# Beyond Proximity: Consequentialist Ethics and System Dynamics

Erika Palmer, PhD Fellow
University of Bergen, Norway

## Abstract

There is very little system dynamics literature that explicitly addresses ethics outside of validation, and the goal of this paper is to renew the ethical discussion in system dynamics by focusing on consequentialism. Consequentialism is a moral philosophy that maintains that the moral worth of an action is determined by the consequence it has to the welfare of a society. As the model is a product of the modeler's decision-making in design, the modeler should consider the life cycle consequences of using the model. In this light, the consequences of the policy is what determines its moral value (ethical/unethical) in a consequentialist perspective. This concept is explored by discussing model uncertainty in an engineering perspective. Models cannot be 100% robust, with all uncertainty removed, because the nature of system dynamics requires assumed causality. Model uncertainty leads to ethical concerns that are often overlooked because system dynamics addresses uncertainty through model validation. If we consider system dynamics as an engineering enterprise, what ethical issues must be considered? In this perspective, the ethical considerations shift from the behavior of the modeler (away from validation) to the model itself and its inherent uncertainty. Given that the ethical considerations are taken away from the model itself and placed on what the model does, the ethical boundaries are extended beyond the proximity of the model. This paper renews the ethics conversation in system dynamics by considering this shift in philosophical perspective and investigates the application of consequentialist moral philosophy to the modeling process and in communication with decision-makers. A model of social assistance in Norway in light of immigration pressure illustrates possibilities for addressing these ethical concerns. This paper argues for an ethical framework, or at the very least, an ethical conversation within the field. The road to an ethical framework in system dynamics must be developed over time through discussions in moral theory and practical application.

Contact information: erika.palmer@uib.no

## Introduction

There is very little system dynamics literature that explicitly addresses ethics outside of validation. However, there are important ethical considerations that fall outside the domain of validation. The use of system dynamics modeling in public policy is an area in which the topic of ethics should be renewed. In public policy decision-making, system dynamics modeling will have an effect on society. The modeler must consider the effect their decisions about subjective elements and relationships will have for those affected by the policy. The ethical concerns go beyond the normative considerations of model and policy design (the purpose of the model and policy) to the assumed causality that is necessary when making decisions in system dynamics modeling. How does one know when a model represents reality accurately enough to build policy? What happens to society if policy is built and implemented from a model that produces the correct behavior, but in the wrong way? This paper explores these ethical concerns.

### Background

Ethics in system dynamics is complicated by its philosophical foundation. Situated in the philosophy of science, system dynamics scientifically analyzes a problem through model development. Ethical questions in system dynamics are concerned with the behavior of the modeler in the context of validation. Are the actions of the modeler ethically right or wrong when making subjective decisions about the model? Consider however that it is not just the behavior of the modeler that is in question, but the model itself. A developing argument in the field concerns whether system dynamics would be better considered as an engineering endeavor, meaning that system dynamics models are engineered artifacts. This artifact is then used to design another artifact (the policy). The result of using this artifact (the implemented policy) causes the consequences for society (good or bad). It is not only the model/policy purpose that is ethically in question, however, but the natural uncertainty in system dynamics models because they are built on assumed causality. Given that system dynamics falls within the realm of engineering, the ethical discussion must consider the consequences of design because of this uncertainty. The point of departure for this discussion is the consequentialist ethical considerations in system dynamics modeling in an engineering context.

### Renewing the Ethical Discussion

There is no standard procedure in system dynamics for making ethical decisions when setting model boundaries and making data and parameter assumptions or a stated requirement that this must be transparent in communicating with decision-makers. The purpose of this paper is to renew and further develop the ethics conversation within system dynamics concerning both the modeling process and in communicating with decision-makers. Developing a basic ethical foundation in system dynamics is necessary for systematically dealing with ethical considerations in modeling, which further enhances the credibility of the field.

The focus of this discussion is the shift in philosophical perspective for system dynamics (from science to engineering) and how this affects the ethical considerations in modeling. However, there is no general understanding within system dynamics that ethics needs to be discussed. The first section of this paper discusses uncertainty and transparency issues in modeling as grounds for having an ethical conversation in system dynamics. Next, the discussion explores how system dynamics' philosophical foundation frames the ethical discussion, which calls for ethical questions to be thought of in a new context-consequentialism. This is then illustrated with a model of social assistance in Norway in light of immigration pressure, ending with a discussion of topics for further research.

## Uncertainty and Transparency

The nature of system dynamics modeling breeds uncertainty, whether this uncertainty is made transparent is decided by the modeler, which is an issue that deserves attention. Transparency depends on the ethical behavior of the modeler, though it is the model itself that is ethically charged. There are many reasons why a modeler would not want to communicate the uncertainty of their model. The audience is funding the project; the modeler does not want to show weakness; the modeler has an ulterior agenda. The issue under discussion is not how this uncertainty is evaluated (see Walker et al. (2003) for a framework in which to address this), but why modelers must consider uncertainty beyond the validation of their models.

### Assumed Causality and Validation

The issue of causality is blurry in system dynamics, especially when communicating with those outside of system dynamics. System dynamics models represent operational behavior; modelers observe relationships in a system and make assumptions about instantaneous causal relationships, which goes against scientific principles of causality. Using the word causality creates communication problems with decision-makers as well because the scientific meaning is often assumed. The system dynamics causality issue is both semantic and philosophical. What system dynamicists mean by causal is different than the scientific definition (a natural law). System dynamics models show how variables operate in relation to flows. Models are one possible structural explanation and not a causal declaration, meaning the models show the how (and only one possible how) and not the why. This does not mean that system dynamics methods should be practiced any differently than what is now current practice; it does, however, mean that we need to think about the methods differently, and this is the philosophical part of the issue.

Models, as a set of aggregated causal assumptions (observed operational relationships) is why (regardless of validation) they must be uncertain-causality is assumed. We speak of robustness when evaluating the uncertainty in system dynamics models. To make a model as robust as possible, modelers validate the model. There are various levels for validating models from the technical validation to the justification of variables. It is assumed that modelers will make sure that their models are as robust as possible (least amount of uncertainty as possible) through validation, and decision-makers assume that the modeler has done this, and it is therefore not necessarily communicated. There are no ethical guidelines for system dynamics, which begs the question: how can the field of system dynamics trust practitioners to do the right thing? How is the decision-maker to understand that the causality is assumed? What level of transparency is shown by practitioners in reality? How is the field of system dynamics to know that everyone is practicing the same "brand" of system dynamics (acting as ethically as possible)? As explained by Forrester (2007), many people building models are not skilled system dynamics practitioners. Because system dynamics software is so easily learned, and many people outside of the system dynamics community use system dynamics modeling, would it not strengthen the field to have ethical guidelines that system dynamicists must follow in order to call themselves system dynamicists?

Many in the field may think that ethical considerations are not an issue. "Show me a model that has had a negative effect on society." "Professional system dynamics practitioners already follow validation procedures." These are two criticisms I have heard about even discussing ethical issues in system dynamics. However, is validation enough to remove uncertainty? Valid models still assume causality. Does the nature of system dynamics, with its assumed causal relationships, require further ethical consideration concerning the societal impact of the model? No matter how valid or robust a model is, the model has aggregated causal assumptions. This does not mean that the model is wrong or not useful; it does however mean that system dynamicists must consider the model in a different light and ask different ethical questions.

Ethical concerns in modeling are also important to consider because of a lack of policy design and implementation focus in system dynamics modeling. Explanatory models may be uncertain, but this is meaningless in terms of societal impact unless policy structure is built to change behavior and is then implemented in society.

### Policy Design and Implementation

Wheat (2010) explained system dynamics models are very often not concerned with policy implementation, merely policy design as parameter testing. At best, adjusting parameters as policy design means poor feasibility and possible policy implementation failure. At worst, it means negative consequences for society. However, it is not just building policy structure beyond parameter testing that must be done to avoid either scenario, understanding inherent uncertainty and communicating this must be considered as well.

Considering uncertainty is outside of the ethical realm of the policy model's purpose. Model purpose holds normative ethical considerations that does not include uncertainty. The focus of this discussion is the uncertainty in every system dynamics model, which has the possibility of negative consequences for society regardless of the normative implications of the policy. The ethical issue at hand is the consequences, or the unintended effects of an implemented policy, produced from a model where subjective elements and relationships were established by the modeler as causal when in reality they are not.

System dynamics modeling produces just one possible design to explain behavior, and policy models designed from the explanatory models will only be successfully implemented if the explanatory model's assumptions are correct (and if implementation issues are fully considered). Because there is no way to remove the uncertainty (and nor does it need to be in order to be useful), this must be made transparent to those that make decisions about policy implementation.

## System Dynamics Modeling in an Engineering Context

Within system dynamics, models are considered causal mathematical models that represent a theory of an actual system. Each causal claim in the model must be supported, and if critics disagree with one equation, then the entire model is disregarded (Barlas 1990). Therefore from the perspective of the philosophy of science, seeking justification for causal claims in a system dynamics model can be difficult. How does one ever truly know when a relationship is causal, and how far does one have to go to support the causal claim? The truth is we, as modelers, cannot know if we have represented causal relationships in our models. We assume causality in our models, which gives rise to one of many designs of the structure that produces the behavior.

Science aims to understand (to know) a system, whereas engineering is steeped not in the true or falsehood of a system, but in how it operates (the how); the *knowledge that* versus the *knowledge how* (Schmidt 2012). System dynamics models are designed to understand *how* a system works, not to understand *that* (why) is works. Olaya (2014) explains how science is very different from engineering (although it contributes to science-i.e. contributes to the scientific method, but does not use the scientific method itself), and that system dynamics is in fact an engineering enterprise. System dynamics was born out of engineering and applied to management science. However, system dynamics has deviated from its engineering heritage by seeking to justify itself as science (i.e. uses the scientific method). If system dynamics is an engineering endeavor, the model does not intend to claim causality. The model is used to understand how the system works (one way among many structural designs), making it useful to decision-makers as a tool for gaining insight into complex systems.

Because both engineering and system dynamics are both concerned with design, system dynamics should concern itself with the operations of the system not the causal relationships. Olaya (2012) states:

> *Operational thinking opposes to mere theorizing activities based on data-analysis, which happens to be the fashionable way (and the "scientific" style in many cases) to study social systems. Instead of developing knowledge by observation to generate general statements through induction, the production of knowledge through operational modeling does not rest on data in order to bring understanding or explanation. Rather, it relies on the generation of dynamic hypotheses that explain the performance of a system in function of its structure that is generated by its operations. Such an approach recognizes human systems as systems that change through time according to free actions of decision makers* (p.2)

System dynamicists design models that represent social systems in order to develop policy to improve a system. The models are intangible artifacts designed by the modeler, and this artifact is then used to design other artifacts. Models are used to design policy; policy includes an entire array of artifacts: regulations, plans, organizational structure, etc. Trademarks of engineering include first and foremost design and operations (knowledge how), but also: using heuristics, making decisions, being creative, using trial and error methodology, having purpose versus being impartial and being particular rather than universal (Goldman 2004). All of these are also trademarks of system dynamics. Because of this, the link between system dynamics and engineering is easily seen (Olaya 2014). This paper does not attempt a full-scale examination of whether system dynamics is engineering or science. However, if we think of system dynamics as engineering, how does this impact validation and ethics?

Science is very concerned with ethics regarding the behavior of the scientist and the validation of their methods. Validation is irrelevant in engineering. An engineered artifact is not true or false. It either technically works or it does not. In engineering, ethical considerations fall outside of validation and the behavior of the practitioner. The purpose of the artifact and uncertainty (robustness) in design are the ethical concerns in engineering. Why was the artifact designed, and how will this affect society (the purpose)? Because the artifact does not claim knowledge of why cause and effect occurs, what is the risk of consequences to society from the uncertainty (robustness) in design? As mentioned earlier, the normative implications of model purpose are not under examination in this paper, as this concerns the nature of specific case studies. In the more general examination of moral philosophy and system dynamics, given that its philosophical foundation is engineering, system dynamicists must consider the consequences of the uncertainty in their models on society.

## Consequentialism and System Dynamics Modelling

Given that system dynamics is an engineering enterprise, what ethical issues must be considered? And why does uncertainty take center stage?

In an engineering context, the ethical dilemmas of the modeling process concern the consequences that arise because of model design, which only surface after the recommended policies of the model have been implemented in society. System dynamics modeling of social systems is no easy task. There is uncertainty in many variables, making this a difficult ethical undertaking.

There are various moral philosophies that could be taken when evaluating decision-making in modeling. This paper does not attempt to explain these different philosophies and how they can be used in system dynamics. The intent of this paper is to illustrate the societal consequences due to the nature of system dynamics modeling, i.e. a consequentialist approach. Pruyt and Kwakkel (2007) provide a good overview of different moral philosophy approaches in system dynamics.

Consequentialism is a moral philosophy that maintains that the moral worth of an action is determined by the consequence it has to the welfare of a society. Consequentialism is a 20$^{th}$ century development in moral philosophy based on 19$^{th}$ century utilitarianism, which holds that the moral worth of an action is determined by maximizing the good and minimizing the bad. The “good” is described as pleasure and the “bad” is pain avoidance (Driver 2011). Fundamentally, consequentialism is the choice between different alternatives, and the moral virtue of each alternative depends on the consequences it causes.

In its extreme form, consequentialism leads to decision-making where “the ends justify the means” or determining “the greater good.” This, however is not the form of consequentialism referred to in this discussion of ethics in system dynamics modeling. The moral value of a system model is determined by the effect it has on society. When policy is designed and implemented based on the design of the structure of the explanatory model, then it is the resulting societal consequences that determines the moral value of the model.

Models cannot be 100% robust, with all uncertainty removed, because the nature of system dynamics requires assumed causality. Therefore all models have the potential for harm (i.e. negative unintended consequences due to uncertainty). This is why communicating uncertainty to decision-makers is essential. Practitioners can only give the best of what system dynamics can offer (unbiased, well-researched models); decision-makers have the moral responsibility of policy implementation, and they must understand the risk of implementing policy built and tested on models that have inherent uncertainty.

Validation of causal claims is a matter of professional ethics found in the sciences, which concerns the behavior of the scientist. The outcome of the causal assumptions in system design and what this means for citizens and society is a matter of consequentialistic ethics in engineering. In an engineering perspective, system dynamics models do not need to be validated because they do not attempt to explain causality. Using the same perspective however, system dynamics models must be designed with the least amount of uncertainty to avoid negative downstream societal consequences. This is where the ethical distinction is made between the modeler and the model. In engineering, the modeler’s behavior is no longer called into question concerning methods, but instead the model is called into questions for the potential impact it could have on society.

Placing the focus away from the modeler and onto the model requires the modeler to expand their ethical awareness beyond the modeling process. In engineering, this is termed the “product life cycle.” So too should system dynamicists consider their model’s life cycle.

## Beyond Proximity

As the model is a product of the modeler's decision-making in design, the modeler should consider the life cycle consequences of using the model. In this light, the consequences of the policy (given the model's level of uncertainty on which is built) is what determines its moral value (ethical/unethical) in a consequentialist perspective. Philosophy of engineering ethical considerations relate to the constructed artifact and the effect this has on society. When engineering social systems, the model and the policy are the artifacts. The consequences of the model design serves as the modeler's ethical guide-What are the causal assumptions? What other design options are possible? What are the risks if the assumptions are wrong (i.e. will it be used to develop policy)? Will the policy developed from it create harm for society if there are indeed incorrect assumptions? It is not always possible to know these answers, but the modeler should ask them and believe that the model is as unbiased as possible with the greatest amount of input from all relevant sources. This may be taken as a given for professional system dynamics practitioners. However, as mentioned above, not all people using system dynamics are professional practitioners.

Given that the ethical considerations are taken away from the model itself and placed on what the model does, the ethical boundaries are extended beyond the proximity of the model.

The concept of ethical boundaries is very well expressed by Bowen (2010):

> *It may be proposed that the articulation of an aspirational engineering ethic can be facilitated by extending the I-You vocabulary beyond proximity, to include a relationship with people who may be distant in place and/or distant in time. Thus, the task of the engineer may be viewed as the development of technical knowledge and technical activities, the world of I-It, in response to an I-You concern for those benefiting from the technical advance. The people affected by the activities may be located far from the place where the engineering work is conceived and planned. In some cases, they may be far from the place where the engineering artefacts are constructed or even far from the place where the completed, engineered artefacts are located* (p.140).

In avoiding downstream negative consequences, and hence attempting to gain moral value, it all comes back to the issue of communication. Decision-makers claim the ethical role in policy implementation. They must know what the causal assumptions are in both the explanatory and policy models. When justification in design is difficult, the modeler may be less inclined to make this known to the client or to their peers. Making these justification break-offs explicit in the communication of the model and a part of the ethical considerations in design, however, is essential. In the words of Ulrich (1987): "As long as he does not learn to make transparent to himself and to others the justification break-offs flowing into his designs, the applied scientist cannot claim to deal critically with the normative content of these designs" (p. 277).

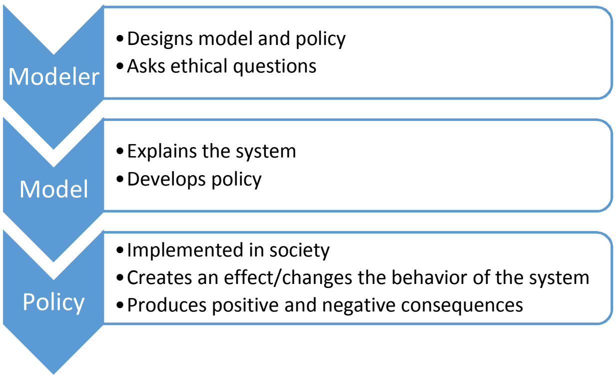


*Figure 1: The modeler's behavior leading to artifacts and the effect of these artifacts on society.*

Figure 1 illustrates the expansion of the ethical horizon and the distancing of ethics from the modeler to the model and policy. The artifacts (model and policy) themselves are neutral in the philosophy of science. Scientific artifacts (theories) are either right or wrong, not ethically good or bad. Ethics in this sense comes back to the behavior of the scientist, not the theory itself. This is the opposite in engineering, where the artifacts themselves are ethically charged.

## Asking the Ethical Questions: System Dynamics and the Norwegian Welfare State

Expanding the boundaries of what is under ethical consideration is easy for a philosophical discussion, but what would this look like in practice? The following list is an example of possible ethical questions that consider the consequences of model design.

| | |
|---|---|
| In designing and building the model, modelers must ask: | How well supported are the causal assumptions? What other structural options are there to produce the behavior? |
| | Have I used all possible input to the model to make it as objective as possible? |
| | Have I introduced bias into the model? How accurate a representation of society is the model? What is the level of uncertainty (robustness)? |
| Pushing beyond proximity (beyond the initial artifacts) requires us as modelers to ask questions such as: | What will the policy do to society if the causal assumptions in the structure are wrong? What is the level of risk that the model is inaccurate? |
| | Have I communicated the uncertainty to decision-makers? |
| | Does the policy produce the good for which it was intended? Are there unintended negative side effects? |
| | Do the side effects of implemented policy indicate that the model design is inaccurate? |

Armed with these questions, let's take a closer look at how this would be applied in a project about the Norwegian welfare state.

### Norwegian Social Assistance and Immigration

A system dynamics PhD project, started in the fall of 2014, is investigating the social and economic sustainability of the Norwegian welfare system in light of demographic pressures such as immigration and aging. As in all modeling projects, this project will require making decisions about subjective elements and relationships in the system and subsystems.

Consider the following simple model of the number of people on social assistance (unemployment support) in Norway with a focus on immigration (figure 2).

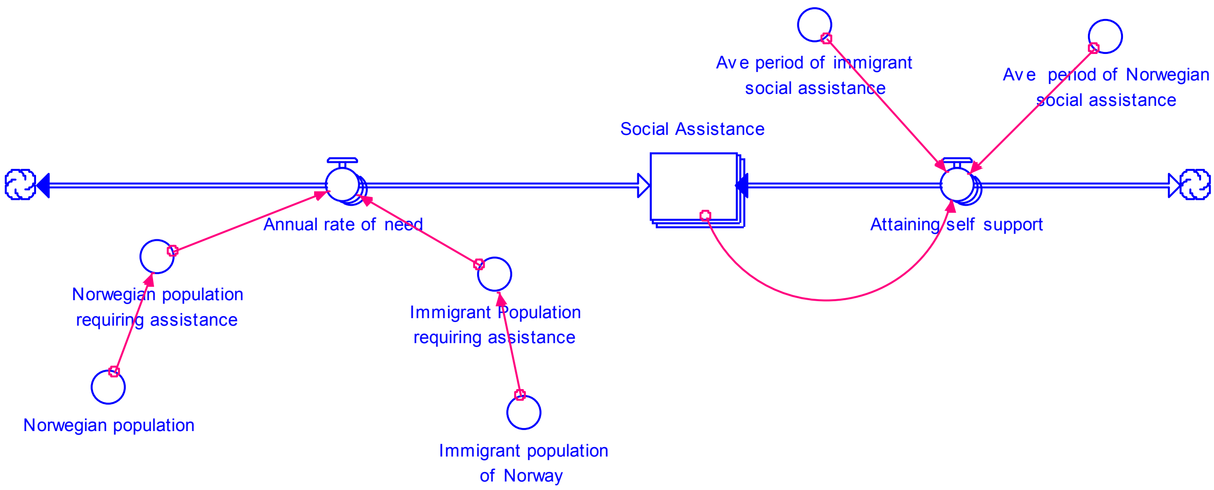


*Figure 2: Simple stock and flow representation of the cost of social assistance in Norway, split between Norwegian and immigrant populations.*

Building a simple model, and aggregating many variables, makes subjective decisions not just implicit, but invisible. For example, decision-making concerning the variable "Immigrant population" makes the assumption that all immigrants are homogeneous. Immigrants can be refugees, labor migrants, students or migrating for family reunification purposes.

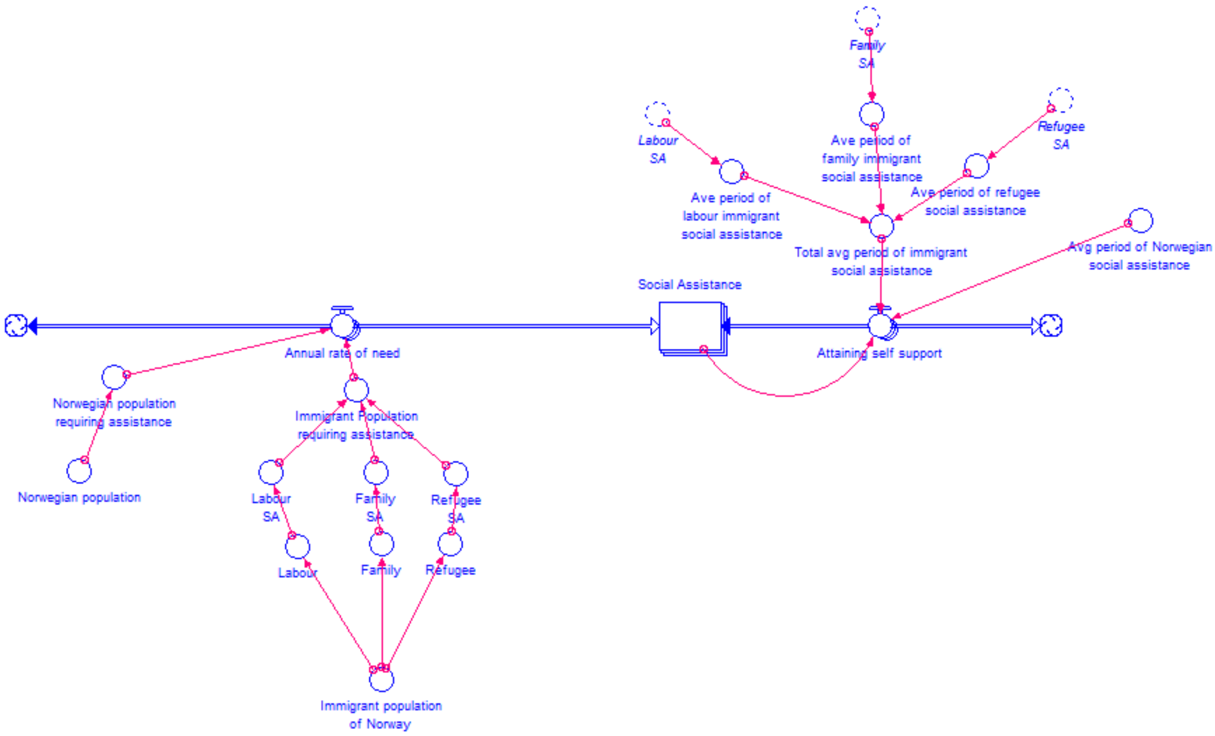


*Figure 3: Disaggregation of the variable "Immigrant fraction requiring assistance"*

In the above model (figure 3), the immigrant population is disaggregated. Student immigrants are taken out because they are usually not eligible for social assistance in Norway (they must prove they have sufficient funding before they are granted a visa.) Refugee regulations explain that refugees are completely supported by social assistance when they arrive, and there is no maximum time for receiving support. It is assumed that family dependence is low because in order to get a visa, they must show they have economic support from the family member in Norway. Labor is also assumed to be low because the immigrants have work contracts when they arrive in Norway. All of these assumptions are supported by Norwegian immigration regulation (i.e. the assumptions are justified).

For the purposes of this discussion, let's assume that all other variables besides labor, family and refugees, accurately reflect reality, and the model behavior replicates the system behavior even with the assumptions made for labor, family and refugees. Let's also assume that this model resonates with the research team, and validation protocol has been fulfilled.

The desired state of the system is a lower amount of people on social assistance, so a policy is introduced to the model that speeds up the process of getting refugees off social assistance through an enhanced assimilation program (assimilation support is already available for refugees in Norway- this policy strengthens it). Figure 4 shows this policy structure in red (the variable represents a larger policy structure.)

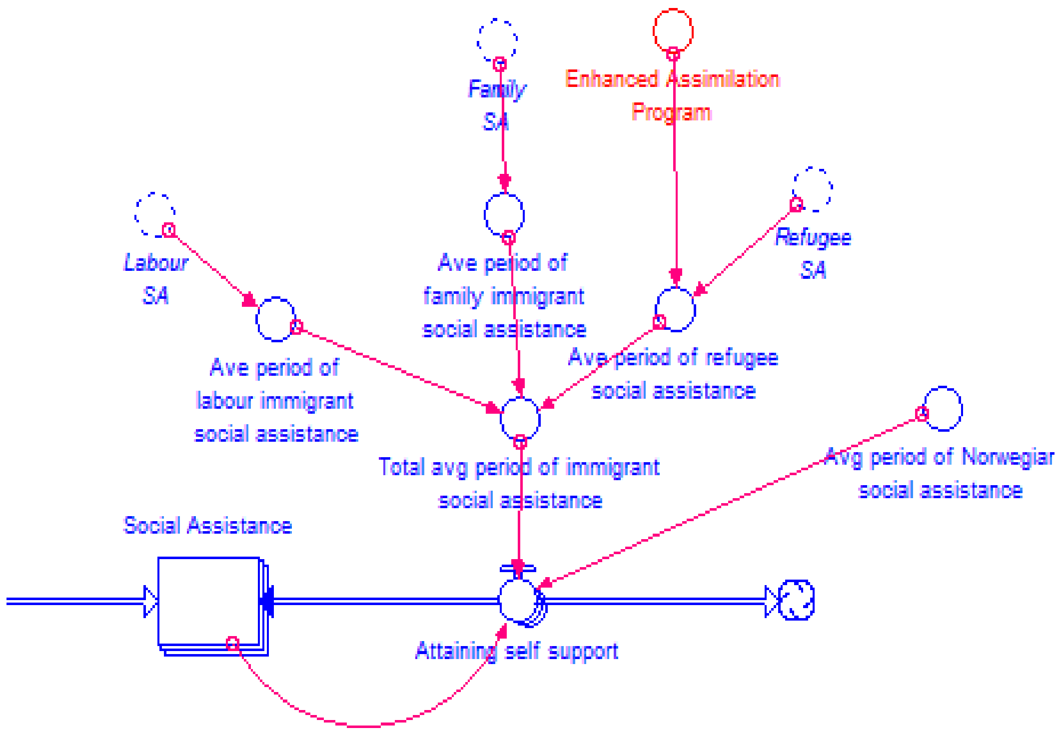


*Figure 4: Cut-out of model showing the "enhanced assimilation program" policy*

Let's assume that this policy has then been implemented in the Norwegian welfare system. However, the total number of people on social assistance has *increased* after implementation. The length of time that refugees are on social assistance has appeared to stay the same as indicated by unchanged unemployment rates among refugees, but for some reason the number of people needing social assistance has increased (controlled for population increase).

In this example, the artifact (the model) is designed by the modeler, which produces an artifact (the enhanced assimilation program) that may have produced negative consequences for society. There are a couple options for a next step. The modeler could return to the model and make more assumptions about the system in order to develop a new policy. This would change the original artifact. The modeler could change the policy structure to produce the desired effect, changing the product of the original artifact. However, using an ethical framework in the first design process could have improved the probability of avoiding the negative effect (see figure 5). Using the questions mentioned at the beginning of this section is a place to start.

- How well supported are the causal assumptions? What other structural options are there to produce the behavior?
  Labor and family populations were assumed to have low rates of social assistance, and refugees were assumed as having a high rate of social assistance. This is supported from immigration regulation in what is required for visa applications. What other academic disciplines would have data concerning this? What research is produced by sociology on rates of social assistance usage by immigrant type?
- Have I used all possible inputs to the model to make it as objective as possible?
  How you reached out to the refugee/labor/family reunification populations to understand what their needs are? Is there a possibility for group model building to understand personal thresholds for seeking social assistance?
- Have I introduced bias into the model? How accurate a representation of society is the model? What is the level of uncertainty (robustness)?
  Are there cultural factors missing because the modeler is from a different culture than the immigrant populations? For example, is there a social stigma associated with seeking social assistance found in some cultures and not in others? Have all alternative explanations been researched? Is labor migrant social assistance higher perhaps because workers are coming on short term work contracts? Perhaps it is better financially to receive social assistance in Norway than to earn a normal wage in their home country. Could refugee social assistance drop substantially after an initially high period of public support?
- What will the policy do to society if the causal assumptions in the structure are wrong? What is the level of risk that the model is inaccurate?
  What is the possible risk of harm to the system by implementing the policy because of uncertainty in the model representing society? If the causal assumptions are incorrect, how will refugees and social support agencies suffer through an enhanced assimilation program?
- Have I communicated the uncertainty to decision-makers?
  Do social support administration and funding agencies and refugee support agencies (i.e. the decision-makers) know that this model is only one of many structural designs that could lead to the system behavior? Even if the policy option of an enhanced assimilation model was the decision-maker's idea, they must be made to understand that it was tested on a structure built with assumed causality (i.e. a level of uncertainty).
- Does the policy produce the good for which it was intended? Are there unintended negative side effects?
  In this example, the answer to the first question is no. The policy did not reduce the number of people on social assistance. The amount of people on social assistance is rising; so the answer to the second question is yes, there are possible unintended side effects. The rising number of people on social assistance could however be from another reason altogether.
- Do the side effects of implemented policy indicate that the model design is inaccurate?
  This should always be explored as a possibility. There is no definitive way of knowing whether the model perfectly represents reality.

The answers to these questions and the ethical concerns raised seem obvious because this is a simple model built for explanatory purposes. Imagine, however, a large complex model or practitioners that have only just begun using system dynamics methods or students learning how to build system dynamics models. Would it not in these cases help to have an ethical foundation in system dynamics?

Considering ethical issues must become part of the modeling process. These procedural (modeling) questions lead to the ethical questions. Figure 5 illustrates the relationships between asking ethical questions and the modeling process.

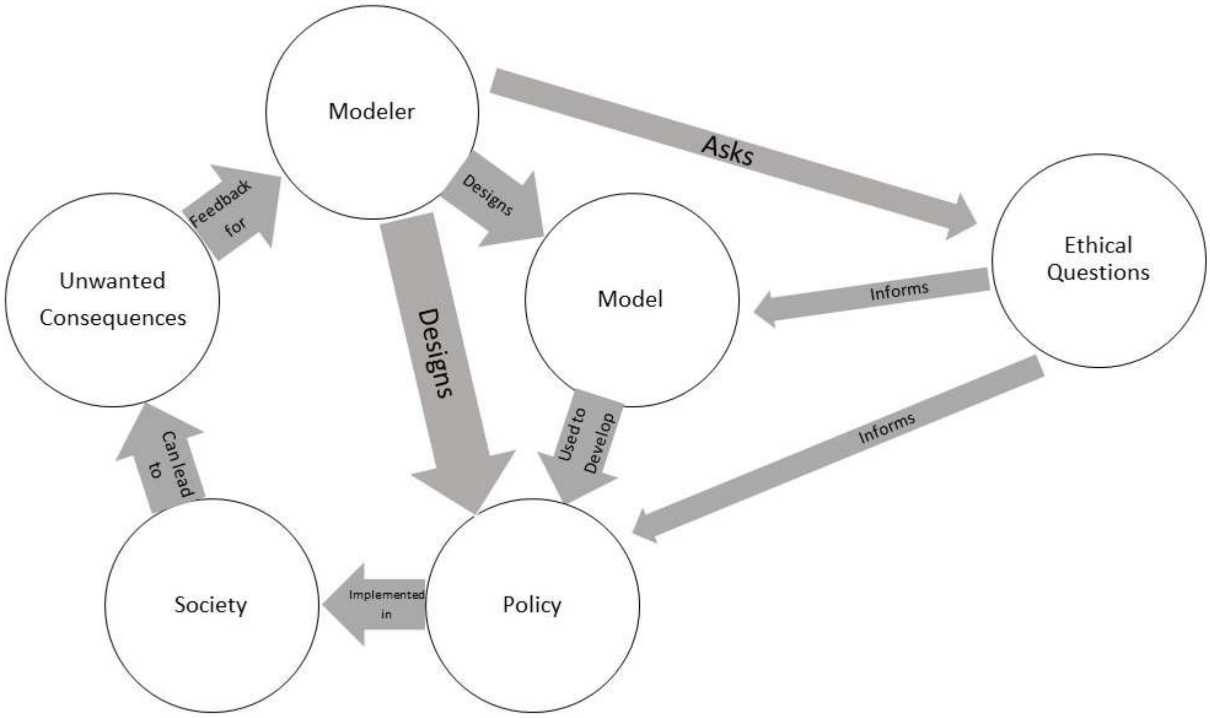


*Figure 5: Relationships between the modeling process and ethical questions*

## Stepping Forward-The Ethical Conversation in System Dynamics

This discussion argues for an ethical framework, or at the very least, an ethical conversation within the field. The road to an ethical framework in system dynamics must be developed over time through discussions in moral theory and practical application. It is with hope that over time a framework will develop into established norms, where each practitioner knows what is ethically expected of them and those new to system dynamics are expected to uphold a certain ethical standard. Because there are many different approaches to system dynamics methodology and many people are practicing system dynamics that are not in the system dynamics community, a strategy for cohesion could be through ethical standards of practice.

## Further Research

This discussion has centered on uncertainty and how to handle it from an ethical point of view. However, it should be noted that while many system dynamics practitioners validate their models to reduce uncertainty, there are methods in system dynamics that embrace uncertainty and use it as grounds for exploration (i.e. Exploratory System Dynamics Modelling and Analysis (ESDMA)). Further system dynamics research in ethics could investigate different system dynamics methods and the implications they have for society. Group model building is another system dynamics methodology that is worth investigating from an ethical perspective. It can be argued that those that build and then use their own models are "making their bed and lying in it," meaning that the consequences from the policy implementation resulting from the model design would be affecting the designers. This leaves the possibility for an ethical loop-hole whereby the system dynamicists could assign the group the ethical responsibility instead of themselves.

## Conclusion

Engineering philosophy provides a unique perspective on ethics in system dynamics. Uncertainty in design has been addressed in system dynamics as something that must be reduced through validation. However, since structural design is variable (even if valid), modelers must ask ethical questions regarding the consequences of design uncertainty; and as a minimum, modelers must make the uncertainty transparent. The extension of ethical boundaries from the modeler to the model leads to tighter control over the societal impact of system dynamics models. It is no longer a question of whether a model is scientifically valid, but a question of whether the model has the potential for harm. As system dynamics is still seeking its own identity, it is imperative that the field continues the discussion of ethics for the sake of its own credibility across disciplines.

## Works Cited


Barlas, Y., & Carpenter, S. (1990). Philosophical roots of model validation: two paradigms. *System Dynamics Review*, *6*(2), 148-166.

Driver, J. (2011). New Problems of Philosophy: Consequentialism, Routledge, Florence, KY, USA.

Forrester, J. W. (2007). System dynamics—the next fifty years. *System Dynamics Review*, 23 (2-3), 359-370.

Goldman, S. L. (2004). Why we need a philosophy of engineering: a work in progress. *Interdisciplinary Science Reviews,* 29 (2), 163-176.

Olaya C (2012). Models that include cows: the significance of operational thinking. In: Proceedings of the 30th international conference of the system dynamics society. St. Gallen, Switzerland.

Olaya, C. (2014). The Scientist Personality of System Dynamics. Proceedings of the 32nd International Conference of the System Dynamics Society, Delft University of Technology, The Netherlands.

Pruyt E., & Kwakkel J. (2007). Combining System Dynamics and Ethics: Towards More Science? In Proceedings of the 2007 ISDC, Boston.

Schmidt, J. A. (2012). What Makes Engineering, Engineering? In J. Carrato & J. Burns (Eds.), Structures Congress Proceedings (pp. 1160-1168): American Society of Civil Engineers.

Ulrich, W. (1987). Critical heuristics of social systems design. *European Journal of Operational Research,* 31 (3), 276-283.

Walker, W. E., Harremoës, P., Rotmans, J., van der Sluijs, J. P., van Asselt, M. B., Janssen, P., & Krayer von Krauss, M. P. (2003). Defining uncertainty: a conceptual basis for uncertainty management in model-based decision support. *Integrated assessment*, 4 (1), 5-17.

Wheat, I. D. (2010). What can system dynamics learn from the public policy implementation literature? *Systems Research and Behavioral Science*, 27 (4), 425-442.