes, to be coherent with the following
     ;;(self coherence of the implementation)
     let s1 floor (random-normal 3 2)
         let s2 floor (random-normal 3 2)
     ifelse people-number = 1 [set studies (list s1)]
     [set studies list s1 s2]
     ;;set incomes or unemployment
     set incomes []
     foreach studies [
       let i 0 let u random-float 100
       if u > unemployment-initial-rate [
                set i max list 10000 (random-normal ((income-mean - (income-sigma))
                       + (k-studies * ? * income-sigma)) income-sigma)]
```

```
        set incomes lput i incomes
      ]
      ;;set experiences
      set experiences list 0 0
      foreach incomes [
       set experiences
          replace-item position ? incomes experiences (0.5 + (random 20 / 2))]
      ;;find flat
      find-flat

      ;;social help
      set social-help? false

      ;;default satisfactions
      set green-space-satisfaction 0
      set services-satisfaction 0

end

;household procedure to find the best flat
to find-flat
  let i min list max list 0 (people-number - 2) 2
  let f nobody let d item i flats-list-by-rooms
  ifelse d != [] [
  set f first d set flats-list-by-rooms
    replace-item i flats-list-by-rooms but-first d]
[set f one-of flats with [occupant = nobody]
  foreach flats-list-by-rooms [set ? remove f ?]]
  set occupied-flat f ask f [set occupant myself]
end

to refurbishment
  ;;setup
  set-random-initial-configuration
  ;;go for first half
  while [not stop?] [go]
  ;;;;;
  ;;proceed to refurbishment
  ;;;;;
  log-out "Refurbishment..."
  ask flats [
    if energy? [
      set energetic-performance energetic-performance * ref-energy-change-factor]
    if standard? [
      set living-standard living-standard * ref-living-standard-change-factor
      ;;need to change rent according to the change of living-standard
      set rent rent * ref-living-standard-change-factor
    ]
  ]

  ;;add new layers for green spaces and services if needed
  ;;delete old, because new layer can be less?
  ask green-spaces [die]
  ask services [die]
  set additional-green-spaces-layer
    gis:load-dataset "[...]/langangen_green_new.shp"
  set additional-services-layer
    gis:load-dataset "[...]/langangen_services.shp"
  setup-action-gis-layers additional-green-spaces-layer additional-services-layer
  ;;new calculation of distances   ask flats [set-cache-distances]

  ;;simulate following years
  set stop? false
  let m max-time
  set max-time max-time * 2
  while [not stop?] [go]
```

```
  set max-time m
end

to go
  log-out word "Going for tick " ticks
  set-data
  if not stop?[
   update-work-situations
   update-social-helps
   update-rents
   calculate-balances
   emigrate
   immigrate
   update-drawing
   ;;add new effects : integration on time step of "satisfaction" regarding to new aspects
   ;;also influence of energy and living standard on rents
   update-life-quality-reporters
   tick
   log-out word "Total time : " (ticks * time-interval )   ]
end

to test-run-duration
  profiler:reset
  profiler:start
  let time 0
  set-random-initial-configuration
  while [not stop?][
    go
    set time time + profiler:inclusive-time "go"
    show profiler:inclusive-time "go"
  ]
  show profiler:inclusive-time "go"
end

to calibrate
  let filename word word "calibration/cal_" timer ".sci"
  print-in-file filename "bref=[];bnorm=[];income-mean=[];rents=[];"
  set bref 5000
  set bnorm 10000
  set income-mean 10000
  let i 1
     repeat 10 [
         repeat 10 [
           repeat 10 [
       set-random-initial-configuration
       let out (list mean [rent / surface] of flats)
       let j 1
       while [not stop?][
       go if (ticks * time-interval) mod 1 = 0 [
       set out lput mean [rent / surface] of flats out]]
       print-in-file filename word word word word "bref(" i ")=" bref ";"
       print-in-file filename word word word word "bnorm(" i ")=" bnorm ";"
       print-in-file filename word word word word "incomemean(" i ")=" income-mean ";"
       foreach out [print-in-file filename word word word
                        word word word "rents(" i "," j ")=" ? ";" set j j + 1]
        set income-mean income-mean + 1000
        set i i + 1
     ]
     set bnorm bnorm + 2000
     set income-mean 10000
     ]
    set bref bref + 1000
    set bnorm 10000
    set income-mean 10000
  ]
```

```
end

to update-life-quality-reporters
  log-out "Calculating life quality reporters..."
  ;snapshot
  if green? or services? or standard?[
;;gain time if nothing pb
  ask households [
    if green? [
set green-space-satisfaction green-space-satisfaction-reporter
]
    if services? [set services-satisfaction services-satisfaction-reporter]
 ]
  ]
end

to-report green-space-satisfaction-reporter
  report norm-p green-space-satisfaction-individual-norm-factor
      [distances-to-green-spaces] of occupied-flat
end

to-report services-satisfaction-reporter
    report norm-p services-satisfaction-individual-norm-factor
        [distances-to-services] of occupied-flat
end

to set-data
      ifelse (ticks * time-interval) > max-time [set stop? true][
 ;;unemployment
  if unemp-ext-data?[
    if unemployment-data != []
   [if (ticks * time-interval) mod unemployment-data-time-scale = 0 [
     set unemployment-initial-rate first unemployment-data
     set unemployment-data but-first unemployment-data]]
  ]
  ]
end

to update-work-situations
  ;;add time experience for workers
  ask households [foreach incomes [
   if ? != 0 [let i position ? incomes
   set experiences replace-item i experiences
         (item i experiences + time-interval)]]]
  ;;some unemployed find jobs and others loose their jobs.
  let u unemployed-number
  let new-workers-number max list 0
     min list u floor (
       random-normal (job-opportunities-per-year * time-interval) (u / 10))
  let unemployed to-list households with [member? 0 incomes]
  repeat new-workers-number [;people finding a job
    if unemployed != [] [
    ask one-of unemployed [
      let w 1 - bool-to-int ((item 0 incomes) = 0)
     ;index of unemployed guy
     ;gets job and new income!
      set incomes replace-item w incomes max list 10000
       (random-normal ((income-mean - (income-sigma)) +
       (k-studies * (item w studies) * income-sigma)) income-sigma)
      if not member? 0 incomes [set unemployed remove self unemployed]
      ]
   ]
  ]
     ;;loose of jobs - ratio has to match unemployment-growth variable
  let job-loosers-number max list 0 min list (actives-number - u)
       floor (random-normal (new-workers-number +
```

```
      (actives-number * unemployment-initial-rate / 100) - u) (u / 10))
  set unemployment-diff job-loosers-number - new-workers-number
  let employed to-list households with [sum incomes > 0]
  repeat job-loosers-number [
  ;people loosing their job
    if employed != [][
    ask one-of employed [
      let w bool-to-int (item 0 incomes = 0)
     ;;looses income and experience
     set incomes replace-item w incomes 0
     set experiences replace-item w experiences 0
      if sum incomes = 0 [set employed remove self employed]
    ]
    ]
  ]
        ;;promotion for experienced workers
  if with-promotions? [
    ask households [
      foreach experiences [
     let i position ? experiences if ? > 0 and ? mod 5 = 0 [
     set incomes replace-item i incomes (item i incomes + 500)]]
    ]
  ]
end

to update-social-helps
 ask households [set social-help? false]
  ;;calculate provisory balance to see if could get the social help
 let eligibles households with [prov-balance < social-help-treshold]
 ask min-n-of min list count eligibles floor
     (social-help-max-recipient-proportion * count households / 100 )
     eligibles [prov-balance]
     [set social-help? true]
end

;aux function
to-report prov-balance
 report (sum incomes - ([rent] of occupied-flat)) / people-number
end

to update-rents
 ;;rents adapt themsleves according to neighborhood value and people wealth
 ;;external control (law), also externalities as unemployment?
  ;;one time per year only? -> can change it
   if ticks * time-interval mod 1 = 0 and rent-updates? [
      ;; update rents
     let r mean [rent] of flats
     let b mean [global-balance] of households

    ask flats [
    let max-rent surface * max-rent-per-square-meter
   set rent min list max-rent (((rent * ((1 + (b - bref)/ bnorm))) ))] *
      (1 + standard-influence-on-rent *
      (living-standard - 1) / 2))]+ (rent-coef * (r - rent)))]    ]
  end

to calculate-balances
  ask households [
     set global-balance balance if social-help? [
     set global-balance min list
    (global-balance + social-help-max-amount) 500]]
end

to-report balance
 ;;basic balance, linear taxes.
 ;;energy consumption : represented as a proportion of the rent
```

```
  ;;all in counted % one month
   report (sum incomes - ([rent] of occupied-flat))
    - (taxes-proportion * sum incomes) - (person-cost * people-number)
    - ([energetic-performance] of occupied-flat * energy-cost)
end

to emigrate
 if drastic? [
   ask households with [global-balance < die-treshold]
     [ask occupied-flat [set occupant nobody] die]]
end


to immigrate
  if new-inhabitants? [
        let i workers-mean-income
        repeat min list
     (count flats with [occupant = nobody])
      floor (max-immigrant-number-per-year * time-interval) [
                create-households 1 [new-household i]]
        ]
end


;;Utilities functions
to-report unemployed-number
  let res 0 ask households [
        foreach incomes [if ? = 0 [set res res + 1]]]
  report res
end

to-report actives-number
  report sum [length incomes] of households
end

to-report workers-mean-income
  let res 0 let c 0
  ask households [
        foreach incomes [ if ? != 0 [set res res + ? set c c + 1]]
  ]
  report res / c
end

to-report unemployment-coef
  report unemployment-diff
end

to update-drawing
  log-out "Drawing..."
  clear-drawing
  gis:set-drawing-color brown
  gis:draw paths-layer-data 2
  gis:set-drawing-color grey
  gis:draw building-layer-data 1
  if green? [gis:set-drawing-color green   gis:draw green-layer-data 5]
  if services? [gis:set-drawing-color red   gis:draw services-layer-data 5]
  if transport? [gis:set-drawing-color orange   gis:draw transport-layer-data 3]
  ask turtles [set hidden? true]
  let mir min [rent] of flats
  let mar max [rent] of flats
  ask patches with [count flats-on self > 0][
    set pcolor scale-color red (mean ([rent] of flats-on self)) (mir - 50) (mar + 50)]
  let mii min [(sum incomes) / people-number] of households
  let mai max [(sum incomes) / people-number] of households
  ask households [
    setxy [xcor] of occupied-flat [ycor] of occupied-flat
```

```
      set shape "person" set size people-number / 2
      set hidden? false
      set color scale-color green ((sum incomes) / people-number) (mii - 50) (mai + 50)
      if member? 0 incomes [set color pink]
       if social-help? [set color yellow]
      ]
end

to log-out [text]
 if debug? [output-print text]
end
```

Local includes

File setup.nls

```
to draw-gis-layers
  ca
  log-out "Loading and Drawing GIS data..."
  ask patches [set pcolor white]
  ;;load gis layers
  set building-layer-data gis:load-dataset
     "[...]/langangen_buildings_pol.shp";user-new-file
  set paths-layer-data
     gis:load-dataset "[...]/langangen_roads.shp"
  set transport-layer-data
     gis:load-dataset "[...]/langangen_transport.shp"
  set green-layer-data
     gis:load-dataset "[...]/langangen_green.shp"
  set services-layer-data
     gis:load-dataset "[...]/langangen_services.shp"
     ;;set enveloppes - these two layers enough?
  gis:set-world-envelope gis:envelope-union-of
    gis:envelope-of building-layer-data
    gis:envelope-of paths-layer-data
  ;;draw buildings
  gis:set-drawing-color black
  foreach gis:feature-list-of building-layer-data [
    ;if gis:property-value ? "ID" = target-id [
      gis:set-drawing-color red]
    ;foreach explode ";" gis:property-value ? "ADRESS" [
       if member? ? adresses [gis:set-drawing-color blue]]
    gis:fill ? 1 gis:set-drawing-color black
    let c gis:location-of gis:centroid-of ?
    ;create-turtles 1 [setxy item 0 c item 1 c
       set label-color red set size 0
       set label gis:property-value ? "ADRESS"]    ]
  gis:set-drawing-color white
  foreach gis:feature-list-of building-layer-data [
  let v ?
  foreach gis:feature-list-of building-layer-data [
    if v != ? and gis:contains? v ?[gis:fill ? 1]]]

  ;;draw roads
  gis:set-drawing-color brown
  gis:draw paths-layer-data 2
  ;;draw other layers
```

```
  ;;if green? [gis:set-drawing-color green
  ;;gis:draw green-layer-data 5]
  ;;if services? [
  gis:set-drawing-color red
  ;;gis:draw services-layer-data 5]
  if transport? [gis:set-drawing-color orange
  gis:draw transport-layer-data 3]
   end


to load-csv-properies [filename property-name layer-data]
;load from csv file of the form ADRESS;PROPERTY
  let data but-first read-file filename
  foreach data [
    let value first but-first explode ";" ?
    foreach layer-data [
       ;gis:set-property-value
     ]
 ]
end


;;set the static agent that are not supposed to change.
to set-static-agents
  log-out "Setting up static agents..."
  ;;loading some building data
  let adresses import-data "data/data.csv" 0
  let energy map read-from-string import-data "data/data.csv" 1

  ;;load questionnaire data
  load-questionnaire-data "[...]/questionnaire.csv"
  ;creation of buildings
  foreach gis:feature-list-of building-layer-data [
    create-buildings 1 [
      set gis-shape ?
      set in-flats []
      set hidden? true
      let i 0 foreach explode ";"
       gis:property-value ? "ADRESS" [
       if member? ? adresses [
      set i position ? adresses
      set building-energetic-performance item i energy]]
      if building-energetic-performance = 0 [
          set building-energetic-performance mean energy]
    ]
  ]
  ;;create abstract network -> BEFORE SETTING FLATS !!!
 ;;(need network to calculate caches distances)
  ;;cluster treshold is fixed? Y, very small
  output-print "Extracting abstract network from GIS network..."
  set cluster-treshold 0.5
  create-network
  ;;setup services and green spaces through their gis-layer passed as a variable
  ;;[the external function is called also during a refurbishment with additional layers]
  setup-action-gis-layers green-layer-data services-layer-data
  ;;creation of flats
  set-flats
end


to setup-action-gis-layers [green-layer services-layer]
  ;;set green spaces - Idem network (targets need to exist!)
  if green? [foreach gis:feature-list-of green-layer [
   foreach gis:vertex-lists-of ? [
    foreach ? [let loc gis:location-of ?
     create-green-spaces 1 [
```

```
        setxy first loc first but-first loc
         set color green set shape "circle"]]]]]

  ;;set services
  if services? [foreach gis:feature-list-of services-layer [
   foreach gis:vertex-lists-of ? [
    foreach ? [
     let loc gis:location-of ?
     create-services 1 [
       setxy first loc first but-first loc
       set color red set shape "circle"]]]]]
  end

to set-flats
  output-print "Filling buildings with flats..."
  create-flats 1 [setxy 0 0 set shape "house" set size 0.5
      set color yellow set occupant nobody]
  let current-flat one-of flats
  let previous-flat nobody
  let filled? false
  let previous-building nobody
  snapshot
  ;;procedure to fill the building with flats seems weird,
  ;;but no direct method to get patches within a gis shape

  while [not filled?][
     ;;fix if in a building
     let fixed? false
     ask buildings [
       let b self ask current-flat [
         ifelse not fixed? [
           if gis:contains? [gis-shape] of myself self [
             hatch-flats 1 [
               set previous-flat current-flat
               set current-flat self
               ask b [
                 set in-flats lput previous-flat
                in-flats set previous-building self
               ]
             ]
             set fixed? true
             ;;since current flat has been fixed in previous flat,
                         ;;able to calculate cache distances to activities
             ;;update these distances if change in configuration
             ;;of green-space/services : case of a refurbishment e.g.
             set-cache-distances
            ]
         ]
        [ if gis:contains? [gis-shape] of myself self [
        ask previous-building [set in-flats remove previous-flat in-flats]
        ask previous-flat [die]]  ;;two and only two max containing shape?
              ]
         ]
     ]
     ;;advance current-flat in space
     ask current-flat [
       ifelse ycor = world-height - 1
           and xcor = world-width - 1 [set filled? true]
        [set ycor (ycor + 0.5 ) mod (world-height - 0.5)
        if ycor = 0 [set xcor (xcor + 0.5 ) mod (world-width - 0.5)]]]
     if filled? [ask current-flat[die]]
  ]
end

;;flat procedure, set caches distances.
;;called when setup or services update
```

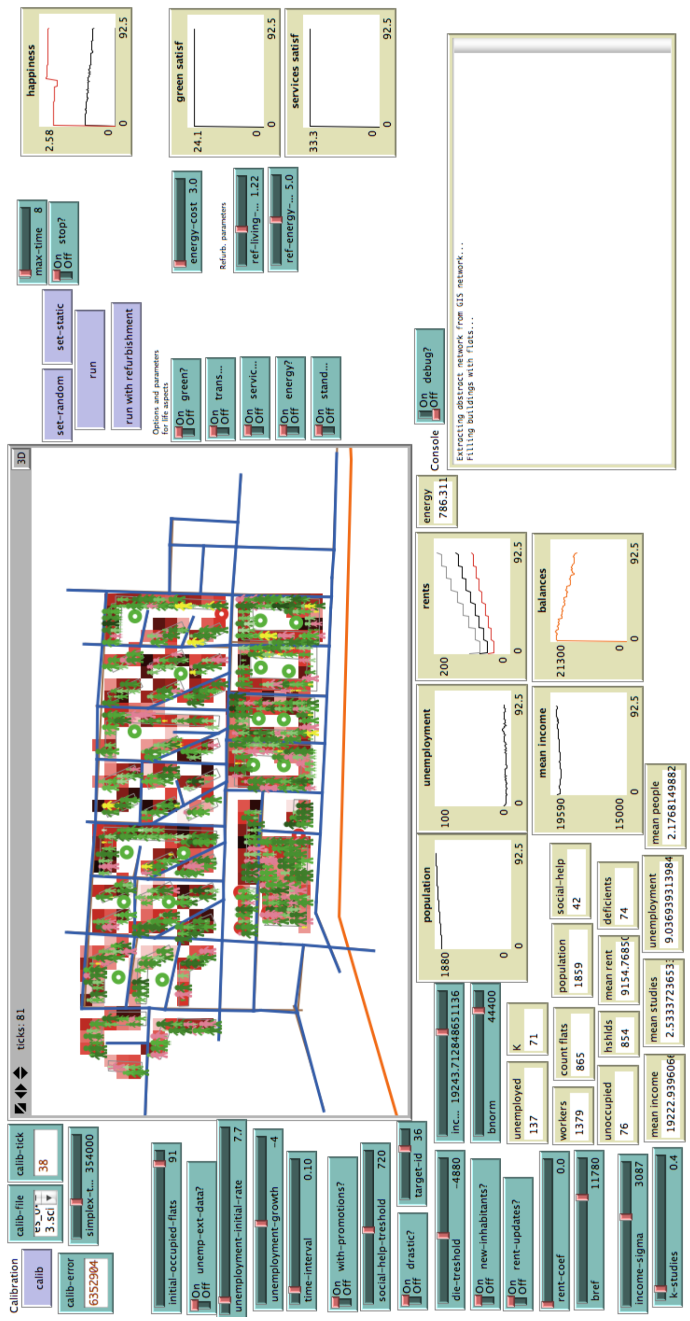
```
;;need snapshot before
to set-cache-distances
  set distances-to-green-spaces []
  foreach sort-on [who] green-spaces [
   set distances-to-green-spaces
      lput distance-through-network ? distances-to-green-space]
   set distances-to-services []
   foreach sort-on [who] services [
   set distances-to-services
      lput distance-through-network ? distances-to-services]
end

to set-static
  draw-gis-layers
  set-static-agents
end


to set-random-initial-configuration
  ;;when multiple iterations (ex calibration),
  ;;don't do it each tick to gain time
  set-static
  log-out "Setting up dynamic agents..."
  ;;set "fixed" global vars
  set couple-proba 0.8
  set children-mean 1
  ;set income-mean 16000
  ;set income-sigma 3000
  set rent-mean 72.45
  set rent-sigma 6.9
  ;set time-interval 0.1 ;6month
  set social-help-max-recipient-proportion 25
  set taxes-proportion 0.1
  set person-cost 1500
  set social-help-max-amount 15000
  set job-opportunities-per-year 100
  set max-immigrant-number-per-year 10
  set max-rent-per-square-meter 200
  ;set bnorm 30000
  set stop? false
  let data read-file "data/unemployment.csv"
  set unemployment-data-time-scale read-from-string first but-first data
  set unemployment-data map read-from-string but-first but-first data

  ;;extended globals
  set green-space-satisfaction-individual-norm-factor 0.01
  set services-satisfaction-individual-norm-factor 20
  set standard-influence-on-rent 0.2
  ;set energy-cost 10
  log-out "Variables"

  ;;fix rents
  ask buildings [
    set rent-per-square-meter random-normal rent-mean rent-sigma
         let energy-per-month building-energetic-performance / 12
         ;;set foreach flat rooms, surface and rent
         ;;and standard and energetic performances
    foreach in-flats [
      let r random-float 1
      ifelse r > couple-proba [ask ? [set rooms 2]]
      [ifelse r > couple-proba / 2 [ask ? [set rooms 3]]
         [ask ? [set rooms 4]]]
      ask ? [
        ;;3 levels of standard
        ; impact on rent? depends of parameter
        set living-standard random 3 + 1
```

```
          ;;surface : simplified by linear to rooms
          set surface rooms * 20
          ;;energetic perf : fixed for all?
          ;;initial value from gis-data, ref change this value.
          set energetic-performance energy-per-month * surface
          ;;rent - initial value so standard is important
          set rent ([rent-per-square-meter] of myself)
              * surface * (1 + (standard-influence-on-rent * (living-standard - 1) / 2))
                 ]
     ]
   ]
   log-out "Rents"

   ;;populate the district
   ;;again quite weird method? lexically sort by (rent,rooms)
   set flats-list-by-rooms []
   set flats-list-by-rooms lput sort-by [
       lexcomp ?1 ?2 (list task [rent])] flats with [rooms = 2] flats-list-by-rooms
   set flats-list-by-rooms lput sort-by [
       lexcomp ?1 ?2 (list task [rent])] flats with [rooms = 3] flats-list-by-rooms
   set flats-list-by-rooms lput sort-by [
       lexcomp ?1 ?2 (list task [rent])] flats with [rooms = 4] flats-list-by-rooms
   repeat floor (count flats ) * initial-occupied-flats / 100 [
         create-households 1 [
            new-household income-mean
      ]
    ]
     log-out "Households"
     reset-ticks
     update-drawing
end


to load-questionnaire-data [file]
   set questionnaire-data []
   file-open file
   show file-read-line
  ;;skip variable names line
   while [not file-at-end?][
      set questionnaire-data lput
       first explode ";" file-read-line questionnaire-data
   ]
   file-close
end

to-report import-data [file index]
   let res []
   file-open file
   while [not file-at-end?][
      set res lput item index explode ";" file-read-line res
   ]
   file-close
   report res
end
```

File calibration.nls

```
;;simple run on the simplex
to calibrate-with-simplex
  set calib-file word word "calibration/calibSimplexMeanSquares_" date-and-time ".sci"
  set calib-tick 1
  print-in-file calib-file "ms=[];incomemean=[];bref=[];bnorm=[];"
  ;let guess [10000 34000 13000]
  let guess [12000 30000 17000]
  ;; income guess has to be greater than treshold, if not bad time
     let tsk task [runmodel ?]
  let result numanal:simplex guess tsk simplex-tolerance 1000
 log-out result end


to-report runmodel [params]
  set bref first params
  set bnorm first but-first params
  set income-mean first but-first but-first params
  set-random-initial-configuration
  ;;data : beware of file length !
  set rents-obj map read-from-string
      but-first read-file "data/rentsNLData.csv"
  set incomes-obj map read-from-string
      but-first read-file "data/incomesSimplexObj.csv"
  set max-time length rents-obj
          log-out "In simplex, running model..."
  log-out word "bref:" bref
 log-out word "bnorm:" bnorm
  log-out word "incomemean:" income-mean
            let out 0
  let i 0
  while [not stop?][
    go
   if (ticks * time-interval) mod unemployment-data-time-scale = 0
       and ticks > 1 and not stop? [
      log-out unemployment-data
      set out out +
       ((((mean [rent / surface] of flats) - (item i rents-obj)) ^ 2))
      + ((((workers-mean-income) - (item i incomes-obj * 1000 / 12)) ^ 2))
      set i i + 1
   ]
 ]
       log-out word "mean-square-error" out
  print-in-file calib-file word word word word
      "ms(" calib-tick ")="  min list out 1000000000 ";"
  print-in-file calib-file word word word word
      "incomemean(" calib-tick ")=" income-mean ";"
  print-in-file calib-file word word word word
      "bref(" calib-tick ")=" bref ";"
  print-in-file calib-file word word word word
      "bnorm(" calib-tick ")=" bnorm ";"
  set calib-tick calib-tick + 1
  set calib-error round out
  report out
end
```

Interface of the model



Appendice G
Source code for evolutionary algorithm design

Main file

```
extensions[table nw]

__includes[
  "[...]/utils/ListUtilities.nls"
  "[...]/utils/FileUtilities.nls"
  "[...]/utils/StringUtilities.nls"
 "evals.nls"
 "network.nls"
]

breed[numbers number]

breed[vertices vertex]

undirected-link-breed[paths path]

globals [
  ;;vars for partition
  ;;In % the minimal ratio between two volumes of partitions
  min-partition-rate
  ;;Max number of connex components (?)
  max-partition-components
  ;;max number of iterations
  max-partition-iterations

  ;;vars for evolutionary algorithm
  ;;table of lists representing configurations
  ;;should be more efficient to check existence?
  ;;PB : don't really know how hascode is calculated and used
  ;;we map the conf of landuses with network description
  ;;: [[node-x, node-y]...],[[[n1-x,n1-y][n2-x,n2-y]]...]
  existing-configurations

  ;;list of best values for objective functions
  ;;should put it in a table associated with conf?
  ;;Yes if recalculation is needed?
  best-objective-values
  current-configuration
  current-evaluation
  ;;values of preced confs
  values
]

patches-own[
 ;;utility var for partition  partition
 ;;landuse variable
 landuse
]

vertices-own[]
paths-own [
 path-length
]

to setup
  ca
  set min-partition-rate 5
  set max-partition-components 5
  set max-partition-iterations 50
  ;;set numbers
  ask patches [sprout-numbers 1 [set hidden? true]]
  ;;set plot
  set-current-plot "pareto"
```

```
  set-current-plot-pen "pen-0"
  set-plot-pen-mode 2
  set values []
end

to-report eval-configuration [objective-names conf]
  ;;name of the objective functions we want to consider
  set current-evaluation []
  set current-configuration conf
  foreach objective-names [
   run word word "set current-evaluation lput "
     ? " current-configuration current-evaluation"
  ]
  report current-evaluation
end

to-report cross-configurations [conf1 conf2]
  ;;confs in arguments are couples
  ;;(conf, nw description) in the std format
  ;;configurations are stored in lists,
  ;;sorted by "patch number",
  ;;which is the number of the turtle on the patch
  ;;this function crosses the two and report the new one.
  ;;new conf is cached outside this function
  ;;(because will at term depend of comparisons)
  ;;we report the couple (conf,network description) in the standard format
  let part sort-on [[who] of one-of numbers-here] random-partition
  let patches-list sort-on [[who] of one-of numbers-here] patches
  let res [] let resnetwork-nodes [] let resnetwork-links []
  let c1 first conf1 let c2 first conf2
  let n1 first but-first conf1 let n2 first but-first conf2

  ;;quite hard to obtain linear complexity for networks ;
  ;;let suppose the number of nodes and links remains small
  ;;get nodes
   foreach first n1 [
    if member? (patch (first ?) (last ?))
         part [set resnetwork-nodes lput ? resnetwork-nodes]
   ]
  ;;and links
  foreach first but-first n1 [
    if member? (patch (first first ?) (last first ?)) part
    and member? (patch (first last ?) (last last ?)) part
   [set resnetwork-links lput ? resnetwork-links]
  ]
  ;;idem for second network
  foreach first n2 [
    if not member? (patch (first ?) (last ?)) part [
    set resnetwork-nodes lput ? resnetwork-nodes]
  ]
  ;;and links
  foreach first but-first n2 [
  if not member? (patch (first first ?) (last first ?)) part
   and not member? (patch (first last ?) (last last ?)) part
  [set resnetwork-links lput ? resnetwork-links]
  ]
  ;;most difficult : create crossing links.
  ;;what heuristic?
  ;;find links with start in part and other not and replace them?
  ;;not optimised, test could be done in above loops?
  ;;does it for only one network? -> randomly chosen
  ;;for now n1,n2. little degueu
  ifelse random 2 = 0 [let n n1 set n1 n2 set n2 n]
  [let n n2 set n2 n1 set n1 n]
  foreach first but-first n1 [
    if member? (patch (first first ?) (last first ?)) part
```

```
     and not member? (patch (first last ?) (last last ?)) part [
       ;;find the closest vertice in n2 which is not in part and link to it
       let p patch (first first ?) (last first ?)
       let closest-vertice first sort-by [
         [distance p] of (patch (first ?1) (last ?1)) <
         [distance p] of (patch (first ?2) (last ?2))] first n2
      set resnetwork-links lput
       list (first ?) (closest-vertice) resnetwork-links
      ]
     ]
    ;;finally connexify the nw?
    create-network list resnetwork-nodes resnetwork-links
    connect-components
    set resnetwork-links []
    ask paths [set resnetwork-links lput
      list (list [xcor] of end1 [ycor] of end1)
     (list [xcor] of end2 [ycor] of end2) resnetwork-links]
     ask vertices [die] ask paths [die]

    ;;for efficience, advance in same time in two listes
    ;;uses the partition property
    foreach patches-list [
      ifelse part != [][
        ifelse ? = first part [
         set res lput first c1 res set part but-first part]
        [set res lput first c2 res]
      ][
        set res lput first c2 res
     ]
     set conf1 but-first c1 set c2 but-first c2   ]
     report list res list resnetwork-nodes resnetwork-links
end

to test-crossing
  setup
  let conf1 constant-conf 2
  let conf2 constant-conf 1
  let conf cross-configurations conf1 conf2
  color-configuration conf
end

to test-cascaded-crossings
   ;;need special setup first
  let conf1 one-of table:keys existing-configurations
  let n1 table:get existing-configurations conf1
  let conf2 one-of remove conf1 table:keys existing-configurations
  let n2 table:get existing-configurations conf2
  let conf cross-configurations list conf1 n1 list conf2 n2
  color-configuration conf
  ;;eval and plot the conf
  let val eval-configuration (list "diversity" "nw-speed") conf
  update-plot val
  table:put existing-configurations first conf last conf
end

to setup-crossings
  ;;we begin with all constants configurations
  setup
  set existing-configurations table:make
  set best-objective-values []
  let col 10
  repeat landuses-number [
   let conf constant-conf visible-color col (130 / (landuses-number - 1))
    ;;generate a random network?
    let network []
    ifelse random-network? [
```

```
      set network random-network
      ][
      ;;heuristic for "real network" -> join neighbors and connected components.
      set network real-network
     ]
    table:put existing-configurations conf network
   set col col + (130 / (landuses-number - 1))
  ]
end

to-report visible-color [num step]
  ;;reports a color from a float which is not black or white
  ;;in order to differentiate
  let origin-color ((floor (num / 10)) * 10) + 1
  report origin-color + (step * 0.8)
end

to-report index
  report [who] of one-of numbers-here
end

to-report constant-conf [n]
  let res []
  repeat count patches [set res lput n res]
  report res
end

to update-plot [val]
  set values lput val values
  let minx 0 let maxx 0
  let miny 0 let maxy 0
  let xvals map first values
  ifelse length xvals = 1 [set maxx 1]
  [set minx min xvals set maxx max xvals]
  let yvals map last values
  ifelse length yvals = 1 [set maxy 1]
  [set miny min yvals set maxy max yvals]
  set-plot-x-range minx maxx set-plot-y-range miny maxy
  foreach values [plotxy first ? last ?]
end

to color-configuration [conf]
  let configuration first conf
  ;;landuse var will be the color
  foreach sort-on [[who] of one-of numbers-here] patches [
   ask ? [set landuse first configuration
   set configuration but-first configuration]]
  ask patches [set pcolor landuse]
  ;;shows network
  ;;option later for efficience purposes?
  create-network last conf
end

to new-vertex
  set color black set shape "circle" set size 0.5
end

to new-path
  set color black set thickness 0.2
end

;;creates a random partition of the world.
;;reports agenset of one of the elements of the partition
;;supposed to be reasonnable : limited number of connex components,
;;quite well balanced
to-report random-partition
```

```
  ;;try of heuristic with variable diffusion
  ;;let put initial number at max-partition-components
  ask patches [set partition 0]
  ask n-of max-partition-components patches [set partition 1]
  repeat max-partition-iterations [
    ;let put some randomness in diffusion process
    ifelse random 2 = 0 [diffuse partition 0.5]
  [diffuse4 partition 0.5]   ]
   let patches-number round ((count patches) * (min-partition-rate +
   random (100 - (2 * min-partition-rate))) / 100)
  report max-n-of patches-number patches [partition]
end

to test-random-partition
  ask patches [set pcolor black]
  set min-partition-rate 5
  set max-partition-components 5
  set max-partition-iterations 50
  ask random-partition [set pcolor white]
end

to movie-random-partition
  let max-time 10
  let frame-rate 4
  movie-start word date-and-time "_partitions.mov"
  movie-set-frame-rate frame-rate
  reset-ticks
  let t timer let tmax timer while [timer - tmax < max-time]
  [if (timer - t) > 1 / frame-rate [
      test-random-partition
      tick
      set t timer
      movie-grab-view
    ]
 ]
  movie-close
end
```

File evals.nls

```
to-report diversity [conf]
  let W 0
  ask patches [let x pxcor let y pycor
    ask other patches[set W W + (1 / distancexy x y)]]
  let r 0
  ask patches [let x pxcor let y pycor
  let t pcolor ask other patches[
  if pcolor != t [set r r + (1 / distancexy x y)]]]
  let d landuses-number / (landuses-number - 1) * r / W
  if d = 0 [report plot-x-max]
  report (1 / d)
end

to-report nw-density [conf]
  ;;need to be called when network is built
  ;create-network
  let n count vertices
```

```
  let l count paths
  report 2 * l / (n * (n - 1))
end

to-report nw-speed [conf]
  ;create-network
  let vertices-list to-list vertices
  let remaining-vertices vertices-list
  let total 0
  nw:set-snapshot vertices paths
  ask paths [let dd 0 ask end1 [
   set dd distance other-end] set path-length dd]
  foreach vertices-list [
    ;;works that way because exact copy of the list ! Dangerous !
    if remaining-vertices != [] [
     set remaining-vertices but-first remaining-vertices]
    ask ? [
       let start ?
      foreach remaining-vertices [
         ask ? [
      let p nw:weighted-distance-to start "path-length"
      if p != false [set total total + (p /(distance start))]]
       ]
    ]
  ]
  let nn count vertices
  report 2 * total /(nn * (nn - 1))
end
```

File network.nls

```
;;random network generation
to-report random-network
  let network-nodes []
  let network-links []
  repeat initial-nodes [
   set network-nodes
    lput list random-xcor random-ycor network-nodes]
  let links-number round ((initial-nodes *
    (initial-nodes - 1) / 2) * initial-nw-density)
  let l 0
  while [l < links-number]
  [let n1 one-of network-nodes
  let n2 one-of network-nodes
  if n1 != n2 and not member? list n1 n2 network-links and
    not member? list n2 n1 network-links [
    set network-links lput list n1 n2 network-links
    set l l + 1]
   ]
   report list network-nodes network-links
end

;;"more real" nw generation
to-report real-network
  ;;create the real network
  create-vertices initial-nodes [
  new-vertex setxy random-xcor random-ycor]
```

```
  ask vertices [create-paths-with ((other vertices)
    with-min [distance myself]) with [not link-neighbor? myself][new-path]]
  connect-components
  ;;export it into std format
  let nw-nodes []
  let nw-paths []
  ask vertices [set nw-nodes lput list xcor ycor nw-nodes]
  ask paths [set nw-paths lput list
  (list [xcor] of end1 [ycor] of end1)
  (list [xcor] of end2 [ycor] of end2)nw-paths]
  ask vertices [die] ask paths [die]
  report list nw-nodes nw-paths
end

to connect-components
  let dmax sqrt ((world-width ^ 2) + (world-height ^ 2))
  let clusters []
  while [length clusters = 0 or length clusters > 2]
  [
    nw:set-snapshot vertices paths
   set clusters nw:weak-component-clusters
  let c1 first clusters let dmin dmax
  let tmin1 one-of vertices
  let tmin2 one-of vertices
  foreach clusters[
     if ? != c1 [
      let d dmax let t1 one-of vertices
      let t2 one-of vertices
      foreach ? [
        let t ?
        foreach c1 [
        ask ? [if distance t < d [
         set d distance t set t1 self set t2 t]]
        ]
      ]
      if d < dmin [set dmin d set tmin1 t1 set tmin2 t2]
         ]
     ]
    if tmin1 != tmin2 [ask tmin1 [
     create-path-with tmin2 [new-path]]]
  ]
end

to create-network [network]
  ask vertices [die] ask paths [die]
  let nodes first network
  let nw-paths last network
  foreach nodes [create-vertices 1 [
   setxy first ? last ? new-vertex]]
  foreach nw-paths [
    let n1 one-of vertices-on patch first first ? last first ?
    let n2 one-of vertices-on patch first last ? last last ?
    if n1 != nobody and n2 != nobody [
      ask n1 [if not path-neighbor? n2 and
        n2 != self [create-path-with n2 [new-path]]]]
  ]
end
```

Appendice H
Source code for utility functions

File TypeUtilities

```
;;type conversion functions

to-report bool-to-int [boolean]
  ifelse boolean [report 1][report 0]
end

to-report int-to-bool [integer]
  ifelse integer != 0 [report true][report false]
end

;;global variables management from names as string
to set-global [variable-name variable-value]
  run word word word "set " variable-name " " variable-value
end
```

File StringUtilities

```
;;basic functions of string processing

;;split the string following the delimiter
to-report explode [delimiter string]
  let res [] let current ""
  let n length string let i 0
  repeat n [
    ifelse item i string = delimiter [
      set res lput current res set current ""]
     [set current word current item i string]
      set i i + 1
  ]
  report lput current res
end

;;concats all elements of the list in one string
to-report implode [l]
  let res ""
  foreach l [set res word res ?]
  report res
end

to-report replace [string motif new]
  let n length string let i 0 let res ""
  repeat n [ifelse item i string = motif [
      set res word res new]
     [set res word res item i string]
    set i i + 1
  ]
  report res
end
```

File SortingUtilities

```
;;sorting utilities

;;lexicographic comparison on a variable number of reporter tasks
;;reporter list is sorted in decreasing importance order
;;boolean reporter
to-report lexcomp [var1 var2 reporterTasksList]
  let res true let fixed? false
  foreach reporterTasksList[
     if not fixed? [
       ifelse [runresult ?] of var1 < [runresult ?] of var2
        [set res true set fixed? true]
        [ifelse [runresult ?] of var1 = [runresult ?] of var2 [set res true]
         [set res false set fixed? true]
         ]
     ]
  ]
  report res
end

to test-lexcomp
  foreach sort-by [lexcomp ?1 ?2 (list task [pxcor] task [pcolor])] patches
   [ask ? [show word word pxcor " - " pcolor]]
end
```

File NetworkUtilities

```
;;functions called in a particular context
;;Create an abstract network of breeds vertexes, paths if and only if :
;;  -  paths-layer-data is a gis polyline layer
;;  -  global var cluster-treshold,
;;remaining-links, remaining-vertices has been defined (not initialised, no pb)
;;  -  breed vertices, undirected-link-breed paths
;;and breed abstract-gis-pathshas been defined,
;;with corresponding variables, that means in code :
;;         breed [vertices vertex]
;;         breed [abstract-gis-paths abstract-gis-path]
;;         abstract-gis-paths-own [
;;             gis-feature
;;             vertexes-list
;;          ]
;;         undirected-link-breed [paths path]
;;         paths-own [path-length]
;;  -  LinkUtilities.nls is in the includes
;;  -  ListUtilities.nls is in the includes

to create-network-vertices-clustering
  foreach gis:feature-list-of paths-layer-data [
    let abstract nobody
    let current-vertex nobody
    create-abstract-gis-paths 1 [
    set gis-feature ? new-abstract-gis-path
    set abstract self]
    foreach gis:vertex-lists-of ? [
      foreach list first ? last ? [
```

```
        let loc gis:location-of ? if loc != [][
        create-vertices 1 [
          setxy min list first loc max-pxcor min list first but-first loc max-pycor
          new-vertex
           ask abstract [set vertices-list lput myself vertices-list]
        ifelse current-vertex = nobody [set current-vertex self]
       [ask current-vertex [create-path-with myself [new-path]] set current-vertex self]
          ]
        ]
      ]
       set current-vertex nobody
    ]
   ]
;;try a simple local clusterize
  set remaining-vertices to-list vertices
  reset-ticks
  while [length remaining-vertices > 0][
    let v first remaining-vertices
    set remaining-vertices remove v remaining-vertices
    ask v [set color blue]
    ask v [fusion-neighbors]
    tick
  ]
end

to fusion-neighbors
   let neigh other vertices in-radius cluster-treshold
   if count neigh > 0 [
    let n nobody
    let x mean [xcor] of neigh
    let y mean [ycor] of neigh
    hatch-vertices 1 [
      set n self
      setxy x y
      ask neigh [
         set remaining-vertices remove self remaining-vertices
        ask my-paths [
         if not member? other-end neigh and other-end != n [
               ask other-end [create-path-with n]] die]
         die
      ]
    ]
    ask my-paths [if not member? other-end neigh and other-end != n [
        ask other-end [create-path-with n]] die]
       die
   ]
end

to create-network
  set remaining-links []
  ;;paths layer is supposed to match the world enveloppe
  foreach gis:feature-list-of paths-layer-data [
    let abstract nobody
  let current-vertex nobody
    create-abstract-gis-paths 1 [
     set gis-feature ? new-abstract-gis-path set abstract self]
    foreach first gis:vertex-lists-of ? [
       let loc gis:location-of ? if loc != [][
       create-vertices 1 [
       setxy min list first loc max-pxcor min list first but-first loc max-pycor
      new-vertex
      ask abstract [set vertices-list lput myself vertices-list]
       ifelse current-vertex = nobody [set current-vertex self]
     [ask current-vertex [create-path-with myself [new-path]]
    set current-vertex self]
      ]
```

```
      ]
     ]
   ]
   local-clusterize
   set remaining-links to-list paths
    while [length remaining-links > 0] [
     show length remaining-links
     let l one-of remaining-links
     set remaining-links remove l remaining-links
     ask l [set color blue set thickness 0.3]
     let inter intersecting l
      if inter != nobody [
        let i intersection l inter
        let x first i let y first but-first i
        create-vertices 1 [
        new-vertex
       setxy x y create-path-with [end1] of l [
         set remaining-links lput self remaining-links]
       create-path-with [end2] of l [
        set remaining-links lput self remaining-links ]
      create-path-with [end1] of inter [
        set remaining-links lput self remaining-links ]
       create-path-with [end2] of inter [
        set remaining-links lput self remaining-links]]
        ask l [ die ]
       ask inter [die]
      set remaining-links remove inter remaining-links
          ]
     ]
    local-clusterize
    ask vertices [set color blue]
    ask paths [set color blue set thickness 0.3]
end

;;particular reduction of network by clustering.
;;(adapted to the network creation procedure and
;;to the real world gis network we work with)
to local-clusterize
    ;;deleting local clusters
    set remaining-vertices to-list vertices
    while [length remaining-vertices > 0][
      let v one-of remaining-vertices
      set remaining-vertices remove v remaining-vertices
      ask v [set color blue]
      let neigh vertices with [
         member? self remaining-vertices and distance v < cluster-treshold and self != v]
      ifelse count neigh > 0 [ask one-of neigh [fusion v]]
     ;;in the other case, if exists one link with distance < epsilon,
     ;;create a vertex at the projection location
     ;;added this requirement to have quite in each case a connex network,
     ;;because then two very close link will connect although they don't intersect at the small scale
     [ask v [
      let ml my-paths
      let x xcor let y ycor
      let ps paths with [not member? self ml and distance-to-point x y < cluster-treshold]
      if count ps > 0 [ask one-of ps [
         let p coord-of-projection-of x y
         let xx first p let yy first but-first p
         let e1 end1 let e2 end2
         ask e1 [hatch-vertices 1 [
                setxy xx yy
                create-path-with e1 [set thickness 1]
                ; thickness for debug purposes at the beginning
                create-path-with e2 [set thickness 1]
                fusion v
                  ]
```

```
              ]
             die
           ; the old link
         ]
       ]
      ]
    ]
  ]
  ask vertices [set color blue]
  ask paths [set color blue set thickness 0.3]
end

to fusion [v]
  set remaining-vertices remove self remaining-vertices
  let v1 self let v2 v
  ;show "fusion"
   ;show v1
  ;show v2
  let x ([xcor] of v1 + [xcor] of v2) / 2
  let y ([ycor] of v1 + [ycor] of v2) / 2
  hatch-vertices 1 [setxy x y
    let n self
    ;show word "n:" n
    ask ([my-paths] of v1) with [end1 != v2 and end2 != v2]
   [show self ifelse end1 = v1 [ask end2 [create-path-with n]]
       [ask end1 [create-path-with n]] die]
    ask ([my-paths] of v2) with [end1 != v1 and end2 != v1]
     [show self ifelse end1 = v2 [ask end2 [create-path-with n]]
     [ask end1 [create-path-with n]] die]
    ask ([my-paths] of v1) [if end1 = v2 or end2 = v2 [die]]
    ask v1 [die]
    ask v2 [die]
    set remaining-vertices lput self remaining-vertices
  ]
end

to-report intersecting [l]
  ;;hard complexity
 let res nobody
  let found? false
  let r-links to-list paths with [self != l]
  while [not found? and length r-links > 0][
    let l1 one-of r-links set r-links remove l1 r-links
    if intersection l l1 != [] and not common-extremity? l l1 [set res l1 set found? true]
  ]
  report res
end

to-report common-extremity? [l1 l2]
  report [end1] of l1 = [end1] of l2 or
    [end1] of l1 = [end2] of l2 or [end2] of l1 = [end2] of l2 or
    [end1] of l2 = [end2] of l1
end

to new-vertex
  set size 0.5 set shape "circle" set color grey
end

to new-abstract-gis-path
  set hidden? true  set vertices-list []
end

to new-path
 set thickness 0.2 set color grey
end
```

```
;;;;;;;;;;; ;; Calcul of distances in the network ;;;;;;;;;;;
;; Requires : nw extension set
;; same breeds as before (need path length for weighted distance !)
;;turtle procedure : distance to other turtle through network
;;snapshot and link distance done in other function, so done just 1 time (efficiency!)
to snapshot
  nw:set-snapshot vertices paths
  ask paths [let dd 0 let e2 end2
    ask end1 [set dd distance e2 ] set path-length dd]
end

;;beware, need snapshot before !
to-report distance-through-network [target-turtle]
  let origin first sort-on [distance myself] vertices
 let destination nobody
 ask target-turtle [set destination first sort-on [distance myself] vertices]
  let res 0
  ask origin [set res nw:weighted-distance-to destination "path-length"]
  ;if res = false [ask origin [set size 3 set hidden? false]
  ;ask destination [set size 3 set hidden? false]]
 if res = false [set res 0]
 ;;Beware : in theory infinity, but for norms calculations, just not taken into account, so ok
 ; for other use not coherent behavior
 ;; SO : network MUST be connex !!!
 ;;add this fix to avoid bugs but can produce instable results

 ;;should add both euclidian distances ? Yes, more precise in that case !
 ;; BUT could exist some cases where the final distance is not the shortest.
 ;;(if network can be reached through projection on links.
 ;;If network can be entered only by vertexes?
 ;;also counter-examples of that fact??? Yes...
 ;; but still, should be good approximation in realistic cases.
 ;;(on random networks?) (write something on that?)

 let dt 0 ask target-turtle [set dt distance destination]
 report (distance origin) + res + dt
end
```

File ListUtilities

```
;;agentset/list functions

to-report to-list [agentset]
  let res []
  ask agentset [
    set res lput self res
   ]
  report res
end

;; normalised norm-p of a vector
;; in this file because applies on a list
to-report norm-p [p l]
  let res 0
  let n length l
  foreach l [set res res + (? ^ p)]
  report (res / n) ^ (1 / p)
```

```
end
```

File LinkUtilities

```
to-report intersection [t1 t2]
  if [xcor] of [end1] of t1 = [xcor] of [end2] of t1 and
   [ycor] of [end1] of t1 = [ycor] of [end2] of t1 [report []]
  if [xcor] of [end1] of t2 = [xcor] of [end2] of t2 and
   [ycor] of [end1] of t2 = [ycor] of [end2] of t2 [report []]
  let m1 [tan (90 - link-heading)] of t1
  let m2 [tan (90 - link-heading)] of t2

  if m1 = m2 [ report [] ]

  if abs m1 = tan 90   [
    ifelse abs m2 = tan 90
      [ report [] ]
      [ report intersection t2 t1 ]
  ]

  if abs m2 = tan 90 [
      let c1 [link-ycor - link-xcor * m1] of t1
      let x [link-xcor] of t2
      let y m1 * x + c1
      if not [x-within? x] of t1 [ report [] ]
      if not [y-within? y] of t2 [ report [] ]
      report list x y
  ]

  let c1 [link-ycor - link-xcor * m1] of t1
  let c2 [link-ycor - link-xcor * m2] of t2
  let x (c2 - c1) / (m1 - m2)
  if not [x-within? x] of t1 [ report [] ]
  if not [x-within? x] of t2 [ report [] ]
  report list x (m1 * x + c1)
end

to-report x-within? [x]
  report abs (link-xcor - x) <= abs (link-length / 2 * sin link-heading)
end

to-report y-within? [y]
  report abs (link-ycor - y) <= abs (link-length / 2 * cos link-heading)
end

to-report link-xcor
 report ([xcor] of end1 + [xcor] of end2) / 2
end

to-report link-ycor
  report ([ycor] of end1 + [ycor] of end2) / 2
end
```

File GISUtilities

```
;; GIS specific general functions

to-report patches-in [gisshape]
  report patches with [
    gis:contains? gisshape self or gis:intersects? gisshape self
  ]
end
```

File FileUtilities

```
;;read and write file utilities

to-report read-file [filename]
  let res []
  file-open filename
  while [not file-at-end?][
    set res lput file-read-line res
  ]
  file-close
  report res
end

to print-in-file [filename output]
  file-open filename
  file-print output
  file-close
end

;;export plot as scilab data
;;need string utilities include
;;don't work with multiple pens !
;;override existing file or write it at the end?
to export-plot-as-scilab [plotname filename var1name var2name]
  if file-exists? filename [file-delete filename]
 let tempfile word date-and-time ".temp"
 print-in-file tempfile ""
  print-in-file filename word "//Export plot as scilab data : "
    plotname
  print-in-file filename word word word
    var1name "=[];" var2name "=[];"
  export-plot plotname tempfile
   ;  let data-list read-file tempfile ;
   ;  show data-list ;
   ;  let data? false
;  let i 1 ;
;  foreach data-list [
;    ifelse data? [
;      let l explode "," ?
;      print-in-file filename word word word word word
;   var1name "(" i ")=" replace first l "\"" "" ";"
;      print-in-file filename word word word word word
;   var2name "(" i ")=" replace first but-first l "\"" "" ";"
;      set i i + 1
;    ]
```

```
;     [
;       set data? (first explode "," ?) = "\"x\""
;       print-in-file filename word "//" ?
;     ]
;   ]
;   ;  file-delete tempfile
end
```

File EuclidianDistancesUtilities

```
;;Euclidian distance calculation utilities functions

;turtle or patch procedure reporting the distance
;to a given link
to-report distance-to-link [l]
  let x1 0 let y1 0
  let x2 0 let y2 0
  let e1 0 let e2 0
  let x 0 let y 0
  ask l [set e1 end1 set e2 end2]
  ifelse is-turtle? self [
    set x xcor set y ycor][set x pxcor set y pycor]
  ask e1[set x1 xcor   set y1 ycor]
  ask e2 [set x2 xcor   set y2 ycor]
  let m1m sqrt (((x1 - x ) ^ 2) + ((y1 - y) ^ 2))
  let m2m sqrt (((x2 - x ) ^ 2) + ((y2 - y) ^ 2))
  let m1m2 sqrt (((x1 - x2 ) ^ 2) + ((y1 - y2) ^ 2))
  if m1m = 0 or m2m = 0 [report 0]
  if m1m2 = 0 [report m1m]
  let cost1 (((x - x1)*(x2 - x1)) +
       ((y - y1)*(y2 - y1)))/(m1m * m1m2)
  let cost2 (((x - x2)*(x1 - x2)) +
       ((y - y2)*(y1 - y2)))/(m2m * m1m2)
  if cost1 < 0 [report m1m]
  if cost2 < 0 [report m2m]
  report m1m * sqrt abs (1 - (cost1 ^ 2))
end

;link procedure which calculates the distance
;to a given point
to-report distance-to-point [x y]
  let x1 0 let y1 0 let x2 0 let y2 0
  ask end1[set x1 xcor   set y1 ycor]
  ask end2 [set x2 xcor   set y2 ycor]
  let m1m sqrt (((x1 - x ) ^ 2) + ((y1 - y) ^ 2))
  let m2m sqrt (((x2 - x ) ^ 2) + ((y2 - y) ^ 2))
  let m1m2 sqrt (((x1 - x2 ) ^ 2) + ((y1 - y2) ^ 2))
  if m1m = 0 or m2m = 0 [report 0]
  if m1m2 = 0 [report m1m]
  let cost1 (((x - x1)*(x2 - x1))
   + ((y - y1)*(y2 - y1)))/(m1m * m1m2)
  let cost2 (((x - x2)*(x1 - x2))
   + ((y - y2)*(y1 - y2)))/(m2m * m1m2)
  if cost1 < 0 [report m1m]
  if cost2 < 0 [report m2m]
  report m1m * sqrt abs (1 - (cost1 ^ 2))
end
```

```
;report a turtle on the projection of point x y
;on the calling link
to-report projection-of [x y]
  let x1 0 let y1 0 let x2 0 let y2 0
  ask end1[set x1 xcor   set y1 ycor]
  ask end2 [set x2 xcor   set y2 ycor]
  let m1m sqrt (((x1 - x ) ^ 2) + ((y1 - y) ^ 2))
  let m2m sqrt (((x2 - x ) ^ 2) + ((y2 - y) ^ 2))
  let m1m2 sqrt (((x1 - x2 ) ^ 2) + ((y1 - y2) ^ 2))
  if m1m = 0 or m1m2 = 0 [report end1]
  if m2m = 0 [report end2]
  let cost1 (((x - x1)*(x2 - x1)) +
    ((y - y1)*(y2 - y1)))/(m1m * m1m2)
  let cost2 (((x - x2)*(x1 - x2)) +
    ((y - y2)*(y1 - y2)))/(m2m * m1m2)
  let mq 0 let xx 0 let yy 0 let m1q 0
  ifelse cost1 < 0 [
    report end1
  ]   [
  ifelse cost2 < 0 [
     report end2
  ][
        set mq m1m * sqrt abs (1 - (cost1 ^ 2))
    set m1q sqrt ((m1m ^ 2) - (mq ^ 2))
    set xx x1 + m1q * (x2 - x1) / m1m2
    set yy y1 + m1q * (y2 - y1) / m1m2
    if count turtles-on patch xx yy = 0 [
     ask patch xx yy [sprout 1 [
       setxy xx yy
       ]
     ]
   ]
  report one-of turtles-on patch xx yy
   ]
  ]
end

;;same as projection but doesn't pose the problem of killing
;the turtle or not (which survived sometimes anyway,
;why? -> because internally created? lost the pointer
to-report coord-of-projection-of [x y]
  let x1 0 let y1 0 let x2 0 let y2 0
  ask end1[set x1 xcor   set y1 ycor]
  ask end2 [set x2 xcor   set y2 ycor]
  let m1m sqrt (((x1 - x ) ^ 2) + ((y1 - y) ^ 2))
  let m2m sqrt (((x2 - x ) ^ 2) + ((y2 - y) ^ 2))
  let m1m2 sqrt (((x1 - x2 ) ^ 2) + ((y1 - y2) ^ 2))
  if m1m = 0 or m1m2 = 0 [report end1]
  if m2m = 0 [report end2]
  let cost1 (((x - x1)*(x2 - x1)) +
    ((y - y1)*(y2 - y1)))/(m1m * m1m2)
  let cost2 (((x - x2)*(x1 - x2)) +
    ((y - y2)*(y1 - y2)))/(m2m * m1m2)
      let mq 0 let xx 0 let yy 0 let m1q 0
    ifelse cost1 < 0 [
    report list [xcor] of end1 [ycor] of end1
  ]   [
   ifelse cost2 < 0 [
    report list [xcor] of end2 [ycor] of end2
  ]   [
   set mq m1m * sqrt abs (1 - (cost1 ^ 2))
   set m1q sqrt ((m1m ^ 2) - (mq ^ 2))
   set xx x1 + m1q * (x2 - x1) / m1m2
   set yy y1 + m1q * (y2 - y1) / m1m2
       report list xx yy
```

```
        ]
      ]
    end
```

Appendice I

Questionnaire Grid used in the frame of ReBo project

A. Bakgrund

1. Hur gammal är du? 23 år.

2. Är du .... ☒ Kvinna ☐ Man ☐ ____________

3. Hur länge har du bott I Långängen?

0-5år	5-10år	10-20år	20-40år	40+ år
☒	☐	☐	☐	☐

4. Vilken är din huvudsakliga sysselsättning?

☒ Anställd
☐ Egen företagare
☐ Pensionär
☐ Student
☐ Föräldraledig
☐ Arbetssökande
Annat, nämligen____________________

5. Vilken är din högsta utbildningsnivå?

☐ Folkskola/grundskola
☐ Realskola
☐ Folkhögskola
☐ Läroverk/gymnasium
☐ Yrkesutbildning/KY
☒ Högskola/Universitet
Annat, nämligen____________________

6. Vilket språk talar du/ni vanligtvis hemma?

☒ Svenska
☐ Svenska och annat språk
☐ Annat språk, nämligen________________

B. Hälsa och välmående

1. Hur nöjd med din nuvarande situation? Vänligen kryssa i det alternativet per kategori som du tycker överensstämmer bäst på dig.

	Mycket missnöjd				Mycket nöjd
	1	2	3	4	5
Din fysiska hälsa	☐	☐	☒	☐	☐
Ditt välmående	☐	☒	☐	☐	☐
Ditt boende	☐	☐	☐	☒	☐
Din utbildning	☐	☐	☐	☒	☐

Fortsättning hälsa och välmående. Hur nöjd är du med följande?	Mycket missnöjd				Mycket nöjd
	1	2	3	4	5
Ditt arbete	☐	☐	☒	☐	☐
Din fritid	☐	☐	☒	☐	☐
Din familjesituation	☐	☐	☐	☐	☒
Din vänskapskrets	☐	☐	☐	☒	☐
Din livssituation överlag	☐	☒	☐	☐	☐

C. Livsföring. Vad gör du på din fritid?

	Varje dag	Varje vecka	Varje månad	Varje år	Aldrig
	1	2	3	4	5
Idrottar/motionerar	☐	☒	☐	☐	☐
Besöker eller engagerar mig i konserter/ kulturevenemang	☐	☐	☐	☒	☐
Är ute i naturen. Ex. vandrar eller plockar bär.	☐	☐	☒	☐	☐
Shoppar/tittar i butiker	☐	☐	☒	☐	☐
Tittar på TV/film	☒	☐	☐	☐	☐
Använder dator (ex. surfar, spelar spel)	☐	☒	☐	☐	☐
Umgås med vänner och familj	☐	☐	☒	☐	☐
Läser tidningar/böcker	☐	☒	☐	☐	☐
Andligt utövande/mental träning Ex. religion, meditation, yoga	☐	☐	☐	☒	☐
Matlagning/bakning	☐	☐	☒	☐	☐
Odling	☐	☐	☐	☒	☐

Annat, nämligen______________________________

D. Ekonomi

Markera på skalan från "Inte alls" till "Mycket väl" För hur väl dessa påståenden stämmer in på dig.

Stämmer:	Inte alls				Mycket väl
	1	2	3	4	5
När jag jämför de månatliga intäkterna med utgifterna så går det ihop utan svårigheter.	☐	☐	☐	☒	☐
Jag är fullkomligt nöjd med min materiella standard, dvs saker jag kan köpa för pengar såsom boende, möbler, bil, resor, prylar, etc.	☐	☐	☐	☒	☐
Om jag får en oväntad räkning på 20 000 kr så kan jag utan större problem betala den inom en vecka.	☐	☒	☐	☐	☐

E. Bostadsområdet

1. Hur **nöjd** är du med följande aspekter? Vänligen fyll i på skalan från "inte alls nöjd" till "mycket nöjd"

	Inte alls nöjd				Mycket nöjd
	1	2	3	4	5
Hur husen är byggda/utformade	☐	☐	☐	☒	☐
Skötseln av fastigheterna i området	☐	☐	☒	☐	☐
Tillgång till torg och öppna platser	☐	☐	☒	☐	☐
Skötsel/städning av torg och öppna platser	☐	☒	☐	☐	☐
Tillgången till park- och naturområden	☐	☐	☒	☐	☐
Tillgång till gång- och cykelbanor	☐	☐	☐	☒	☐
Möjlighet att ta sig fram till fots/med cykel	☐	☐	☐	☒	☐
Kollektivtrafiken till/från Långängen	☐	☐	☐	☒	☐
Tillgång till gator och vägar till/från Långängen	☐	☐	☒	☐	☐
Tillgång till kommunal service	☐	☐	☒	☐	☐
Tryggheten i Långängen kvällar och nätter	☐	☐	☐	☒	☐
Tryggheten i Långängen dagtid	☐	☐	☐	☒	☐
Tillgång till olika typer av mötesplatser	☐	☐	☒	☐	☐
Långängen i dess helhet som plats att bo och leva på	☐	☐	☐	☒	☐

2. Hur **viktigt** tycker du att det är med olika tänkbara **satsningar** i Långängen? Vänligen svara på skalan från "inte alls viktigt" till "mycket viktigt".

Satsningar på..	Inte alls viktigt				Mycket viktigt
	1	2	3	4	5
..att bygga fler bostäder	☐	☐	☒	☐	☐
..renovering av befintliga fastigheter	☐	☐	☐	☒	☐
..fler grönområden	☐	☐	☐	☐	☒
..bibliotek	☐	☐	☐	☐	☒
..gång- och cykelbanor	☐	☐	☐	☒	☐
..vägarna	☐	☐	☐	☒	☐
..kollektivtrafiken	☐	☐	☐	☒	☐
..lekplatser	☒	☐	☐	☐	☐
..olika typer av mötesplatser	☐	☐	☐	☒	☐
..affärsutbudet	☐	☐	☐	☐	☒
..motionsanläggningar	☐	☐	☐	☐	☒
..bättre städning och underhåll av gator och allmänna platser	☐	☐	☐	☐	☒
..ökad trygghet och säkerhet	☐	☐	☐	☒	☐
..mindre skadegörelse	☐	☐	☐	☒	☐

Annan satsning som du tycker är viktig, nämligen:

3. Hur är samhällsklimatet i Långängen? Hur väl stämmer påståendena nedan överens med hur det är i Långängen. Svara på skalan från "inte alls" till "mycket väl"

Stämmer:	Inte alls				Mycket väl
	1	2	3	4	5
I Långängen ställer vi upp för varandra	☐	☐	☒	☐	☐
I Långängen finns mycket konflikter mellan invånare	☐	☒	☐	☐	☐
Långängen är ett socialt segregerat område	☐	☒	☐	☐	☐
Långängen är en bra plats för barn att växa upp på	☐	☐	☐	☒	☐

4. Funderar du på att flytta från Långängen ☐ Ja ☒ nej

5. Här nedan finns en kartbild över Långängen. Vänligen **markera platser där du trivs särskilt bra** och gärna vistas på när du är ute? Sätt en tydlig markering (ring) runt de plaster du tänker på. (Max tre platser)

6. Här nedan finns en kartbild över Långängen. Vänligen **markera platser där du <u>inte</u> trivs och känner dig särskilt otrygg** på? Sätt en tydlig markering (ring) runt de plaster du tänker på. (Max tre plaster)

F. Lägenheten

1. Hur nöjd är du med följande aspekter i din lägenhet. Vänligen markera på skalan från "inte alls nöjd" till "mycket nöjd".

How are you satisfied with following objects!

	Inte alls nöjd				Mycket nöjd
	1	2	3	4	5
Naturligt ljusinsläpp	☐	☒	☐	☐	☐
Ljudisolering i huset (ex. mellan dig och grannar)	☐	☒	☐	☐	☐
Ljudisolering utifrån (ex. från gatan)	☐	☒	☐	☐	☐
Temperatur sommartid	☐	☐	☐	☒	☐
Temperatur vintertid	☐	☒	☐	☐	☐
Ventilation och luftkvalitet i lägenheten	☐	☐	☒	☐	☐
Köksinredning	☐	☐	☐	☒	☐
Badrumsinredning	☐	☐	☐	☒	☐
Förvaringsutrymmen för kläder	☒	☐	☐	☐	☐
Förrådsutrymmen som hör till lägenheten	☐	☒	☐	☐	☐
Trivsel överlag	☐	☐	☐	☒	☐

Tell your flat answer following affirmations -

2. Om dig och din lägenhet. Hur väl stämmer följande påståenden? Vänligen svara på skalan från "inte alls" till "mycket väl".

Stämmer:	Inte alls				Mycket väl
	1	2	3	4	5
Jag trivs bra i min lägenhet	☐	☐	☐	☒	☐
Lägenhetens standard är bra	☐	☐	☒	☐	☐
Jag känner mig säker i min lägenhet	☐	☐	☐	☒	☐
Jag känner mig stolt över min lägenhet	☐	☐	☒	☐	☐
Jag känner mig stolt över huset	☐	☐	☒	☐	☐

Importance of possible investments

3. Hur viktigt tycker du att det är med olika tänkbara **satsningar** i din lägenhet? Vänligen svara på skalan från "inte alls viktigt" till "mycket viktigt" för de olika förbättrings- och förnyelseåtgärderna.

Förbättra/Förnya..	Inte alls viktigt				Mycket viktigt	Gäller ej mig
	1	2	3	4	5	
..köksinredningen överlag (vitvaror, diskbänk, skafferi etc)	☐	☐	☐	☐	☒	☐
..köksinredningens användbarhet (arbetshöjd på diskbänk/köksbänk etc)	☐	☐	☐	☐	☒	☐
..badrumsinredningen överlag (WC, handfat, dusch/badkar etc) Bathroom furnishment	☐	☐	☒	☐	☐	☐
..badrummet överlag (väggar, golv etc)	☐	☐	☐	☒	☐	☐
..ytskikt på väggar och golv i vardagsrum	☐	☐	☐	☐	☒	☐
..vardagsrummets fönster	☐	☐	☒	☐	☐	☐
..ytskikt på väggar och golv i sovrum	☐	☐	☐	☐	☐	☒
..sovrummets fönster	☐	☐	☐	☐	☐	☒
..ytskikt på väggar och golv i hallen	☐	☐	☐	☐	☒	☐
..ventilation från spis (dvs köksfläkt eller motsvarande)	☐	☐	☐	☒	☐	☐
..ventilation i badrum bathroom Ventilation	☐	☐	☐	☒	☐	☐
..ventilation i lägenheten i övrigt.	☐	☐	☒	☐	☐	☐
..ljudisolering inomhus	☐	☐	☐	☐	☒	☐
..ljudisolering utifrån	☐	☐	☐	☐	☒	☐
..temperatur inomhus på våren Temperature Spring	☐	☐	☒	☐	☐	☐
..temperatur inomhus på sommaren " Summer	☐	☐	☒	☐	☐	☐
..temperatur inomhus på hösten " Autumn	☐	☐	☐	☒	☐	☐
..temperatur inomhus på vintern " Winter	☐	☐	☐	☐	☒	☐
..förvaringsutrymmen för kläder Facilities for clothing	☐	☐	☐	☐	☒	☐
..förrådsutrymmen (vind/källare)	☐	☐	☐	☐	☒	☐

Annat som du anser skulle vara viktig att förbättra/förnya, nämligen________________________

Vilken av ovanstående satsningar skulle det vara motiverat att betala för?________________________

G. Inflytande och samverkan

1. När det gäller **bostadsområdet**, vad tycker du är viktigt att du som boende har inflytande över?

___

2. Om du hade möjlighet, skulle du vilja vara mer engagerad än vad du är idag gällande **bostadsområdet**?

☒ Ja ☐ Nej ☐ Vet ej

3. Känner du dig involverad i beslut som rör **din lägenhet**?

☐ Ja ☒ Nej ☐ Vet ej

4. Hur viktigt skulle du värdera att följande saker är rörande inflytande och kommunikation. Vänligen markera på skalan från "inte alls viktigt" till "mycket viktigt".

	Inte alls viktigt					Mycket viktigt
Boende ges inflytande i planeringsfasen vid eventuell renovering av lägenheterna i Långängen	☐	☐	☐	☐	☐	☒
Boende ges möjlighet att påverka förslag om eventuell renovering	☐	☐	☐	☐	☐	☒
Information om eventuell renovering till boende i Långängen	☐	☐	☐	☐	☐	☒

5. När det gäller din lägenhet, vad tycker du är viktigt att ha inflytande över vid en eventuell renovering?

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6. Känner du att du har fått gehör för dina önskemål och synpunkter du ställt till Familjebostäder?

☐ Ja ☒ Nej ☐ Har ej haft några önskemål/synpunkter

7. Övriga synpunkter: