

# **Self-Organizing Geography**

## *Scaled Objects and Regional Planning in the U.S.*

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The deficiencies of any kind of central planning are exposed by comparison with the paradigm of complex, evolutionary systems. Ideologically, market-democracies borrow that paradigm, subject to the distortions imposed by economic and political concentrations of power that seek control of resources. Economic space-time (geography) is a resource very much subject to such would-be concentrations of control by “top-down” forms of planning. In the U.S. particularly, the dichotomization of “land use” and “transport” planning and the ongoing contention about how such planning should be allocated and supported by models, illustrates the divergence between the ideological theory and contention for control. This paper traces some history of that contention and offers the scale hierarchy as a prescriptive framework that respects both the evolved governance hierarchy and the distributed preferences and uncertainties such governance must accommodate.

## **1 Introduction**

In the 1970's, the U.S. Department of Transportation, inspired by Ilya Prigogine [1], sponsored work on self-organizing models of cities and regions. These nonequilibrium, evolutionary, models integrated land use and transport for long-range planning and have been adopted by some countries for regional and environmental planning. However, the work was never adopted by the intended market in the U.S.: The Metropolitan Planning Organizations (MPOs) that maintain regional models for 20-year long range plans as required for federal-aid transport project programming [2]. The interest in integrating transport and land use models—in short, true models of human geography—has never gone away and efforts continue to revamp the conventional (non-integrated, deterministic, quasi-equilibrium) models used by almost all of the nearly 400 MPOs. But the divergence between theory and practice was clear from the beginning, in the debate between planners and highway engineers that resulted in the 1962 Highway Act that created the MPOs.

It is often said that the highway program, now the federal-aid surface transport program, got the country out of the mud at the beginning of the 20<sup>th</sup> century, and into the muddle of congestion, pollution and sprawl by the middle of the last century. There are no political jurisdictions commensurate with urban-regional interactions: In lieu of such jurisdictions, MPOs were created by federal law to allocate federal funds via regional planning under multiple jurisdictional goals, striving toward the models and the process to deal with geographical complexity. This paper observes that a notion of scaled objects exists in the MPO process, but that these objects are mis-allocated from both a political and technical-capability perspective.

## **2 The Problem of Planning in a Market Democracy**

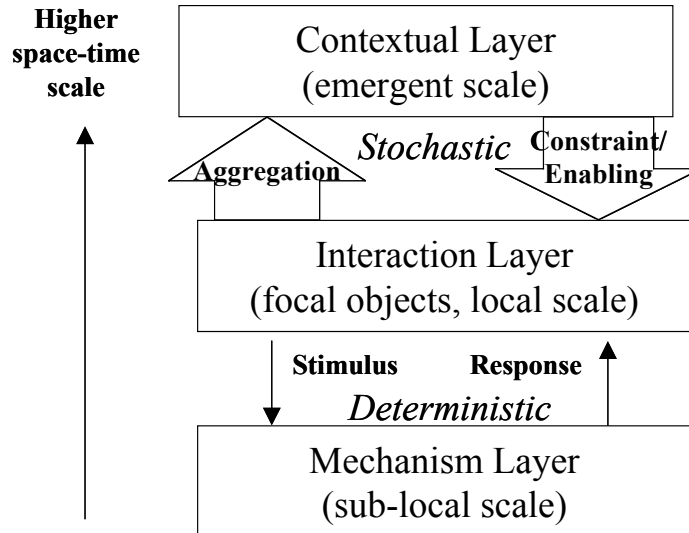
Scale is a key parameter of planning, and in the ideological contention over what is individual, what is in “the market”, and what is “public”. Scale has spatial and temporal dimension. Space includes the diversity of interests concerned and the number of choices affecting a plan. The time horizon is the interval between the dissatisfaction that initiates planning and the (hopefully) satisfactory outcome of planning. Uncertainty in planning grows exponentially with scale and requires the definition of objects appropriate to each scale of planning (which is just prospective decision making).

All complex societies encounter the Tragedy of the Commons (TOTC). The TOTC is simply the generation of externalities (e.g., congestion, pollution, and sprawl) from individual activities. The term “externality” refers to the scale differentiation between a purposeful action and unintended consequences that emerge as context for those actions. Location, thrice cited by realtors as the determinant of property value, is an emergent property of geography from human interaction. Emergence scales objects above the individual level, and so justifies governmental planning that involves police (regulatory) and eminent domain (project construction) powers. But planning, that is also a code word for socialism, raises ideological questions in a market-democracy because it adds an inevitable top-down component to

what is idealized as a bottom-up emergent organization. Debates about planning, including the dichotomy of land use planning—“bad” and delegated to the lowest jurisdictions—and transport planning—“good”, and assumed by the highest eminent domain jurisdictions—continue to represent an ideological schism and concern the allocation of scaled objects in planning to jurisdictional levels.

## 2.1 Scale Hierarchy

Emergence, as desirable or undesirable externalities, indicates self-organization and complexity within a scale hierarchy. The scale hierarchy concept used here owes much to Stan Salthe [3] who eloquently described it in the biosphere, with applications to adaptive control systems, government and any sort of complex system. The basic scheme is in figure 1:



**Figure 1.** The triadic layer structure of the scale hierarchy.

The scale hierarchy is triadic and centered on a focal layer partitioned into interacting objects such as purposeful individuals or jurisdictions with local information limits that correlate with geographical space-time extent. Obviously both mobility and telecommunications give individuals information about a variety of places that can be geographically separated. However, many planning issues involve discrete and compact jurisdictions, each of whose information and interests are correspondingly discrete and compact. Below the focal scale are mechanisms that the interactors control reliably in order to act on their purposes: For instance, individuals use a mode to go places. The relation is *relatively* causal and deterministic. The stimulus-response couple can be learned from experience, or is governed by physical “law”.

Above the focal scale is a context of action that in self-organizing systems also emerges from interaction. Geography is a good example. The relation between the focal and contextual scales is *relatively* stochastic: No local action determines context and context does not determine local action. Even though each actor perceives a context that is static over the scale of local action, the context is evolving non-deterministically at its scale. Context can be physical (roads, buildings), or logical (the price of housing, or a set of rules). Context both constrains and enables. It may be said that the focal-mechanism interaction represents *development*, while the focal-contextual interaction represents *evolution* within the overall self-organizing system, analogous to the “evo-devo” complementation in biology.

We can shift the focal scale layer to other space-time physical, or conceptual, scales such as jurisdictions. However, there must be a distinction between the physical and *ex officio* individual at different scales. Every person, no matter what their position of political or economic power, has the same physical scale limits and uses mechanistic physics. However, the idea of an *adaptive* command structure is that a higher official is in a contextual relation to subordinates: The scale relation must be such that it is not deterministically rigid, but allows a degree of freedom between higher “strategy” and local “tactics”. The functional differentiation of scales is determined by this rule of loose, indeed stochastic, vertical coupling.

The political issue of planning is in the contention between a tighter corporate/military command hierarchy and a looser scale hierarchy. Few deny the need for a contextual layer of rules. As Hayek [4] emphasized, there are evolutionary or common laws (nomos) and legislated laws (thesis) that might also be called “developed” laws. Historically, geography has been a self-organized network mostly beyond thesis. The *right-of-ways* (links) co-evolved with common law, *rights-of-way* rules. The power to condemn land for purposefully established roads or tracks is governmental eminent domain power. That power supports thesis, in the form of the federal-aid surface transport program, and many other planning and environmental regulations in what is here dubbed Eminent Domain Planning (EDP). The problem is how the scale hierarchy of geography should relate to a set of scaled objects in EDP.

## **2.2 Scaled Objects in Transport Planning**

The region is a scaled object in EDP. MPOs were federally created to program federal-aid transport projects absent regional political jurisdictions, and a region is legally defined in census terms as an urbanized area. MPO boards include county jurisdictions overlapping the urbanized area. The state department of transportation, and regional transit authorities, as the actual recipients of federal aid and the actual project builders/operators, are also voting MPO members. Conceptually, a region is a super-jurisdictional area defined by externalities, at least air pollution and congestion as related to traffic. The MPO produces long range plans (LRPs) over 20-year horizons at five-year updates, and Transportation Improvement Programs (TIPs) at 2-year updates [23 USC 134]. Nominally, the LRP is a strategy and the TIP the

programming menu for the sequence of project steps (tactics). The MPO itself, but sometimes the state, operates a regional network model for the LRP to certify TIP entrants.

Eminent domain clearly scale-ranks jurisdictions (federal-state-local...) but the ambiguity is the degree of freedom allowed between political levels. The federal-aid program, in which no projects (with the exception of those on federal lands) are built or operated by the federal government, is a response to historically-strong constitutional scruples against federal involvement in “internal improvements”. Table 1 shows the year 2000 proportions of highway user revenues collected (that are themselves only 63.5% of highway disbursements) and highway disbursement [5, Table HF-10]. The federal highway trust fund revenues go mostly to states, providing significant leverage for major highways, and similarly for about \$5 billion per year in federal aid to transit authorities. States and localities chafe under the categorical constraints of top-down funding, and the federal planning/environmental procedure that comes with the funding.

**Table 1:** Distribution of Highway Revenues and Disbursements in 2000

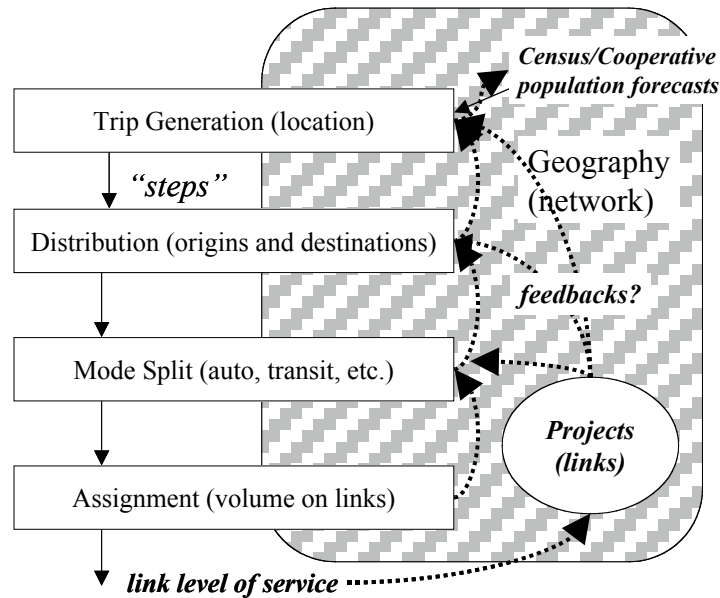
	<b>Federal</b>	<b>State</b>	<b>Local</b>	<b>Total</b>
<b>User Revenue \$billions</b>	\$29.7 B	\$49.0 B	\$2.3B	\$81.0B
<b>Row %</b>	36.7%	60.5%	2.8%	100%
<b>Disbursed \$billions</b>	\$2.3B	\$77.9B	\$47.3B	\$127.5B
<b>Row %</b>	1.8%	61.1%	37.1%	100%

One ambiguity in EDP concerns accountability for projects. This is called the ping-pong planning syndrome, enunciated in Mowbray [6]. It refers to the experience of highway opponents who are referred from planners to politicians up the eminent domain chain, finally to discover that federal authorities claim no determination of what projects get built. This ambiguity of accountability destroys the political enfranchisement of citizens to affect plans politically. The MPO is nominally the local-approval authority for expenditure of significant public funds, but the MPO is not an electoral jurisdiction, and is strongly affected by state and MPO planning technicians. A second ambiguity concerns the relation of LRP to TIP. There is a strong normative contention, especially on the part of federal certifiers of MPO activity, that the LRP should not be a “staple job” of projects that simply go into the TIP: In other words the LRP and its network modeling should be a contextual strategy. But achieving this is hindered by technical limits of analyzing and predicting the evolution of geography.

### 3 Models of Geographical Complexity

The conventional MPO network model has four “steps”, as shown in figure 2. The

hierarchical view of the model represents a nest of contextual conditions that can be entered as sequential steps, and hence the common name of “four step” for the model. The focal step is assignment of trip paths to transport links, summing to volumes that can be compared to capacity as a level of service (LOS) measure of link performance. LOS is the primary criterion for projects of capacity expansion. Assignment is an equilibrium problem of trips trying to take shortest routes while the TOTC of congestion alters what is the shortest route, invoking the feedbacks from volume to travel time to volume. The significant issues about the four-step model concern how it handles all the other feedbacks that exist in geography. It should be noted that a new model structure called TRANSIMS [7] is being introduced. While TRANSIMS has its origins in self-organizing concepts, its use will not fundamentally alter the problem of feedbacks and scaled objects, especially with “land use” that remains an optional module under TRANSIMS.



**Figure 2.** The “four step” regional network model.

Many efforts have been devoted to various levels of feedback within the four-step or TRANSIMS structures. However, the fundamental problem is really in the scaled allocation of EDP decisions versus the scaled dynamics of geography. The regional decision-object of EDP, as a 20-year LRP, needs a context, but geography itself, especially as affected by multiple 5-year cycles of LRPs and TIPs, *cannot be taken even approximately as a stable context for long-range strategic planning.*

Regional models analyze limited sets of alternatives for LRPs. The models artificially create what looks like a planning context by eliminating feedbacks and entering upper layers as static constraints. The models then deliver equilibrium

predictions of geographical state, especially traffic LOS performance and its related air pollution emissions at a 20-year future. While sensitivity analyses are often done, their value as externally defined variations in improperly identified models is questionable. However, the business of the MPO in programming projects is mostly based on *current* LOS deficiencies that create the menu of projects “tested” by the LRP modeling as a *pro forma* step before TIP approval. The LOS deficiencies make projects “necessary”. This inverts what is supposedly a “strategy”-driven process. It promotes the ping-pong planning syndrome because tracing accountability back up the scales only returns to local conditions. The modeling does not invite close examination by its policy customers, who are neither technicians nor interested in destabilizing the political-power enhancements of distributing federal-aid funding.

The regional modeling of the LRP is used throughout the project-scale environmental analysis to defer strategic questions such as regional air pollution (a project can increase emissions but be “OK” under aggregate emissions budgets) or the transfer of bottlenecks throughout the network by removing a bottleneck in one location. Yet project link-level predictions of the regional models are *not* made public to allow scrutiny of their relation to projects. This helps suppress the fact that the regional models *do not have* the accuracy at the assignment level to resolve link LOS within the critical project-decision thresholds. The models are expected *at best* to be within a 15% volume error against *current* volume data [8, Figure 7-4, Maximum Desirable Error for Link Volumes] and that performance is consistent with the few model results that are available for inspection. But that error encompasses the whole range between acceptable LOS and link capacity (designated LOS D to F). The 20-year forecast of such models has *unknown* prospective validity. However, comparing LRPs from the 1970’s and 1990’s for the DC area shows that fast growth areas, where location and transport interact intensively, have errors around 100%. There is a significant uncertainty gap between the regional and project level. This has been recognized in federal attempts to introduce an intermediate level of analysis as the “major investment” or “corridor” study that addresses some area beyond local scale (especially for modal choice, trip generation and bottleneck-shift effects) but hopefully with higher resolution and less error than regional models.

The self-organizing models [9] [10] [11] included the range of geographical feedbacks, as nonlinear morphogenetic equations, in an urban and inter-urban hierarchy, to simulate realistic geographical evolution. Computer limitations in the 1970’s prevented the self-organizing models from being convincingly detailed. TRANSIMS today, with its heritage from cellular automata and its lavish use of computer power on micro-scale (individual trip) simulations represents the capability to implement the self-organizing models. The basic reason fully integrated models have not been pursued is that there is no expectation that any equilibrium exists for geography in full (viewed as a problem of network design with both competitive location and congestion). Geography modeled as a nonequilibrium system cannot provide either a context or control object for EDP. The nonequilibrium is only exacerbated by a policy of dissipating resources at traffic bottlenecks.

The lessons and experiences from self-organizing system modeling show that it

is impossible to get them adopted before the institutions and organizations that must use them are ready. The models developed over the years since the mid-seventies in collaboration initially with the USDOT, and later with the European Commission were not used or adopted. They clearly showed the importance of an integrated approach to social and economic development, demonstrating that land-use, transport, the geographical extension of the urban zones, retail and commercial development as well as housing and public services all interact. This leads to a complex cascade of effects as the spatial multipliers work through the system, changing patterns of demand and supply of goods and services, and the transport flows of these. Only now, some twenty-five years after the work was initiated has the first tentative use been made of these methods. This has been by the Asian Development Bank in attempting to assess the spatial social and economic impacts of new transportation infrastructure investments in West Bengal. Also, Guy Engelen, now at the RIKS institute in Maastricht, the Netherlands, working with Roger White has developed some versions of the self-organizing models of spatial interaction that the Netherlands government has successfully used. There are impressive presentation and display tools for the interaction of users with the models and this certainly contributes to their success. In the US, the idea of coupled land-use/transportation models is only now being developed by the Oregon DOT. If planning can be done at a truly strategic level, integrated models with the real freedom of geography to self-organize can be admitted.

#### **4 An Allocation of Scaled Objects**

The ambiguities in EDP, the political and technical challenges to procedure, and the limits of modeling in a complex geography all demand a clearer allocation of scaled objects to decisions and decision-support models: The uncertainty demonstrable in “strategic planning” must be matched to appropriately scaled strategic decisions, not “projects”. The current EDP process is ill-adapted to geographical variety, especially central city versus suburb, versus rural areas. The self-organizing models explicitly include the dynamics of geography whose complexity forces the basic question of how to allocate distributed, adaptive, but coordinated decisions about geography.

A prescription refers back to the basic scale hierarchy of Figure 1. A valid conception of the MPO is as a focal *collective* of interactions among local jurisdictions over project planning. If an artificially defined “region” is reified as a non-elective jurisdiction, it is too big to deal with projects and too small to deal with “strategies”—especially inter-regional resource redistribution—in a megalopolitan world. In any case, states are the next legitimate sovereignty above local governments (and the true sovereignty of localities varies greatly among the United States). Since there are many important multi-state (and even international) urbanized areas, the interaction of sovereignties at any scale cannot be avoided. Each of these scales needs a proper context for the interaction, but synthesizing a pseudo-jurisdiction to reify the peer collective muddles both the sovereign context and the proper degree of freedom of the constituents (as we see empirically with the MPOs). The project scale properly belongs to the locality of one or more infra-regional jurisdictions. The strategic level is above that, and of indefinitely large—certainly

multi-metropolitan and by the constitutional doctrine of the commerce power, national—scale.

Federal-aid transport thesis implements such a contextual strategy in several ways. However, the redistributed resources mediated by EDP are part of the muddle of the TOTC: By being divorced from “local” development and traffic-generation accountability, most of the funding is for more capacity for more traffic congestion. Looking back on the origins of the interstate freeway program that was the proximal motivation for the MPOs [12], the explicit strategy of reforming metropolitan areas for the sake of automobiles has met its limits and is obsolete. The *increasing* use of federal thesis by Congress to mandate specific “earmarked” projects is a clear violation of scale on behalf of political power concentration.

Strategic context should not decide plans or projects, but rather the *rules* of interaction relevant to geography. We should be looking in nomos for the rules regarding externalities in physical space-time. Among those are the evolved rules of rights of way and of damages. We have seen the *rights-of-way* laws (i.e., traveler rights), still on the books for pedestrians and bicycles, eradicated *de facto* by the automobile’s more powerful consumption of space (i.e., speed, momentum) accompanied by the externalities of noise, pollution and physical threat. Further, the eminent domain *right-of-ways* (i.e., strips of land, pavements and structures) for freeways and arterials disrupt local link networks and the pattern of development. This exercise of EDP is contrary to the historical co-evolution of access and place, and as reflected in historical procedures for laying out of roads. This dichotomization of “important roads” from places leads to the typical “sprawl” pattern of new development on cul-de-sacs or strip-malls debouching onto clogged arterials: We haphazardly develop networks of minimal local connectivity and maximum traffic generation. In terms of externalized damages, we need to apply accountability at the individual level and at the scale of local jurisdictions: The case of an upstream polluter needs to be extended to generators of traffic. By focusing only on link LOS, the externality (congestion) is accommodated rather than called to account, and it is the damaging party, not the damaged party, that EDP now favors with more capacity for the new traffic. Congestion tolls have long been advocated, but in the U.S. federal-aid law has long prevented tolling of the major highways (excepting separate toll-authority roads not under federal aid and recent “HOT” demonstrations mostly associated with *new* freeway construction).

Resource redistribution for development goals is a decision-object at the highest level of eminent domain. The federal-aid highway program, and its transit appendages, started out with that purpose. But the surface transportation program has devolved to a supposedly “equitable” (but in fact categorically and modally biased) channeling of funds from source back to source. If there are no differential inter-regional strategies as objects at the federal level, then the imposition of top-down eminent domain has outlived its rationale. EDP instead has entered the muddle of the TOTC of excess traffic, through a cross-subsidized consumption of metropolitan space. Rather than assuming some centralized plan—or even regional programming of projects to expend top-down resources—we need explicit context for the

interactions among politically enfranchised jurisdictions. Our very abhorrence of state and federal intervention in local affairs demands that their decision objects be truly contextual and allow local degrees of freedom. The self-organizing models demonstrate, rather than obscure, the predictive uncertainty in regional and inter-regional evolution. Geography is too complex for direct large-scale intervention, and must evolve as a ruly interaction among localities with well-defined accountability and local information. This prevents large-scale intervention at the project level, but exposes the dynamical parameters and feedbacks of interaction that need to be addressed contextually. That most likely includes breaking the positive feedbacks that now exist between generating congestion and getting top-down funding. The self-organization of geography is a matter of growth *and* limits.

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