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Representing urban development plans and regulations as data: a planning data model

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Abstract. Using plans and regulations when making decisions about urban development requires access to the many plans and regulations of many different organizations, both private and public. Current information technologies, the Internet and the World Wide Web in particular, make access to data from such disparate sources feasible. Using these technologies to implement a 'system of plans' approach to urban development planning will, however, require a widely shared data model for structuring the content and meanings of plans and regulations and a widely shared language, based on this data model. This paper presents an initial version of a planning data model (PDM), several use cases that set the scope of such a data model, and illustrations of how the current version of the PDM supports these use cases. Further work can build on this data model, including an XML (eXtensible Markup Language) implementation for sharing the information. These tools will enable urban development decisionmakers to conceive of planning as involving many actors whose many plans can provide useful and usable information.

In a world in which authority and influence are distributed, the various organizations deliberating and making urban development decisions benefit from access to information from many sources. These sources will include the products—such as plans and regulations—that emerge from previous deliberations by the same and other organizations. These plans may be formal, such as adopted public plans, or informal, such as community charrette reports or inferences from the minutes of planning commission meetings, and may be produced by different public or private entities at different times. In community charrettes, planning commission meetings, and expert collaborations, as the focus of attention is shaped and decisions are made, participants must be able to access and use plans, including 'plans in the making'. Plan making—consideration of combinations of actions before decisions about these actions are made—requires representations with which ideas can be created, communicated, tested, and then used.

The need to access and use the content of plans and the need for ways of representing plan-making ideas suggest that a shared data model should encompass the phenomena of urban development and the phenomena of plans and regulations. Query and model tools can then manipulate this content. Current information technologies, the Internet and the World Wide Web in particular, make access to data from such disparate sources feasible. This approach, which we call a 'system of plans' (SoP), emphasizes using the many plans that will already exist and focusing plan making on gaps among existing plans from the perspective of particular actors (Hopkins, 2001). This approach requires, however, a widely shared data model—a common reference schema for data storage—for structuring the content and meaning of this information and a widely shared language, based on this data model, for accessing and manipulating these data.

The SoP approach to planning also depends on institutional willingness to invest in the standardization, metadata, and institutional mechanisms necessary to sustain such access across organizations (Nedovic-Budic and Pinto, 2000). In the United States, as well as in many other situations, many local agencies plan, regulate, and invest through largely independent authority, but with long-standing recognition that the actions of other entities, both government and private and across local to national scopes, will matter in reaching intended outcomes. Formal and informal institutions have thus emerged in support of such mutual coordination, including regional planning agencies, councils of governments, federally designated metropolitan planning organizations for transportation planning, and informal technical advisory committees of staff of public works departments among municipalities and sanitary districts. These cooperative efforts provide examples of success in creating collaborations in equivalent situations and provide initial institutional frameworks to start from.

Implementation of such a system can be achieved iteratively, emerging from many actions. Initial implementations might be as basic as a single municipality encoding its action (or implementation) section of its plan as a database to keep track of what it has done in relation to its stated objectives. With spatial identifiers, its policies or regulations could be accessed for presentation to planning commissioners for particular cases. The payoff here may be sufficient to make it worthwhile for a single organization, and as with the experience of sharing data models in GIS, other municipalities can implement these capabilities more efficiently by imitation, which encourages standardization. In association with standardization of GIS data at the metropolitan region or county level, plan data can be included with less additional institutional effort or cost, and thus be shared among municipalities and infrastructure agencies. Some states mandate local planning with particular content and subject to review, which means these states have an incentive to standardize data about plan content. Federal funding of transportation in relation to air quality creates significant funding and incentives for coordination of content between transportation and land-use plans and among these and environmental regulations. Data sharing is not costless, but there are internal incentives from each entity to have better access to such data, their own and those of others, and there are external incentives to be able to coordinate to obtain funding from higher levels of government.

New tools and techniques will affect comparative capabilities of different participants and can be used intentionally to advantage currently disadvantaged persons or organizations. It is thus pertinent to devise better building blocks with which to achieve these aims. Good data models and tools can increase the scope of discussion rather than narrow it. For example, the planning data model (PDM) proposed here makes explicit that there are many different actors who are concerned about issues and who have differing capabilities. It is thus consistent with notions of planning as a multivoiced activity rather than merely a type of government decisionmaking. This paper focuses, however, on the technical ideas behind a PDM, not on these implications.

Development of a robust, widely shared data model will require concerted, long-term efforts by many active users who will generate ideas and test them. Whereas in the past much of the scholarly work has been focused on plan making, a shared data model must give equal importance to using plans. This paper describes an initial version of such a data model for urban development planning. First, we explain what a PDM might accomplish based on precedents in other fields and in planning. Second, we identify three broad sets of tasks as 'use cases' to set the intended scope and capabilities of the PDM. Third, we describe and explain the current version of an evolving PDM. Fourth, we describe more specific instances of the application tasks to illustrate the scope of the current version of the PDM. Finally, we conclude by identifying next steps building on this work, in particular initial ideas about an XML (eXtensible Markup Language) implementation of the PDM for intelligent access to the information and the potential to enhance urban development modeling.

Ideas to build on

Our work on a PDM builds on three threads of previous work: the logic of making and using plans, planning support systems, and geographic information science. All of these threads are couched within the contemporary perspective of urban planning as a collaborative activity in a world of distributed authority and influence in which plans are one kind of relevant information.

Elsewhere (Hopkins, 2001) one of us argues that there are several different ways in which plans work, that each of these is distinct from ideas of regulation, collective action, and collective choice, and that all of these concepts are important in expressing the meanings and content of plans and regulations. He argues that plans are information about interdependent decisions and that plans are useful when these decisions are indivisible and irreversible and the decisionmakers have imperfect foresight. Plans lay out lists of actions (agenda), if–then rules for repeated situations (policy), aspirations (vision), ex ante solutions (design), contingent action trees (strategy), and objectives.

In practice, many plans are made by many agencies. They are made with different functional, geographic, and organizational scopes and at different times. Many different decision situations arise, most of which can benefit from access to some of the information in many of these plans, not just from one plan of one particular organization. But just being able to see these plans and information would be information overload. We need a way to represent the content of plans, the meaning, so that indexes and search tools can find and display in useful and usable ways the information that is likely to matter in particular situations. We use the concepts of agenda, policy, vision, design, and strategy as ways in which plans work, and the concepts of interdependence, irreversibility, indivisibility, and imperfect foresight, as underlying relationships that make plans useful.

Planning support systems (PSS) are tools and techniques to enhance the effectiveness of planning through information technologies. Ironically perhaps, most PSS work, as presented, for example, in Brail and Klosterman (2001), focuses on the task of making plans rather than on the tasks of using plans. The activity of making plans is infrequent, dispersed, idiosyncratic, and highly unstructured in practice despite relatively codified procedures in textbooks such as that by Kaiser et al (1995). Making plans is, however, amenable to claims of support through providing separate, well-defined tools for forecasting or accounting for land-use change. The activity of using plans, on the other hand, is frequent (arguably ubiquitous) and in many cases is carried out within the semistructured deliberations of planning boards, community meetings, city council meetings, or court proceedings. From conventional arguments that computer-enhanced support systems are most likely to be valuable in repetitive, incompletely structured situations, PSS are more likely to be successful if they support planners, legislators, and citizens when using plans in deliberative decisionmaking rather than, or at least in addition to, when making plans.

Deliberations and decisions about urban development should be able to access various analytical models of urban development processes. The PDM, therefore, should include within its scope the representation of inputs and outputs of such models so that implications of plans and regulations for particular choices can be interpreted through using these simulation models. Many of the data entities for these models are also necessary to describe plans and regulations, so these capabilities are easily met.

Although there are many computing tools and models that might be used to support planning, none of them at present can be used in combinations sufficient to gain significant use in the open-ended situations faced in practice (Brail and Klosterman, 2001). Although PSS focused on collaboration have been developed (Armstrong, 1994; Jankowski and Nyerges, 2001; Jankowski et al, 1997; Shiffer, 1992; 1995), these systems also face the problem of accessing information beyond that specifically built into the systems by their developers for specific clients.

Hopkins (1999) sets out a framework from which a data model for PSS might be developed. That framework focused on representing the phenomena of urban development and activity patterns and the views of that data pertinent to tasks of planning. This paper builds explicitly on that framework of object classes for urban development acts and adds explicit representation of plans as information with particular uses in decisionmaking. The proposed PDM includes the phenomena of plans as well as the phenomena of urban development about which plans are being made.

Although aspects of urban development and plans are related to geographic features as developed in geographic information science, other aspects are fundamentally different. Working from the geographic information science perspective, Couclelis (1991) and Worboys (1994) identified key concepts of situation versus site and time, contingency, and expectations, which are central in representing plans. Laurini (2001) reviews data models currently used in PSS, and to a large extent these focus on the objects of urban development, not on the content or meaning of plans. Current work by Laurini and colleagues (Keita et al, 2004) on the "Towntology Project" also focuses primarily on urban development objects, not on plans. Plans themselves are about these urban development objects, so this paper elaborates on the semantic relationships between objects that are present in plans. Webster developed geographic information system (GIS) data models for physical plan monitoring, focusing on the geographic representation of urban development objects and attributes being monitored while representing plans only as intended outcomes (Webster, 1994; Webster and Omare, 1994). The PDM proposed here elaborates the content and meaning of plans so that they can be accessed as information when deliberating about decisions.

Developing a PDM requires an effort similar to the efforts that have resulted in GIS. What GIS are able to do now rests on a long history of fundamental intellectual developments (for example, see Chrisman, 1997; Longley et al, 2001). One version might start with Berry (1964) codifying geographic phenomena in time and space, include the idea of topological data structures (Peucker and Chrisman, 1975), and move on to more recent object-oriented models (Worboys, 1994; 1995; Zeiler, 1999). The OpenGIS Consortium has developed a reference data model for geographic information, which is described in detail at http://www.opengis.org/info/orm/03-040.pdf. This widely accepted data model is just now enabling the kind of wide accessibility for geographic data that we might eventually achieve for planning information with a PDM.

Use cases: using plans, making plans, and analyzing urban development ideas

The current PDM is intended to support three closely related tasks: using plans, making plans, and analyzing urban development ideas. Explanations of each demonstrate the relationships among them and frame the implied scope of a PDM. Staff planners use plans when consulting with those proposing a development project and developing a staff recommendation. Planning commissioners use plans when deliberating as a commission and voting on a recommendation to the city council. Making plans is in some ways similar to any other decision situation and thus has the characteristics just described for using plans. Crucially, however, plans involve multiple actions and decisions, and thus require means for representing 'plans in the making' as more complex than a single decision. To evaluate alternative actions or discover the implications of an action for evolution of a human settlement system, we use models to analyze the system. Each of these use cases is presented here as a vignette of a typical situation.

Using plans

A landowner and a developer who has acquired an option on the land propose a mixed-use development in an area currently zoned for residential. Having noted that the current comprehensive plan sets compact development and reduced auto use as goals, and that recent planning commission discussions have considered mixed use as a strategy, they consult informally with planning staff about the potential for rezoning (or perhaps handling under special provisions such as planned unit development or special use provision). Planning staff consider the comprehensive plan, a recent neighborhood plan that identifies densification and lack of retail services as an issue, a mass transit district proposal for increased service in this area, and a university plan to acquire additional land south of the neighborhood preventing further development in that direction. After informal neighborhood meetings with the developer and planning staff, staff develop a recommendation to the planning commission for approval of a modified form of the proposal. The planning commission holds a public hearing at which neighbors and the developer argue their views by referring to all these plans and others, as well as to the zoning and subdivision ordinances and the capital improvements program. The planning commission considers all of this in its deliberations, and makes a decision to recommend to the council a further modified version of the proposal.

Similar plan-use examples include deliberations about a capital improvements program within the budget and public works departments, planning commission, and city council; deliberations by the mass transit district about an investment in fixed guideway transit; and deliberations by the designated metropolitan planning organization (MPO) about transportation projects. The last carries over to the task of making plans because it usually involves many interrelated projects, which are interdependent, irreversible, indivisible, and face imperfect foresight, and thus decisions about these projects constitute plans (Hopkins, 2001).

Making plans

Outlying residents express increasing concern about directions of future development. Many retail activities and the associated tax revenue have recently moved to locations in an adjacent city. New interest from developers in major projects is apparent in recent land acquisitions. The city staff recognize that, although they have made several area plans recently, these plans are inadequate to address the issues and decisions arising in the current situation. They initiate a work program for a major revision of the comprehensive plan. This work program includes creation of a citizens' steering committee, a round of neighborhood meetings, a round of technical focus group meetings, frequent reporting to the planning commission and the city council on the status of the work, and eventually deliberation, public hearings, and a planning commission recommendation on a plan. Another view of this process is that it creates and sustains an evolving set of planning issues, goals, ideas, and evaluative criteria, which are discussed in light of an evolving set of pertinent data organized from existing sources or collected to respond to particular questions. The staff keep track of converging and contradictory ideas and evaluations of these ideas so that plans eventually emerge and are catalogued for use.

Similar plan-making examples arise from state mandates to make plans of particular kinds with particular frequency. Federal requirements for transportation planning and related land use, a project proposal for a site that begs a revised area plan for the neighborhood, a lack of capacity in sanitary waste treatment that forces a plan for plant expansion, and concern about a neighborhood 'in transition' that leads to city council members requesting a neighborhood plan to satisfy constituents. The diverse scopes of these situations require analyzing and modeling of human settlements that encompasses a similar scope of actors, activities, and facilities.

Analyzing urban development ideas

In the above stories about using and making plans, it is essential to be able to describe proposals, consider how each fits into the current and evolving situation, and keep track of multiple evaluations of each. All the players put models to work to accomplish these tasks. The developer uses a model of predicted demand for particular uses and configurations of these uses as well as a model of costs of development. The neighbors, implicitly at least, use models of property-value change, local revenue generation, and service-cost predictions. The city or special districts use models of traffic, revenue generation, services costs, sanitary waste capacity, runoff and drainage, and school capacity. The MPO uses transportation-network models in relation to land use. All these model users are trying to understand how variables of interest to them might change with or without a proposed project or the set of proposed investments and regulations in a plan.

Similar model-using examples occur when an MPO makes a transportation plan, a city devises a neighborhood-rejuvenation plan, a mass transit district reroutes or adds bus lines, a sanitary district decides when and where to build a plant of what size, a state agency assesses habitat fragmentation, or a regional agency develops a water-quality plan. To relate these models to the fundamental question of how the world will evolve with or without a proposed action, the models must be able to communicate in a common way with representations of the proposal as input and the concerns as output.

The PDM supports three use cases: using plans, making plans, and analyzing urban development processes. Using plans requires representing the content of plans in relation to decisions that can be made so as to choose among alternatives in light of expected consequences. Making plans requires representing ideas that may become components of plans and the manipulations of these ideas through which plans emerge. Analysis requires representation of pertinent aspects of states of the world, and inputs and outputs from the analysis. Many of the data-model entities required to support these three use cases are common across all three.

A planning data model

The current version of the PDM is presented in three levels of detail with associated definitions and examples. The first level describes the relationships among entities representing the world, entities representing changes in that world, and entities representing plans. Figure 1 uses icons to identify the abstract object classes in the PDM and their relationships. This diagram simplifies the entities and relationships in order to emphasize the overall structure. The entire system described in figure 1 is a state of the world and approximately the right-hand half describes planning and actions. That is, planning and action are embedded in states of the world and change states of the world. The explanations below describe, first, entities of urban development and, then, entities essential for encoding the meaning of plans. The explanations of encoding plans are the more important new contribution of this PDM.

First, we define the entities in figure 1 and then elaborate each of the major entities further through additional diagrams. Entity labels are in bold typeface to distinguish them. **Actors** include **persons**, **organizations**, or **populations** of **persons** or **organizations**. Any individual is a **person**, who may have multiple **roles** as elaborated later. A group of **persons** organized in **roles**, **responsibilities**, and decision rules is an **organization**. So, for example, households, firms (in the economic sense), neighborhood groups, government agencies, and city councils are **organizations**. The social structure of a neighborhood might be represented as an **organization**. **Populations** are collections of **actors** without organizational structure, such as the population of persons in a census tract or the

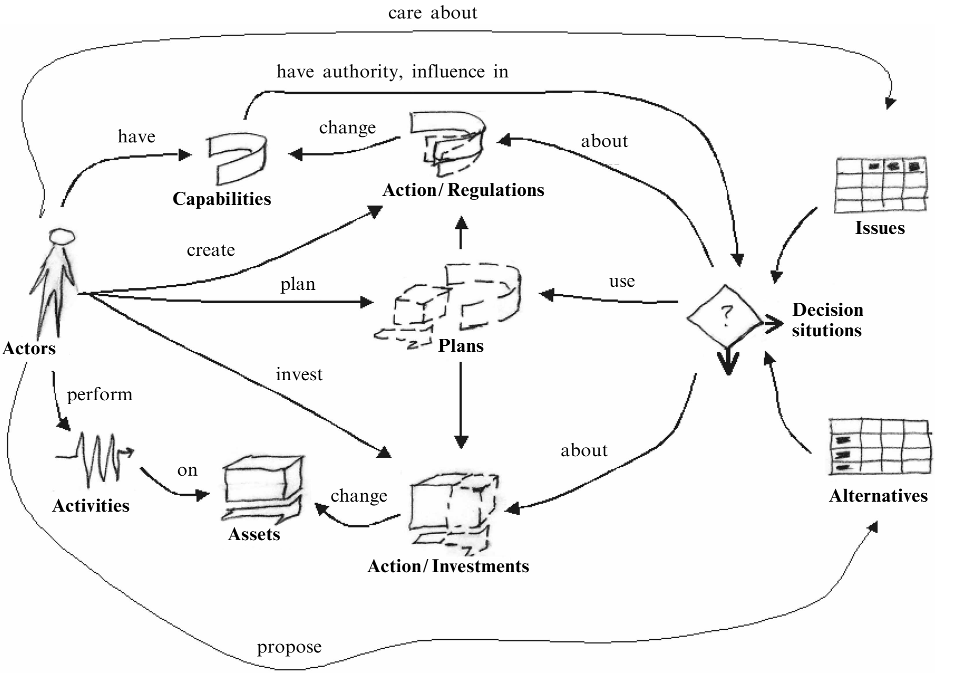
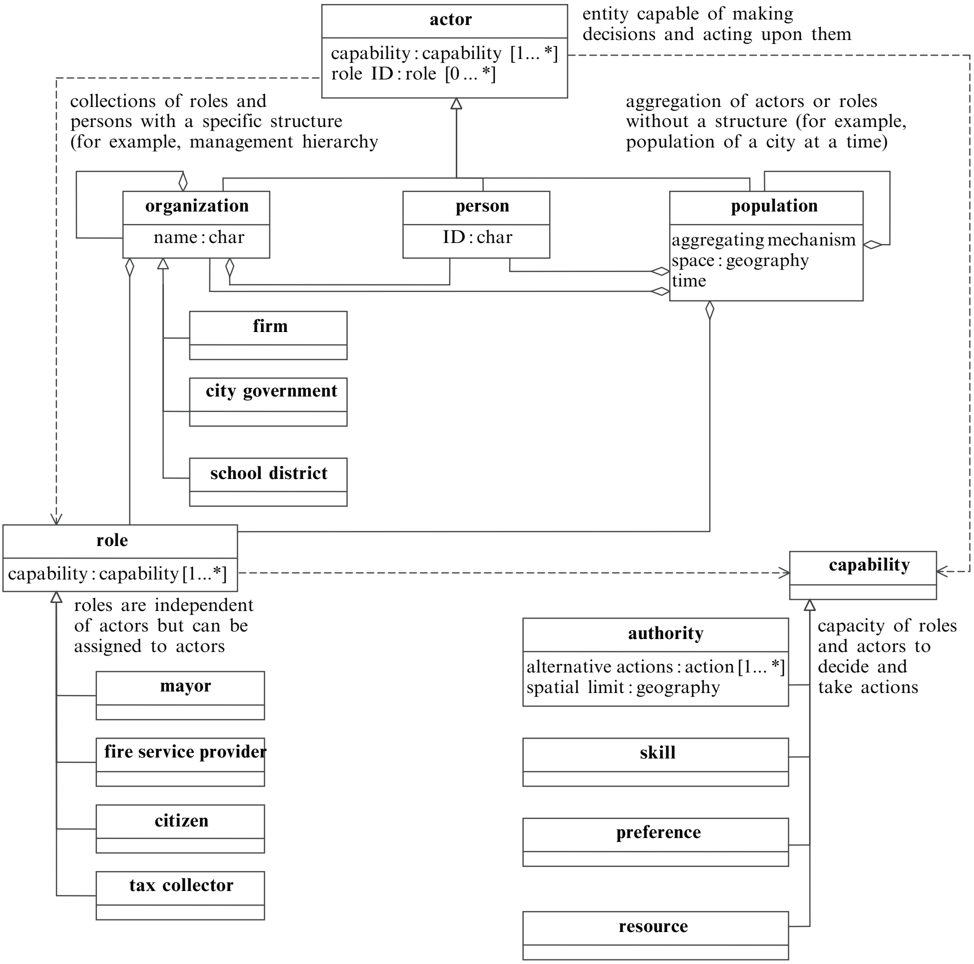


Figure 1. Elements of planning data model.

population of firms in a municipality. **Assets** include **buildings**, **networks** (such as streets), and **designated areas** such as land zoned industrial. **Investments** change the state of **assets**, creating, destroying, expanding, or contracting them. **Activities** are things that **actors** do, such as residing, producing, consuming, or trip making in or on **assets**. **Activities** are one way of defining land uses to be allocated in space. **Actors** have **capabilities**, including **preferences**, **authorities**, or **rights**, **skills**, **responsibilities**, **financial capacity**, and **behavioral norms**. **Learning**, **regulations**, and **transactions** change **capabilities** of **actors**. **Plans** are primarily about **investments** (changing assets) and **changing capabilities**. **Actors** make **plans**, perceive particular **issues**, make proposals for **action**, and have **authority** and **influence** in **decision situations**. In **decision situations**, **actors** use **plans**, confront **issues** and **alternatives**, and make **decisions** for **action**.

Note that these object classes can be used to describe states of the world, the content of **plans**, and the **decision situations** in which **plans** are used. The current state of urban development can be described with these entities, including dynamic descriptions of current trends or mechanisms of change. For example, **investments** could describe urban expansion or redevelopment as an ongoing process. These descriptions can be data about reality or states as expressed in plans or analytical models. Ideas for **plans**, such as changes in **buildings**, land-use **activities**, or transportation capacities can be described as **plans** are being made. The **issues** and arguments behind these ideas can be recorded so that this knowledge is available when **plans** are used. These object classes are elaborated in the following diagrams.

Figure 2 (see over) elaborates the description of **actors** as **persons**, **organizations**, and **populations**. **Actors** have **roles** and many of the **capabilities** of **actors** are associated with **roles** rather than directly with **actors**. For example, the **authority** of a mayor goes with the **role**, not with the **person**. Also **roles** can exist without an **actor** associated with them, so that the **authority** of a mayor is defined regardless of the **person** holding the office, but the influence a particular mayor may have depends

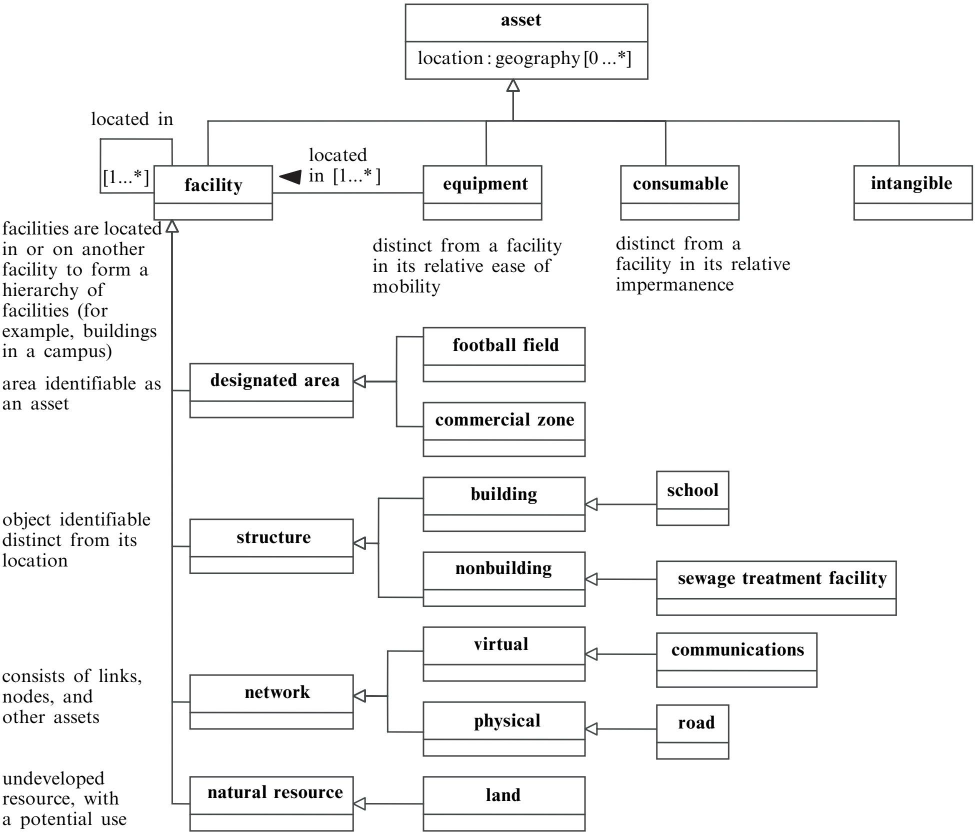


[1... *] means the attribute should be defined at least once and can be present any number of times.
[0 ... *] means that the attribute need not be defined at all or can be defined any number of times.

Figure 2. Elaboration of actors.

both on the **role** and on the **person**. Similarly, an **actor** can have multiple **roles** whose combination will determine the set of **capabilities** the **actor** possesses. **Organizations** are groups of **persons** with a particular structure of **roles** and **capabilities** associated with those **roles**. **Populations** by contrast are **actors** or **roles** that are grouped for descriptive purposes, and have at least one common attribute, space and time chief among them. **Populations** can be of **persons**, of **organizations**, of **roles**, or of **populations** themselves. **Actors** have **capabilities** either directly as **actors** or through the **roles** they play. These **capabilities** include **authority** (for example, ownership), **influence** (for example, major donor to political campaign of mayor), **knowledge** (for example, awareness of neighborhood issues), **skill** (for example, technical competence in financial analysis), and **resources** (for example, access to finances).

Figure 3 elaborates the description of **assets**. **Assets** can be **facilities**, **consumables**, or **intangibles**. **Facilities** are physical objects, such as building **structures**, or **networks**, such as streets. They can also be **virtual networks**, such as microwave networks, or **designated areas**, such as protected habitats or land zoned for development. **Assets** are related to other **assets**. For example, **equipment** may be assigned to a particular **facility**.



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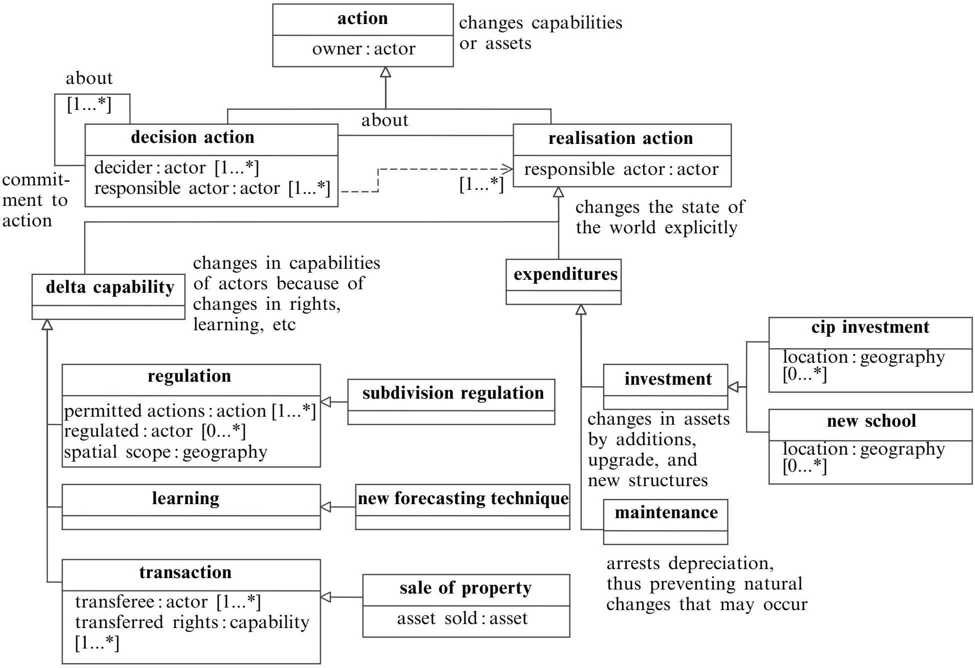
[0 ... *] means that the attribute need not be defined at all or can be defined any number of times.

Figure 3. Elaboration of assets.

Land or water in a river could be defined as an **asset** from which resources are used. **Buildings** could be located on a site or a dam on a river at a location at a time or for a period of time. **Actors** in their **roles** can own, lease, hold government **jurisdiction** over, have maintenance **responsibility** for, or have other use **rights** in **assets**.

Figure 4 (see over) elaborates **actions**. **Actions**, not to be confused with **activities**, change **assets** themselves or their relationships to **activities** or **actors**. **Actions** are central to the planning domain and include **decisions** and **realized actions**. **Decisions** are commitments to **actions** that have not yet been realized. Thus a **decision** by a city council to invest in a road project is distinct from the realization of that road project on the ground. **Decisions** and **realized actions** include **regulations**, **investments**, and **transactions**. **Actions** can also **change capabilities** of **actors** and include **changing rights** and **responsibilities**. It is useful to distinguish between **realized actions** and **decisions** as commitment to **actions**, because responses to **actions** by other actors may be based on **decisions** or **expected actions** before an **action** is realized. **Actions** have consequences either realized or expected, which are generally distributed over space as well as time.

Activities occur on **assets** and are performed by **actors**. Traffic flow on a street **network** (commuting), shopping by a **person**, and retail services in a building are **activities**. **Activities** are different from **actions**, in that **activities** describe aggregates of behaviors that are not fundamental changes to the system of **assets** and **capabilities**, and for which **decisions** to act are not explicit. **Activities** are also constrained by



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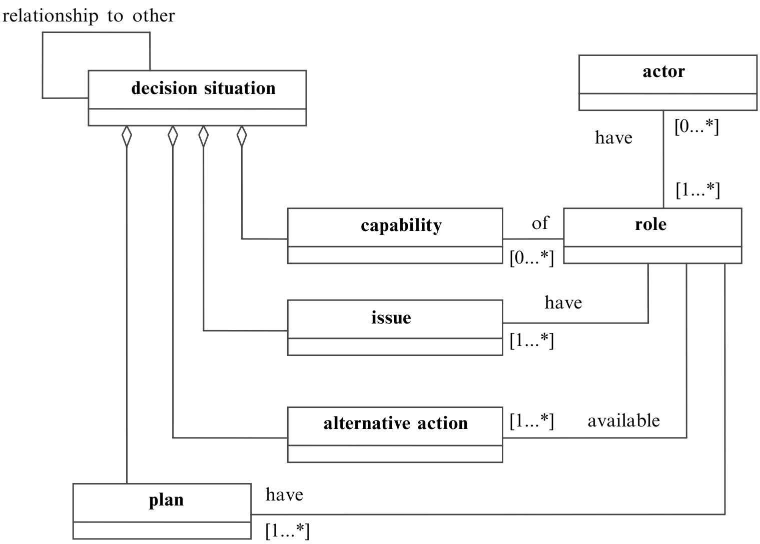
cip—capital improvements program.

Figure 4. Elaboration of actions.



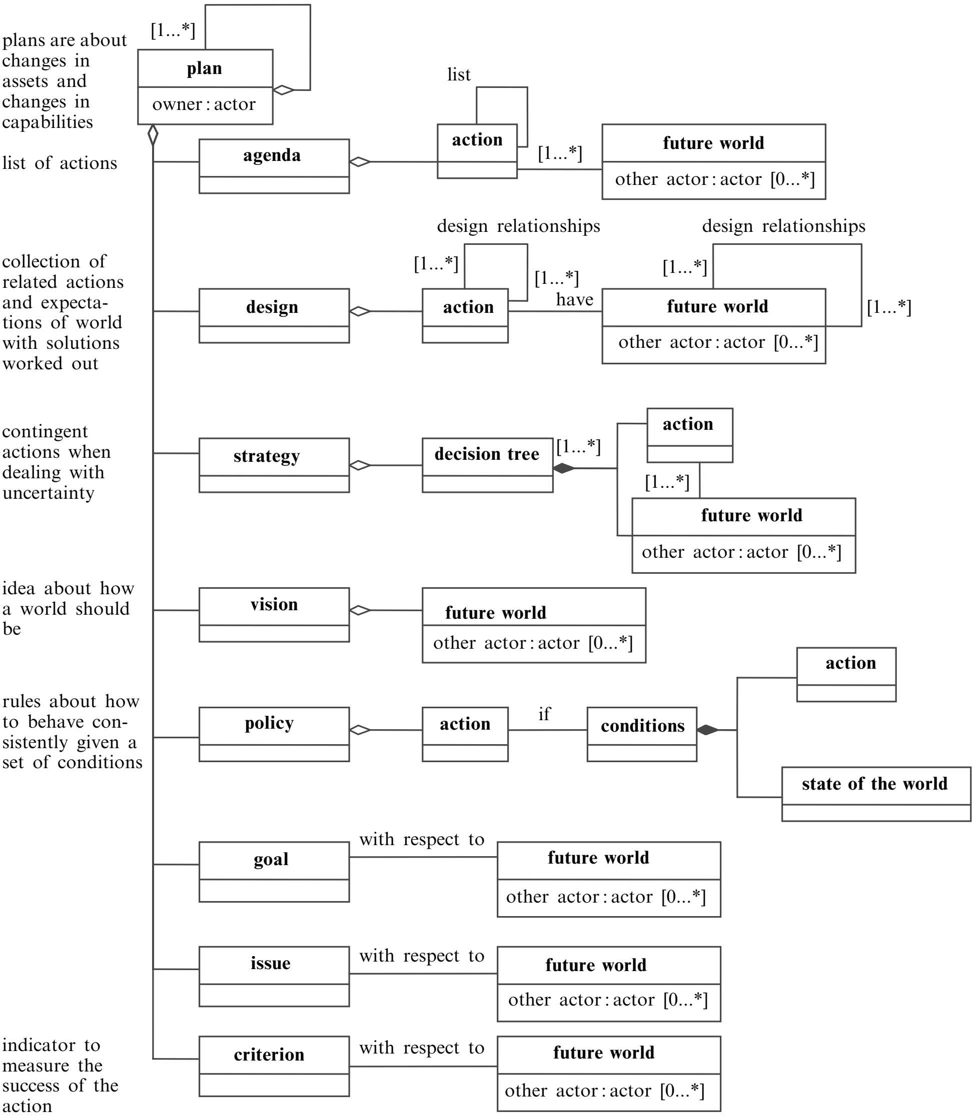
[1... *] means the relationship should be defined at least once and can be present any number of times.
[0 ... *] means that the relationship need not be defined at all or can be defined any number of times.

Figure 5. Elaboration of decision situations.

capabilities of **actors**, but it might not always be possible to identify a one-to-one relationship between **activities** and **actors**. An **activity** may have effects on **assets**, notably depreciation. **Activities** are also subject to capacity constraints and congestion relative to **assets**.

Figure 5 elaborates **decision situations**. **Decision situations** consist of **authorities**, **influences**, **issues**, **alternative actions**, and **plans** all of which are associated with **roles** and **actors**. These concepts in combination set the nature of a particular **decision situation**. In particular, **authority** defines who has what discretion to make or participate in making **decisions** about what **assets**, **activities**, **actors**, **plans**, **regulations**, and so on.

Figure 6 elaborates **plans** as composed of **visions**, **agendas**, **policies**, **designs**, and **strategies**. Each of these defines a particular kind of relationship among **actions**



[1... *] means the attribute should be defined at least once and can be present any number of times.
[0 ... *] means that the attribute need not be defined at all or can be defined any number of times.

Figure 6. Elaboration of plans.

and among **actions** and **consequences** in a **plan**: expected **consequences**, lists of **actions**, if–then condition for **actions**, interdependence among **actions** with respect to **consequences**, and decision-tree contingencies among **actions** and **consequences**. Some elements of **plans** may be represented in more than one way. For example, particular **investments** in roads might be represented as an **agenda** in a capital-improvements program and as a **design** for a **network** in a transportation plan. **Plans** also incorporate **indicators**, including **issues**, **goals**, and **criteria**, which serve to assess **consequences**. A **strategy** might be expressed in relation to **goals** that are responsive to **issues** and measured by **criteria**. Each of these concepts can be elaborated further (see Hopkins, 2001).

An **agenda** is a list of **actions** to be performed by **actors**. The list itself has no internal relationships; it is unordered. However, items in an **agenda** may have attributes that could create order, such as date of completion or a priority rank. **Agendas** could also account for constraints, such as cumulative costs relative to a budget constraint.

A **policy** is an if–then statement, which is applied repeatedly given a situation. The given situation (the 'if' clause) may be attributes of **states of the world**, **action**, or a collection of these. The **action** prescribed (the 'then' clause) is taken by an **actor** and thus depends on **capabilities** of the **actors** to whom the policy is intended to apply. The **actor** to whom the **policy** applies may be different from the **actor** who created the **policy**.

A decision tree can be construed as a **strategy**. **Strategy** involves uncertain outcomes and contingent **actions**. The initial node of the **strategy** is an **action** contemplated by the **actor**. Because of uncertainty of expected consequences of the **action**, planning would necessarily involve considering various unrealized but possible **consequences**. At a decision node the **actor** can list a choice of **actions** that will be available to be taken and the uncertain **consequences** for each of those choices. A preferred choice of action based on preferred expected consequences from each decision node can be identified based on **issues**, **goals**, and **criteria**. Listing all possible outcomes is unrealistic, however, so a **strategy** is always incomplete at best.

Unlike the other aspects of **plans**, **design** is a curious collection of amorphous relationships among **actors**, **actions**, **assets**, **activities**, and the **relationships** that bind them. Hence, **design** could be considered a collection of **metarelationships**. **Design** for urban systems is not elaborated as a situation that needs to be solved, but as a solution that has already been worked out. **Designs** could be about **actions** of **actors** or **expected outcomes** of those **actions**. Alexander's work in pattern languages provides one basis for defining designs (Alexander et al, 1977). Rowe (1991) has argued that design has to be cognizant about relationships between entities that are not physical.

On the basis of these arguments, we can classify the **relationships** between **action** and their consequences into three types: **spatial**, **temporal**, and **functional**. A proximity relationship between schools and residential land use is a **spatial relationship**. Adjacency is another example of a **spatial relationship**. A construction-management plan for a highway project is a **design** consisting primarily of **temporal relationships** about **actions**. Temporal relationships can include collections of sequences of **actions** or **consequences** that are, or need to be, realized. **Functional relationships** could be about interdependent **consequences** or **actions**. Compatibility of **activities** is a **functional relationship**. A transit-oriented design would include relationships of travel and wait time to the density of population it serves and the extent of service. A bubble diagram of circulation corridors and functional spaces is a design representation of a set of **functional relationships**.

Vision is an idea about where one would like to be. It serves as motivation and a guiding principle for making decisions. Are the expected **consequences** of a **decision**

consistent with the **vision**? It is a collection of formal or figural statements about the idea of an envisioned scenario.

Issues, **goals**, and **criteria** are all **indicators** of the state of the world, generally in relation to the perspective of particular **actors**. The intent of **agendas**, **visions**, **policies**, **designs**, and **strategies** can be expressed in relation to these **indicators**.

Issues are about the difference between desirable states of the world and perceived existing states of the world. It is imperative to note that perception is individual and hence **issues** are strongly linked to **actors**. **Issues** cannot exist without existing for at least one **actor**. As mentioned earlier, **decision situations** arise when **issues** exist, there are at least two alternative **actions** available for the **actor** in question, and there is an **authority** and **influence** structure to frame the deliberation and the decision making.

Goals are expressed as desired **states of the world**, or more specifically desired attributes of entities and relationships that define the **state of the world**. They are not necessarily consistent, and different **goals** of one **actor** may be contradictory as well as **goals** among different **actors**.

Criteria are **indicators** about existing or expected states of the world expressed in measurable terms. **Criteria** can be effects, such as the level of air pollutants, or value statements, such as a preference ordering among levels of pollutants. **Criteria** could be attributes of entities describing states of the world or they could be computed from such attributes. **Preferences** are in relation to particular **actors**.

Planning data model and requirements of use cases

Does the proposed data model encompass the entities pertinent to the use cases? We consider here three more specific instances of the use cases: using plans in planning commission meetings, revising a comprehensive plan, and analyzing urban development ideas. These specific cases are indicative of other instances within each of the three more general use cases—using plans, making plans, and analyzing urban systems.

Using plans

To assess whether the proposed data model could support using plans in a planning commission process, we break the vignette described above into subtasks and identify the data-class types that would enable support for that task. The subtasks are given in italics in the following paragraphs.

A developer who has acquired an option on a parcel of land proposes a mixed-use development in an area currently zoned for residential. The proposal itself is expressed primarily in terms of **investments**, changes in **assets** including **buildings**, **networks**, and **designated areas**. The argument for rezoning is based on the **activities** proposed for these **assets** and the **regulations** applying to those **activities** when carried out in the proposed **assets** at the particular parcel location.

Having noted that the current comprehensive plan sets compact development and reduced automobile use as goals and that recent planning commission discussions have considered mixed use as a strategy, the developer consults informally with planning staff about the potential for rezoning, or perhaps handling the proposal under special provisions such as planned unit development or special use provisions. These ideas in **plans** are accessible as **policies**, **visions**, and **designs** expressed in formal plans and informal discussions. The idea of mixed use is expressed as a mix of **activities** in close proximity, probably on different floors of the same **building**.

The planning staff considers the comprehensive plan, a recent neighborhood plan that identifies densification and lack of retail services as an issue, a mass transit district proposal for increased service in this area, and a university plan to acquire additional land south of the neighborhood preventing further development in that direction. These **plans** of other agencies (**organizations**) are also accessible because they are expressible as aspects of **plans**. Density is units of **actors**, **activities**, or **assets** per unit area: population density, employment density, or dwelling-unit density. Transportation analysis can be undertaken based on **actors**, trips (as **activities** of **actors** on **networks**), **network** capacity, and **actor** attributes and **capabilities** affecting mode choice.

After informal neighborhood meetings with the developer and planning staff, the staff develops a recommendation to the planning commission for approval of a modified form of the proposal. The staff recommendation is developed in a **decision situation**, the staff's **decision** about the recommendation. It is formatted for use in another **decision situation**, the planning commission meeting. The recommendation is presented in terms of **issues** and **alternatives** with reference to **plans** and **regulations**. These entities should be elaborated to support argument and explanation, for which argumentation modeling has been developed (for example, Gasper and George, 1998; Laurini, 2001, pages 165 – 174).

The planning commission holds a public hearing at which neighbors and the developer refer to all these plans and others, as well as to the zoning and subdivision ordinance and the capital improvements program to argue their views. The public meeting depends on the same sources expressed in the same entities as the staff recommendation, and is open to additional aspects of **plans** and **regulations**. The capital improvements program is expressible as an **agenda**, but specific projects may be expressed as **designs** and some projects may relate to each other as **strategies**.

The planning commission considers all of this in its deliberation, and makes a decision to recommend to the council a further modified version of the proposal. The planning commission **decision situation** plays out and creates the inputs to another **decision situation**, the city council meeting.

At the current level of abstraction, the data model appears sufficient in scope for this use case. The next step in developing the data model will be to apply it more specifically in a particular planning commission case.

Revising a comprehensive plan

To assess whether the PDM has scope to support plan making we describe an instance in two ways: first as a process among actors, then as the evolution of ideas. These two descriptions recognize that the PDM must support the actors in the process and the ideas they create.

Outlying residents express increasing concern about directions of future development. Many retail activities and the associated tax revenue have recently moved to locations in an adjacent city. New interest from developers in major projects is apparent in recent land acquisitions. The city staff recognize that, although they have made several area plans recently, these plans are inadequate to address the issues and decisions arising in the current situation. **Plans** are revised when the **decision situations** in which they are used demand revisions and new ideas because **actors** raise **issues** of concern and identify **criteria** that are not being met. These concerns can be described in terms of states of the world expressed as **assets**, **activities**, and **capabilities**.

The planners initiate a work program for a major revision of the comprehensive plan. This work program includes creation of a citizens' steering committee, a round of neighborhood meetings, a round of technical focus group meetings, frequent reporting to the planning commission and the city council on the status of the work, and eventually deliberation, public hearings, and a planning commission recommendation on a plan. Throughout this process, the planning staff must keep track of which **actors** addressed which **issues**, proposed which **actions**, and identified which **criteria**. The steps in this process include many informal and formal **decision situations** that result in **decisions** about **visions**, **agendas**, **policies**, **designs**, and **strategies** to be included in the emerging **plan**. Some participants will focus on **investments** and others on **regulations** because of their differing **authorities** in the process.

Another view of this process is that it creates and sustains an evolving set of planning issues, goals, ideas, and evaluative criteria, which are discussed in light of an evolving set of pertinent data organized from existing sources or collected to respond to particular questions. The staff keep track of converging and contradictory ideas and evaluations of these ideas so that plans eventually emerge and are catalogued for use.

In almost all plan-making situations, there are already many **plans** to work from. Frequently, an early step in the comprehensive planning process is to collect existing **plans**, including earlier versions of the comprehensive **plan** and **plans** by other **actors**. The use of existing **plans** will have left a record of **actions** taken and the differences between these **actions** taken and **actions** implied by **agendas**, **visions**, **policies**, **designs**, or **strategies** in the **plans**. These differences will suggest needed revisions to **plans** to achieve greater consistency between **plans** and **actions**. Some of these **plans** will have been made by and remain under the **authority** of other **actors**, so that the revisions will be in how particular **actors** interpret these **plans** by others for their own **decision situations**. Discovering these differences and developing interpretations require data about **actors**, **actions**, plan content tied to expected **actions**, and information about **authority** (**capability** generally) over **plans** and **actions**. These requirements fall within the scope of the proposed PDM.

The crucial requirement for supporting collaboration among citizens and experts is to be able to represent and keep track of 'plans in the making'. A **plan** in the making can be represented by the same entities as a plan if each element can be identified by its attributes as tentative and if combinations of tentative elements can be identified as tentative—incomplete in both scope and detail—versions of possible **plans**. In addition, these elements and combinations must be identifiable with different **actors** who may be proposing, advocating, opposing, or questioning them. The issue of displaying these ideas to communicate among collaborators is in part separable from the question of data modeling. Thus a discussion about **assets**, such as a tram rail **network** and its attributes, might rely on visualization as well as numerical analysis. The current data model is intended to support either, but does not encompass the specifics of how these displays or calculations are accomplished because there is already well-established software capable of these display and computation tasks. The proposed PDM is sufficient to support such display software.

Useful scenarios about the future should include two aspects: a sample of ideas about different future **states of the world** or **future worlds** and relationships between these **future worlds** and **actions** available to **actors** contemplating these **future worlds**. The scenarios approach assumes that **future worlds** are uncertain and therefore focuses on imagining possibilities rather than on achieving a correct forecast. Representing such **future worlds** in a data model again requires some kind of versioning analogous to the versions of plans in the making. Scenarios, like **plans**, may be incomplete in scope and detail, especially as these scenarios are being devised. In order to relate **future worlds** and **actions**, these scenarios must incorporate in some explicit fashion relationships among **actions** and **consequences**. The proposed PDM represents **states of the world** not as cross sections in time but as processes among entities so that these relationships can be considered.

If we can imagine **future worlds** and **actions**, then it will be useful to assess these **future worlds** and from this derive assessments of **actions** in relation to these **future worlds**. Evaluation thus should be able to encompass both **states of the world** and specific **actions** and to do so from the perspectives of different **actors**. The proposed

PDM can support effectiveness matrices that compare alternative **actions** or alternative **future worlds** with respect to **criteria**. The PDM also accounts for relationships among **actions** and dynamic **states of the world** and thus can support 'soft' forms of decision analysis that consider choices of **action** in the face of uncertain and ambiguous **future worlds**.

The PDM is intended to support all of these tasks. The PDM has the scope to support a comprehensive plan-revision process, recognizing that the process is a loosely coupled set of tasks. Although the general character of the tasks involved is sufficiently identifiable to argue that a PDM is possible, the PDM can be used in the unpredictable iterations, parallel processing, and sequences in which these tasks are carried out.

Analyzing urban development

In the above stories about using and making plans, it is essential to be able to describe proposals, consider how each fits into the current and evolving situation, and keep track of multiple evaluations of each. All the players put models to work to accomplish these tasks. Each of the actors will want the PDM to represent dynamic **states of the world** to describe the past, the present, and possible **future worlds** using concepts, variables, and processes consistent with their own ideas about what is important and how the world works.

The developer uses a model of predicted demand for particular uses and configurations of these uses as well as a model of costs of development. **Assets** and **activities** occurring in these **assets** can describe the physical proposal and intended use patterns. Forecasts about **actors** as **households** will characterize expected demand. Costs can be calculated as attributes of particular **designs** based on **relationships** among **assets**, **activities**, and **actors**.

The neighbors, implicitly at least, use models of property-value change, local revenue generation, and service-cost predictions. The city or special districts use models of traffic, revenue generation, services costs, sanitary waste capacity, runoff and drainage, and school capacity. Most of these **actors** are interested in competing **indicators**, which can be calculated using the entities and **relationships** that describe a **state of the world**. For example, vacancy rate can be calculated from the attributes of the occupancy rates by **actors** (**households**) of **assets** (**dwelling units**) or of the level of **activity** (number of employees) at each **asset**. Thus, for example, the PDM would evidently support an affordable housing analysis based on a stock of **assets** by **dwelling unit** type and demand by **household** types. For regional planning purposes, the location choices of industries as **activities** could be modeled by accessibility to other **activities**. Accessibility would be a **criterion** that could be calculated from other entities describing the **state of the world**.

All these model users are trying to understand how variables of interest to them might change with or without a proposed project or the set of proposed investments and regulations in a plan. The PDM encompasses **actions** in the system being modeled and the variables endogenous to most models of urban development. A participant who wants to model **persons** as a homogeneous **population** of rational agents in a discrete choice model can do so. Another participant who wants to focus on changing preferences of recent immigrants through interaction of individual **persons** can also do so. Such focus on **persons** is important and one of the unusual features of the proposed PDM, but it also includes **assets**, **activities**, and **criteria**.

Conclusions and future work toward a planning markup language

This paper is our first report of work on a PDM. Recognizing that we still have a long way to go and that many gaps and ambiguities will be discovered, this initial data model appears to have the scope to address the intended use cases. It is, however, still at an abstract level and will have to be elaborated in greater detail before substantially better assessments of the data model can be made. The data model will certainly evolve, perhaps in its basic structure, as we begin encoding instances and creating compliant datasets and software tools. Two extensions—support of urban development modeling and expression in XML—are in progress.

The PDM presented here can also be used to incorporate planning behaviors into models of urban development, to link complementary models of different phenomena related to urban development, and to support use of multiple models. The first enables analysis of phenomena such as planning for expansion of urban growth boundaries. The second enables linking, for example, of transportation, land-use, and air quality models. The third enables deliberations to consider urban futures predicted by different models intending to capture the same phenomena, but in different ways.

An important next step will be using the PDM to structure and organize information so that it can be accessed and used by human and intelligent software agents. In a number of domains, extensions of XML are used to represent data in a meaningful and useful fashion by attaching to it specifically defined tags that refer to an underlying data model and give structure and meaning to the data. XML was developed primarily for structuring, storing, and transporting data over the Internet; it separates representation of content from any processing associated with it, such as presentation for human audiences. Processing is left to parsers, which can process the same content for different purposes depending on the context.

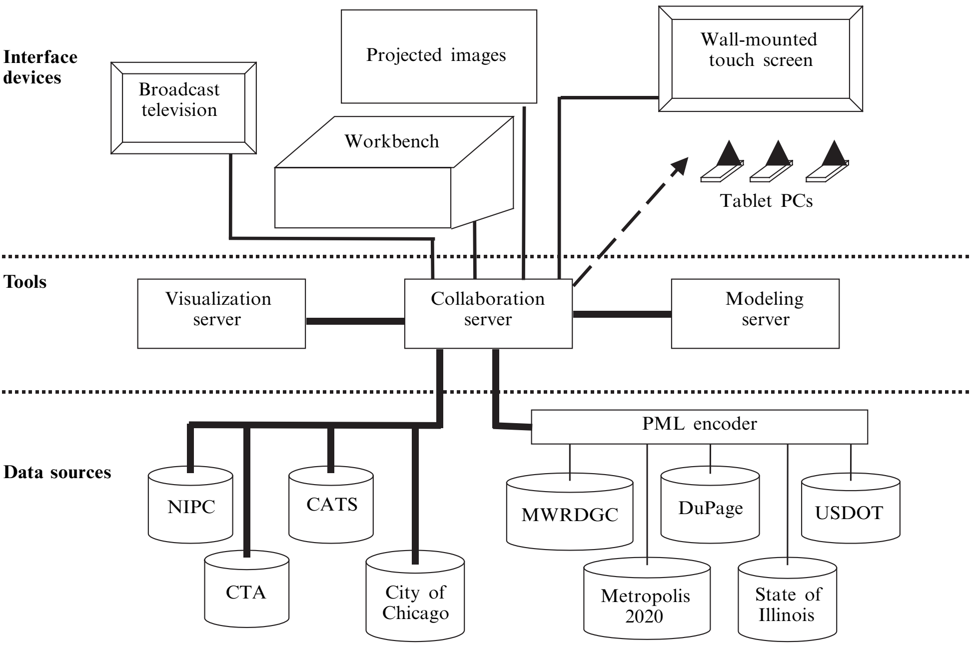


Figure 7. System architecture for implementation of Planning Markup Language (PML) with PML-supported links shown with bold lines.

An XML implementation of the PDM, which we have termed Planning Markup Language (PML), would make planning content widely available. XML schemata and some instantiations can be found at http://www.rehearsal.uiuc.edu/projects/pml/. The basic purpose of PML is highlighted in the system architecture diagram in figure 7. The three major tiers in this diagram are (1) input and output mechanisms, (2) servers to support visualization, collaboration, and modeling tools, and (3) data and information sources. The thick connecting lines show that PML is the means of communicating among the tool servers and data sources. In practice, we should not assume that we could achieve complete PML compliance, so data sources that are not PML compliant will require an encoder or reference schema. This system architecture could support the three applications (use cases) described earlier.

PML has a close precedent in the development of the Geography Markup Language (GML). GML defines a set of markup tags for describing spatial geometry that is consistent with the OpenGIS Consortium's model for geometry and the W3 Consortium standards for XML (Lake, 2000). Schema specifications for GML are given at http://www.opengis.org/techno/documents/02-023r4.pdf. As another extension of XML, PML can directly incorporate the GML schema in specifying geographic entities or geographic aspects associated with PML entities. Therefore, there is no need to recreate these capabilities, which are useful in but not sufficient for PML.

The PDM and this basic system architecture enable us to go beyond the limitations of current planning support systems, which are largely single tools with a single purpose using data from a single source. It enables us instead to create web interfaces as workspaces—CollaborationSpaces—in which participants can use the many tools and information sources available, including in particular plans. To realize this potential, however, the PDM must be widely used. It must be sufficiently open that many plans and regulations can be successfully encoded and must have sufficient acceptance that many plans and regulations will be encoded.

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References

Alexander C, Ishikawa S, Silverstein M, 1977 *A Pattern Language: Towns, Buildings, and Construction* (Oxford University Press, New York)

Armstrong M P, 1994, "Requirements for the development of GIS-based group decision support systems" *Journal of the American Society for Information Science* **45** 669 – 677

Berry B J L, 1964, "Approaches to regional analysis: a synthesis" *Annals of the Association of American Geographers* **54** 2 – 11

Brail R K, Klosterman R E (Eds), 2001 *Planning Support Systems* (ESRI Press, Redlands, CA)

Chrisman N, 1997 *Exploring Geographic Information Systems* (John Wiley, New York)

Couclelis H, 1991, "Geographically informed planning: requirements for planning relevant GIS" *Papers in Regional Science* **70** 9 – 20

Gasper D R, George R V, 1998, "Analyzing argumentation in planning and public policy: assessing, improving, and transcending the Toulmin model" *Environment and Planning B: Planning and Design* **25** 367 – 390

Hopkins L D, 1999, "Structure of a planning support system for urban development" *Environment and Planning B: Planning and Design* **26** 333 – 343

Hopkins L D, 2001 *Urban Development: The Logic of Making Plans* (Island Press, Washington, DC)

Jankowski P, Nyerges T L, 2001 *GIS for Group Decision Making* (Taylor and Francis, London)

Jankowski P, Nyerges T L, Smith A, Moore T J, Horrath E, 1997, "Spatial group choice: a SDSS tool for collaborative spatial decisionmaking" *International Journal of Geographical Information Systems* **11** 566 – 602

Kaiser E J, Godschalk D R, Chapin F S J, 1995 *Urban Land Use Planning* (University of Illinois Press, Urbana, IL)

Keita A, Laurini R, Roussey C, Zimmerman M, 2004, "Towards an ontology for urban planning: the Towntology Project", paper presented at the 24th Urban Data Management Symposium, Chioggia, http://lisi.insa-lyon.fr/~townto/download/towntology_project.doc

Lake R, 2000, "Introduction to GML: Geography Markup Language", Galdos, Inc. http://www.w3.org/Mobile/posdep/GMLIntroduction.html

Laurini R, 2001 *Information Systems for Urban Planning: A Hypermedia Cooperative Approach* (Taylor and Francis, London)

Longley P A, Goodchild M F, Maguire D J, Rhind D W, 2001 *Geographic Information Systems and Science* (John Wiley, New York)

Nedovic-Budic Z, Pinto J K, 2000, "Information sharing in an interorganizational GIS environment" *Environment and Planning B: Planning and Design* **27** 455 – 474

Peucker T K, Chrisman N R, 1975, "Cartographic data structures" *The American Cartographer* **2** 55 – 69

Rowe P G, 1991 *Design Thinking* (MIT Press, Cambridge, MA)

Shiffer M J, 1992 *A Hypermedia Implementation of a Collaborative Planning System* PhD thesis, Urban and Regional Planning, University of Illinois at Urbana-Champaign, Urbana, IL

Shiffer M J, 1995, "Interactive multimedia planning support: moving from stand-alone systems to the World Wide Web" *Environment and Planning B: Planning and Design* **22** 649 – 664

Webster C J, 1994, "Structured methods for GIS design part 1: a relational system for physical plan monitoring" *Computers, Environment and Urban Systems* **18**(1) 1 – 18

Webster C J, Omare C N, 1994, "Structured methods for GIS design part 2: an object oriented system for physical plan monitoring" *Computers, Environment and Urban Systems* **18**(1) 19 – 41

Worboys M F, 1994, "A unified model of spatial and temporal information" *Computer Journal* **37**(1) 26 – 34

Worboys M F, 1995 *GIS: A Computing Perspective* (Taylor and Francis, London)

Zeiler M, 1999 *Modeling Our World* (ESRI Inc., Redlands, CA)