INTERNATIONAL UNIVERSITY OF JAPAN
Public Management and Policy Analysis Program
Graduate School of International Relations

DCC5350 Public Policy Modeling
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Introduction to Public Policy Modeling

This class note introduces public policy modeling and provides fundamental concepts and modeling paradigm.

> *"A decision analysis approach can help in identifying important sources of uncertainty and representing that uncertainty in a quantitative way. … Decision analysis allows people to make effective decisions more consistently. Although decision analysis provides structure and guidance for systematic thinking in different situations, it does not claim to recommend an alternative that must be blindly accepted. Instead of providing solutions, decision analysis is perhaps best thought of as simply an information source, providing insight about the situation, uncertainty, objectives, and trade-offs, and possibly yielding a recommended course of action. Thus, decision analysis does not usurp the decision maker's job."*
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> Clemen, Robert. 1991. *Making hard decisions: An introduction to decision analysis*. Boston: PWS-Kent Publishing.

1. What Is Public Policy Modeling?

Public policy modeling (management science or operations research) focuses on decision making and problem solving through utilizing systematic means and scientific methods. This approach 1) assumes decision making situations; 2) solves policy problems; and 3) uses mathematics and computer (computer software packages) extensively in order to take advantages of their deductive logic, objectivity, conciseness, and fast computation.

Policy modeling, a type of policy analysis and evaluation, is broader than management science (using a system approach to implement actions) and operations research (focusing on problem solving) in that it 1) has interdisciplinary focuses of physical, economic, social, and political systems; 2) employs broader range of techniques; 3) focuses on formulation of models and solutions rather than technical details and computation.

Public management and policy problems are often difficult to handle because of their complexity and inherent uncertainty. Policy analysis and modeling may provide systematic ways of avoiding bad decisions and improving accountability. However, policy analysts should keep going back and forth between the model and the real world to check the validity and plausibility of what they are doing until the policy problem is resolved.

2. What Is a Model?

A model by definition is a mental construct that simplifies the real world. This abstraction of reality ignores unimportant details of the real world and highlights significant factors

influencing problem solving. A good model can represent the real world by capturing its salient features and essential information and should be simple (parsimonious) enough.

A too complicated model or accurate portrayal of reality is less practical and more costly (time-consuming) to handle, whereas a too simple model, like a toy only for fun, is less useful. There is trade-offs between accurate representation of reality and simplicity of a model, precision and tractability in Hillier and Lieberman's (2010) terminology.

A *deductive method* (mathematical method) draws a conclusion to specific case from a set of general premises. By contrast, an inductive reasoning reaches a conclusion (general statement) from specific cases or examples. Premises or a series of assumptions are needed for approximation or simplification of the real world.

Deductive Reasoning	Inductive Reasoning
Politicians never care about ordinary citizens Bush is a politician Bush does not care about ordinary citizens	Politician A does not care about ordinary citizens Politician B does not care about ordinary citizens too … Therefore, Politicians never care about ordinary citizens.

If the underlying assumptions of a method are not met, the method is not valid and its prediction (inference based on the method) is not reliable. Therefore, policy analysts should keep asking if the underlying assumptions of their model are reasonable and trying to find better way of modeling the policy issue.

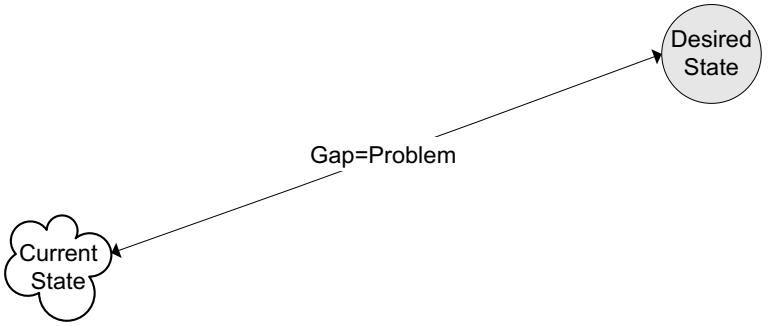
3. Policy Modeling Process

Policy modeling has a series of steps to make its approach systematic. However, these steps are neither a linear process nor one-shot game.

1. Definition (identification) of the policy problem
2. Classification of the problem
3. Formulation of the model
4. Solving the model
5. Sensitivity analysis
6. Presentation and decision-making
7. Implementation and evaluation of the model

4. Definition of the policy problem

Careful policy analysts or public managers can recognize a significant public problem (e.g., heavy snowfall in the City of Minami Uonuma) and define it clearly as a policy problem.

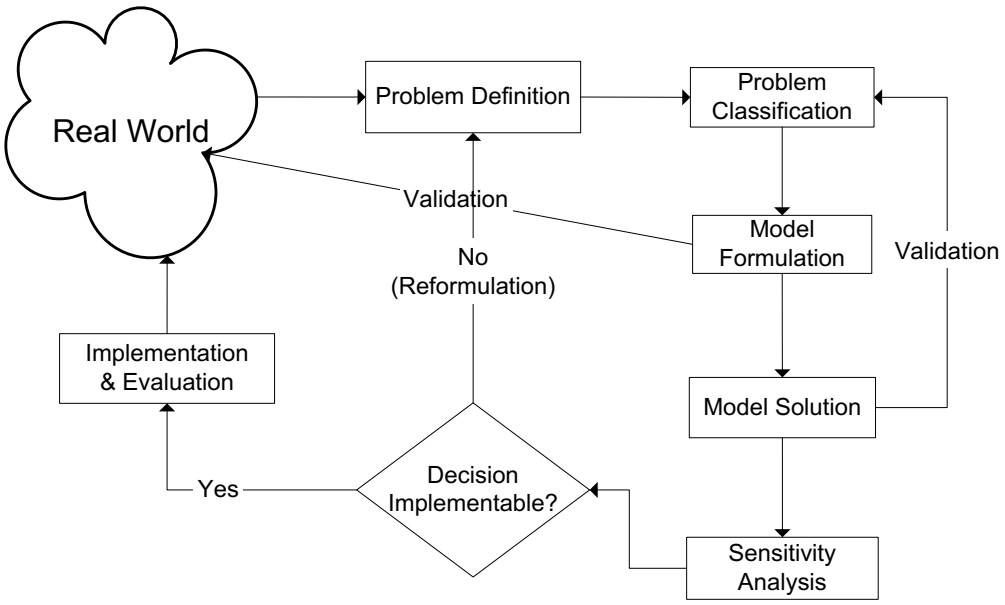


The problem should be "right" one from the public management and policy standpoints. A personal or private problem like purchasing apples is not a right policy problem. Policy analysts have to describe current status, state appropriate objectives, and possibly include potential sources of the problem.

A policy problem is defined as a gap between the status quo (current state) and desired state. A current state is a place from which you are suffering now, while a desired state is a place where you want to reach or a goal that you want to achieve.

Suppose that current unemployment rate is 40 percent and many people became frustrated with such high unemployment. And people appear to be happy if the rate is as low as 10 percent. In this case, a policy problem is defined as an unemployment rate gap (30%=40%-10%) between current 40 percent state and desired 10 percent state; that is, government wants to reduce unemployment rate from current 40 percent to 10 percent (policy goal). In this respect, a public policy is a governmental effort to solve a public problem by changing a policy situation from the current state (40% of unemployment) to the desired state (10%).

If policy analysts (in particular, those who do not care about ordinary citizens) fail to identify a problem, nothing will happen. If they recognize a problem but define it incorrectly, the model employed and its solution will be misleading, if not disastrous. "It is difficult to extract a 'right' answer from the 'wrong' problem!" (Hillier and Lieberman, 2010:9). Garbage in, garbage out (GIGO)! Also this is a sort of "Type III Error."



5. Classification of the problem

Policy analysts have to know the nature of the problem to be examined. Let us consider following four dimensions.

5.1 Programmed versus nonprogrammed

If the problem is totally new to a policy analyst, it is a nonprogrammed problem. A programmed problem is what you have experienced and thus easy to deal with. The experience of decision-makers determines if a problem is programmed or nonprogrammed.

For example, removal of heavy snowfall is a programmed problem in Minami Uonuma but a nonprogrammed one in Singapore.

5.2 Level of knowledge (role of chance in the model)

- If the outcomes that will occur are predictable, the level of knowledge is ***certainty***. You already know the right answer just as the God knows perfectly if a kid is good or not. The God is always 100 percent sure; If the God is only 90 percent sure, the God is not, by definition, a god any more. The outcome is not *probabilistic* under certainty.
- If you are not 100 percent sure and just know possibilities (which outcomes will occur) and a probability for each possibility, your knowledge level is called ***risk***. For example, when tossing a coin, you know that the outcome is either head or tail and the probability of either case is .5 (50% of chance of getting head or tail). But you don't know exactly whether you will have head or tail in a particular trial; You can only say that there is 50 percent chance to have head and another 50 percent chance to get tail.
- If you know what possibilities are available but don't know their probabilities, this is ***uncertainty***. For instance, we know that earthquakes and volcano eruptions will occur in Japan and Indonesia, but we don't know when and how likely. Can you tell me when an earthquake will hit IUJ and its likelihood (probability)? A fortuneteller might say, "It will be January 1st, 2014 with 99 percent of chance." But nobody knows his prediction is correct or not. If he/she were the God (certainty), he/she should have said, "There must be a level 7.45 earthquake 15.24 meters south of IUJ gym at 13:35 on January 1st, 2014," because the God does not make any mistake.
- The final level is ***ignorance*** where you know neither possibilities (outcomes) nor their possibilities. For instance, do you know how many alien species exist outside the solar system? How about probabilities of each alien species? If you say No, your knowledge level on aliens is ignorance.

		Probability		
		Determined (100%)	Known	Unknown
Possibility	Known	*Certainty*	*Risk*	*Uncertainty*
	Unknown	-	-	*Ignorance*

- In the public management and policy world, problems tend to be so complicated that public managers oftentimes encounter risk and uncertainty. A problem under certainty is not a public problem any more and a problem that nobody knows does not deserve public managers' time and effort; Don't try to solve such questions as "Can a man survive without air?" and "What kinds of welfare programs will be popular in the year 2999?"

5.3 Static versus Dynamic (Importance of time)

- If time does not matter, the problem is *static*. A linear equation is static because the problem remains unchanged regardless of time. It will be static to decide an optimal amount of investment given current information available; time does not play a role.
- If decisions are made sequentially over time or the consequences of those decisions have lagged effects on subsequent activities, the problem is *dynamic*. If an anti-corruption policy triggers a series of events (increase in risk of receiving bribe → increase in corruption price or bribery→change in strategies to give and take

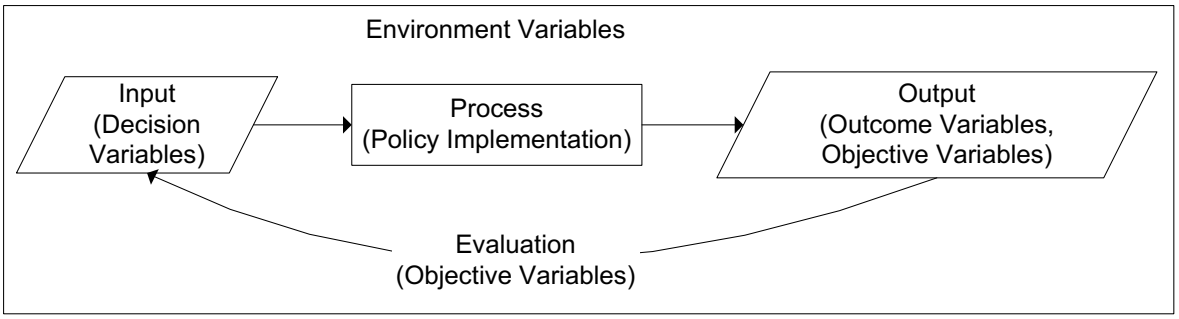
bribe→decrease in probability of detecting bribery→increase in corruption…) as time goes, the policy problem is dynamic.

5.4 *Strategic* versus *non-strategic*

- If there are interactions (reactions) between environment and decision makers, the problem is strategic. Removal of heavy snowfall is not, for instance, strategic; The weather (God) does not consider how human beings are doing. If your pray for no more snow is heard by the God and he/she decides not to "pour" out the snow upon IUJ, then heavy snow problem is strategic; Of course, this scenario is not likely at all! If a subsidy program for the poor is misused by the rich and the program was adjusted properly in response to the unintended outcome, the welfare problem is not non-strategic, but strategic.

6. Formulation of the model

Once a policy problem is classified properly, a model is formulated and validated. A model consists of input (decision variables), output (outcome variables), environment (environment variables), and criterion components (objective variables) as shown in the following diagram. It is very important to distinguish one from the others because this distinction reflects your understanding of a public problem and shapes your model. Process or policy implementation transforms policy input into output.



6.1 Input component: Decision variables

You need to identify "shocks" that you can make in order to change the status quo. These shocks or changes are *decision variables* or *policy variables* that can be directly controlled by decision makers.

Each public manager has different decision variables depending on his/her status (rank or grade) in hierarchy and ability. An increase of a basic interest rate might be a decision variable of a top executive of the national bank, while a war on terrorism is not (probably the president's decision variable). A virtual machine server system, which requires high performance computing technology, might be a decision variable in the U.S. to improve efficiency and security, but not in a poor developing country. The number of courses to take is your (as a student) decision variable because you can decide it. But an increase in the minimum TOEFL score is not your decision variable but university's; you may not control the minimum score. These variables are considered independent variables (IVs) because they influence the dependent variable (outcome variable).

6.2 Environment component: Environment variables

Unlike decision variables, *environment variables* cannot be directly/indirectly controlled by decision makers. Public managers should differentiate controllable decision variables from uncontrollable environment variables by carefully examining their current status and situation where he/she is encountering. You must ask, "Can I control it?" when determining a decision variable or environment variable. Environment variables are not independent variables but something given to you.

As a student, you may control the number of hours of studying at IUJ (decision variable) but may not decide the weather in Minami Uonuma even if you hate heavy snow (environment variable). You may ask to change the curriculum, but you cannot change it directly because the curriculum is an environment variable to you; by contrast, IUJ can change the curriculum that is controllable to IUJ (decision variable). A budget is given to public mangers (environment variable) but controllable to Congress (decision variable). Therefore, do not try to change the weather, location, earthquake, and nuclear radiation level, PMPP curriculum, PMPP faculty members at IUJ; these variables are beyond your ability!

6.3 Output component: Outcome variables

Given environment variables, changes in decision variables (policy variables) will produce various results. Such results are called *outcome variables* or *result variables*. These dependent variables (DVs) are what decision-makers want to achieve by indirectly changing decision variables; decision-makers cannot access outcome variables directly.

Politicians oftentimes promise such rosy slogans as "Rebuilding Japan" and "Welfare Heaven." These are highly abstract outcome variables. Decision variables instead ask, "how?" For instance, "Constructing five new Shinkansen lines" can be a decision variable to achieve the result variable "Rebuilding Japan." Some outcome variables are intended but others are not. A decision variable might produce unintended result that is not predicted at all. A decision variable of "New Shinkansen lines," for instance, may result in serious damages to an endangered species and collapse of local economies that might be neither intended nor predicted.

6.4 Criterion component: Criterion variables

In order to determine the success or satisfaction of a policy variable, you need have criteria by which system performance (or the impact of the decision variable) is evaluated. These *criterion variables* or *objective variables* can be found among outcome variables. Of course, criterion variables are intended and need to be specific. For instance, "Rebuilding Japan" is not a good criterion variable because it is not specific but too abstract (too high in the value hierarchy). No one knows if "rebuilding Japan" is successful or everyone has his/her own answer. One possible objective variable may be "10 percent `year-on-year` increase in GDP."

6.5 Process and validation

The process is *relationships* among input and output variables in your model. Once you identify decision variables, environment variables, outcome variables, criterion variables, you

need to validate the model. If it is not valid, you must carefully investigate the phenomenon in the real world again and redefine the problem.

7. Solving the model

- Generate a complete list of available alternatives (limited by environments or constraints); predict the outcome for each alternative; evaluate the outcomes by the criterion variable for each alternative; compare the alternatives; and then choose the best alternative.
- Use algorithms, if known and applicable, or try simulation approaches.
- Growing computing power and tools make it easy and less costly to solve models. Policy analysts may take advantages of computer software packages such as LINDO (LINGO), SAS/OR (and simulation studio), QSB+, and Excel Solver.
- If there is no solution, you may need to alter objectives or constraints (decision, outcome, and/or environment variables). In case of multiple solutions, you need to add criteria to select a solution.
- Check if the solution and prediction are reasonable by plugging in actual data or extreme values. If they are not realistic, step back to the problem classification stage (or problem definition stage in some cases).

8. Sensitivity analysis

Sensitivity analysis asks, "Will the solution (values of decision variables) change dramatically if a slightly different value in an environment variable (constraint) is used?" If yes, the solution is not reliable and/or accurate, or the model might be formulated inappropriately. So called "what-if analysis" (or post-optimality analysis) is one type of sensitivity analysis.

9. Presentation and decision-making

"Policy analysis is client-oriented advice relevant to public decisions and informed by social values" (Weimer and Vining, 1999:27). Policy analysts should provide useful advice to their clients (e.g., senior managers and chief executives) who oftentimes do not have solid mathematical knowledge and skills. Therefore, the model and its solutions need to be presented in intuitive (client-friendly) and professional manners.

Due to political and other reasons, not all good models and their solutions can be implemented in the real world. If a model and its solution are not accepted, policy analysts need to get back to problem definition and/or problem classification steps to reformulate or refine the model. It is possible that a problem is defined incorrectly and/or the stated objective (policy goal) is not what the clients *really* want.

10. Implementation and evaluation

When a solution is accepted by decision-makers, it can be implemented and its performance will be evaluated. If the solution does not work well, policy analysts need to iterate policy modeling process in order to reformulate the model and obtain better solutions from it.

11. Classification of Modeling Techniques

Policy modeling techniques may "roughly" be classified as follows. A stochastic (probabilistic) model incorporates probabilities of events, where a deterministic model seeks an optimal solution under certainty (perfect or complete knowledge). In a strategic model, a play determines his/her decision depending on what his/her counterpart decides. Time matters only in a dynamic model. A game theory may be static or dynamic, and deterministic or stochastic (in most cases).

	Static	Dynamic
Deterministic	Optimization Linear programming (LP) Nonlinear programming	Dynamic programming Discrete and continuous time methods
Stochastic (probabilistic)	Decision theory (decision table/tree) Utility theory	Markov chains Queuing model (Monte Carlo) Simulation Event-based and time-based methods
Strategic	Static game theory	Dynamic game theory

12. An Example of Formulating a Model: Identifying Components and Variables

Think about your imminent academic issue at IUJ. This is not a public issue though. Assume that you are currently living with family members; you depends heavily on financial aids (scholarships) that are closely related to your performance in previous terms (that is, if you get poor grades, you are likely to lose your scholarship); and IUJ does not have any plan to change PMPP settings including faculty, curriculum, and requirements within two years.

12.1 Identify "policy problem"

What is your critical academic issue that you have to deal with at IUJ? What is your goal of studying here? This task might sound tedious or self-evident to you but is not as simple and clear as you imagine. I believe that you are dreaming of a healthy and happy life with your family members. But this ultimate goal of your life in a value hierarchy, although true, is too far away from your current situation at IUJ. You need to clarify your "workable goal" at IUJ. Non-workable goals include "relaxing," "saving money," "seeking a significant other," "making good friends" and the like. Your workable goal at IUJ might be to earn M.A. in public management (in a good health condition).

12.2 Classify this policy problem

- Non-programmed (You never experienced this master degree program)
- Uncertainty (You know two outcomes: M.A. degree or not. But, you never know the probability of getting the degree)
- Dynamic (Your performance in this term influences subsequent terms. If you get F in public policy modeling, you need to take it again next year. If you get a poor GPA and thus fail to get scholarship, you need to work harder to earn tuition in subsequent terms)
- Strategic (Here are two players: you and instructor/IUJ. If you ask to change reading materials, your instructor may adjust reading assignment. If you violate IUJ's rules, you may be kicked out in a worst situation)

12.3 Determine decision variables.

Decision variables are what you can control. Do not try to control your budget that is determined by a contract with your sponsor.

- Courses to be taken (you need to meet the requirement). Yes, required courses are not controllable (not negotiable) but you can decide whether or not to take them (if you do not take required courses, you may not graduate).
- Time and effort level for studying and doing homework
- Time and effort level for taking care of your family members (trade-off between study and leisure)
- Purchasing textbooks and other materials (e.g., laptop, notebook, and pencils)
- Exercise (if you are sick, you may not finish coursework and/or thesis on time)
- Prudent and decent behavior (for friendships and compliance with IUJ policy).

12.4 Identify relevant environmental variables

Look for variables that influence your policy problem (earning M.A. degree) but you cannot control.

- Weather (You may be sick and tired of heavy snow and sticky summer in the Minami Unonuma City)
- PMPP requirement (required courses) regardless you like it or don't
- IUJ policy and faculty members
- Others settings in Minami Uonuma (e.g., ski resorts, hot spring, and AEON)
- Scholarship or budgets (limited money influence time and effort for studying at IUJ).

12.5 Identify relevant outcome variables

Think about what you will get as a result of your choices of decision variables. If you do not study hard with long studying time and high effort level, for instance, you may not earn sufficient credits for graduation and GPA required for writing your thesis. If you study hard without doing anything about friendship, health, and family life, likely outcomes include no friendship, sickness, and family troubles. If you minimize spending (do not purchase textbooks and others), you will save some money (probably "big money" in your home country) but you won't be able to obtain good knowledge and high grade.

- Number of courses taken or credits earned
- Grades of individual courses
- Master thesis
- Knowledge, experiences, and skills you obtained
- Friendships
- Health condition
- Family life (marriage, children, etc.)
- Money (you save from financial aids)

12.6 Identify relevant criterion variables

Choose key variables among outcome variables that are used to evaluate success or failure of the policy (studying at IUJ). In order to get M.A. in public management, you must satisfy course requirement (including GPA) and pass the oral exam of your thesis. You knowledge and friendship, by contrast, are not directly related to your M.A. degree.

- Course requirement (# credits, GPA, and the like)
- Master thesis (oral examination)

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