

# Ontology for Land Development Decisions and Plans

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**Abstract.** The focus of geographic and other ontologies of urban development has been to represent locations with object attributes or objects with locational attributes. Urban information systems should also represent decisions, which have or could have locational attributes. Development processes are critically influenced by expectations about declared intentions manifest through plans and records of decisions. This paper provides an ontology of decision situations characterized by actors participating, intentions expressed, and alternatives considered. We argue that these elements are closely tied to and interdependent with other aspects of urban ontologies, which typically focus on physical objects of development. An ontology of plans and decisions will enable sharing of information among actors and consideration of disparate and distributed information.

**Keywords:** Plans, Decisions, Urban Ontology

## 1 Introduction

Representations of urban development have focused on spatial objects over time and attendant functional relationships [1]. Important components of urban development processes, however, include intentional actors who plan for their own actions and respond to decisions and plans that are made explicit by others. A city is not only a physical entity, but also an *institutional entity*. This paper develops an ontology of the actors, decision situations, and plans that make up the institutional structure of a city. This institutional ontology is essential in order to represent considerations and strategies for providing urban infrastructure.

Hopkins [2] argues that two types of actions are crucial in planning: Investments and Regulations. Investments are changes in assets. Regulations are changes in capabilities of actors more specifically in rights. Plans are statements of intentions about how these investments will be made, at least in the sense of some level of implied commitment. Urban planning is concerned with the choices of actions (or combinations of actions) situated in a spatio-temporal context and intended in relation to goals. Laurini [3] describes some of the approaches to operationalise planning documents in urban information systems.

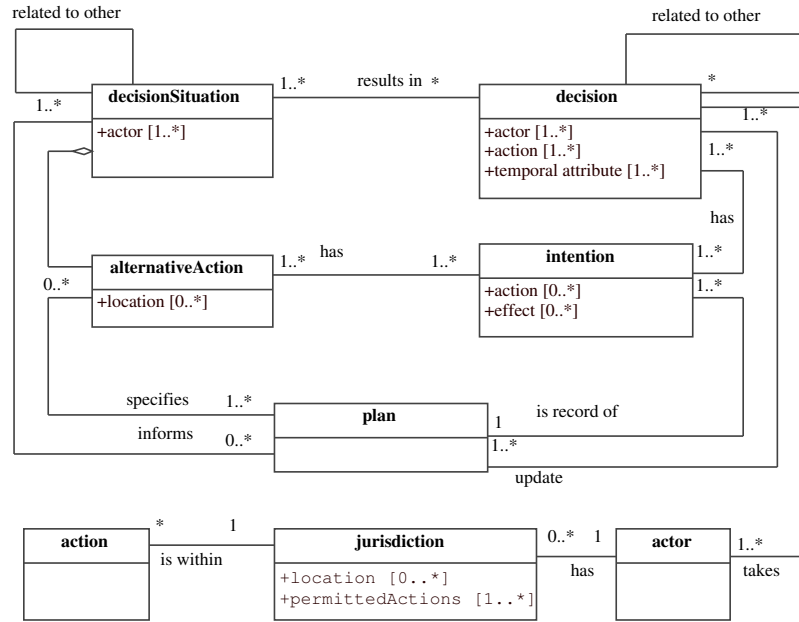
When the definitions of choices, goals, and actions are broadly construed, planning is about intentions, decisions taken prior to action, and possible ‘sequences’ or otherwise related sets of actions. Plans are records of such decisions, including their intentions and recognized relationships among actions. This theory of planning is consistent with the theory by Bratman [4] who argues that intentions are predicated upon plans and vice versa. However, in order to keep track of intentions of others as well as our own, we need an ontology that is general enough to be useful and extendible enough to apply to many different legal and other institutional contexts [5].

Planning, by the State or otherwise, requires that plans consider the nature of interdependence of our own planned actions on others’ plans and the evolving set of circumstances. To plan effectively, one must be cognisant of information regarding the following questions. 1) What is the ‘State of the World’? 2) What institutional framework (rights, regulations, and norms) permits certain kinds of actions and prohibits others? 3) What are the intentions of other players in the process? 4) How are changes to the institutional framework fashioned? 5) What changes to the state of the world are implied by changes to assets and regulations? Relevant answers to these questions are needed in a system that could support making plans, and using plans. The questions become interesting because of the issues of space, time, interdependence, and contingency in land use planning.

In this paper, we argue that representing decisions in urban planning ontologies is important from the urban planning perspective. Decisions raise expectations, provide indications of commitment, and are typically precursors to actions that change some aspect of the world. Our approach is different from “Argumaps”, which represents arguments with spatial attributes as described in [6] or [3]. Argumaps are useful to chart various alternative arguments and positions of interested stakeholders that are tied to specific locations thereby aiming to reconcile them. In contrast, representing decisions and attendant decision situations helps in discovering alternative as well as contingent decisions when the decision making capacity and authority are distributed.

## 2 Decisions, Actions, and Effects

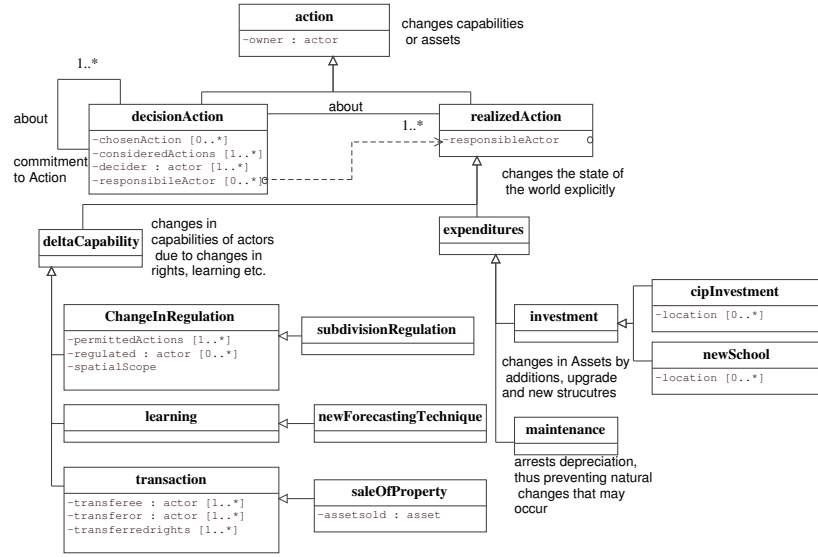
Elsewhere, in [5], we have described an ontological framework for representing urban development processes. The purpose of this paper is to elaborate the descriptions of the decisions of the intentional actors who populate urban systems and the relationships between them. A decision situation is characterised by the actor or a collection of actors who are deciding, alternatives considered, and plans that inform it. A decision situation may or may not result in an explicit decision. When the decisions are being made, recognition of interdependence with other decisions is informed by the plans (Fig. 1). The actors have the capability to make such a decision, specifically the decision is within the jurisdiction of the actor. A decision situation considers alternative actions and chooses a subset of these to be pursued at a future date. Plans help in decision situations by pro-



**Fig. 1.** Plans & Decisions

viding information about the framework within which the decision fits and by addressing the questions of irreversibility and interdependence with other decisions and actions. Plans, as records of intentions, are continually modified, when new information about these dependencies emerge. Figure 2 describes the concept of realised actions in relation to decisions. These actions have certain effects, intended and unintended. By making these decisions explicit, especially through adopted urban development plans or by any other such public proclamations, the actors shape the expectations of other actors, which influence other decisions and actions. It is thus important to sort out the differences between decisions and actions. We characterize decisions as information about intended actions. A decision to build a road is different from building the road. The increase of the traffic flow on the road and the resultant rise in the property values of adjacent properties are effects of building the road. However, speculative development may raise the property value of the adjacent property even before the road is built, merely as an effect of publicly announcing, in some credible fashion, the decision to build the road [7].

It is to identify these distinct effects that we distinguish decisions from actions. Using Bratman's terminology, a decision is an explicit 'volitional commitment'[4]. While actions change the state of the world, decisions merely provide information about how these actions are situated in the future. These decisions may not result in realisation of any of the chosen actions, changes in the poli-



**Fig. 2.** Action Class Diagram – Adapted from [5]

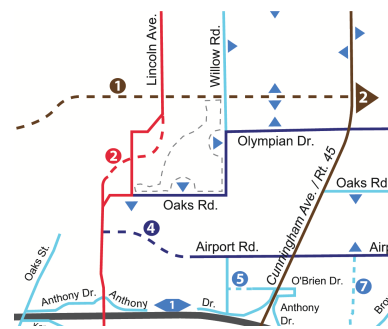
cies, or any other changes in the ‘state of the world’. The mere fact that these decisions are taken provides indications about commitment, thereby generating expectations and thus influencing other’s decisions. This section’s title may convey some sense, perhaps slightly misleading, of a sequential relationship of decisions, actions, and effects. A decision to act need not result in the actual action, and the action may not realise its original intentions; the relationships between them are more circuitous and thus richer.

### 3 Types of Decisions: Location, Alternatives, and Policies

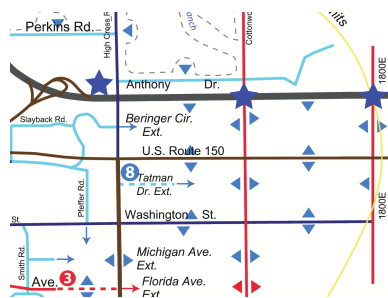
Figure 3 explicitly illustrates distinctions between different types of decisions that are manifest within plans. Numerous other examples of these types of decisions as well as other types can be found in plans.

A decision that has a spatial attribute is illustrated in Fig. 3(a). The realignment of the existing Olympian Drive north of Urbana to a new location is marked in the plan. While the new road has not yet been built, and the existing road is still in use, it is useful to have information about the decision, the intent to realign this road, which will also lead to a sequence of other decisions. At the time of the publishing of this plan, the intended alignment, represented by the dashed line ends at Illinois Route 45, and the decision to terminate it at that junction or to continue it to High Cross Road has been deferred to a later date.

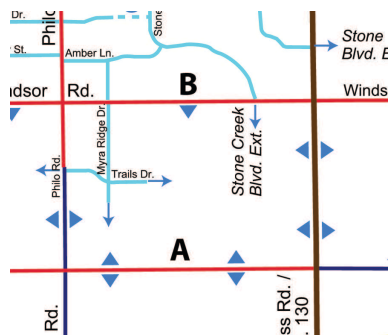
Figure 3(b) illustrates another type of information in plans, a restricted set of alternatives for which a decision is not yet made. The exact location of the



(a) Relocation of Olympian Drive



(b) Alternatives for Interchange



(c) Policies for Sub-collector Streets

1 Olympian Drive relocation and extension west from U.S. Route 45

2 Olympian Drive termination at U.S. Route 45 or continuation to High Cross Road

★ Interstate 74 interchange alternatives when needed as Urbana grows east. High Cross Road, Cottonwood Road, 1800E.

**Direction and approximate location.**

▲ The exact location of roadways and/or right-of-way dedication shall be determined depending on factors including (but not limited to) proposed development plans, natural features and safety needs.

**Pre-determined location for extension**

↑ The desired location of roadways and/or right-of-way dedication is known though further study is required to determine the final design.

- Interstate
- Major Arterial
- Minor Arterial
- Major Collector
- Minor Collector

**Fig. 3.** Types of Decisions - Excerpted from [8]

interchange on Interstate 74 has been a contentious issue for the City of Urbana and the neighbouring residents. While the location of the interchange has not been determined, three alternatives (represented by three stars at High Cross Road, Cottonwood Road, and 1800E) have been identified. It would appear from

the information in the plan that the future decision on where the interchange will occur will consider only these three alternatives or slight modifications of these.

Figure 3(c) illustrates a policy specification as information in a plan. The policy is that two sub-collector streets should be built between two existing parallel collector streets (**A** and **B** in the figure), which are generally 1.6 kilometres apart. While the exact locations of the rights of way of these sub-collectors were ambiguous at the time the plan was published, the policy is nevertheless very pertinent information about the city's intent about infrastructure investments. The triangles are intended as 'sliders' indicating the need to identify the end points and connecting alignments when other decisions about land subdivision are made in the future. The intersection node may be specified, however, if a sub-collector already exists on the other side of **A** or **B**, which then fixes the location of the endpoint in the interest of continuity. This situation is represented by a different kind of arrowhead as shown in the legend.

These examples demonstrate, though not exhaustively, different types of decisions that are made and their implications for making inferences about changes in the physical state of the world. They demonstrate different sets of alternatives considered and chosen, and different kinds of information about intentions before resulting action. While not all decisions are made explicit in publicly available plans, most government decisions have to be made public in some way prior to initiation of actions. These examples also point to the spatial, topological, and temporal relationships among decisions, which result in similar kinds of relationships among the actions and effects.

### 3.1 Location

Hopkins et al. [5] argue that none of the attributes of urban development are fundamentally tied to a location. In particular, it is reasonably obvious that decisions themselves may not have locations as attributes. The actions that are a part of the decisions may have locations. The actor's jurisdiction may have a spatial attribute. This divorcing of the location from the ontology of the urban processes is important. Planning information systems have long relied on the intellectual development of geographic information science which is fundamentally focused on spatial objects, but planning requires a different frame [9].

Assets, from the urban planning perspective, may have locational attributes. An investment changes the attributes of the asset by bringing it into being or otherwise modifying it. Thus a decision to build a new road has spatial attributes by the virtue of spatial attributes of the road. Regulations are more akin to policies, which need not specify ahead of time particular locations to which they apply. However, regulations may have a spatial scope of applicability, typically a subset of the spatial scope of the jurisdiction of the actor who is regulating. The policy of choosing only two connecting streets between the collectors (Fig. 3(c)), for example, eliminates the choice of building three or one sub-collectors. Further, the policy is also about maintaining connectivity with other roads. It fixes the location of the intersections as and when new roads get

built. A regulation specifying the minimum size of the lots in a particular zoning classification implicitly restricts how close the sub-collector streets can be, and thereby eliminates certain alternative locations from consideration.

Persistent debates about representations of geography, for example, object-field, crisp-vague dichotomies are particularly relevant to planning [10–12, e.g.]. In particular, the representation of inherent uncertainty about the location of the right of way of the sub-collectors can be represented as a probability field that exists between the two major collectors and gets modified by various events. The intended alignment of the Olympian drive is uncertain until the right of way is acquired by the city. However, geography is not central to the ontology for urban planning purposes. Location is but one attribute of urban development objects. The location of the effects of the decisions can provide a clue to which decisions might be related. However, other aspects of decisions, for example, jurisdiction of actor, which may not have a locational attribute, can also provide indicators to supplement understanding of how the decisions are related. In some cases, abstractions of locations are useful in determining the relationships between decisions. In Fig. 3(c) the notion of connectivity of a network of roads help narrow the alternatives where sub-collector should be built.

### 3.2 Alternatives

Alternatives are mutually exclusive actions. The exclusivity arises either because of capability constraints of actors or locational constraints of situating the action in a spatio-temporal setting. Keeping track of alternatives as they are modified, discarded, and used in a decision making process is useful because, as illustrated above, reporting intentions requires information about alternatives. In many urban development processes, these alternatives must be considered in a ‘public’ planning process. Alternatives can be of different types because:

- Multiple entities cannot occur simultaneously.
- ‘Same’ entity cannot happen in multiple instances.
- Multiple things may not occur in the same place.
- Same purpose can be achieved by different actions.

The possible locations of the interchange in the earlier example are alternatives. One interchange at one location can be built, but not all three because they are intended to serve the same purpose and they would create traffic conflicts if built close together. But in considering where to build the new interchange, it should be noted that there are three alternatives, which were considered at the time of the plan to dominate all other choices of locations, while no one of these three alternatives dominated the other two. In the future, as additional decision situations occur, this set of available alternatives may change, be reduced or expanded.

It is not useful to think of these three alternatives as separate decisions, to build or not to build each one, because they share an intention. The decisions are alternatives *with respect to* each other. I can either build the interchange at

$A$  or  $I$  can build it at  $B$  or at neither place. That is, if  $I$  decide to build an interchange at  $A$ ,  $I$  automatically also decided that the interchange at  $B$  is not going to be built in this particular context. A particular alternative thus has to include relationships with other alternatives.

If a plan specifies an alternative action in recognition of other intentions, then the planning process has recognised that other plan and represents its intentions about actions in its knowledge base. For example, a transportation plan might specify building extra lanes on an interstate highway whereas a plan by the local business organisation, in a directly contradictory approach, specifies that the rail network should be strengthened instead of building the lanes. Implicitly these are alternative uses for the same budget capacity toward the same intent for accessibility. When one plan recognises that the other includes an alternative action set, then a locational query could recognise the semantic relationship of alternatives in the two plans.

A plan might also specify multiple possible locations for the same road. While the recognition of ‘sameness’ of two proposals is not a trivial endeavour, it is possible that the plans might recognise these actions as the ‘same’ either in their intent or in their effect [13, 14, e.g.]. Thus intentions or effects can be used to identify the existence of alternatives.

In most cases, however, plans are circumspect about alternatives. To recognise that two actions are alternatives, expert knowledge about the situation is usually required. Such knowledge might involve, for example, recognition of budgetary constraints, which may preclude pursuing one kind of action when pursuing another. There may not be sufficient budget or borrowing capacity to build a new fire station and a new highway interchange, which become alternatives with respect to budget even though they are not alternatives with respect to intended purpose. The knowledge about ‘priors’, which are necessary and cannot be pursued simultaneously, might be involved to recognise the actions as alternatives. It may not be possible to build a new subdivision, for example, until the sewer services are extended. We can attempt to recognise the alternatives from the issues of location in a geographic context, location in a temporal context, and responsibilities actors and capabilities of actors, including their jurisdictions and budgets.

In all of the above examples in Urbana, the decisions have winnowed out various alternatives, which affect the implied commitment to a particular alternative. In the case of Fig. 3(c), the alternatives are effectively uncountable, subject only to policy restrictions on the distances between two parallel roads. Figure 3(b) considers three alternatives for future decisions, and Fig. 3(a) has specified a particular alternative as a decision. These differences can be viewed as differences in the types of commitment, by the deciding actor, to a particular set of alternatives [15]. A decision is an expression of a level of commitment to action. If we monitor whether or not an action is taken after the decision is taken, we can track the commitment of the particular actor to decisions and, conceptually at least, derive empirical estimates of commitment. More likely, we will use subjective estimates of commitment analogous to subjective probabilities.



### 3.3 Policies & Regulations

Information about assets, actors that hold rights over these assets, and regulations or transactions that change those rights is pertinent information for planning. An ideal system would track these changes of assets and changes of rights over these assets to arrive at “plan ready information” [16]. If we postulate that agents are planning continuously by amending old plans, updating them or discarding them in light of new information, relevant information about decisions needs to stay current.

Regulations are ‘If-then’ rules [17]. The ‘Antecedent’ describes the conditions when the particular regulation will hold and the ‘Consequent’ describes the rights through permission or by denial. Even when the regulations are performance based, the consequent can be used to describe the rights. Storm water runoff, for example, is often regulated to preclude any kind of development that alters the runoff characteristics of the site, thus circumscribing certain rights. Such regulations specify the attributes of effects of actions, thus giving wider latitude than regulations that specify a set of permitted actions in their consequent. In order to determine if a particular action is permitted or prohibited by the regulatory regime, it is then necessary to check not only the attributes of the action satisfying the regulation, but also the effects.

Rights have spatio-temporal dimensions. For example, sale of a property is an action that changes the rights of a current rights holder. The State can enact regulations about how this sale of property can be executed and what procedures should be complied with so that the State will guarantee this transaction, all without specifying when exactly the sale would occur. Hence, representing the time of the sale of the property is not sufficient to describe rights. We should be able to represent these events—sale, regulation, leasing, renting, and taking by the government—which routinely alter the set of rights and transfer these rights to other parties.

Policies are different from regulations because regulations are codified by statutory provisions and policies are merely a decision rule that gets applied repeatedly. A policy is chosen in anticipation of occurrence of repeated decision situations of similar kind. A policy could be announced for the sake of maintaining credibility, so that similar situations would be responded to in similar ways. However, policies and regulations share the same structural relationships between the antecedent and the consequent and thus could be modelled in similar fashion.

## 4 Relationships among Actions and among Decisions

The meaning of a decision changes when an action specified by the decision is carried out or when another explicit decision renders the earlier decision ineffective, perhaps by reducing its commitment to zero. We should keep track of these types of interactions for decisions and actions.

The difficulty of specifying the identity of objects, is also evident in specifying the identity of the decisions. For example, if a city annexes adjacent property into

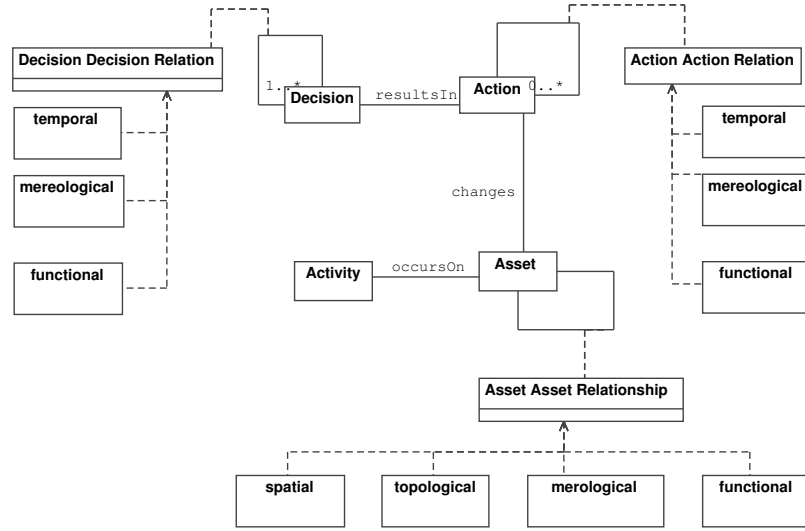


Fig. 4. Relationships among Decisions, Actions and Assets

its own jurisdiction, has the identity of the city changed? Similarly, a decision to build an interchange at either of the three locations is modified at a later point, by another decision that actually chooses the location. It is sometimes important to keep track of the sequences of decisions that resulted in the action to discover patterns of intents and effects.

Decisions do not typically happen in isolation but are linked to one another. The linkages can be temporal such as two decisions that have to be taken simultaneously. Or they can have spatial relationships such as intended investments that must be spatially adjacent. They can also be contingent or interdependent as shown in Fig. 4.

Almost all temporal relationships that are between actions happen between decisions [18]. However, the translation is not unique. For example, an action of relocating Olympian Drive is *followed by* the action of giving up the right of way of the current Olympian Drive (a finish-start relation among actions). The relationship between the two decisions, however, is *simultaneous*. The decision to build one interchange in East Urbana is followed by another decision about the location of the interchange. The result, however, is a single action.

Two decisions may be made by different actors but they may share a temporal relationship. An obvious example is a sequential play in a game theoretic sense between two actors. Consider the relationship between a decision of the Federal government funding of the construction of levees and a decision of a speculative developer to invest in the flood prone area. The speculative investment may occur prior to the building of the levees action or even before the decision to build the levees. A small homeowner, who is risk averse, may require more assurance about

the flood protection of the area and thus may wait to rebuild a home until either there is a credible commitment to building the levees or even until after the levees get built. These relationships, which depend crucially on the notion of decisions as levels of commitment, have to be identified ahead of time and formulated as policies or strategies with which to monitor other's decisions to trigger one's own decision situations. The policies and strategies form the plans of the particular actor. Thus, decisions may be prior (and thus interdependent) on other actions or other decisions. Actions, by the same token, are interdependent on other decisions and actions.

If decisions are perfectly separable from each other, then the decision making process is simpler. However, most urban land development decisions ought to consider the effects of decisions of other actors and effects one's own action.<sup>1</sup> A zoning change near a proposed interchange is not very effective unless the interchange is built. Speculative investment in that parcel of land to develop it into a commercial strip, while purchasing the land when it is still zoned and used as agricultural land, necessarily depends on information about *what* decision about the interchange is likely to be taken and *when*. This information by its very nature is imperfect and subject to revision.

Typically, when a decision is taken, many implicit decisions are also taken. For example, to decide to build a new school would already imply commitment to, among other things, specify a location, provide infrastructure, staff it, and seek budgetary approval. In this sense all these decisions are encompassed in the decision to build a new school. However, it is unwise to assume that all such subsequent decisions are considered in complete detail and resolved in the current decision making process. The status of the decision—the alternatives that are chosen, timing, actors interested etc.—has a ripple effect on other decision situations that are yet to come, and sometimes that have already passed. In these situations, this ontology for urban planning, which takes into account the substantive knowledge about how plans, actions and actors work, will be useful.

The decision to build a new interchange at a particular location (Fig. 3(b)) is not a decision of one actor. The Federal government through its Department of Transportation, and the state's department of transportation must also decide to fund the project. The metropolitan planning organisation has to conduct a study about the traffic and other impacts of the project. The county and the city governments have to budget their shares of funding. As such, this decision is a decision-set by an ad hoc collection of actors. If any of those actors decides otherwise, the action is prevented from being taken. In particular, even after the decision is taken to build an interchange at the particular location, for example by the City of Urbana, the responsibility of carrying it through may lie with another actor, who is not involved in making the decision.

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<sup>1</sup> A decision may be taken by a collection of actors agreeing to it, by various decision rules, including majority or unanimity. Such an actor would be an organisation or a collective. See [5].

## 5 Conclusion

A description of a continually developing ontology is available at <http://www.rehearsal.uiuc.edu/projects/pml/>. An ontology of urban development is necessary for building an Information System of Plans (ISoP), which should include substantive knowledge about how planning affects decision making and vice versa. An ISoP allows us to use multiple plans in decision making and modify plans continually to keep them relevant. This ontology enables sharing of information when authority and capabilities are distributed among disparate actors.

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