Questioning Forrester's Ethics: Historical Case Analysis of Ethical Dilemmas in Modeling & Simulation

Timothy Clancy [1*], Raafat Zaini[2]

[1]National Consortium for the Study of Terrorism & Responses to Terrorism (START) University of Maryland, College Park, MD, USA
[2]Integrated Science and Technology, College of Integrated Science and Engineering, James Madison Univeristy, Harrisonburg, VA, USA

* Corresponding Author, timc@umd.edu

Acknowledgments: Professor Khalid Saeed (WPI), Rod McDonald (JMU), and Len Malczynski for providing models and papers related to this article.

Abstract:
Students, researchers, and practitioners face ethical dilemmas in modeling & simulation (M&S). Motivated over a set of D-Memos on humanitarian aid, we proposed a case method to conduct ethical analysis for M&S efforts. We tested the method against Forrester's 1968 *Urban Dynamics* and Forrester & Runge's 1971-1974 D-Memos on humanitarian aid, arose the original concerns. Our findings indicated the erasure of Black populations from *Urban Dynamics* raised more ethical concerns than the humanitarian aid works. We suspect Runge's efforts to systematize ethical perspectives in his D-Memos may have been a contemporary reaction to perceived ethical criticisms of Forrester's *Urban Dynamics*. Our method revealed many surprises: the novel contributions of Runge decades ahead of his time and forced reevaluation of incorrect beliefs on adoption of *Urban Dynamics* beyond our field. Rather than being isolated to the historical cases they arose in, the ethical dilemmas identified in these cases remain relevant for study today mirroring dilemmas in current simulation efforts such as climate change. We encourage the adoption of our method as a regular practice for students and to integrate ethical considerations into confidence-building measures on significant M&S efforts. This method will help enhance the holistic view in M&S practices.

Introduction

Recently, a System Dynamics Society committee reviewed Forrester's comments in the MIT Seminar series about the limitations of humanitarian food aid and several D-Memo findings he was basing his remarks on published in the early to mid 1970s. The concern arose from Forrester's comment on the video, based on several D-Memos, which said providing humanitarian aid in the form of food may only have a short-term benefit and create long-

term harm. The question the committee examined had two parts. First, were Forrester's comments and the D-Memo findings supportable from a contemporary or historical ethical perspective. Second, what should the Society do with the material based on that finding? Two things became apparent as part of that process, which one of the authors participated in. There was a wide interpretation of the ethical question of the underlying materials and what the Society's response should be, and there was no clear method or framework to evaluate these kinds of ethical dilemmas.

In many fields of science, we take for granted that the research, distribution of findings, and taking actions upon those findings are inherently ethical processes, and strong ethical frameworks have arisen in a large range of fields, including medicine, national security, legal, human research, etc. But to what extent do we subject computer simulations to the same scrutiny as the development of a human clinical trial of a new medicine or weapon? What ethical frameworks should we consider the positives or perils of a policy arising from human-computer interaction? With the advent of Artificial Intelligence (AI), the potential for Artificial General Intelligence (AGI), and a myriad of human-AI-simulation combinations ahead of us, these ethical questions are becoming more important. What ethical perspectives should the designers of such efforts take into account? What builds not just confidence but trust in the outcome from policymakers? How can or should new students and stakeholders entering the computer modeling and simulation field be guided to consider ethical perspectives in complex systems? Complex systems pose particular problems for traditional ethical standards because variables can never be isolated, initial conditions are never fully replicated, and results are never fully reproducible. The ethical standard of medicine, a so-called gold standard double-masked with a placebo trial, would be unethical to run on multiple countries suffering from famine and requiring humanitarian aid. Computer simulations answer these challenges by allowing experimentation within a model capable of replicating real-world conditions with enough verisimilitude without being in the real world. However, undertaking computer simulation efforts introduces their ethical dilemmas in design, formulation, and boundary selection and to what extent scientific and engineering teams must enter the realm of diplomacy and advocacy to support model adoption.

In this paper we propose a case study approach as a first step to address gaps on this issue suitable for students developing their craft and practitioners alike. Case studies have long been used to examine historical and contemporary issues as tools for learning, reviewing, and assessing risk. We study two cases, both of which begin with Forrester but then extend to other modelers picking up on the work. One case is taken from the concern raised at the Society, that of the role of humanitarian food aid in times of famine that began with Forrester's presentation to the National Council of Churches in 1971 and continued through the publication of several D-Memos. The other case we have selected, the canonical model of urban dynamics, began before the humanitarian food aid case in 1968 but continued for decades after. We have selected these two cases arbitrarily because of their proximity in time, both begin with work done by Forrester, and presented in chronological order show how questions of making clear modeler values and ethics arising in the first case were were addressed in the second case.

Despite the provocative title, we are not questioning Forrester's ethics or any involvement in the models. However, we use case study ethics to raise questions and reflections from various ethical perspectives. Our research questions, therefore, are:

1. What ethical perspectives should we consider in our modeling and policy recommendation approaches?
2. What is the proposed framework for an ethical case study we can use?
3. Through these cases, what can we learn about ethical implications local to each case but also applicable to the field and a broader interaction within an ethical system?

Literature Review

Although there are many perspectives on ethics, three particular perspectives arise frequently: consequentialist, deontological, and virtue. A consequentialist perspective holds that the "consequences of actions form the basis for valid moral judgments about those actions…the morally right action is an action that produces the most good.[1, p. 509]" This means for any individual act, the ethical value of its action can only be known in the future. However, this does not limit consequentialism to retrospective. Consequentialist ethics, therefore, are temporally anchored, and moral judgments are reserved for the fullness of time to unveil whether the intended good outcome resulted from the action taken. In contrast, a deontological ethical perspective does not assess the "goodness or badness of actions" as a consequence but as an "inherent property of the action itself[1, p. 509]." Deontological ethics "is concerned with duties and the consistent application of rights, obligations, and principles, as its name suggests (the Greek deon means ''one must'' or ''duty'') [1, p. 509]." A consequentialist might inform a deontological perspective, but it is codified in rules, regulations, or expectations that agents can follow at any given time and assume they are acting correctly. Deontological perspectives view ethics as a system in which the proper application of a given body of knowledge is most likely to produce the most ethical result across the system, even if there may be areas of less ethical outcomes within the system. The final perspective, virtue ethics, "focuses neither on the consequences of actions nor on the actions itself; instead, goodness and badness are attributes of an agent. To act good, agents should strive to become virtuous [1, p. 509]." Virtue ethics focuses entirely on the agent committing the action at the time they are making it. Grossly simplified, a virtue perspective focuses on modeler behaviors, a deontological perspective on modeling practices, and a consequentialist perspective on modeling results.

System dynamics seems well-equipped to tackle these ethical perspectives in our modeling process. The perspective of system dynamics simulations is of an operational causality that simulations present a realistic depiction of 'how stuff works' in a complex system. System dynamics quantitative simulations must define characteristics representing this operational causality perspective. First, models are based on causal feedback structure; second, accumulations and delays are foundational; third, models are equation-based;

fourth, the concept of time is continuous; and finally, the analysis focuses on feedback dynamics[2]. This encompasses sufficient capability to incorporate each perspective, causality between the agent and the action for virtue ethics, the benefit of a time horizon to evaluate a consequentialist outcome, and a body of knowledge on modeling techniques and modeler behaviors to accommodate a deontological perspective.

However, the literature on ethics in model creation or modeler behavior in system dynamics computer simulation is light. In the field's grounding works, neither Forrester [3] nor Meadows[4], [5] mentioned ethics outside of the context of an ethical case to be modeled. In standard textbooks, when the word is brought up, it is usually in the context of the modeler's duty to act in a certain way. These are often proposed as modeler behaviors to "reflect consciously about side effects[6, p. 209]." Or of the modeler's "…ethical responsibility to carry out your work with rigor and integrity… let the modeling process change your mind... "speak truth to power,"…even if it means you get fired[7, p. 85]." In the description above, these fall into the virtue ethics case with aspirations to deontological perspectives. The primary ethical vehicle is the virtuous action of the modelers themselves and the behaviors they represent. Alongside these are general claims that one should follow best practices and rules of proper modeling, which aspires to a deontological approach to ethics. However this has not been as fully developed in system dynamics as in other fields. For example – what specific tools are in the system dynamics toolbox? Which of them is most important to follow for having ethical outcomes? Simply saying 'all of them' is insufficient. In the practice of law, for example, the ethical behavior of lawyers is not left to chance – but governed by strict procedures of how opposing counsel are allowed to interact with one another's clients, produce documentation for review, or interact with the court. Likewise, research involving human subjects governed by Institutional Review Boards (IRB) goes beyond an appeal to the virtue of the researchers and performing 'good science'; they have explicit step-by-step instructions to initiate, review, monitor, and address gaps in research ethics.

Outside of these core works, the discussion on ethics has been limited and mostly within the last 15 years [1], [8], [9]. Ironically, as part of our case analysis in this work, we uncovered an in-depth treatment of ethical forms and their implications in system dynamics modeling [10] from 1974.

Method

We use a qualitative case method to examine two specific historical simulations and the bodies of work they spawned. Both cases are rich with ethical implications dealing with national or global problems of importance at the time of modeling and continuing today. The first case is the canonical urban dynamics modeling effort in 1968, following decades of work. The second is a body of work that began with a presentation to the National Council of Churches in 1971 and continued via several D-Memos through 1974 on the implications of humanitarian assistance to foreign countries. Contrary to the presumption some may take of the title, our method is not to attack or defend either work, but rather use both

cases to illustrate an approach of using historical cases to emerge ethical issues, discuss them, and learn how our findings.

We propose organizing our cases in the following format of sections.

HISTORICAL CONTEXT For each case, we begin with a summary of the historical context to ground the reader in the problem at the time. For this, we leverage Turnley's method[11] and, as best we can determine, identify the problem was trying to solve, the intended audience for whom the modeling was conducted, the perspective within the system from which the problem was modeled, the bias if known or suspected of the modelers, and the funding which supported the effort. This summary is not intended to be a full historical treatment but grounds the reader in sufficient context to understand the following discussion.

REVIEW OF MODELING PROCESS Next, we summarize the modeling process at a very high level of aggregation. In this summary we are not seeking to grade a paper based on recent debates on quality within the Society[12] but rather illuminate key decisions and choices made in the process. Again relying on Turnley[11], we ask questions of the interface between the methods to probe how model boundaries were selected, what was the theoretical domain (if known) of the modeling approach, whether data was collected for to purpose of the effort or how data was vetted, and how the interface of data, theory, and model was created: participatory model building, elicitation from experts, qualitative expression, etc.

INITIAL FINDINGS OF PROCESS In the next step, we summarize the key findings from the modeling process. Since these are canonical works located sometime in the past, we place an arbitrary limit of 10 years after the first publication. In this period, we look not just for what the key policy findings were but also how "disagreements among experts on theoretical approaches or interpretation" or "uncertainty inherent in the data itself" were handled [11, p. 13]. We look to see if there was any discussion or recognition of the ethical implications of the original work or its initial reaction at the time.

EXTENDED FINDINGS In this second-to-last step, we extend the period from 10 years to the current date, summarizing the ramifications of policy implementation, subsequent research, and updates. Again, this is a summary to ground the reader for the ethical discussion to follow and is not intended as exhaustive literature.

DISCUSSION OF ETHICAL PERSPECTIVES In the findings section of the article, we examine each case within the information provided above, subjecting it in turn to the three ethical frameworks in turn:

- Consequentialist: What was the outcome of attempting to apply the models in policymaking? If that was successful, what was the outcome of the recommended policies?

- Deontological: What does the case tell us about rules or techniques we should build into our body of practice on modeling?
- Virtue: What are the ethical obligations of the modeler, both the original modeler and those who take up the work later to continue it?

Cases

Urban Dynamics

Urban Dynamics represents a canonical model from which many ethical questions and considerations arise. The authors thought they knew the origin and context of the modeling, but a deeper investigation raised significant ethical questions of racial erasure, failure to gain stakeholder adoption, and to what extent future modelers have an ethical obligation to reexamine and update models made years or decades ago by different modelers?

Historical Context

In system dynamics, we often present the origin of canonical models as birthing, Athena-like, and fully formed from a simple problem statement absent of any historical context within which the problem arose. Plane rides and chance encounters feature prominently. The common story in the field of the origin of *Urban Dynamics* is that it began by way of contingency when a retiring mayor of Boston (1960-1967) took office at MIT as a visiting professor to Jay Forrester, who had developed system dynamics methods for studying complex systems [13, p. ix]. They were joined by Daniel J. Finn and Joseph S. Slavett, as well as MIT Students.

However, the immediate historical context of Urban Dynamics is key for thoroughly understanding its ethical case. In the forward by Collins, a joint statement of the National League of Cities and the United States Conference of Mayors describes the (emphasis in original text) "crisis of the City is in reality a *national* domestic crisis [13, p. vii]" describing it as "urban jobless require welfare paid for by Federal dollars nationally collected, inadequate urban schools cast upon the nation another generation of people unprepared to make their way, urban traffic congestion adds millions of dollars to the cost of items on neighborhood store shelves around the country[13, p. vii]. Although the source for this statement has not been found, its date of July 1968 likely places it within or accompanying a Congressional legislative session focused on passing the Housing & Urban Development Act of 1968. And for those who lived during this time or have studied it, 1968 is not just a random year in which a mayor leaves politics to join MIT.

In Boston between 1960 and 1970, corresponding with Collins's tenure, a second wave of Black migration from the US south to north resulted in an increasing share of Black people from 9% to 16%[14, p. 14], [15, p. 1]. Racial tensions were high throughout Collins's career as mayor, escalating in the so-called 'ghetto' riots that occurred nationally from 1964-1969 and in the 'long hot summer' of Boston in 1967 and the Grove Hill riots of which Collins was

Mayor presided over a controversial response. The joint statement articulating the problem case the book is based on, issued in July 1968, occurred just three months after the assassination of Martin Luther King and a wave of riots that swept across cities in the United States. Although some violence occurred in Boston, it was spared the worst of the post-assassination riots due to the cooperation of Mayor Kevin White (who had replaced Collins) and James Brown at a concert that just happened to be held the night after the assassination. These riots didn't just express anger at political assassination – systemic formal and informal racial discrimination was widespread. Legal mechanisms such as restrictive HOA covenants, red-lining, and yellow-lining had confined Black populations from expanding outside of narrowly limited city areas. Highway construction projects championed by Eisenhower in the 1950s frequently resulted in the wholesale demolition of large swaths of these neighborhoods, disrupting their economic patterns and creating physical divisions between previously whole communities. In scholarly literature, a theme arose over these decades leading to 1968 that "Black housing is slum housing," treating it as a "pathology," ignoring evidence of high-quality Black housing or Black demands for better housing and instead using reinforcing negative stereotypes about Black families to inform stereotypes of Black housing that were commonly referred to with terms such as slums or ghettos[16, p. 149]. It is impossible to believe that neither Collins nor Forrester were unaware of this connotation, which begs the question. There are #X references to slums in Urban Dynamics and #Y references to ghettos, so to what extent was Urban Dynamics modeling Black housing? And if so, to what extent were racial perspectives integrated into the modeling process and policy recommendations?

Review of Modeling Process

Discussed at length in the book[13, pp. 12–36] and more briefly in two accompanying articles published shortly after that [17], [18], the method of creating the *Urban Dynamics* model became a standard for system dynamics. The design process begins with observations of the behaviors of a class of problems, creating a computer simulation consisting of stocks and flows arranged in feedback capable of recreating those observations, and then introducing policies as tests. There is little emphasis on domain literature review or data collection, as the representation is of an abstract simulation of the class of problems facing cities rather than any one city[18, p. 241].

The model city is represented in nine stocks and 22 flows spread across three subsystems: industrial, housing, and the movement of people. The first two subsystems are modeled to demonstrate a lifecycle of growth and decline. In the industrial sector, this is represented by the generation of new businesses, which age into mature and then declining businesses[17, p. 8]. Housing consists of three substructures and like enterprise, the housing stock's age determines its value and the nature of its occupants. It is this pairing of structural age and character of occupation that provides the "reasons for decline…a new commercial building is occupied by a healthy, successful commercial organization, that uses relatively more managers and skilled workers than those who are unskilled…[and]…as residential buildings age; there is a tendency for occupancy to increase as well as shift to a lower economic category of the population[18, p. 244]. The simulation of the base run represents 250 years and begins with mostly empty land. For the first hundred years, available land is

expanded, creating new businesses and new, premium housing while existing industry and housing on previously developed land begins aging into its lower value representations[17, p. 10]. This sets up the key dynamic of the model, which is when land availability reduces after ~100 years, and the expansion of new business and premium housing is reduced to the level of demolition of declining businesses. This sets in place a vicious behavior where limited new, unbuilt lands, means that existing stocks of both industry and housing age, resulting in increasing underemployed and "that the depressed areas of our cities are areas of excess housing.

The area's economy cannot maintain all of the available housing. Because of low incomes, people crowd into some dwelling units while other buildings are abandoned, stand idle, and decay…the stagnating urban area has become a social trap. Excess housing beckons people and causes inward migration until the rising population drives down the standard of living far enough to stop the population inflow [18, p. 246]." This finding leads to the proposed policy, which is stated plainly in an accompanying article, is: "a slum demolition program removes 5 percent per year of the most deteriorated category of housing. At the same time, incentives have been added and hindrances removed to favor a more rapid construction of new enterprise [17, p. 11]." Over the next fifty years the city reverses its decline with increases in new and mature businesses, higher professional and labor populations, and lower underemployed populations.

Notably absent from the modeling process or subsequent documentation produced contemporaneously by Forrester and his colleagues is any significant discussion of race. In a paragraph opening Chapter 7, Forrester argues:

> "Some might argue to the contrary that today's underemployed Negro minority is less apt to rise in status by diffusion into existing economic activity than by merging into a self-respecting, self-disciplining, and self-leading group. Were the latter the more promising course of action, Negro concentration in high-density slum areas might be a necessary prelude to self-generating social change. This study assumes that extreme concentration of economic and social groups is detrimental. That success will be more easily achieved in a single economic system than in two separate and parallel systems[13, p. 115]."

Despite the adoption of euphemism connotating race throughout the original work, racial conditions are barely mentioned. It is appearing less than a handful of times. Once initially, race is subsumed into a "mixture of many components" that determine attractiveness, which becomes the essential mechanism driving *Urban Dynamics*[13, p. 5]. Race appears again as a footnote midway through the work when explaining the concept of free mobility into and out of a city. In the footnote, attractiveness is again presented as a:

> "multidimensional concept and includes factors such as legal restrictions, prejudice, racial and ethnic groupings, and anything else that influences a person to move," and though some factors are represented explicitly, the rest are combined into a constant mobility coefficient "on the basis that they can be treated as constants and are not

involved as dynamic variables in the model of urban change here being explored[13, p. 116]."

We cannot find evidence that race is treated as one of those explicit variables, so here in the footnote, Forrester erases race as a potential dynamic that drives urban change. Despite the context of the time he is living in and during which this model was created. This is made more curious given a brief treatment in Appendix B of racial impacts on inflow and outflow to the city modeled on two factors. First, the impact of the second wave of racial migration (historically known as the Second Wave of the Great Migration) and restrictive covenants, red-lining, and other methods of restricting outflow mobility of Black populations into more affluent urban or suburban areas[13, p. 253]. These are sterilized of the racial context in which they occurred by indicating that migration is due to "agricultural mechanization". At the same time, the inability of Black populations to move into suburbs is a result of the "rejection of Negroes by the more affluent urban and suburban sections[13, p. 253]" rather than an intentional and systemic policy of red-lining, yellow-lining, restrictive covenants prohibiting the movement of Blacks and sustained racial harassment of incoming Blacks into new areas.

Although the experiment does show an increase in unemployed and under-skilled workers concentrated into aging housing by these factors, in contemporary works, Forrester avoids confronting head-on the racial implication. For example, Forrester contends that the "age of the building tends to determine the character of its occupants[18, p. 244]" rather than considering racially based policies and racial prejudices can funnel people of a given skin color ***into*** a building ***upon which*** a character is projected onto them. The dynamic of a projected pathology onto Blacks is mentioned in contemporary literature[16].

Initial Findings of Modeling

The book and contemporary D-Memos emphasize four levers of change identified as moving away from 1) new funding as a cure-all, 2) adjusting tax laws to no longer favor aged infrastructure, 3) adjustments in population density, using zoning to reduce population density allowing more space for business development, recognizing and accepting certain stressors are specific to a current land use and adjusting the land use will simply adjust the stressors, and creating realistic goals, specifically that include "negative forces powerful enough to limit the population and population density" including policies that "maintain high prices of land and rents, or a housing shortage, or a job shortage…or limited transportation, or limited land area that does not communicate with other areas, or zoning to control density or a bad array of 'quality of life conditions'[19, pp. 262–264]."

Shortly after *Urban Dynamics,* Forrester proposed an agenda to achieve national consensus around the model with three main efforts. First, improving the model. This would be achieved by both "soliciting" criticism and incorporating "valid" suggestions while explaining and dispelling concerns that are "not relevant [19, p. 265]." As well as expanding the modeling approaches of *Urban Dynamics* into other areas of "social behavior," including treating welfare as a substructure that may itself be creating a "social trap" that "keeps

people from supporting themselves [19, p. 265]. Second, using the model to propose sweeping actions including "modifying state constitutions and laws, city ordinances, real estate and income tax regulations, and national laws" requiring the expansion of the effort to include "lawyers, real estate advisors, tax consultants" and others with "social-legal" expertise in the current system [19, p. 265]. Third, exposure to select groups of stakeholders in fora of 500 individuals for one-week seminars designed to refine further the model, its proposals, and the agenda [19, p. 265].

An early goal of this agenda was to establish *urban dynamics as a planning tool endorsed by the US Department of Housing and Urban Development. This goal led to the first of four historical applications of urban dynamics we have identified in the literature, which,* taken together, present a mixed record.

In Lowell 1971, methodology disagreements between a HUD-appointed econometric oversight board and system dynamics modelers, exacerbated by the "interface gap between model and critic, contributed to the communication gap[20, pp. 200–201]." In the 1974 Boston application system dynamics, practitioners failed to "understand the importance of short-term political objectives within a set of larger, long-term goals[20, p. 204]." The insistence on long-term perspectives over decades discussed in both *Urban Dynamics* and D-1480 risked the short-term stakeholder support necessary to reach a long-term engagement, and again, the project was dropped. Concord in 1975 was the first successful use of the model in city planning, though not along the lines originally discussed in the original work. Whereas "Lowell wanted the revival promised by Forrester's book. Boston wanted painless growth, free of difficult tradeoffs. Concord, wanting just to be left alone, interpreted the urban [dynamics] theory to fit its needs[20, p. 207]," adopting or discarding elements to meet their particular needs. Importantly, the interface gap between model and model consumers was reduced, with greater accessibility and interaction between the town leaders and system dynamics modelers through and around a model used for gaining insights as much as planning. The Marlborough 1976 engagement had a key difference where one of the *Urban Dynamics* modelers took an official position in city development. Without the use or reference to the model, the theories of Urban Dynamics were implemented with initial success in gaining the support of both political leaders and community groups. But the success also showed that perhaps the model interface itself was the problem and suggestions of repackaging the findings into more accessible formats was a solution.[20, p. 209].

Academic criticism of *Urban Dynamics* was strong after its release. One common critique is that Forrester's boundary and aggregation choices leave no interaction dynamics within the city and the city as an isolated island, excluding interactions with suburbs and national policies other than inflow and outflow migration[21]. An early academic extension and analysis of Urban Dynamics, found in D-2054, explicitly modeled suburbs that had been implicitly included in the earlier work. This work demonstrated that suburbs drained city resources, created demand for city services, reduced transportation accessibility, and that suburban commuters took urban jobs[22, p. 8]. This began a series of efforts around the boundary problem of what constituted inflows and outflows to and within the city. Some of

these works included treatments of suburbs and a national environment for greater complexity in inflows. In comparison, subsectors within the model of up to 16 different zones created more intra-flow complexity in the city itself[23, p. 7]. Although these additions did not challenge the general nature of the theory of *Urban Dynamics*, that aging infrastructure created an inescapable dynamic of decline, the addition of detail showed that by adding suburbs or subdividing zones within a city, policy plans that were limited to those areas could create what appeared to be successful results in some while creating negative results in others[23, p. 29].

Another critique is that Forrester fell prey to Meadows warning of a modeler "…that their most important assumptions are implicit…and almost never documented, not because modelers wish to hide them, but because they are largely unconscious of them[4, p. 367]." Early commentators noted that Forrester's value definitions of what constituted attractiveness (e.g., managerial professionals are attractive and unskilled workers are not) put a thumb on the scale for findings that suggest removing the ratio of unskilled workers in underemployed homes[21]. Most importantly, given the historical context in which the model is created, is the erasure of race as a driving factor of condition.

Forrester responds to some of these criticisms, indicating that it is current social policies "that is generating greater troubles" and "if we were malicious and wanted to create urban slums, trap low-income people in ghetto areas, and increase the number of people on welfare" we should follow current policies[24].

Extended Findings

After the initial four engagements listed above, interest in *Urban Dynamics* shifted to a more academic and less applied basis. In 1980, an engagement with Palm Coast development saw the introduction of lessons learned and the advancement of technology to close previous gaps and some successes. The model, now available on desktop PCs through Stella, and an engagement focus on "providing answers to immediate planning questions, not on trying to provide a proven "valid" model…[and]…the ability to try many different data assumptions and to compare many different scenarios turned the model from an abstraction into an everyday planning tool[20, p. 211]."

However, this success in Palm Coast was an outlier, and *Urban Dynamics, on its fiftieth anniversary,* still struggled under the challenge of the initial Lowell failure to validate the tool for use by HUD. Instead of being a mechanism for raining a new generation of urban leadership," one of its designers described it instead "as a curiosity, a relic of the past that few have heard of and most dismiss[20, p. 211]*"* that has had had little impact on urban planning. This perception continued afterward that *Urban Dynamics* remains both a source of academic interest, especially within the system dynamics community, and a potential source of change to urban conditions, it has never been adopted in a widespread fashion by city planners[23]

Discussion of Ethical Perspectives on Urban Dynamics

Though Urban Dynamics rarely addresses ethical questions as directly as our next case, it is an excellent case study rich in ethical tradeoffs. It combines a contemporary national crisis with America's long lingering history of systemic racism, creating a case rich in ethical dilemmas. Given that it remains a contemporary source both for learning system dynamics and for modeling city planning, these dilemmas have increased rather than reduced over 60 years.

However, it would be a mistake to think insights gained from studying urban dynamics are limited to this application or that they are some historical artifacts. None of the ethical perspectives discussed below, or the questions raised, are any less important to significant works now than they were then.

Virtue Perspective

The virtue perspective of urban dynamics raises several key immediate questions. On the surface of the exercise, reducing unemployment and economic suffering seems virtuous. But is it still virtuous when the reduction of unemployment is obtained by a racial tradeoff, harming one population to benefit another?

Do system dynamics practitioners have a virtue ethical obligation to engage with the communities of stakeholders they seek to change with an eye to the consequences, foreseen and unforeseen, they may cause upon those populations?

What is the obligation to include contemporary context in considering the problem and conceptualizing the model? Is boundary selection an exercise in virtue ethics—determining what context to include or not?

One of the difficulties of virtue perspective analysis in historical cases is getting inside people's mental models in our past. This is more the realm of the historian's craft than modeling one. We can't ask and know what Forrester et al. were thinking unless they wrote it down in a form transmitted over time to reach us. And once individuals pass, we can no longer ask the questions ourselves.

As agents of their given time and context, should we have expected Forrester et al. to consider the impact on racial populations due to their policies? Given the history and context it's hard to imagine they weren't aware this might be a factor. Indeed, racial critique was raised shortly after the model's publication. In a D-Memo from 1970, the commission of racial discrimination is noted. However, although the D-Memo recognizes racial discrimination as a significant problem, it downplays the issue as an "emotional preoccupation" that results in "losing sight of the basic obstacle of economic recovery [25, p. 18]."

Consequentialist Perspective

From the perspective of consequentialism, after a failure to reach accord with Housing & Urban Development in the Lowell application, the model never really had the impact either Forrester's agenda [19] or co-modelers envisioned it having [20]. This raises two considerations. First, to what extent are potentially harmful policies, based on the context of the problem, reasonable to model? Second, what obligations above and beyond modeling do modeling teams have to facilitate adoption of their work on important topics?

We suggest that if a model is purely an academic exercise intending to go no further, this may be fair. But clearly the intent of Forrester was for a much larger impact, which means even from a consequentialist perspective, the modelers had a greater duty to facilitate change and mitigate any potential harm that might have come had their model been accepted as a planning tool. Economic and housing planning models are rife with racist assumptions that have created decades of impact, so it is not hard to conceive that had the urban dynamics planning recommendations gained widespread attention, the failure to significantly consider race might have had similar unintended but avoidable consequences.

The failure of adoption also suggests another consequentialist obligation on modelers and development teams in managing adoption with stakeholders that go beyond modeling itself. Assuming the counterfactual that HUD had adopted the model and taking a premise that urban dynamics did hold the key to reversing urban decay without unduly burdening any race in that pursuit, then in that counterfactual analysis, the consequentialist perspective a higher obligation to do what was necessary to accommodate change is required. It's impossible to know at a distance whether any combination of soft-skills techniques could've facilitated adoption. But as a heuristic, in complex systems and wicked messes, often getting everyone to agree on the same problem is 48% of the problem, solving that problem through some technical method such as system dynamics is 4%, and getting everyone to agree on the same solution is the remaining 48%. In this admittedly notional breakdown, if 96% of solving wicked mess problems requires soft skills, then modeling teams envisioning significant change must consider, plan, and build their efforts around change efforts as much as technical accuracy. Or partner with groups who have that skill. It is not clear from the literature whether the urban dynamics modeling team made any significant connections with the numerous housing groups present during the legislative session of the HUD Act of 1968 and mentioned in the foreword, of which Collins was a significant member and participant. Although scientists and engineers may disdain such "political" lobbying groups, building coalitions of widespread support, anchored on strong modeling results but encompassing all the levers of change, is as much a consequentialist ethical requirement as a virtue ethical obligation to avoid erasing marginalized voices.

A final aspect of consequentialist perspectives is to what extent canonical models should be updated with new information to consider a fuller understanding of consequences, both from the model policies and parallel developments in the problem of interest over time, even if we forgive Forrester et al. From the virtue ethical perspective above, at what point in

the last 60 years should race have become an explicitly modeled property of urban dynamics?

Deontological Perspective

The previous two sections offer some suggestions for deontological consideration. From the virtue perspective, a rules-based approach to treating topics impacting systemically oppressed populations should be considered at a minimum.

From the consequentialist perspective, what is the obligation to explore the consequences of items left outside a boundary selection? How long would it have taken to uncover racial-based policies such as red-lining, yellow-lining, and restrictive HOA covenant policies creating hard barriers to Forrester et al. envisioned free migration flow into and within the city across improving neighborhoods? Although subscription was not available at the time if it is now, is there a rules-based obligation to take advantage of these techniques to explicitly model harm to potentially vulnerable populations? Where does the obligation arise, in all models or only ones of a certain threshold? This is where system dynamics practices remain in their infancy, compared to more established fields that have not left such ethical considerations to chance are modeler choice.

Perhaps the easiest starting place is to expect that these considerations are given some space in the text in a work of significant length, like urban dynamics. Frustratingly, the original work itself is light on any ethical discussion. Not until *D-Memo 1480 Understanding Urban Dynamics* in 1970 could we find literature explicitly discussing ethical implications by asking when "…the best alternatives are recommended. But best for whom: the rich the poor, the absentee landlords the stockbrokers [25, p. 11]?" In answering this question, Barney acknowledges there is no explicit discussion of values in the original *Urban Dynamics* but states two implicit value preferences of Forrester: "the solution must be lasting (decades at least) as opposed to temporary (a few months to a few years), and the solution must lead to increased upward economic mobility for the Underemployed [25, p. 12]."

This implicit value statement represents an aspirational and developing approach to embedding a deontological approach to ethical consequences into modeling techniques. With its ability to compare counterfactual histories and hypothetical outcomes through simulation, system dynamics can model ethical tradeoffs in concrete, explicit, testable, and reproducible ways. From this beginning, the effort was taken up further in our next case.

Humanitarian Food Aid

The Humanitarian Food Aid case begins just years after Urban Dynamics was published and contemporaneously with some of the most impactful system dynamics work in general, including the publication of the world model. The case emphasizes a tension between a virtue ethical perspective, wanting to do the right thing to feed the hungry, and a consequentialist ethical perspective of considering the tradeoff of potential future human suffering. It also carries forward the thread of deontological exploration raised in D-1480:

can the simulation be used to compare ethical tradeoffs in explicit, transparent, and reproducible ways?

As with urban dynamics, the questions and discussions raised in this case, though specific to its time, are not unique in their nature in our field. Today, questions of balancing the benefits of current vs. future humans and the tradeoff of who pays for past transgressions against perceived current norms are at the center of the climate change debate, and who owes what to whom both in current negotiations on implementing policy and weighing future harm against current needs.

Historical Context

In a presentation of the Division of Overseas Ministries of the National Council of Churches on November 4, 1971, Forrester called upon work in the world model to present issues of consideration in how Churches allocate food aid in needy countries. (Although the Church's presentation was eventually included in a book by Meadows [26], for this paper, we are using the original D-Memo [26].)

The historical context flips the progression of urban dynamics history, where the most important context to understand occurred before the work. In this case, however, although famines had been an ongoing source of concern from 1950-1970, preceding Forrester's address in 1971, it was only after his presentation that the most historically significant events unfolded. The world or 'global food crisis', as it has come to be known, began in 1972 with the confluence of several macro dynamics: a strong El-Nino weather pattern disrupting normal growth seasons; an increase in grain demand from socialist countries, including the USSR; the emergence of global energy and economic pressures; combined with a policy of leading grain exporters (the US, Canada, and Australia) "subsidizing farmers to not produce grain and intentionally running down reserves to drive up prices[27, p. 930]." This resulted in reduced domestic output in many areas simultaneously as the price of exported foodstuffs rose, leading to widespread famines through 1975 and millions of deaths. International institutional responses to this crisis focused on providing self-sufficiency rather than direct food aid [27, pp. 930–931]. This lack of coordinated international response was exacerbated by commercial preference to prioritize trade in more profitable commodities and the ongoing Cold War US policy to isolate trade with communist countries which led to an embargo of food aid to Bangladesh in 1974, because it traded with Cuba [27, p. 931]. During this entire crisis, the work presented by Forrester in a speech with no specific models on humanitarian aid in 1971 was expanded upon by Dale Runge first in creating a causal loop diagram (CLD) and later a simulation model of humanitarian food aid, both published as D-Memos in 1974[10], [28].

In this case, another key historical perspective vital to understand is the historical context in system dynamics. The development of urban dynamics in 1968 was only the second or third major model after the initial industrial dynamics modeling [29]. But by the presentation of D-1633 to Churches, system dynamics had entered a crucial period. Occurring barely over a year after the initial work for the Club for Rome, the presentation occurs contemporaneously with the release of both Forrester's World Dynamics [31] and

Counterintuitive Behavior *of Social Systems* in 1971. The next year 1972, Meadows, Meadows, and Randers would collaborate and extend world dynamics in *Limits to Growth* [30] and *Carrying Capacity of the Globe* in 1972[31]. These two years weren't just banner years for publications – but the crucible in which system dynamics took an early lead and strong voice in raising concerns about global growth. This context is important to remember because, at least at its start, the humanitarian food presentation is an extension of the dialogue raging on global limits more than it is an isolated stand-alone conversation with Church elders. This becomes clear in a review of the modeling process and a realization Forrester had no model in mind other than world dynamics when he spoke at the NCC meeting.

Review of Modeling Process

Unlike urban dynamics, which began its public life as a fully-fledged, well-developed model published as a book, the modeling process of humanitarian aid relief began with no model and only progressively evolved into models through the work of Dale Runge, a then-PhD student of Forrester. The presentation by Forrester and Randers in 1971 contained in D-1633 Churches does not rely on a specific model purpose-built for this presentation [26]. Instead, a "Note to the Reader" advises consideration of four recently published studies [27, p. iv], including *World Dynamics* [32], *Carrying Capacity* [31], *Counterintuitive Behavior of Social Systems*[24], *Limits to Growth*[30], and *Principles of Systems* [3]. (Note the dates listed in the footnote do not align with currently known publication dates of the final works and, in some cases, may have referred to works in process.) On the suggestion of Forrester, Runge takes up the themes of D-1633 Churches in D-1904-3 Ethics by creating a context-specific causal loop diagram (CLD) of the humanitarian aid dilemma[10, p. 4]. By D-2106 Potential Evil, Runge has advanced the CLD into what we now refer to as an exploratory model "kept very simple, to focus clearly on the underlying issues presented by food-relief programs [28, p. 2]." The model represents the donor perspective and excludes historical, social, and political realities of the gap between the donors and the recipient and any past relationships that could have led to the situation in the first place [10]. We can find no evidence of further work developing a calibrated or specific country model based on this version. Unfortunately, after finishing his Ph.D. in 1976, Dale Runge joined MIT as a junior faculty member in the Sloan School, where he died unexpectedly in 1978[33].Unlike urban dynamics, which began its public life as a fully-fledged, well-developed model published as a book, the modeling process of humanitarian aid relief began with no model and only progressively evolved into models through the work of Dale Runge, a then-PhD student of Forrester. The presentation by Forrester and Randers in 1971 contained in D-1633 Churches does not rely on a specific model purpose-built for this presentation [26]. Instead, a "Note to the Reader" advises consideration of four recently published studies [27, p. iv], including *World Dynamics* [32], *Carrying Capacity* [31], *Counterintuitive Behavior of Social Systems*[24], *Limits to Growth*[30], and *Principles of Systems* [3]. (Note the dates listed in the footnote do not align with currently known publication dates of the final works and, in some cases, may have referred to works in process.) On the suggestion of Forrester, Runge takes up the themes of D-1633 Churches in D-1904-3 Ethics by creating a context-specific causal loop diagram (CLD) of the humanitarian aid dilemma[10, p. 4]. By D-2106 Potential Evil, Runge has advanced the CLD into what we now refer to as an exploratory model "kept

very simple, to focus clearly on the underlying issues presented by food-relief programs [28, p. 2]." We can find no evidence of further work developing a calibrated or specific country model based on this version. Unfortunately, after finishing his Ph.D. in 1976, Dale Runge joined MIT as a junior faculty member in the Sloan School, where he died suddenly in 1978[33].

Initial Findings of Modeling

Both studies[10], [28] use a simplified computer simulation model. The simulation shows how food relief affects population dynamics and food consumption over time. In scenarios without food relief, the population eventually stabilizes at high birth and death rates due to the natural balance between population size and food availability. In scenarios with food relief, population growth continues unchecked, leading to increased dependency on food aid. When food relief is stopped, the population suffers significantly due to the sudden lack of food. Both studies[10], [28] use a simplified computer simulation model. The simulation shows how food relief affects population dynamics and food consumption over time. In scenarios without food relief, the population eventually stabilizes at high birth and death rates due to the natural balance between population size and food availability. In scenarios with food relief, population growth continues unchecked, leading to increased dependency on food aid. When food relief is stopped, the population suffers significantly due to the sudden lack of food.

Providing capital and technology policies to increase local food production temporarily improves food availability. However, it ultimately leads to a larger population facing food shortages unless coupled with effective birth control measures. The model findings suggest that the most effective approach involves increasing local food production and reducing birth rates. This combination leads to a sustainable balance with higher standards of living.

The paper concludes that addressing birth rates is necessary to ensure efforts to improve food production to improve sustainable living standards. It suggests that long-term suffering may result from short-term humanitarian actions if not carefully planned and managed.

The initial impact of this model was outsized to its D-Memo origins. With a national interest on the topic of famines the New York Times initially picked up the use of computer simulations before Runge even finished his first memo D-1904-3 [34]. And a later New York Times article, “Triage-Who Shall be Fed? Who shall Startve?” by Wade Greene describing Runge’s second work, D-2106-1, was read into the Congressional record by former United States Vice President and then Senator Hubert Humphrey from Minnesota[35, pp. 561–564] just two and a half months after it was published[28]. These efforts were part of the larger debate on the role of ‘triage’ in addressing world hunger.

Extended Findings

As a work by Forrester in a crucial period, D-1633 Churches, has enjoyed moderate discussion in both system dynamics, crisis management, and religious ethics publications.

Long term discussion of D-1904-3 Ethics and D-2106 Potential Evil has been limited. Runge's sudden death meant D-1904-3 and D-2106-1, as far as we can find, would be his primary contributions to modeling humanitarian aid and proposing methods of ethics in system dynamics. We could find no peer-reviewed advancement of the D-Memos or further work on a research agenda around the concepts presented in these D-Memos. Perhaps due to its 'unpublished' status and limited availability, both in system dynamics and more broadly, Runge's important work appears to have been 'lost' for decades except for the few who worked directly with him.

Forrester makes a brief reference to the findings of the D-Memo's in response to a question in the videotaped MIT Seminar series of the 1990's. Only recently, in the last decade, have Runge's colleagues such as Saeed resurfaced the D-Memos in several works all relating to the use of system dynamics to illuminate policy metaphors [36], [37]. Likewise, although there has been some discussion of ethical approaches in system dynamics modeling in the last 15 years [1], [8], [9] these made no reference to Runge's work. Our work here, hopefully, again resurfaces Runge's important and original contributions of embedding ethical tradeoffs into the simulation directly, decades ahead of similar work by others. We discuss his approach to ethical considerations below.

Discussion of Ethical Perspectives

Inspired by Forrester [26], Runge[10] suggests a dynamic framework for ethical evaluation that incorporates both relativist and temporal dimensions. The framework includes three categories: static absolute, static relative, and dynamic relative. The absolute view suggests that certain actions are inherently good or evil; while the relative view maintains that the context in which an action takes place helps determine goodness or evilness. He suggests that ethical relativism recognizes historical, environmental, or situational variations that could lead to different ethical views. Since the absolute and the relative view do not introduce the time factor and merely represent a static view of the right or wrong, he goes on to add the dynamics view that considers both the short-term and the long-term effects. A visual representation for the aforementioned ethical dimensions is illustrated in Figure 1. Note that Runge did not mention a dynamic-absolute dimension.

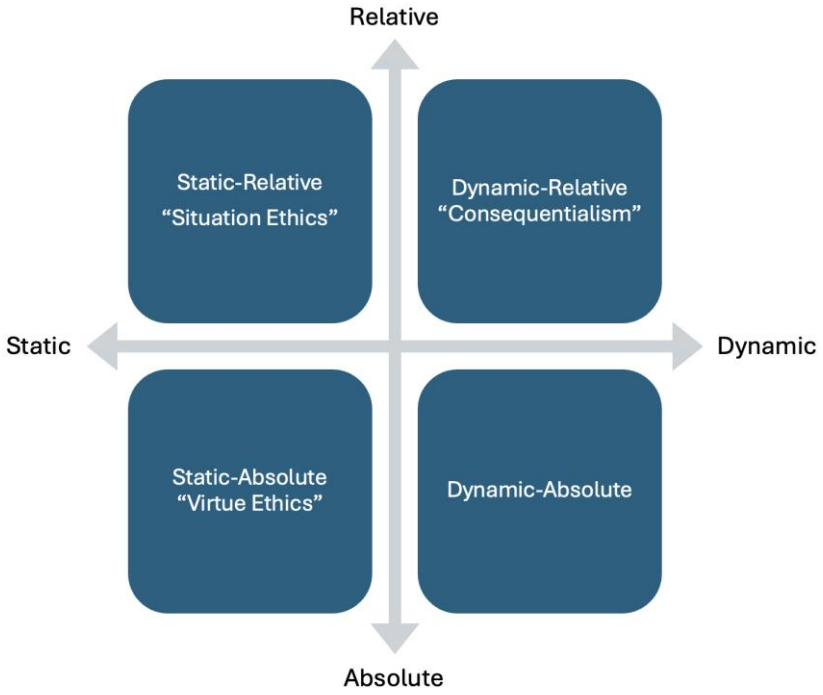

Figure 1: An illustration for the Runge's ethical dimensions.

We suggest that the static absolute view is like the virtue perspective and adheres to fixed rules without consideration for context (e.g.: providing food aid to the needy). In contrast, the static relative view considers situational contexts or "Situation Ethics" (e.g.: in a limited resource context, allocating aid could be based on the degree of need and the possibility of survival). The dynamic relative view, and potentially the dynamic-absolute, extend further, considering the long-term effects of aid (providing aid now could result in later dependency and catastrophic long-term results), which is the closest to the consequentialist perspective. He advocates that these ethical dimensions are crucial for framing food aid policies in a manner that is both morally and practically sound.

Virtue Perspective

In both pieces, Runge [10], [28] was explicit about his model boundaries and fidelity of his hypothetical model. It was not clear in his narrative that he invited others to falsify his model assumptions, test his model validity, expand its boundary, or apply it into a real-world case. This might be in part that his work was inspired by Forrester's [26] presentation to churches that preceded his work three years earlier.

In both pieces, Runge [10], [28] was explicit about his model boundaries and fidelity of his hypothetical model. It was not clear in his narrative that he invited others to falsify his model assumptions, test his model validity, expand its boundary, or apply it into a real-world case. This might be in part that his work was inspired by Forrester's [26] presentation to churches that preceded his work three years earlier.

Consequentialist Perspective

The literature does not show any follow up work for both Forrester an Runge. We are not aware of any real-world application of the policy recommendations other than the examples of different aid organizations like the United States Food for Peace Program and the Ford Foundation[10] . It is important to say that Runge cited several authors to support We are not aware of any real-world application of the policy recommendations other than the examples of different aid organizations like the United States Food for Peace Program and the Ford Foundation[10] . It is important to say that Runge cited several authors to support his model policy recommendations; namely Paddok (1973) for the withhold relief policy, Heady and Timmons(1967) for the increase of capital Investment policy, and Winterbottom (1973) of the capital investment and birth control policy. These scholars have made significant contributions to the discourse on food aid and economic development, each advocating for different strategies to address the complex issue of food insecurity in developing countries. Their perspectives provide a diverse range of approaches, from withholding aid to encouraging investment and population control, reflecting the multifaceted nature of the challenge.

Deontological Perspective

Modeling such sensitive topics entails emphasizing the perspective it is based on and about engaging multiple stakeholders to engage with its preliminary findings. These can be codified in methods that emphasis the importance of including ethical dimensions as criteria for satisfying the operational perspective of system dynamics work[38]. Ethical dilemmas are part of the latent dynamics in any human-centric system, and may represent forms of policy resistance both expected and unexpected. Just as we develop generic structures to replicate commonly reoccurring phenomena[39] Runge's work began a short lived but important deontological effort of building generic ethical structures that could be used and reused in modeling different problems.

Across the perspectives Runge [28] advocates for using the dynamic standard [10] to address the ethical responsibilities of religious institutions amidst the global shift from growth to equilibrium. Utilizing both Virtue Ethics and Consequentialism, the study highlights the necessity for a nuanced ethical approach that balances the cultivation of moral virtues with considering long-term consequences. Virtue Ethics emphasizes the importance of wisdom, justice, courage, and temperance in guiding actions toward sustainable living and global well-being. At the same time, Consequentialism focuses on the outcomes of actions, particularly their sustainability and impact on future generations.

The paper articulates the potential tension between Virtue Ethics and Consequentialism, illustrating the challenge religious institutions face in promoting immediate humanitarian virtues while addressing the long-term consequences of resource limitations and ecological sustainability. It advocates for evolution in religious teachings, suggesting a shift towards a dynamic that not only fulfills immediate humanitarian needs but also consider the broader, long-term impact on the Earth's ecological balance. This integration invites a reevaluation of moral responsibilities, highlighting the pivotal role religious institutions could play in

fostering a harmonious balance between human activities and the Earth's limits, thereby ensuring a sustainable future for all.

Discussion

Our findings demonstrated an early utility in the proposed case, anchored on the three ethical perspectives and their ability to produce useful insights. This isn't surprising at first glance. Any reflective exercise done in the absence of regular practice can yield insights to both the field and, when systematized in an accessible format, others. But the case framework also showed promise as a method to force closer examination and uncover unexpected results obscured by the passage of time and cultural stories to the authors, who have PhDs in the field. Having inherited urban dynamics as we received it with its own Athena-born origin story, we did not anticipate locating it within a vibrant and controversial context of racial conflict. Nor how quickly it was rejected as an applied planning tool and relegated to academic curiosity. We likewise were unaware of early treatment on systemizing ethics in simulations, preceding more recent work by nearly 50 years. We recognize the limitations of a method where the sample size is n=2. The framing of our case may have missed additional insights, and in pursuing more cases, new elements may arise to add to a framework. But care should be taken, both in our proposed framework and any expansions, not to make an effort to cumbersome. Some exploration is better than none. The utility of many fields for a criterion of completeness must be weighed against the ease with which any practitioner, at any level, can approach these important topics.

For our third research question about cases, we can learn a broader set of ethical implications and a system of ethical interaction. Each case individually, and especially taken together by understanding the continuity and overlap of efforts, remains relevant to today's most significant modeling efforts. It's easy to tut-tut over the erasure of race with the benefit of hindsight. Still, at least one of the authors of this work has modeled ethnographic segments in zones of conflict and now wonders to what extent he may have made the same oversight in selecting which civilian segments get included or not, or at least how transparent those decisions were made. Likewise, the questions raised in humanitarian aid that were so controversial, whether countries that behaved "well" should fund the needs of countries that didn't, remain relevant in reverse with climate change. In the modern case, countries that never benefited from carbon-based economies to the extent of other nations are now being asked to shoulder the burden, both in reducing carbon-based economic activity and being subject to many of the effects. We are not saying that clear answers in past works can be transplanted into current, but rather, the same questions and considerations remain relevant.

We also return to formulating the interaction between virtue, deontological, and consequentialist perspectives. And that these are not perspectives in isolation from one another but elements of an evolving system of ethical practices. They represent modeler behaviors, modeling practices, and a consequentialist perspective. By selecting two cases close in time to one another, we were able to see this interaction play out in just a few years worth of publications. The questionable virtue choice of excluding racial context or

discussion of ethical implications *Urban Dynamics,* recognized immediately by internal critiques and brought up within the field briefly in *D-Memo 1480 Understanding Urban Dynamics,* leading to a full-throated engagement on ethical questions in *D-Memo 1904-3 Ethics of Humanitarian Food Relief* that could have led to suggested deontological techniques of modeling tradeoffs. Likewise, the inability to gain stakeholder support for further use led, in both cases, to the works becoming isolated academically and not applied significantly, a consequentialist outcome that could lead to both virtue behaviors of earlier stakeholder engagement and even deontological suggestions of stakeholder engagement training. This paper itself is a piece of this interacting system, as we present cases with opportunities to learn from all three perspectives; future works might be formalizing ethical practices (as other fields have done) as part of a deontological approach that ensures virtue behaviors and minimizes consequentialist harm.

In this way, we see the three perspectives operating in a system paradigm depicted in Figure 2. The system's perspective is simultaneously of an individual along their career and a field along its evolution. The system is anchored on an iterative modeling process, depicted as a negative balancing loop that seeks to close the gap based on the scope of the problem. Based on the remaining gap to close modelers make choices of a nature that Meadows warned over: “problem definition, choice of method, boundary, and selective omission of facts about the system” that are often “largely unconscious” to the modeler [4, p. 367]. This leads to modeling methods producing both simulations and real-world impacts and a comparison to the remaining gap to close against the current problem scope. We note that this iteration process, as presented in the cases, encompasses both model perspectives of a single individual conducting iterative work and a field perspective of work spanning decades across different individuals, teams, or organizations on a persistent problem, such as is the case with the legacy of urban dynamics.

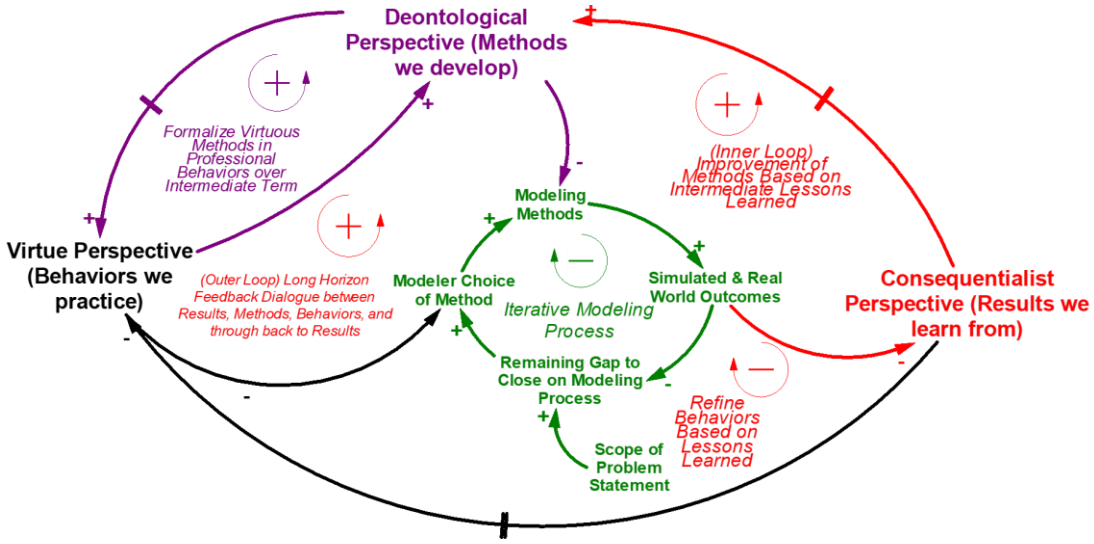

Figure 2: System Paradigm of Interaction between Ethical Perspectives

Surrounding this centered iterative modeling process are the three ethical perspectives. Beginning on the left of Figure 2 is the virtue perspective of behaviors that constrain implicit modeler choices. We model this with a negative polarity under the premise that beginning with an infinite set of potential modeler choices, any virtue perspective will narrow that set down to reflect the virtue perspective of the modeler. Note that this construction doesn't require us to specify which virtues are good or bad, just their presence. As individual virtue behaviors are systemized into deontological methods on the top of Figure 1, those, in turn, serve to increase a given virtue perspective, ultimately narrowing the universe of modeler choices. Likewise, the systemization of deontological rules acts as a constraint on modeling methods, as seen in the recent debate on quality that occurred in the field and Society within which different schools of thought attempted to limit the set of acceptable methods based on their perspective [40]. Improving both the deontological and virtue perspective are lessons learned from the consequentialist perspective, which can only come after a time delay based on simulated and implementation of real-world results. These time delays reflect the key nature of sufficient time to understand the ramifications of a seemingly virtuous or deontological action as to its consequences. This system paradigm is far from complete, but it is useful to demonstrate how ethical perspectives can operate in a dialogue productively more than a competition for supremacy.

We close the discussion with two observations that surprised the authors. First was that despite approaching this topic from the initial concern raised at the Society on the aspect of humanitarian aid, we found the D-Memo's series a very useful case study of modelers and models grappling with the implications of ethics, uncovering as we went one of the earliest published systemic treatments of ethics in system dynamics. Whether one agrees with the conclusions of the work or not, Runge made an effort to make his ethical assumptions explicit. Where we found cause for controversy, surprisingly, wasn't in work labeled "The Potential Evil in Humanitarian Food Aid" but rather in *Urban Dynamics,* which simply

erased the racial experience and historical context of Black struggles in urban centers and the explicit and implicit connection to housing, of which one of their modeling members had overseen the police response to Black housing riots just a year prior. This avoidance of context succeeded, as *Urban Dynamics* and its successive body of knowledge became known more as a potentially innovative method of city planning proposing alternative options rather than an all too familiar tale of the erasure of the Black experience.

The second surprise was that, despite how early system dynamics models like urban dynamics are presented as having a lasting impact, crucial stakeholders were to ignore the findings and their implications. One can imagine a scene all too familiar to any system dynamics practitioner who, upon making the key decision-maker presentation or struggling for a month to validate a work, is politely thanked for their efforts, if not their insights, excused from the room, and then the organizations or institutions carry on as they always have been.

But this shows the importance of engaging with past and current works on an ethical grounding. How should current students, educators, practitioners, and Society members engage with potentially controversial or problematic past efforts? Certainly, it is a common practice with many historical materials to provide context in grounding the work, as we have here. However, we propose actively engaging the materials is better within that context than other potential options. We do not endorse a view that, regardless of current discomfort with any of the questions raised herein, these, or any other works, should somehow be avoided in discussion or, worse, excised or removed from the available knowledge of the system dynamics community. Or that only those works that made it into full policy adoption deserve consideration. Doing so buries the potential to learn from past mistakes and successes. It infantilizes current and future field members who, without their consent, are 'protected' from what someone else has determined on their behalf is objectionable material. Worse, it sets the stage for a feedback loop where we are doomed to repeat the past without understanding it.

Conclusion

A recent System Dynamics Society committee inquiry into the ethical implications of D-Memos 1633, 1904-3 and 2106-1 revealed a lack of both a formal case study metod and frameworks within which to evaluate ethical issues that arise in modeling and simulation. Three ethical frameworks are particularly pertinent to modeling and simulation. A virtue perspective, focusing on modeler behaviors. A deontological perspective focused on modeling practices. And a consequentialist perspective focused on modeling results. Yet despite the suitability of modeling & simulation to explore tradeoffs and the importance of ethical practices given the nature of problems we often seek to solve, ethics literature in system dynamics is limited.

In this work we proposed an ethical case framework and used it to examine two historical cases connected to Forrester's work. The first case is the *Urban Dynamics* model published in 1968 and the decades-long work flowing from that. The second case, which originally

drew the questions of the committee, began with Forrester's 1971 presentation documented in D-1633 Churches presentation on dealing with humanitarian aid continued by Runge in D-1904-3 Ethics of Humanitarian Food and D-2106 the Potential Evil of Humantiarian Food-Relief. Both cases occurred as keystone contributions during national debates on the policies they modeled, and at least in the case of *Urban Dynamics* a legacy of further mordeling.

The proposed ethical case method asks for an investigation and exploration of the historical context within which the problem under study arose, a review of the modeling process, the initial findings and immediate criticisms within the first ten years of the start of the work, and an extended finding analysis of work after the initial ten years. At the end of each modeling, discussing the three ethical perspectives: virtue, deontological, and consequentialist requires considering the work from more than one angle.

Our findings demonstrated the value of a case study method. Despite recent concerns around the recommendations of D-1633 Churches by Forrester and subsequent D-Memos D-1904-3 and D-2106 work by Runge, we found the *Urban Dynamics* case more fraught with ethical questions. This is due to the erasure of the immediate, relevant, historical context of the Black population struggles from 1960-1967, resulting in protests and riots, often related to housing and the assassination of Martin Luther King in 1968 that preceded the articulation of the problem found in the forward of the book by only a few months. Yet any mention of race or racial implications is largely absent from this and later works. Instead, terms such as "slums" and "ghettos", common euphemisms for Black housing at the time, are used in proxy. The policy recommendations made, the demolition of old, less valuable businesses and low-income housing to make way for new enterprises and perceived higher value managerial class housing, bears striking similarity to gentrification policies when we replace the euphemism with Black housing and Black businesses to make way for white housing and white businesses. This is not to say that Forrester or his collaborators were racist. Still, the ethical implications of failing to consider race, given the immediate context and possible impact of policies, require reflection across virtue, deontological, and consequential lines. These ethical lapses were noted in the immediate aftermath of the publication of *Urban Dynamics.* The D-1904-3 and D-2106 works by Runge, building upon the D-1633 Churches case, and following closely on the heels of the ethical criticism of *Urban Dynamics,* uncovers an immediate reflection and response to the lack of engagement on ethical issues Though the policy recommendations may be controversial, and the title's provocative, Runge's *1904-3 Ethics of Humanitarian Food Relief* and *D-2106-1 Potential Evil in Humanitarian Food Relief* made transparent and explicit the challenges and tradeoff assessments of how to value a current, versus a future, human life; and whether countries that were not the 'cause' of dilemmas of famine should be required to support other countries that 'failed.' Thinking of any of these ethical dilemmas as historically isolated would be a mistake. In all manner of work today system dynamicists are modeling populations and making boundary selections of which segments are or are not involved. The tradeoff analysis between the current and future value of life and which countries should pay the bill to stave off global disaster are even more relevant in climate change than in the context of famines in the 1970s. Our case analysis demonstrated that rather than

operating in isolation, opposition, virtue, deontological, and consequentialist perspectives act in a system of ongoing action and interaction, both in individual modeling efforts but also in the iterations of a field continuing to attempt to tackle persistent problems over time.

We hope to show in our work that rather than treating historical cases with difficult ethical implications in the past as something to be removed from the body of knowledge or at least avoided, instead an active and structured engagement with the material.
The better option is to use a case method. This process allows exploration of historical and current modeling and simulation efforts to learn and reflect on the ethical implications of each case and systematize that information in a growing body of knowledge.

We believe the ethical case analysis method is a useful tool for educators to add to their curriculums to expose students to the kinds of ethical tradeoffs they will be asked to make in their models. Likewise, as notes to the journals of our fields or presentations within the Society, when issues of ethical controversy on modeling efforts arise, a case method is useful to document congruent or divergent concerns and systematically review them.

Although this is very early work and only consists of the two cases presented here, we hope that others consider using our proposed ethical case method framework, or their own, and continue studying historical and contemporary modeling & simulation efforts to contribute to this necessary aspect of our field in system dynamics modeling & simulation.

Sources

[1] E. Pruyt, "Multi-actor systems and ethics," *Int Trans Operational Res*, vol. 17, no. 4, pp. 507–520, Jul. 2010, doi: 10.1111/j.1475-3995.2009.00729.x.
[2] A. Naugle, S. Langarudi, and T. Clancy, "What is (quantitative) system dynamics modeling? Defining characteristics and the opportunities they create," *System Dynamics Review*, p. sdr.1762, Feb. 2024, doi: 10.1002/sdr.1762.
[3] J. W. Forrester, *Principles of systems*. Cambridge, Mass., Wright Allen, 1968.
[4] D. H. Meadows and J. M. Robinson, *The electronic oracle: computer models and social decisions*. Chichester ; New York: Wiley, 1985.
[5] D. H. Meadows, *Thinking in systems: a primer*. London: Earthscan, 2009.
[6] E. Pruyt, *Small System Dynamics Models for Big Issues: Triple Jump towards Real-World Complexity*, vol. 1.0. Delft, The Netherlands: TU Delft Library, 2013.
[7] J. Sterman, *Business dynamics: systems thinking and modeling for a complex world*. Boston: Irwin/McGraw-Hill, 2000.
[8] E. K. Palmer, "Beyond Proximity: Consequentialist Ethics and System Dynamics," *Etikk i praksis - Nordic Journal of Applied Ethics*, Feb. 2017, doi: 10.5324/eip.v11i1.1978.
[9] E. Palmer and B. Wilson, "Models with Men and Women: Representing Gender in Dynamic Modeling of Social Systems," *Sci Eng Ethics*, May 2017, doi: 10.1007/s11948-017-9923-1.
[10] D. Runge, "The Ethics of Humanitarian Food Relief," MIT, Cambridge Mass, D-Memo D1904-3, May 1974.

[11] J. G. Turnley, “Where is the Method in the Madness? Questions for systems dynamics modeling teams,” presented at the System Dynamics Winter Camp, Alberquerqe, NM, Jan. 09, 2015.
[12] T. Clancy, S. P. Langarudi, and R. Zaini, “Never the Strongest: A Taxonomy Reconciling Schools of Thought in System Dynamics,” *Working Draft*, p. 5, 2019.
[13] J. W. Forrester, *Urban dynamics*. in System dynamics series. Waltham, MA: Pegasus Communication, 1994.
[14] “US Censuses of Population and Housing: 1960 for Boston Standard Metropolitan Statistical Area,” US Department of Commerce - Bureau of the Census, Washington, D.C., Census Tracts PHC(1)-18. [Online]. Available: https://www2.census.gov/library/publications/decennial/1960/population-and-housing-phc-1/41953654v1ch7.pdf
[15] “Census of the Population and Housing: 1970 Census Tracts Boston Metropolitan Statistical Area,” US Department of Commerce - Bureau of the Census, PHC(1)-29, 1970. [Online]. Available: https://www2.census.gov/library/publications/decennial/1970/phc-1/39204513p3ch05.pdf
[16] D. R. Meyer, “Blacks in Slum Housing: A Distorted Theme,” *Journal of Black Studies*, vol. 4, no. 2, pp. 139–152, Dec. 1973, doi: 10.1177/002193477300400203.
[17] J. Forrester, “A Deeper Knowledge of Social Systems,” *Technology Review*, vol. 71, no. 6, pp. 1–11, Apr. 1969.
[18] J. Forrester, “Systems Analysis as a Tool for Urban Planning,” *IEEE Trans. Syst. Sci. Cyber.*, vol. 6, no. 4, pp. 258–265, 1970, doi: 10.1109/TSSC.1970.300299.
[19] J. Forrester, “Toward a National Urban Consensus,” MIT, Cambridge Mass, D-Memo D-1291, Mar. 1970.
[20] L. E. Alfeld, “Urban Dynamics - the First Fifty Years,” *System Dynamics Review*, vol. 11, no. 3, pp. 199–217, Fall 1995.
[21] L. P. Kadanoff, “From simulation model to public policy: An examination of Forrester’s ‘Urban Dynamics,’” *SIMULATION*, vol. 16, no. 6, pp. 261–268, Jun. 1971, doi: 10.1177/003754977101600603.
[22] L. E. Alfred and W. Schreder, “Chapter Five: Urban Dynamics and the Suburbs: A Preliminary Analysis and Model Extension,” MIT, Cambridge, MA, D-Memo D-2054, Apr. 1974.
[23] P. Sanders and F. Sanders, “Spatial Urban Dynamics,” in *Proceedings of the 2004 international system dynamics conference*, Oxford, UK, 2004.
[24] J. W. Forrester, “Counterintuitive behavior of social systems,” *Theor Decis*, vol. 2, no. 2, pp. 109–140, Dec. 1971, doi: 10.1007/BF00148991.
[25] G. O. Barney, “D-1480 Understanding Urban Dynamics,” MIT, Cambridge Mass, D-Memo D-1480, Nov. 1970.
[26] J. W. Forrester, “Churches at the Transition between Growth and World Equilibrium,” Sloan School of Management, Massachusetts Institute of Technology, D-Memo D-1633, Nov. 1971.
[27] C. Gerlach, “Famine responses in the world food crisis 1972–5 and the World Food Conference of 1974,” *European Review of History: Revue européenne d’histoire*, vol. 22, no. 6, pp. 929–939, Nov. 2015, doi: 10.1080/13507486.2015.1048191.

[28] D. Runge, “The Potential Evil in Humanitarian Food-Relief,” MIT, Cambridge Mass, D-Memo D-2106-1, Oct. 1974.
[29] J. W. Forrester, “Industrial dynamics: a major breakthrough for decision makers,” *Harvard business review*, vol. 36, no. 4, pp. 37–66, 1958.
[30] D. H. Meadows, J. Randers, and D. L. Meadows, “The Limits to Growth (1972),” in *The Future of Nature*, L. Robin, S. Sörlin, and P. Warde, Eds., Yale University Press, 2017, pp. 101–116. doi: 10.12987/9780300188479-012.
[31] J. Randers and D. Meadows, “Carrying Capacity of the Globe,” *Sloan Management Review*, vol. 13, no. 2, p. 11, 1972.
[32] J. Forrester, *World Dynamics*. Cambridge, MA: MIT Press, 1971.
[33] “Dale E. Runge 10/7/1942 - 9/2/1977 (update),” Dartmouth Class of 1964. [Online]. Available: https://1964.dartmouth.org/s/1353/images/gid180/editor_documents/runge-obit-1977.pdf
[34] W. Sullivan, “Computer ‘Model’ of World Sought to Cope With Food Shortage,” *New York Times*, p. 31, Aug. 10, 1974.
[35] “Triage: A Bankrupt Doctrine,” 122 vols. Congressional Record, Washington, D.C., pp. 510–606, Jan. 16, 1975. [Online]. Available: https://www.congress.gov/bound-congressional-record/1975/01/16/senate-section
[36] K. Saeed, “Circumscribing System Dynamics Modeling and Building Confidence in Models a Personal Perspective.” Rochester, NY, May 15, 2017. doi: 10.2139/ssrn.3093080.
[37] K. Saeed, “Systems thinking metaphors for illuminating fundamental policy dilemmas.,” *Department of Social Science and Policy Studies Working Papers.*, Mar. 2016, [Online]. Available: http://digitalcommons.wpi.edu/ssps-papers/5/
[38] C. Olaya, “Cows, agency, and the significance of operational thinking: Cows, Agency, and Operational Thinking,” *Syst. Dyn. Rev.*, vol. 31, no. 4, pp. 183–219, Oct. 2015, doi: 10.1002/sdr.1547.
[39] D. C. Lane and C. Smart, “Reinterpreting ‘generic structure’: Evolution, application and limitations of a concept,” *System Dynamics Review*, vol. 12, no. 2, pp. 87–120, 1996, doi: 10.1002/(SICI)1099-1727(199622)12:2<87::AID-SDR98>3.0.CO;2-S.
[40] T. Clancy, S. P. Langarudi, and R. Zaini, “Never the strongest: reconciling the four schools of thought in system dynamics in the debate on quality,” *System Dynamics Review*, vol. 39, no. 3, pp. 277–294, Jul. 2023, doi: 10.1002/sdr.1740.