Modelling the configuration and dynamics of urban space

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Abstract: - Excessive CO2 emission and its effects on global warming has become a primary issue of urban and regional planning. Cities' space-uses and intra-urban traffic are the main contributors to global warming. Space-uses as well as traffic patterns are processes exhibiting characteristic dynamic properties. Focusing on sustainability issues in planning thus means to deal with cities as processes rather than just spatial structures. The problem of representing cities as processes lies in the complexity added by introducing the dimension of time. It is hopeless to model cities in terms of, e.g. time geography. [9] We thus propose a more pragmatic approach, an approach that combines a bottom-up representation of a characteristic overall topological feature of urban space with a top-down representation of an overall dynamical feature that the city, when looked at as a process, exhibits. The overall topological feature of urban space results from describing cities as facilities made for reasons of the exploitation of the advantages of close proximity to a large number of other people. The overall dynamical feature of the city conceived as a process relies on the dynamical stability of the activity patterns that space-uses characteristically consist of. By thus combining topology with dynamics we show the possibility of modelling the city as a process with the standard data available.

Key-Words: - urban space and urban dynamics, city rhythms, sustainable settlement structure, systems theory, environment and sustainable development, optimization, walkable cities

1 Introduction

Managing the threats of global warming and thus reducing CO_2 emission has become the major challenge of today's urban and regional planning strategies towards sustainability of societies' livelihood. Besides targeting policies and technologies capable of reducing emissions in the fields of traffic, industry and housing, a more far-reaching solution has to be found regarding the very avoidance of emissive activity. The post-oil city will have to be walkable, i.e. vastly dispensing from the need of automotive traffic. What is at issue is a redesign of existing structures in the sense of re-compactification. The planning tools available thus far are poorly equipped to meet this challenge. What is needed is a representation of the city that allows searching the solution space of the problem of decarbonisation by ways of simulating self-organized adaptation.

Simulation models of urban development are known since the sixties of the last century. The main types of models developed back then were traffic simulations and the simulation of economic growth and decline. Ira S. Lowry was one of the main proponents of models simulating traffic and land use at the micro level. Jay W. Forrester became famous by presenting a model simulating the economic performance of urban areas on the macro level. [13,4] Both these types of models have lived through ups and downs since then, neither has become a common planning tool however. The reason is that both types are large scale models consisting of vast numbers of equations, dealing with hundreds of parameters and being enormously data hungry.

The approach proposed here starts from extracting a dynamical picture of the city from census data. These data encompass residents, workplaces, commuters and destinations of commuter trips and thus allowing modelling the daily redistribution of day and night population of the city. Modelling these rhythms is basic in two respects. Firstly, the post-oil city is the city having succeeded to minimize the share of car traffic in this daily redistribution. Intra-urban automotive commuter trips are the main source of traffic emissions. Secondly, the daily redistribution of day and night population is the heartbeat of the city when looked at as a living organism. Living organisms, moreover, are hierarchically ordered systems of synchronized rhythms when looked at as processes. Modelling cities as systems of synchronized

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rhythms is a powerful and very economic way of modelling the city as a process because it enables us to utilize the powerful paradigm of dynamics in describing this process. [1][12]

2 Problem Formulation

For searching the solution space of the problem of de-carbonisation, a representation or model of the city is needed which allows a simulation of the overall effect of re-arranged patterns of space-uses and densities on the intra-urban commuter traffic volume. This model has to make highly efficient use of the standard data available. It would be hopeless to describe the processes making up the city in detail. Nor is it possible to account for the sum total of the trajectories of the agents (people and vehicles) populating the city in terms of, e.g., time geography. [2] [9] In order to describe the city as a process, certain statistical features of the activity patterns have to be identified which have the potential of depicting the entirety in a representative way.

2.1 The city as a process

A stumbling block formidably hindering the description of the city as a process is the usual distinction between stocks and flows. Distinguishing between stocks and flows means to restrict processes to processes of change. Rest and duration, however, are processes as well. Above all, the difference between stocks and flows is in fact just a question of scale. What appears as a stock in the short run turns out to be a flow in the perspective of years or decades. Buildings, e.g., are usually considered stocks, but they turn out to be material flows in the long run, necessitating regular re-investment cycles for continuing to be usable facilities. Certain parts need renewal in intervals of five to ten years, others only every ten to twenty years. For practical reasons, renovating activities are synchronized so that when roofs and facades are renewed, most probably windows, doors and wall painting will be renewed as well. Space-uses, when conceived as activity patterns, also assume the shape of rhythms. The movements they consist of tend to return to their initial conditions regularly and to recover as rhythms after disturbances. They thus show the characteristics of what dynamics conceive as *stable* processes. Rhythms are the epitome of stable processes. The daily redistribution of day and night population is just the master clock of the whole system of city rhythms in terms of activity patterns. Day population in the urban agglomeration is centralized to a higher degree than night population since work places are located more centrally on average than residences. The work-daily exchange rhythm overarches shorter rhythms like the daily activities of production and consumption, whereas it is locked into longer rhythms as weekly, monthly or yearly rhythms which modulate it. The weekly rhythm e.g. modulates the work-daily rhythm in the way that weekend trips towards the countryside alternate the work-daily rhythm. On weekends, the day population is less centered than the week-daily night population. The view of the city as a dynamic system of synchronized, hierarchically ordered rhythms is apt to display the city in its entirety as a basically stable process.

Stability, as a property of processes, does not mean that nothing happens, but that, what happens, happens over and over again. Stable are such processes that tend to return to their starting point (initial conditions). Both the stability and instability of processes have measures in time. The measure of the stability of a process lies in the relaxation time, i.e. in the time that the rhythm needs for recovering after disturbances. Instability, as a property of processes means that disturbances are amplified instead of being dampened. Since processes strongly amplifying disturbances become highly sensitive to small differences in the initial conditions, they tend to turn small causes into big effects. Instable processes, accordingly, are characteristically difficult to forecast. The measure of the instability of processes is the time horizon within which sensible forecasts are still possible. For cities, both stable and instable processes are constitutive. Self-organization, according to dynamics, results from a coupling of stable processes with instable processes. Instable processes, nevertheless, are hard to model. We thus focus on the city as a system of rhythms. Even the detailing of the rhythms overarched by the daily rhythm faces difficulties regarding data requirements. There are no social data available on the level of single buildings or even blocks. As a makeshift, we resort to the spatial structure embedding the activity patterns which await being modeled as rhythms. What, hence, is the structure of urban space that is as basic as the rhythmic nature of the activity patterns?

1 For an introduction see Kaplan & Glass 1995.

2 In the sense of Hägerstrand 1970.

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2.2 The nature of urban space

Elaborating the most basic and pervasive properties which lie at the heart of the space occupied by space-uses means having to look for the very reasons why cities exist. Cities have come into place and time because of the benefits that accrue from living in close proximity to a large number of other people. The structure of urban space thus relies on the conditions under which the living together of a large number of people in close proximity becomes beneficial. Proximity presupposes that the activities making up the city are densely packed and allowed to interact throughout the whole system. Dense package of activities unavoidably causes interferences and disturbances which have to be dampened at least in order to make them bearable. The solution to this problem, observed in settlements world-wide, lies in separating and shielding rooms by walls and doors. At the same time, however, the spaces accommodating the activities have to be accessible from all the other spaces accommodating activities to enable contact and exchange. The combination of shielding and access is a problem not as trivial as it may seem on first glance. If there was unconditional access to the spaces, the problem of disturbances would prevail. If the rooms were to be directly connected, the connection channels would rapidly become space-filling. Again, however, the two-fold problem of separation and connection is solved in the same fashion observed world-wide: Each space in a configuration of spaces is accessible via another space and is itself giving access to other spaces. Space-uses thus consist of a systematic mix of occupation and circulation. By thus passing accessibility from one room to another, chains or trees of rooms are forming that are connected by thresholds facilitating and, at the same time, filtering access. The trees establish an hierarchical order of accessibility: The main street gives access to the side street which in turn gives access to the lane, which in turn gives access to the door way giving access to the staircase, which in turn gives access to the hall of the flat giving access to the corridor, which gives access to the separated rooms of the flat. Even inside the flat the structure of being accessed and giving access to is continued in the way that the room gives access to the cupboard which gives access to the box which contains the necklace. This chaining of access can be observed when looking at floor plans, houses, building blocks, neighbourhoods, districts and the overall city structure itself. In this way, architectural space continues without break into urban space. Thus there is a well-defined hierarchy, leading from central spaces at the top of the trees of accessibility to peripheral spaces at the bottom. At each level of the tree, when stepping down successively from top to bottom, the relation of being given access and giving access to is repeated, though with the inclusion of filters which preserve the shielding functions of walls. Such filters may be doors, security personal, symbols like road signs or architectural marks. When stepping down the tree the general characteristic is as follows: the space lying higher in the hierarchy giving access to the space situated lower in the hierarchy is more public than the one accessed, which in turn is more private. Thus, a gradient regarding the public or private character of the spaces thus connected is emerging. Instead of an all-or-nothing dichotomy, the difference between publicity and privacy is established as a matter of degree.

2.3 Space Syntax

Remarkably, the differences of accessibility as a main trait of the nature of urban space can be measured by the method Space Syntax, developed since 1984 at the University College of London by Bill Hillier and colleagues [10,11]. Space Syntax represents the chains or trees of connected spaces graph-theoretically, thus rendering possible the measuring of topological distances within the configuration of spaces. The topological distance between a given space and the rest of spaces in the configuration gives expression to the unequal distribution of accessibility within the configuration. The parameter called depth measured hereby correlates to a remarkable degree with the observed pedestrian flows in the city. This means that by the outcome of the Space Syntax analysis we can link the concepts of centrality and accessibility to dynamic concepts of movement flows and so-called “live centrality”. Space Syntax thus makes the concept of urban space operational in terms of configuration. Yet, there are shortcomings due to the purely spatial analysis. In Space Syntax, there is no dimension of time and so, no notion of dynamics. For modeling the activity patterns that space-uses consist of, the chains or trees of connected spaces are more relevant than the overall distribution of accessibility in the configuration space. Moreover, the filtering function of the thresholds giving and controlling access is disregarded. This filtering function is essential for establishing the ladder of steps between maximally public and the intimately private rooms.

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3 Problem Solution

For modeling the activity patterns in the hierarchy below the circadian rhythm it is of utmost interest that there is an almost perfect match between the hierarchy of rhythms and the hierarchy of nested spaces. It is so and so often that we move back and forth between desk and shelve in our room before leaving it for visiting a collaborator in her or his room. We go back and forth in the office tract before leaving it to have lunch in the coffee house nearby. In the coffee house we meet friends or colleagues that behave like ourselves and return to their working place after lunch. Back there, they resume the characteristic oscillatory pattern until, in the evening they go home, i.e. to where they started in the morning. Characteristically, we commute a number of times within our city before leaving it for other cities in our own country, that we travel back and forth so and so often within our country before leaving it for foreign countries or continents, from which, however, we again shall return to from where we started. It is always the threshold between a space that is more private and a space that is more public that we cross when leaving (or coming back). The office room is more private and less public than the corridor, the corridor is more private and less public than the staircase, the staircase is more private and less public than the pedestrian walkway, the pedestrian walkway is more private and less public than the side street, the side street is more private and less public than the transit road, the transit road is more private and less public than the arterial road, the arterial road is more private and less public than the highway, the highway is more private and less public than the interstate. It is always this kind of hierarchy that we are climbing up and down when switching from shorter rhythms to longer ones (and back again).

The combination of – and interplay between – the description in terms of synchronized rhythms and the description in terms of nested spaces renders it feasible to extend the simulation beyond the circadian rhythm. In order to demonstrate this we propose to start with a bottom-up description of the city in question as a hierarchy of nested spaces. For a representative sample of blocks we identify the hierarchy with the help of existing (building permission) plans and maps. The higher levels will be charted city-wide. At the same time, the basic rhythm of redistribution of day and night population will be modeled in a top-down manner. Starting with the representation of the overall redistribution of population on the basis of residents and working place data, the detailing starts with correlating the overall picture with the main traffic flows. The available traffic census data will be used for tracing – and visualizing – the daily profile of the traffic flows in the major roads and the subway lines. Bottom-up, then, scenarios will be developed for simulating the activity patterns of the space-use of selected buildings of the blocks in the sample. Activities will be visualized as rhythmic movements of persons in rooms, corridors, on floors, in the neighbourhood. In a further step, the places of modal split in the traffic flows will be mapped and correlated to the mapping of the hierarchy of nested spaces. Since there are no reliable data regarding the percentage of commuter traffic of total volume and since there are no traffic censuses in minor streets, the tracing of the traffic flows between the intermediate and the bottom level has to done by way of back and forth plausibility. The aim is not an empirically precise model, but a hypothetical model that highlights the parameters that need to be measured empirically in order to turn the model into a theory. The aim is to generate a model that allows visualization of the city as a process. It is only on the basis of such a model that we can think about going into the simulation of adaptive reactions of the city shape to changing boundary conditions.

4 Conclusion

Since urban space is not only densely packed but also intensely used, the characteristic configuration of urban space should be able to find its correspondence in the characteristic configuration of activity patterns taking place in the form of rhythms in the city. When we compare the hierarchy of these synchronized rhythms with the hierarchy of the nested spaces of the urban configuration, we face an almost perfect match. We observe a structural invariant repeating itself over a hierarchy of scales in a self-similar way in both time and space. Thus, the hierarchy of synchronized rhythms is a projection into time of the same configuration of activity patterns that project into space as the hierarchy of nested spaces [7].

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