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Master Thesis

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A Value Sensitive Agent Based Simulation of the Refugee Crisis in the Netherlands

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Abstract

The refugee crisis of 2015 was exacerbated by logistical breakdowns among the institutions responsible for asylum seeker reception. As such, asylum seekers suffered distress not only from their flight from conflict, but also from their living conditions in the host country. An agent based model was developed to characterize the wellbeing of refugees in the context of asylum logistics. The model's theoretical underpinning is Schwartz's theory of values that is implemented as a decision procedure and well-being operationalization. We analyze the degree to which values drive outcomes for relevant stakeholders: refugees, government, and non-government organizations. The outcome of the values analysis revealed points of the model which require further attention. We performed in silico experiments comparing simulated historical conditions to counterfactuals. Finally, the results gathered may be used for actionable policy recommendations to government stakeholders.

Chapter 1

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Part I

Background

Chapter 2

Introduction

What began as peaceful protest in Syria amidst the Arab Spring escalated into a brutal civil war in which both state and armed non-state actors targeted civilian populations [7]. The intolerable conditions of the protracted conflict, collapse of health infrastructure, barrel bombings, and political persecution prompted forced migration [26] [90]. Subsequently, 1.6 million displaced people left Syria for Europe and surrounding areas [42]. The influx of refugees was logistically problematic for both government and non-government organizations (NGO) responsible for housing, processing, care and integration of refugees [66]. Moreover, poor mental health outcomes can not attributed entirely to traumas faced in the refugee's home country, but also to the conditions faced while undergoing the asylum procedure [68]. As such, models which aim to address the logistical shortcomings of the refugee crisis must be sensitive to both refugee wellbeing and logistical requirements.

However, the complexity required to make logistical recommendations based on a rich characterization of refugee wellbeing rules out linear modeling methods [4]. Agent-based models (ABM) address problems, not by offering discrete solutions, but by simulating the context in which the problem resides [8] [33]. Growing a problem space from the ground up requires codifying sociological theory. The present investigation organizes agent behavior according to Schwartz theory of values, which are essentially an ordered set of beliefs about the world whose relative importance motivates action[78]. Critically, Value driven behavior is motivated by multiple and often contradictory principles, such as refugee wellbeing and operational cost [74].

The present simulation employs a Value driven ABM of the asylum procedure to address the following concerns. First, to what degree does inter-institutional cooperation, or lack there of, contribute to logistical bottlenecks? Second, to what degree do NGOs contribute to mental health outcomes? Third, what is the relationship of government and NGO values to refugee outcomes. Finally, the tangible result of the research is to develop an interactive artifact which researchers and policymakers can employ to entertain the outcome of varying scenarios.

The rest of the chapter is organized as follows. First, Section 2.1 outlines the context of the problem. Second, Section 2.2 contains the research questions, assumptions, and limitations. Third, Section 2.3 illustrates the goals which must be met in order to address the problem. Finally, section 2.4 provides a road-map of the rest of the thesis.

2.1 Context

2.1.1 Crisis Logistics

During the 2015 refugee crisis, the volume of asylum applicants posed a logistical problem for government and NGOs responsible for housing, processing, care and integration of refugees [66]. Humanitarian response logistics, the supply and delivery of aid and resources in a crisis situation, had to be robust and flexible to survive demand shocks and adapt to varying needs [15] [55]. Furthermore, humanitarian logistical stakeholders need to cooperate, and cooperation broken down at multiple levels. European states failed to equitably share refugee reception responsibility [12]. Institutions responsible for refugee reception did not all respond with the same urgency. For example, the two key Dutch governmental agencies with which refugees interact, the Central Orgaan opvang Asielzoekers (COA) and Immigratie en Naturalisatiedienst (IND), responsible for housing and immigration, respectively, were uncoordinated in their response to the crisis. As such, the wait times for IND decisions extended from 8 days to 18 months. Consequently, COA was left with a logistical bottleneck [50]. Additionally, NGOs who typically provide auxiliary support to government agencies face market pressure which discourages cooperation [83] [24]. The breakdown of cooperation negatively impacted quality of service delivery [68].

2.1.2 Health Impact

Investigations into the treatment and care of refugees found the following needs unmet: daytime activities, social contact, financial support, accommodation, psychological distress, and mental health treatment [57]. Moreover, there are dependencies between the psychological distress and the functions of their care providers, COA. Psychological distress stems from a lack of integration activities, sufficient accommodation, perceived stigmatized use of public transportation, and insufficient allowance to participate in local community [84]. Taken together, there is a connection between cooperative service delivery and the wellbeing of those receiving the service.

2.1.3 Humanitarian Logistical Modeling

Previous work modeling humanitarian response logistics has largely focused on aid delivery in developing nations, adapting methods and terminology from commercial logistics [96]. First, humanitarian logistics must accommodate uncertain supply and demand [13] [16]. In addition, storage and control of humanitarian goods is often sensitive to local political influence [96]. Moreover, routes between supply locations are often unreliable, requiring multiple modes of transportation [67]. While most of the aforementioned models focus on the delivery of medical supplies, some have addressed concerns more related to the present study, such as optimal staffing arrangements for NGOs [34]. In addition to operational costs, humanitarian logistical models take into account deprivation costs, the increase in suffering that accumulates from lack of a good or service [67]. However, the deprivation costs of mental health treatment are difficult to quantify and researchers have difficulty quantifying human suffering [96].

2.1.4 Values

values are a sociological framework for analyzing behavior. Essentially, values are an ordered set of affected beliefs whose reconciliation motivates action [76]. Critically,

values permit contradictory behavior. For example, an individual may highly value both security and benevolence, owning a gun for self defense but also volunteering with a local shelter. Moreover, values provide a basis for quantifying mental health by providing insight into subjective wellbeing. That is, the congruency between an individual's values and opportunities their environment affords for acting upon them is a predictor of subjective wellbeing [73]. As such, a computational model of values can be used as the basis of quantified wellbeing.

Until recently, values have remained in the sociological domain [78] [75] [74]. Recent work applying values in an ABM context has illustrated its efficacy as a tool for public policy analysis [29]. In the context of EU smoking regulations, values proved to be a useful mechanism to account for cultural differences in regulation adherence [29].

2.1.5 Agent Based Models

Notably, ABMs and simulations have been employed for modeling aspects of the refugee experience at varying levels of abstraction. First, work has been done to model the dynamics of large scale movement patterns [43] [82] [22]. Additionally, ABMs have been developed that predict the destination of refugee movements [53] [41] [37]. Further efforts were made to standardize and automate the deployment of refugee movement models, which can be deployed in varying conflict contexts [21] [85]. Second, ABMs have been developed on lower levels of abstraction. Hailegiorgis and Crooks developed a disease spread model that spans multiple refugee camps [38]. Focusing on a single camp, Johnson and colleagues developed a model that focuses on the relationship between camp security forces and local populations [51]. Similarly, Anderson et al. developed a single camp model of refugee health that employs a decision mechanism with notable parallels to the value system. That is, refugee agents make decisions according to a weighted hierarchy of needs and desires [4].

2.1.6 Summary

Taken together, uncoordinated crisis response resulted in a logistical bottleneck whose effects were felt in negative mental health outcomes, the gravity of which merits investigation. Though existing methods of humanitarian logistical analysis exist, they are primarily focused on optimization and are constrained by strict assumptions of homogeneity and linearity. The values framework allows for behavior motivated by multiple and often contradictory performance metrics. Furthermore, values provide an easily calculable proxy for mental health. ABMs provide a useful tool for exploring policy questions in which there is no clear correct answer and stakeholders are heterogeneous, such as refugee crisis response. However, previous ABM implementations have largely focused on migration patterns at a level of abstraction too high to capture meaningfully the individual refugee experience. Those that simulated directly the experience of individual refugees focused more on physical than mental health.

2.2 Problem

The forthcoming simulation combines an institutional level logistical framework with an individual level model of mental and physical health. As such, degree of cooperation between agents providing services has consequences for refugees on the receiving end. Furthermore, agent behavior at all levels is Value motivated, allowing for behavioral nuance and a basis for mental health. Finally, the resulting artifact will be a publicly

available tool which policymakers and researchers alike can make use of to observe the results of variable scenarios.

2.2.1 Research Questions

The ABM was developed in order to answer the following questions.

Research Question 1 To what degree are the values of institutional agents, COA, IND and NGOs, outcomes for other agents and cities?

Requirements Research Question 1 requires performing an input parameter sweep on values of institutional agents. Consequently, variance in values can be correlated with refugee outcome variance, indicating value influence on outcomes.

Research Question 2 How does inter-institutional cooperation effect bottleneck response during simulated shocks?

Requirements Research Question 2 requires a between-groups comparison of cooperative and uncooperative COA and IND agents. Cooperative agents adjust their budgets and staff in accordance, whereas uncooperative agents do so independently.

Research Question 3 What is the influence of NGOs on refugees and municipalities?

Requirements Research Question 3 requires a two-fold analysis. First, NGO influence must be analyzed in a binary fashion, indicating which outcomes require either the presence or absence of NGOs. Second, a parameter that limits the growth of NGOs must be swept to generate a range of outcomes corresponding to NGOs of varying influence. Then, outcome variance can be correlated with variance of the NGO influence limiting parameter. The two-fold analysis is necessary as there is a difference between the complete absence of NGOs and an NGO with no initial influence.

General Requirements All three questions are predicated on the development of a novel simulation, which required the following preparatory measures. First, information was gathered, interviews with subject matter experts (SME) were conducted, and literature was reviewed and compiled into a case study on the asylum procedure in the Netherlands. Second, the case was then codified into implementable procedures. Third, literature regarding values was reviewed and compiled into an implementable values framework and agent decision procedure. Fourth, an ABM was iteratively developed which placed asylum procedures into the Value framework such that the research questions could be addressed, analyzed and discussed.

Assumptions The model makes the following assumptions

1. Auxiliary buildings are constructed on time
2. Additional public funding is available on request
3. The supply of social housing is low but constant

4. Dublin Procedure does not apply
5. Refugees have full information about local activities

As the focus of the present simulation is on the behavior and living conditions of refugees during the asylum procedure, then the actual process of constructing a residential facility can remain implicit. Second, during emergency situations the funds required for the construction of additional housing facilities exceeds the budget, but the gravity of the situation justifies the use of additional public funding. Third, social housing is awarded by a priority system. Typically, refugees are given a high priority; however, the dynamics of priority are variable across municipalities. Due to a lack of data on what drives that variability, it is best kept constant. Fourth, the Dublin procedure which returns asylum seekers to the European country where they first arrived is not included [47]. The Dublin procedure is not included so as to restrict the focus to intra-state asylum logistics. Fifth, a key component of the simulation is activities for refugees. We assume that once an activity is organized on a specific day, all of the local refugees are aware of its occurrence. This is a placeholder assumption to be used until information can be filtered through social networks.

Limitations

1. Value Interaction Condition Relaxed
2. Local Population Approximated
3. No NGO competition
4. Limited learning

First, the reasons for the relaxation of the value interaction condition is described in Chapter 4 Section 4.3.2. Second, the local population is approximated rather than explicitly modeled as per the principles of Critical Systems Heuristics, in which features are only added to model in order to support the modeling of the key stakeholder: the refugee [89]. Lastly, NGOs do not compete. The NGO situation within the Netherlands is largely dominated by one large umbrella organization, Vluchtelingenwerk, described in Chapter 3 Section 3.3.2. Though smaller NGOs surely compete for funding and support from the aforementioned, there is insufficient data on NGO competition within the Netherlands. In addition, there is very little learning in the simulation. Only one agent learns in the process of anomaly detection. However, the majority of agent behavior involves no learning.

2.3 Goals

The goals of the simulation are as follows.

Goal 1 *Consult with literature and SMEs to codify asylum policy, asylum procedure and simulation requirements.*

Goal 2 *Implement a decision mechanism and wellbeing metric based on Schwartz's theory of values*

Goal 3 *Build a model that utilizes values to capture both refugee and logistical behavior*

Goal 4 *Analyze the degree to which values correlate with outcomes*

Goal 5 *Use model to make recommendations to stakeholders*

Goal 6 *Define development plan for the continuation of the project*

2.4 Thesis Overview

The rest of the thesis is organized as follows. Chapter 3 reviews the relevant literature on ABMs, the Asylum Procedure and values. Chapter 4 contains a formalization of values and the Value Decision Procedure. Chapter 5 contains the model description as per the Overview, Details, Design (ODD) protocol. Chapter 6 contains the development of the project over time, remarks on validation, and a description of the artifacts. Chapter 7 contains the research question hypotheses and methods. Chapter 8 contains the results and discussion of the three experiments and Chapter 9 contains the general discussion of the project. Finally, Chapter 10 addresses the goals, takes stock of novel contributions that were made, and outlines directions for future research.

Chapter 3

Literature Review

3.1 Introduction

This chapter addresses **Goal 1: Consult with literature and SMEs to codify asylum policy, asylum procedure and simulation requirements.** First, the field of humanitarian logistics is covered. Second, the asylum procedure, the logistical operation modeled in the present investigation, is characterized. Third, refugee mental health is described for the purpose of defining a human cost against which to measure logistical efficacy. Fourth, ABMs will be introduced. Finally, ABMs focused on simulating housing logistics and the refugee experience will be reviewed.

3.2 Humanitarian Logistics

Before delving into the logistical operation at the heart of the present investigation, it is necessary to define humanitarian logistics and review previous literature. After reviewing the various sub problems within humanitarian logistics, the key attributes of humanitarian logistics necessary for the present investigation will be made clear. Humanitarian logistics is that which accommodates uncertainty and optimizes against a social cost metric. These terms will be clarified in the following section.

3.2.1 Definition

Humanitarian logistics is similar to that of commercial enterprises with the exception of two key differences. Though both are concerned with managing a supply chain consisting of inventory and delivery of goods and services, humanitarian logistics must accommodate greater uncertainty in supply, demand and inventory routing, and take into account social cost.

The goods and services typically managed in humanitarian logistics are accommodation, medical supplies, and knowledge [13]. Knowledge delivery is a question of staffing, and humanitarian staffing is unique in its reliance on volunteer labor [34]. Before delving into the mechanics of delivery and staffing, it is best to first address inventory.

3.2.2 Inventory Management

The two key components of inventory management are acquisition and storage [96]. First, swift response to a disaster whose arrival is uncertain requires goods and ser-

vices ready-at-hand, the quantity of which is an approximation of the needs of first responders. After the initial phase of a disaster has past, a steady stream of goods and services must be ordered whose quantities are determined by predicted demand given the current rate of demand change. Second, goods and services storage systems in humanitarian logistics are rarely equipped with state of the art record keeping systems. That is, humanitarian inventory managers often rely on rough approximations, the result of which is inaccuracy of acquisition requests. Furthermore, humanitarian inventory management is sensitive to the often corrupting politics of the region. [96].

Previous attempts to model humanitarian inventory management account for the uncertainty in acquisition and storage Beamon and Kotleba [13]. According to Beamon and Kotleba, inventory management under uncertain conditions is the process of knowing standard and emergency quantities and inventory levels. That is, given stable demand, what quantity must be ordered at what inventory level such that demand can still be met from existing inventory during shipment time. As demand becomes unstable, an emergency quantity must then be derived for a secondary inventory level in the event that demand reduces inventory levels faster than anticipated. In the aforementioned models, the designer chooses a risk level dependent on the severity of emergency from which a standard inventory level can be derived. Subsequently, from the standard inventory level the expected backorder rate, unmet demand, can be determined. Then, from the backorder rate the standard and emergency quantities can be derived. Back-orders provide a unique metric for both humanitarian organizations and the people they serve. As a back-order is indicative of unmet demand, it is a social cost of unaddressed welfare as well as "bad press" for the humanitarian organization dependent on media coverage [13].

3.2.3 Delivery

The delivery of humanitarian goods and services differs from commercial enterprises in a number of ways [96]. First, social cost is critical in calculation of route planning, though practitioners rarely operationalize human suffering as a cost. Second, delivery routes are value sensitive. Third, there are strict delivery order and time constraints as the utility of certain goods or services is contingent on the reception of another. Fourth, demand knowledge is rarely centralized with inventory managers, but rather distributed to intermediate depots, referred to as push and pull logistics [96].

Distribution problems are typically modeled as inventory routing problems (IRP), graphs whose nodes are either inventory supply, storage, or demand and edges are transportation costs. Agents must then traverse the graph to minimize transportation costs. Previous humanitarian IRP solutions consist of operational cost minimization, ordered delivery locations or ad hoc delivery decisions. Perez and colleagues recently reformatted the IRP to include social costs for routing in humanitarian relief operations [67]. Social cost can be quantified as a function of time, commodity type and deprivation cost. The deprivation cost is the amount of suffering incurred by the lack of a certain commodity. For example, water would have a different deprivation cost than food. Deprivation costs increase exponentially over time. The author's IRP solution then requires minimizing operational cost as well as social cost, where operational cost is a sum over all modes of transport, vehicle types, fuel costs and time. Social cost is summed over population in need by deprivation cost for each commodity in each node [67]. Similarly, IRP solutions developed for defense purposes lend them selves well to the humanitarian sector, as both accommodate uncertainty. Unlike the above described model, Shekh and Blom accommodate uncertainty by distributing decision making across heuristically informed delivery agents. Possible heuristics include

delivery to most in-need demand nodes, demand surge compensation and inter-node communication [16].

3.2.4 Staffing

Unlike commercial enterprises, NGOs depend heavily on volunteer labor, often with high turnover and limited contract duration [34]. As volunteers are not paid, preference and skill set are key factors in task assignment. Moreover, humanitarian staffing relaxes the assumptions that the labor pool contains sufficient skills to complete a task and the skill set of each member of the pool is fully known. Falasca and Zobel address the issue of humanitarian staffing as an optimization seeking to minimize two objective functions, shortage costs and undesired assignments. The first pertains to cost of leaving tasks unassigned for a given period of time. The second pertains to the cost to an individual volunteer of performing a task outside of one's preferences. The optimization problem is then solved using either efficient frontier, goal programming or fuzzy logic approaches [34].

3.2.5 Housing

Humanitarian housing logistics borrows much from commercial construction by seeking to minimize total project duration and cost. However, humanitarian housing logistics also optimizes with respect to social cost. The sub-problems within humanitarian housing logistics are location determination, resource allocation, and material selection. Furthermore, the bulk of humanitarian housing logistics literature focuses on natural disaster response.

With regards to location determination of post-disaster housing, El Awar incorporated both social and operational cost reduction into a single multi-criteria optimization model. Specifically, a suitable location for post-disaster housing should minimize the economic impact on the families of the displaced, maximize safety of housing facilities, minimize environmental footprint, and minimize cost of construction [30] [32]. Following up on previous research, El Awar automated the location optimization procedure into a rapidly deployable software package for aid workers in the field [31]. In addition, Hosseini and colleagues developed a multi-criteria optimization model to select locations for temporary housing units (THU) following a natural disaster. The model seeks to maximize THU resident wellbeing, minimize disruption of the community surrounding the THU, minimize THU expenditures, minimize environmental footprint, and maximize THU construction worker wellbeing [46]. Further optimal location models have been developed that integrate GIS data into the optimization procedure. Such models have been found to be effective in determining flood risk of post-disaster housing [72]. Location prediction is another related field of humanitarian housing logistics research, especially useful when displaced people are responsible for constructing their own shelter. Bramante and colleagues developed a predictive model that takes as input topographical GIS data, population density and availability of open space to predict a distribution of informal housing following a natural disaster [19].

In addition, previous research has focused on resource allocation and material selection. First, resource allocation requires balancing limited resources, time, and funds, requiring multi-variate optimization. Previous research by Ashuri and Tavakolan has developed time-cost-resource optimization models which minimize project duration, total cost, and resource allocation variance [6]. Second, Hosseini et al. developed a decision making model for THU material selection. The aforementioned model takes into account social considerations, such as compatibility with the occupants culture,

comfort and security, in addition to economic and environmental considerations [45].

In summary, humanitarian housing logistics research is primarily concerned with where units are built; however, some literature also addresses materials and resource allocation [45] [30] [32]. Critically, humanitarian housing logistics uses social cost as a metric against which to optimize when making the aforementioned decisions.

3.2.6 Conclusion

The defining features of a humanitarian logistical operation are accounting for uncertainty and integrating social cost [96] . The former requires the supply chain manager to approximate the variance in demand and have sufficient reserve supply to overcome demand surges. The latter pertains to an umbrella term encapsulating backorder rates, deprivation costs, and shortage costs. All of the previous metrics describe the suffering incurred by the lack of a particular good or service. Much previous humanitarian logistics literature concerns disaster response and necessary inventory management and routing problems [67]. Of more pertinence to the present investigation, humanitarian logistical literature also touches upon housing and staffing; however, the models rely on optimization rather than agents [30] [31] [34].

3.3 Asylum Logistics

3.3.1 Introduction

The following section describes the Dutch asylum procedure, the logistical operation being modeled. First, the key actors, COA, IND, and NGOs will be identified. Second, the asylum procedure itself will be described. Third, the potential for logistical failure and dysfunction will be described.

Note, up until this point the term refugee was used as a general word to encompasses the range of legal statuses. As the scope is now focused more specifically on the Netherlands, more specific terms will be employed which indicate a specific refugee legal status.

3.3.2 Key Actors

The key figures in the Dutch asylum procedure are COA, IND, refugees and NGOs. COA and IND are responsible for refugee housing and legal processing, respectively [64] [48]. Furthermore, NGOs are responsible for providing refugees auxiliary support, influencing public opinion and lobbying [94].

IND IND is responsible for decisions regarding the change in legal status of a refugee. IND staff members interview asylum seekers and decide whether the recounted experience qualifies for a asylum [48]. The conditions of asylum are as follows:

1. In your country of origin, you have real reasons to fear persecution because of your race, religion, nationality, political convictions or because you belong to a particular social group.

2. You have real reasons to fear the death penalty or execution, torture or other inhuman or humiliating treatment in your country of origin.

3. You have real reasons to fear that you will be a victim of random violence due to an armed conflict in your country of origin.

4. Your husband/wife, partner, father, mother or minor child has recently received an asylum residence permit in the Netherlands

If the above conditions are met and supported with credible documentation, then the applicant receives asylum and a residence permit [48].

Asylum procedure duration depends on IND staffing. When IND has insufficient staff available to register and interview asylum applicants, wait times increase, causing a bottleneck [49].

COA COA is the asylum seeker's housing authority. COA is responsible for providing housing, security, and a minimum quality of life to asylum seekers [64]. COA regularly checks in with residents to assess their condition and provide support when necessary.

Furthermore, COA maintains a number of facility modalities for different purposes. The Centrale Ontvangslocatie (COL) receives and registers externally displaced persons (EDP). Procesopvanglocatie (POL) facilities house asylum seekers (AS) while IND reviews their cases. The Asielzoekercentrum (AZC) houses both those with a temporary residence (TR) awaiting a social housing allocation and extended procedure asylum seekers (ASE). There are other facility modalities that are not included in the simulation dedicated to unaccompanied minors, families, and asylum seekers who have committed crimes [63].

Finally, COA is also responsible for forecasting future occupancy levels. Every three months, a two year prognosis is calculated based on historical data. Every month, occupancy levels are monitored. Buffer housing is maintained for crisis periods in which occupancy increases beyond capacity [62].

In summary, COA must maintain its buildings of varying modalities, keep an adequately sized staff to look after the health of residents, estimate future occupancy levels, and ensure that adequate buffer housing is available for crisis periods [62], [64], [63].

NGO Vluchtelingenwerk (VWN) is the largest NGO involved in the asylum procedure. VWN supports asylum seekers both during and after the process by providing information, resources and organizing activities.

During the process, VWN provides orientating information to asylum seekers regarding their rights and to which services they are entitled [94]. A related NGO, the Legal Aid Board (RVR), provides lawyers to each asylum seeker to help with the gathering of documents in preparation for interviews [70]. VWN operates a helpdesk to assist in answering legal questions as they arise. Of particular interest to the current simulation, VWN funds smaller initiatives to improve the wellbeing asylum seekers, such as music lessons for children and language classes [94].

In addition, VWN influences lawmakers and the public at large. VWN funds go to parliamentary lobbying and internal research. Furthermore, VWN launches marketing campaigns and events, such as the 'AZC Open Day,' to bring public awareness to asylum seekers. VWN funds come from private donors, businesses, government grants and the Dutch Post-Code Lottery [93].

In summary, assuming VWN to be representative of a heterogeneous coalition of NGOs involved in the Dutch asylum procedure, NGOs are responsible for the following:

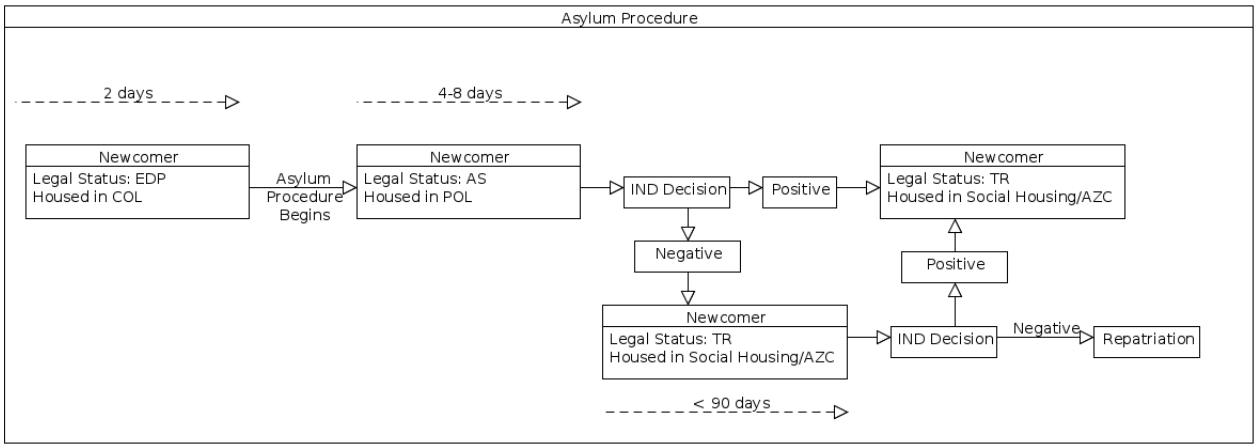


Figure 3.1: An overview of a simplified asylum procedure. The times included on the dashed lines are what is expected during non-crisis periods

supporting asylum seekers through practical assistance and quality of life improving activities, raising funds from the public, and influencing the public through marketing and lobbying efforts.

3.3.3 The Asylum Procedure

The asylum procedure is the logistical operation around which the present investigation revolves. A graphical overview of its basic steps can be found in Figure 3.1 Logistically, the asylum procedure consists of housing asylum seekers as they move through the varying stages of the legal procedure and ensuring there are sufficient facilities for residents during times of crisis.

The Dutch asylum process, which has been described as 'secure but segregated,' proceeds as follows [9]. Before obtaining formal AS status, an individual who applies for refugee status is an EDP. A displaced person receives a health examination and registers as an asylum seeker at the Centrale Ontvangslocatie (COL) in Ter Apel. After two days, the EDP is sent to a Procesopvanglocatie (POL) facility where their legal status changes to AS and they begin the general asylum procedure.

After an intake interview in the POL, IND repatriates asylum seekers from designated safe countries. If the asylum seeker appeals the decision or IND requires more time to decide, the asylum seeker is transfered to the Asielzoekercentrum (AZC) for the extended asylum procedure. Their accommodation and care is managed by COA, who provides a weekly allowance of 50 euro. COA tightly controls movement in and out of the AZC, and residents must report regularly [9]. During non-crisis periods, the general asylum procedure lasts from four to eight days. Furthermore, the maximum wait time for a decision was six months. Due to insufficient staff during the 2015 crisis, general asylum procedure decisions took up to 15 months and extended asylum procedure decisions up to 18 months [50].

After refugee status is granted, an asylum seeker receives a residence permit, TR status, for five years. Then, the Dutch government supplies the refugee with social housing nearby the AZC, which are typically in rural zones. Though the stated time limit for a house is two weeks, many wait much longer. Refugees with a TR status

continue to reside in the AZC while awaiting their housing. With refugee status, one can receive social security benefits, enroll in a university, and work. They are then obligated to undergo an integration course on Dutch language and culture. After passing the exam, they are then qualified to apply to become a permanent Dutch resident [9].

3.3.4 Asylum Living Conditions

There is a broad range of AZC facilities, and COA administrations are heterogeneous. On the integrated end of the spectrum lies facilities such as Plan-Einstein in Utrecht, which features a piano in the lobby. Thanks to generous funding and NGO partnerships, residents can take entrepreneurship workshops, enroll in English classes, and engage in a myriad of integration activities [92]. COA logistics personnel were quick to point out that Plan-Einstein is the exception to the rule and a product of Utrecht's unique progressive policies. In contrast, recent case studies reveal bleak but livable conditions in other facilities. Rooms can be shared with up to eight people, with an average amount of personal space of five square meters [9]. Facilities can be cold and interaction with non residents is tightly controlled. Some facilities have a nearby football field, but otherwise there are commonly little to no organized activities. This results in a lack of social engagement and community development [95]. Moreover, community development is constrained by constant movement between facilities, the justifications for which are often unknown to the asylum seeker in question. Alcohol and marijuana abuse are common forms of self-medication employed to cope with empty days [50].

3.3.5 Logistical Failures

From 2012 to 2015, the number of asylum seekers in Europe rose from 350,000 to 1.6 million [42] [9]. Specifically in the Netherlands, the number of monthly asylum applications jumped from approximately 1000 per month in January to 7114 per month in August 2015 [1]. The Netherlands was ill equipped to handle such large volumes of applications due to breakdowns at multiple levels.

Inter-State Breakdowns At the highest level, European states failed to cooperate with burden sharing agreements [12]. By opting out of accepting migrants, defecting nations increased the burden on those countries who opted in to receive refugees. Burden sharing agreements are normative, non-binding, and upheld by an alliance of states who opt in to the agreement. Furthermore, the smaller the state, the smaller the consequence for leaving the alliance and visa versa for large states, such as Germany, which could not afford to the leave the alliance. As such, certain states bore a disproportionately large burden due to an incentive structure deemed 'the exploitation of the large by the small' [88].

Inter-Institutional Breakdowns Within the Netherlands, IND and COA failed to cooperate during the initial response to the crisis which resulted in a bottleneck. According to interviews with COA, IND and COA have asynchronous funding schemes, such that the latter makes budgetary alterations faster than the former. Consequently, IND didn't hire additional staff until it was too late, and the number of asylum cases that can be processed depends heavily on the size of IND staff [50] [49]. As a result, asylum procedure wait times increased dramatically. Eventually IND hired sufficient staff and streamlined their operations to handle more cases at a time [49]. According to

interviews with COA employees involved in logistical operations, the auxiliary facilities on hand were insufficient to the number of asylum seekers simply waiting to begin the procedure. In fact, the 1000 bed auxiliary facility in Ter Apel was filled within the first week. According to the COA, the magnitude of the crisis at hand exceeded the scope of prepared emergency plans. As such, they simply sought to purchase or rent as many facilities as they could. The 2016 agreement with Turkey drastically reduced the number of asylum applications [58]. Consequently, many facilities leased with long term contracts currently remain empty, according to one COA caseworker interviewed.

NGO Dysfunction In contrast, NGO dysfunction is tied less to resource constraining crises than the NGO structure itself. In fact, NGOs secure contracts and subsequent resources explicitly during times of crisis [39]. However, despite widely held conceptions of the proliferation of NGOs as evidence of a global civil society, closer analysis reveals a dysfunctional sensitivity to market forces, which reinforces perverse incentives [39] [24].

According to Cooley and Ron, NGO behavior is best analyzed in the new economics of organization framework (NEO), which characterizes the behavior of organizations in terms of the contractually bound material incentives [24]. NEO analysis requires framing an issue in terms of principals, those who want something done, and agents, those who are contracted to do it.

Increasingly, the United Nations High Commissioner for Refugees (UNHCR) contracts out labor to NGOs, who are often more agile than its own operations [39]. The donor funding UNHCR is the initial principle, and they are the agent and subsequent principle to the NGO agent. Given that allocation of international aid is a political decision, the values of the legislators determine the conditions set upon the agent. Legislators value short term demonstrable results that secure reelection, and so they fund humanitarian operations with short term contracts whose renewal is dependent on demonstrable results [24].

The startup costs of an NGO accepting an initial contract, renting facilities, and hiring staff are high and put the NGO in debt, which can only be paid off by contract renewal. Given the contract renewal dependency due to high startup costs and comparatively long duration of humanitarian crises, indebted NGO agents are incentivized to either supply misinformation to their principals or only focus on problems with demonstrable solutions [24] [54]. As there are few humanitarian problems with demonstrable solutions, NGOs tend to cluster densely around one regional conflict to compete for contracts. NGOs tend to go where the recipient culture already speaks the same language, is a former colony, and has a level of democratic stability despite its poverty. That is, NGOs deliver aid to the easiest recipient [54]. While literature the NGO's dysfunctional funding structure is the result of case studies on conflicts in Rwanda and Kosovo in the 1990s, the short term contract structure remains largely in place [24].

3.3.6 Conclusion

This section outlined the logistical focus of the present investigation and its pitfalls. The asylum procedure is simply the housing of asylum seekers while they await IND decisions regarding their legal status [9]. The gravity of the situation exacerbated by a lack of coordination by the key actors involved resulted in a logistical bottleneck. Due to IND's late response to the influx, COA's housing resources were exhausted quickly [50]. As such, COA was forced to prioritize housing over care for resident wellbeing, resulting in dismal living conditions [95]. While, due the recentness of the events, the

role of NGOs is still unclear, there is historical precedent of NGOs prolonging services for the sake of self-preservation [24]. The following section details the consequences of this on asylum seekers undergoing the process, informing the basis of a social cost metric.

3.4 Refugee Mental Health

Mental health forms the basis of social health upon which a logistical behavior can be evaluated for the following reasons. First, previous research shows that the psychopathology of refugee populations is rooted less in previous traumas of the home country than the conditions encountered in the host country [68]. Second, the causes of poor mental health outcomes are rooted in functions of organizations responsible for their care [84] [64]. If organizations responsible for refugee wellbeing fall short, then there must be some logistical breakdown responsible. As such, mental health will be used as the basis for social cost and merits investigation.

3.4.1 Unmet Needs

Assuming the needs of asylum seekers are in accordance with the general populace if it were not for the misfortune of their circumstance, identifying those needs which commonly go unmet among asylum seekers characterizes their unique set of needs. In the Netherlands physical health care needs are largely provided for [35]. As such, the present simulation focuses primarily on mental health.

The Camberwell Assessment of Need (CAN) is a commonly used index of assessing quality of care by health and human service providers. One study found the chief unmet needs of asylum seekers in the UK are daytime activities, social contact, accommodation, psychological distress, and mental health, in that order [57]. A similar study on asylum seekers in the Netherlands found psychological distress, social contact, daytime activities, travel, psychotic symptoms, safety to self, childcare, and financial support go unmet in that order [84]. Follow up interviews revealed dependencies among the unmet needs. Psychological distress depends on degree of integration; that is, it is exacerbated by loneliness and attenuated by acculturation and community. Furthermore, among adults psychological distress also depends on family size and available accommodation. Among youths, psychological distress depends on availability of activities, and when activities are available, the COA allowance is often insufficient. Inability to travel due to perceived cultural embarrassment is also a source of distress. Taken together, psychological distress results from an inability to address one's needs due to legal, cultural, or environmental factors [84].

The aforementioned needs are compounded by traumas from previous experience and permanent attributes. A review of mental health literature on refugee children found that the following factors are relevant to mental health outcomes: parental or personal exposure to violence, being female, being an unaccompanied minor, legal status, state of conflict in country of origin, lack of family cohesion, and family mental health conditions. On the other hand, mental health outcomes are better among younger asylum seekers with financial support and family cohesion [35].

3.4.2 Points of Intervention

Raising the issues of asylum sensitive and independent mental health risk factors begs the question of what steps can be taken by immigration and asylum officials to im-

prove mental health outcomes. Among children, same ethnicity foster care, positive educational experiences, available activities, and local companionship yield improved mental health outcomes [35] [84]. Among adults, stable housing, acculturation, available economic opportunity, lack of threat of repatriation yield improved mental health outcomes [68].

Addressing psychological distress and trauma through counseling and traditional psychotherapy is often ineffective among refugee populations. The aforementioned methods place heavy emphasis on individuals talking about their experiences, which is fairly standard and not unnecessarily stigmatized in medical contexts in the west. However, African and Middle Eastern cultures view talk therapy with less efficacy and associate emotional vulnerability with shame and embarrassment. As such, some degree of acculturation is necessary for counseling and psychotherapy to work effectively among refugee populations [81].

3.4.3 Quantifying Mental Health

Before subjective wellbeing and mental health can be implemented in a simulation, they must first be quantified. Anderson et al., whose ABM employs means towards similar goals as the present investigation, based their model of refugee health on Kahneman's theory of Objective Happiness (OH) [52]. Rather than relying on self-report indices of well being, Kahneman proposes a type of 'hedonometer,' which can be derived from bottom-up data. That is, happiness is the temporal integral, the area under the curve, of a time series of agent utility, referred to as the Good Bad scale (GB). There are two key assumptions made in calculating the GB time series. First, the criteria used to evaluate the quality of an agent's state must be sufficiently rich to capture the whole range of agent experience. Second, the GB must have a zero point. Moreover, OH indices are comparable as long as the temporal integrals are rescaled by their durations. That is, an agent can be as happy last week as they were in the month of March [52].

The present simulation departs from Kahneman's theory, instead employing a definition of quantified wellbeing that is grounded in Schwartz Values [73]. As Values will be fully described in chapter 4, there is no need to overview Value based wellbeing here.

3.5 Agent Based Models

Enthusiasm for ABMs is rooted in the shortcomings of traditional optimization and its assumptions: homogeneity and linearity [10]. Attempting to optimize problems with heterogeneous agents and non-linear behavior is intractable in a linear optimization context [4]. ABMs work around the tractability problem by not offering an optimized solution. Rather than guarantee a solution, an ABM generates the context in which in the problem resides from the ground up [8] [33]. Policy problems require heterogeneity as multiple stakeholders must be represented. Furthermore, policy models must account for non-linearities as a common purpose of modeling policy is to explore unintended consequences of policy [17].

The basic ABM frameworks are as follows. Agents are autonomous entities who make decisions based on a set of rules [17]. As early as 1970, John Conway's Game of Life ABM showed that the interaction of very simple rules can yield very complex behavior [23]. Agents interact according to a schedule that can be random or ordered, and interaction can range from stochastic to deterministic, depending on the task at hand [69]. Finally, ABMs are designed at a specific level of abstraction, which indicates

the level of detail actually rendered versus assumed to occur [18]. The remainder of this section reviews ABMs relevant to the problem at hand.

3.5.1 Previous ABMs

There are ABMs that focus on the refugee experience and those that focus on construction logistics. However, none focus on both. Construction focused ABMs are limited in scope to supply chain management prior to and during construction, not the experience of those residing in the building afterward. The majority of ABMs that model some aspect of the refugee experience are limited to movement models following conflict. Some ABMs have been deployed at a smaller level of abstraction, focusing on aspects of individual refugee health within a single or small group of camps.

Housing Models

ABMs modeling housing construction logistics largely focus on supply chain management, ensuring that all necessary building materials have been procured at a reasonable price in a reasonable amount of time. ABMs are useful in supply chain simulation as contractors involved are 'claims conscious'. That is, very willing to demand settlements from another party if they believe a fair deal is not being procured [86] [71].

First, Anumba and colleagues developed a model in which agents collaborate to procure materials and construct a building according to various specifications [5]. For example, one agent designs specifications, another evaluates the occupant safety of the design, and a third evaluates the cost and feasibility. Through collaboration and negotiation, agents are capable of constructing a building which optimizes for arbitrary constraints [5]. The remaining construction logistics ABMs focus exclusively on supply chain management and not on actual construction.

In addition, Tah et al. claim that system dynamics models fail to capture the adaptive character of supply chains, to which ABMs are more suited [86]. The resulting ABM involves the collaboration and competition of a variety of agent types, including project managers, steel workers, and roofers. Furthermore, the authors found that increasing the number of agents per type invites competition between agents, improving performance [86].

Subsequent models make use of the multi-attribute negotiation model [56] [98] [99]. Similar to the previous models, heterogeneous agent types representing designers, contractors and building owners negotiate and collaborate in organizing a construction supply chain. Using the multi-attribute negotiation model, agents have weighted preferences for features such as cost material quality, safety, and environmental impact. Agents negotiate potential contracts based on the combination of material attributes and weighted preferences [98] [99].

In summary, previous models of housing logistics focus narrowly on coordinating the supply chain necessary for construction and partially on the act of construction itself. Such housing models do not take into account the wellbeing of the residents.

Refugee Movement Models

A number of ABMs have been developed to model the movement of refugees. For instance, Collins and Fryden built an ABM which models group formation during long distance movement [22]. The model is a theoretical exploration rather than a reality calibrated simulation; however it characterizes the process of group formation during

refugee flight from conflict. Group formation is a variable payoff decision as it both slows down movement but allows for increased security [22].

Geo-spatially explicit ABMs of migration patterns have roots in environmental disaster response and climate change. Kniveton, Smith and Wood used an ABM to simulate migration patterns during times of varying environmental, social, and political conditions [53]. Similarly, Hassani-Mahmooei and Parris simulated forced migration due to environmental and socio political conditions, such as poverty and public health conditions [40]. Finally, the work of Uno and Kashiyama geo-spatially explicitly simulates forced migration following natural disasters [91].

Strictly focused on refugee movement, Groen developed a refugee movement ABM that simulates flight from violent conflict [37]. Groen's model takes data from the United Nations High Commissioner for Refugees (UNHCR) on camp population size and the Armed Conflict Location and Event Data Project on conflict location and severity. Together with graphical information systems (GIS) data pulled from Google Maps, Groen's ABM simulated the change in populations following violent conflict [37]. Suleimenova, Bell and Groen built on the previous work of Groen et al. 2016, automating much of the procedure. Using the same simulation engine developed by Groen et al. in 2016, Suleimenova et al. automated the extraction of GIS calibration data such that destination prediction models can be rapidly deployed [21] [85].

In addition, Herbert et al. used a geo-spatially explicit ABM to predict the refugee flight destinations following violent conflict [43]. The model used conflict death toll, GIS data on transportation infrastructure, regional political alliances, and topography coupled with a set of rules corresponding the immigration policies of neighboring states. Essentially, death toll magnitude determined the distance covered and GIS data the path taken as simulated refugees fled conflict [43]. Sokolowski, Banks and Hayes took a similar approach to Herbert et al., employing a geo-spatially explicit model of movement in response to conflict. However, the scope of Sokolowski and colleague's model was focused specifically on the city of Aleppo and aimed to explore the varying reasons for flight in addition the the location of flight destinations [82].

Unlike the previously mentioned movement models, which focused on movement within a single or small cluster of states, Hattle, Yang and Zeng applied a similar methodology to migration into Europe [42]. Rather than dictate movement patterns by GIS transportation infrastructure data, the model focused on the intersection of refugee preferences and European state migration policies and available resources. Consequently, Hattle et al. derived a set of recommendations that can be used to better negotiate pan EU burden sharing policies [42].

While the usefulness of predicting movement patterns following violent conflict is useful for disaster relief operations, the level of abstraction is too high to characterize the wellbeing of individual agents. Moreover, movement models say little about the experience of refugees after they've arrived at the destination location. As such, ABMs of a lower level of abstraction lend themselves better to policy design.

Refugee Health Models

Public health concerns of refugees at the camp and inter-camp levels is one line of ABM research. First. Crooks and Hailegiorgis have developed a number of agent based models which simulate the epidemiological aspects of the refugee experience. Specifically, Crooke and Hailegiorgis model the spread of cholera within and between refugee camps in Dadaab. Given geo-spatial data on water sources and sanitation levels, the resulting models predict the geography and timing of a cholera outbreak [38]

[28] [27]. Second, Anderson et al. have developed a health focused ABM that includes both refugees and the institutions responsible for their care [4] [3]. The simulation featured a single health center which has resources, staff and security. Refugee agents have four states: sick or healthy and in or outside of the health center. Interestingly, Anderson and colleagues employed an action decision mechanism similar to that of the current investigation. Essentially, each agent has an ordered, weighted set of desires whose order depends on the agent's attributes and weights depend on the frequency of desire satisfaction. As such, actions are chosen in a manner similar to the Value decision mechanism as per the implementation in section 4; however, grounding the order of desires in agent's attributes undermines the contextual independence component of the Values definition.

Conclusion Construction logistics ABMs are concerned with modeling supply chains, collaboration and negotiation in order to mitigate claims between contractor agents. The models largely serve to optimize the planning and physical construction of a building, with little attention paid to the wellbeing of those who later reside within [56] [98] [86] [5]. Furthermore, ABMs which explicitly model the refugee experience are of a high level of abstraction, focusing on movement trajectories following violent conflict [82][43][21] [85][91] [22]. However, some ABMs focus on individual refugee health within a single or small group of refugee camps [4] [3] [38] [28] [27]. Such smaller scale models are in line with the types of policy recommendations which the present investigation aims to achieve.

3.6 Chapter Summary

In summary, there is a need for an asylum focused logistical ABM that includes social cost as a performance metric for the following reasons. First, existing humanitarian logistics models are largely supply chain optimization methods, which despite their utility in the field, do not capture the properties of a complex adaptive system. Second, refugee oriented ABMs are largely of a level of abstraction too high for meaningful policy insights and those that are do not place sufficient emphasis on mental health as a social cost. Third, the logistical shortcomings have clear mental health consequences for the asylum seekers involved. As such, an ABM that models the humanitarian logistics of asylum should include quantified mental health as a form of social cost. The following chapter outlines the sociological theory underpinning the current investigation and its use in the model.

Part II

Methods

Chapter 4

Values Formalization

4.1 Introduction

This chapter addresses **Goal 2: Implement a decision mechanism and wellbeing metric based on Schwartz's theory of values** by outlining Schwartz's Value theory, which underpins all agent behavior in the simulation. First, Values will be defined as per their use in the simulation. Second, Value mechanics will be formalized. Third, Values as a basis for quantified wellbeing will be formalized. Fourth, limitations of the current implementation of Values will be discussed.

4.2 Definition

Defining a universal theory of values first requires illustrating the necessity from which Values emerge. Subsequently, the components of the definition can be grounded in Value afforded utility with respect to reckoning with the aforementioned necessity.

Values are necessary to cope with the human condition, composed of biological needs, social interaction protocols, and the individual requirements for group survival and health [77]. Evolutionarily, coping is a group behavior, as isolation is not a recipe for reproductive success. Moreover, group coping requires a vocabulary with individuals can articulate their state with respect to the human condition. Finally, articulated experience requires a cognitive representation of experience [76]. Taken together, Values emerge from the socially articulated cognitive representation of an individual coping with the human condition.

According to Schwartz, Values are abstract drivers of behavior characterized by the following six criteria [76].

1. values are beliefs grounded in feeling
2. values motivate actions towards specific goals
3. values are not circumstantial
4. values inform evaluations of states
5. values are ordered
6. value ordering determines how values motivate which actions

The first criterion separates a value from other types of belief, such as factual knowledge, by its emotional affect. Second, a value incites behavior when the goal associated with the value is possible and goal completion is said to satisfy a Value. Conversely, a practically impossible to satisfy value frustrates the individual. Third, values are context independent, though context may determine the possibility of satisfying a particular value. Fourth, when an agent deliberates about future actions and the resulting states, overall Value satisfaction is the metric of comparison. Fifth, Values are ordered by the importance an individual ascribes to them. For example, one might value Hedonism more so than Security. As will be seen later, the order of values has implications for the frequency with which they require satisfaction. The last criterion pertains to interactions between Values, which form the basis of attitudes. That is, the relation between high importance values at the expense of low importance values is an attitude [76] [74]. For example, compare the attitude of a someone who places a high importance on both stimulation and tradition who consumes a hallucinogenic drug as part of a religious ceremony against the attitude of someone who values tradition at the expense of stimulation who votes for restrictive drug policy [76]. Clearly, relative difference in ordering is a critical determinant of attitude. Before enumerating the modalities of Values, it is critical to grasp how they were derived.

Value	Goal
Self-direction	Independent action, increased autonomy
Stimulation	Novelty, increased variety
Hedonism	Pleasure, satisfaction of own desires
Achievement	Personal success, self-improvement
Power	Control or dominance over others or resources
Security	Safety and stability of self and others
Conformity	Homogeneity of behavior and attributes through restraint
Tradition	Maintenance of previously valued behaviors
Benevolence	Improving the condition of those in one's community
Universalism	Respect and appreciation for those outside of one's community

Table 4.1: An overview of the Schwartz's 10 Values [76]

The ten values, presented in table 4.1, were derived from the Schwartz Value Survey (SVS) and the Portrait Values Questionnaire (PVQ) [76]. The SVS consists of two lists. The first contains single word goals, such as 'Harmony' or 'Mastery.' The second contains desirable behaviors. Both lists are intended to cover the full range of coping mechanisms for the human condition, as defined above. For each item on each list, the SVS provides a ranking corresponding to the degree by which the item either guides or is in line with their behavior [76]. The PVQ functions similarly to the SVS but is aimed at young children. Participants listen to verbal descriptions of people whose state and behavior correspond to the goals and desirable behaviors of the SVS. Then, participants rate their self-identification with the described person. Both the SVS and PVQ have been administered in over 50 countries to some 60,000 participants, producing a large and culturally diverse set of results. The Values described in the following subsection are the result of factor analysis of SVS and PVQ data [79].

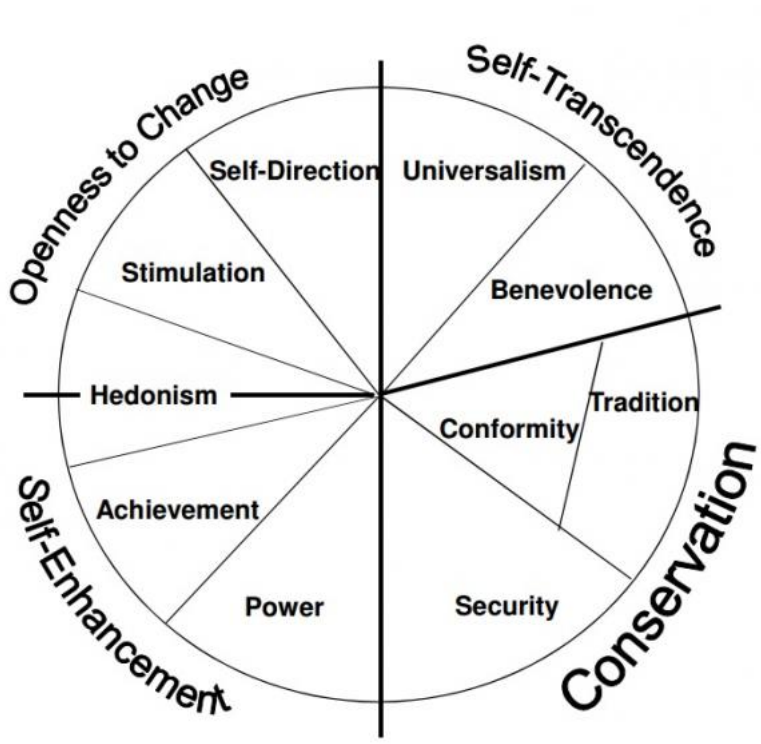


Figure 4.1: Schwartz values can be arranged circularly such that neighboring values are highly positively correlated and opposite values are highly negatively correlated. The present values framework will only use the quadrants in place of the individual values.

4.2.1 Quadrants

The placement of Values in figure 4.1 corresponds to their correlation. Any two Value goals opposite one another on the circle undermine each other's satisfaction. The circular organization yields four high level quadrants, Self-Transcendence, Self-Enhancement, Conservatism, and Openness-to-Experience, each of which contains highly correlated Values. Quadrants differ on two axes, the individual versus social dimension and the gain-approach versus loss-avoidance dimension. The former is self-explanatory but the latter relates to whether the Value motivates behaviors which protect against threats or vulnerably seeks improvement. Grouped by quadrant, the modalities, as summarized in table 4.1 are as follows.

Self-Enhancement Values located in the Self-Enhancement quadrant are those which strengthen an individual's condition. That is, Self-Enhancement is largely individually focused on loss-avoidance; however, Achievement has a social dimension. Self-Enhancement is the inverse of Self-Transcendence.

Hedonism Self-gratification and bodily pleasure goals motivating Hedonism, which invokes the individual biological needs aspect of the human condition.

Achievement The goal of Achievement is an individual's successful and demonstrable meeting of socially determined standards. Achievement motivated behavior seeks approval from the group, as such it is concerned with the protocols for social interaction component of the human condition.

Power In the individual dimension, Power is rooted in control of resources, both material or social, which addresses the human condition's biological needs. Collectively, Power motivated behavior is that which signals resource control as a form of social status, which reflects the human condition's protocols for social interaction aspects.

Openness-to-Change As per the name, Openness-to-Change quadrant Values all imply an accommodation and pursuit of variance. Consequently, Openness-to-Change is the inverse of Conservatism in its focus on individual experience and gain-approach.

Stimulation Individual search for experiences novel in comparison to the status quo motivate Stimulation associated goals. Novel experiences include are those whose excitement is greater than normalcy yet less than threatening. Stimulation is largely an individual Value.

Self-Direction Autonomous beliefs, choices and actions motivate Self-Direction. Counter intuitively, there is a social dimension to Self-Direction as autonomy requires a conscious rejection of socially imposed norms.

Self-Transcendence Values under the Self-Transcendence umbrella place wellbeing of others above the wellbeing of the individual. As such, Self-Transcendence is the social and gain-approach inverse of Self-Enhancement.

Universalism Prioritizing the wellbeing of others independent of group identification motivates Universalism. Moreover, concern for the environment also pertains to Universalism. The aforementioned pertains to the social interaction protocol component of the human condition.

Benevolence In contrast, prioritizing the wellbeing of others within one's group is Benevolence. Benevolence touches upon the requirements for group survival and wellbeing aspects of the human condition.

Conservatism Conservative values are in the inverse of Openness-to-Change values in their emphasis of reinforcing the status quo. Moreover, Conservative values are largely social as the status is defined only by the aggregate. Though some aspects of security have individual implications, Conservatism as a whole is socially focused on loss-avoidance.

Security The goal of Security motivated behaviors is the stability and safety of the group and relations therein. With respect to the human condition, Security touches upon individual biological needs by reducing material threat and requirements for group survival. Furthermore, Security sets individual requirements for group survival by reinforcing pro-safety behavior.

Conformity An inhibition of individual behavior in pursuit of group homogeneity motivates Conformity. By constraining behavior to the set of group approved actions, Conservatism touches upon both the protocols for social interaction and requirements for group survival aspects of the human condition.

Tradition Essentially the temporal component of Conformity, Tradition is motivated by inhibiting individual behavior in pursuit of continuation of historical behavior. Tradition sets individual requirements for group survival and wellbeing. Moreover, Tradition motivated behaviors ingrain cultural and religious practices, which determine the protocol for social interaction component of the human condition.

4.2.2 Truncating Values

In the present investigation, Value quadrants will be used in place of individual values. Schwartz makes the claim that the circular correlation of values is evidence that Values are a continuum that can be arbitrarily subdivided [76]. A complete value characterization requires an exhaustive list of an agent's goals and behaviors. Given that COA and IND are hesitant to divulge their strategies, an exhaustive list is impossible. However, the information compiled from interviews and available case studies maps onto the four quadrants [95] [50] [9]. As such, the quadrants themselves will be treated as values.

4.3 Value Mechanics

4.3.1 Water Buckets Analogy

Value based decision making and its underlying mechanics are best introduced by the water buckets analogy [44]. An agent's Values are a set of water buckets. Each has

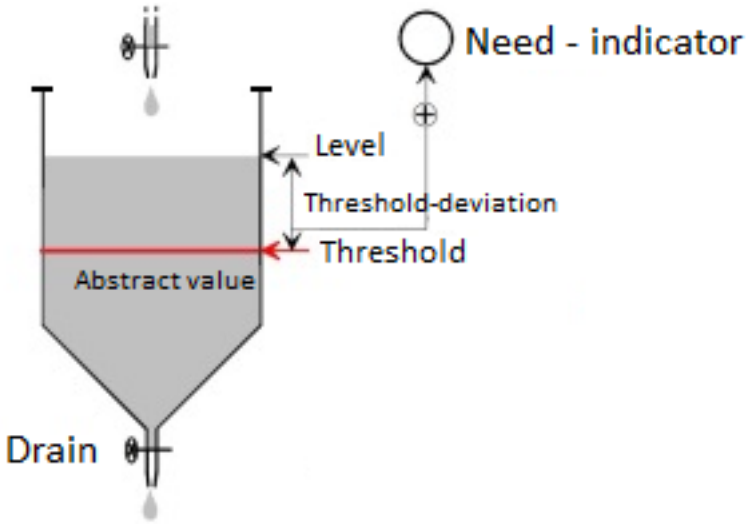


Figure 4.2: A sample water-bucket borrowed from Dorner et al. (2006) due to its theoretical similarity to the values framework. The level corresponds to current value satisfaction. Note that the value illustrated has been satisfied.

a hole in the bottom and drains at a constant rate. The agent draws a line on each bucket whose height indicates the importance of that particular value. When the water is above the line the value is said to be satisfied and otherwise unsatisfied. Each action contributes to a goal associated with a value. When an agent performs an action, water in poured into the value bucket associated with the goal that the action contributes to. The amount poured into the bucket is the difference between the top of the bucket and the importance line. As such, high importance values receive a smaller amount of water than low importance values. Finally, when choosing which action to perform, the agent takes into account the water levels below the importance lines and selects the action that minimizes the total volume of space below the lines.

Under such a schema, value importance determines action frequency. As more important values result in less water poured into the bucket, the action must be must be repeated many times for the value to be satisfied. Conversely, low importance values can be satisfied with a single occasional action due to the larger amount of water poured into the bucket.

4.3.2 Formal Mechanics

The mechanics of values are as follows:

$$\vec{v_\theta} = (v_1, v_2, ...v_4) \tag{4.1}$$

$$\vec{v_t} = \vec{v}_{t-1} - (\vec{v}_{t-1} \times d) \tag{4.2}$$

Equation 4.1 refers to the satisfaction threshold that an agent has for each value, indicative of the importance the value is ascribed. Each $v \in \vec{v_\theta}$ is in $[0, 100]$. For the purposes of the present simulation $\vec{v_{\theta_0}}$ corresponds to $Self - Enhancement$, $\vec{v_{\theta_1}}$ corresponds to $Self - Transcendence$, $\vec{v_{\theta_2}}$ corresponds to $Conservatism$, and $\vec{v_{\theta_3}}$ corresponds to $Openness - to - Change$.

Equation 4.2 refers to an agent's current value satisfaction at time t. Note, current value satisfaction, $\vec{v_t}$ decays with a steady rate of d.

$$\vec{v_s} = [100, 100, 100, 100] - v_\theta \tag{4.3}$$

$$\vec{s_\alpha} = (e_1, e_2, ...e_4) \tag{4.4}$$

Action Performance Equation 4.11 denotes a vector whose elements correspond to the amount by which $\vec{v_t}$ is increased upon performing an action. Note, 100 is the maximum importance that can be ascribed in $\vec{v_\theta}$. Every action α has a value-index, α_i which corresponds to the Value satisfied by performing α. Let $\vec{s_\alpha}$ in equation 4.4 denote an action satisfaction vector where $\vec{s}_{\alpha_i} = 1$ and $\forall j \in \{1, 2, 3, 4\}$ s.t. $j \neq \alpha_i$ $\vec{s_j} = 0$. Multiplying $\vec{s_\alpha} \times \vec{v_s}$ ensures that when performing action α, $\vec{v_t}$ in increased only in the elements whose index corresponds to α_i as per equation 4.5.

$$\vec{v}_{t\alpha} = \vec{v_t} + \vec{s_\alpha} \times \vec{v_s} \tag{4.5}$$

Action Selection Actions are not evaluated according to the degree to which they satisfy values, but rather by the degree to which they reduce the discrepancy between $\vec{v_\theta}$ and $\vec{v_t}$. As such, the first step in action selection is obtain a prioritized values list, $\vec{p}$. Equation 4.6 indicates how the $\vec{p}$ is calculated. First, $\vec{L}$ calculates the difference between current value satisfaction and $\vec{v_\theta}$ and $find(e, \vec{v})$ returns the index of an element of a vector.

$$\begin{aligned} &\text{let } \vec{L} = \vec{v_\theta} - \vec{v_t} \\ &\text{and let } find(e, \vec{v}) := \{i : \vec{v_i} = e\} \end{aligned} \tag{4.6}$$

---

procedure $descending - sort(\vec{v})$
  $\vec{v_s}$ = [0,0,0,0]
  i = 0
  while |v| > 0 **do**
    $\vec{v_{s_i}}$ = arg-max($\vec{v}$)
    i += 1
    $\vec{v} = \vec{v} \setminus \max(\vec{v})$
  return $\vec{v_s}$

Recall that the indices of $\vec{L}$, $\vec{v_\theta}$, and $\vec{v_t}$ all align with the same values. As such, Then, $\vec{p}$ can calculated by getting the indices of elements of $\vec{L}$ in decreasing order. $\vec{L_s}$ is the descending-sorted $\vec{L}$.

$$\text{let } \vec{L_s} = descending - sort(\vec{L}) \tag{4.7}$$

$$\forall l \in \vec{L_s} \text{ let } \vec{p_i} = find(l, \vec{L}) \tag{4.8}$$

Now that $\vec{p}$ corresponds to vector of value indices sorted by the difference between $\vec{v_\theta}$ and $\vec{v_t}$, actions can be selected. Let α denote an action and A denote a set of possible actions.

procedure Select-Action($\vec{p}$, A)
  action = $\emptyset$
  for p $\in \vec{p}$ **do**
    if $\exists\ \alpha \in A$ s.t. α_p = p **then**
      action = α
      break ▷ ends iteration
  return action

The procedure *Select − Action* works by iterating through $\vec{p}$, where each element of $\vec{p}$ is a value of decreasing priority. Then, the agent checks the set of possible actions A to see if there is an action α whose value index, α_i corresponds to the current value. If so, the action is selected and the iteration ends. If not, the iteration continues to the next value in $\vec{p}$.

Inter-Value Interaction

$$\forall i, j \text{ s.t. } i \in \{1, 2\} \text{ and } j = 4 - i : \tag{4.9}$$

$$\begin{cases} \vec{v}_{\theta_j} = 100 - i & if v_{\theta_i} > v_{\theta_j} \\ \vec{v}_{\theta_i} = 100 - j & otherwise \end{cases}$$

Equation 4.9 describes the condition value interaction. Essentially, values on the opposite side of one another are inversely related. This condition is a component of Schwartz's theory and included for the sake of a complete formalization of his theory. However, the condition is relaxed in the present investigation as too strictly restricts the parameter sweep necessary for research question 1. Furthermore, the condition does apply well in a four value framework. The negative correlation between opposite values is problematic, because the values in between need to be positively correlated with their neighbors. For example, if an agent has values with SE = 70 and ST = 30, then both OTC and C face the problem of being positively correlated with their immediate neighbors who are negatively correlated with one another. Only the mean of the SE and ST could satisfy that. However, OTC = 50 and C = 50 is problematic because two values cannot have the same importance due to the importance of value ordering in the original definition.

Conclusion Taken together, each agent is characterized by a vector of thresholds for each value, $\vec{\theta}$ and a current degree of value satisfaction at time t, $\vec{v}_t$. The latter decays at a steady rate, yet can be increased through actions. The degree to which executing an action replenishes a particular value in $\vec{v}_t$ depends on the relative importance of each value, characterized by $\vec{v}_s$. Finally, actions are evaluated by the degree to which they minimize the discrepancy between $\vec{v}_\theta$ and $\vec{v}_t$.

4.3.3 Wellbeing

$$v_u = \sum \vec{v}_\theta - \vec{v}_t \text{ s.t. } \forall i \in \{1, 2, 3, 4\} : \vec{v}_{u_i} = \begin{cases} 0 & \vec{v}_{u_i} < 0 \\ \vec{v}_{u_i} & otherwise \end{cases} \tag{4.10}$$

$$\vec{v}_{wb} = 1 - \left(\frac{v_u}{\sum \vec{v}_\theta} \right) \tag{4.11}$$

The present values formalization provides a convenient quantification of wellbeing and, subsequently, mental health. Simply, wellbeing corresponds to the proportion of total value allocation,$\sum \vec{v}_\theta$, to total value satisfaction below the threshold, v_u, evident in equation 4.11.

The aforementioned definition is rooted in the idea that happiness itself is not a value, but rather an emergent quality felt by an agent when the environment affords the opportunity for value satisfaction [73]. That is, wellbeing is the value congruence between agent and environment. Furthermore, Schwartz investigated the relationship between distress and values. He found that distress stems from the perception that the environment threatens the agents ability to satisfy his or her values. Furthermore, the effect was more pronounced when using a simplified quadrant value set, instead of the entire value set [80].

4.3.4 Limitations

The present values formalization suffers a key drawback in using static value satisfaction that is best illustrated by example. Consider an action *Donate* whose amount depends on the budget of the agent performing the action. Under the current formalization, *Donate* satisfies values to the same degree regardless of whether the agent puts forth 50 or 5,000 euro. It has been proposed that certain actions are coupled with a scalar multiplier to indicate the gravity of their execution [44]. However, hard coding a priori action multipliers doesn't provide the level of fluid decision making that continuous value satisfaction yields.

4.4 Conclusion

Taken together, Schwartz's theory of values offers a compelling framework for modeling realistic agent behavior. Values allow for agents to pursue multiple goals, dedicating time and energy proportional to each value's importance [76] [78] [75]. Furthermore, values provide a basis from which wellbeing can be calculated [80] [73]. In the current simulation, value mechanics are used in the action deliberation phase of the agent's step function and in the calculation of wellbeing.

Chapter 5

Simulation Architecture: ODD

5.1 Introduction

This chapter addresses **Goal 3: Build a model that utilizes values to capture both refugee and logistical behavior**. Here we describe describe the model according to the Overview, Design Concepts, and Details (ODD) protocol [36]. First, entities and their low level state variables are defined. Then, their behavior and interactions are described. Key concepts and design features are summarized. Finally, procedures and algorithms in pseudocode are listed in the submodels.

5.2 Purpose

The purpose of the model is to use the values framework described in Chapter 4 to characterize the wellbeing of asylum seeking refugees in the context of asylum logistics. The goal is not to perfectly simulate the full range of experience of asylum seekers or the institutions with which they interact, but to build a workable prototype in which values are the critical driver of outcomes. Moreover, the aforementioned prototype must be sufficiently modular such that it can be easily extended.

5.3 Entities and State Variables

This section contains the relevant state variables for key objects and agents in the simulation. Models and cities are objects. COA, IND, NGOs and newcomers are agents. The word newcomer is used in place of refugee for is political neutrality and because refugee denotes a specific legal status. The newcomers in the present simulation will change legal status numerous times. Agent variables are italicized in the text for clarity and agent names are in normal print. If a variable is referenced in the abstract and not in reference to a specific agent, it is not italicized. Some parameters will be defined whose use is clarified in section 5.5, such as values. The current section only requires that readers are aware that agents use values in a decision making procedure.

5.3.1 Model Preview

It is helpful to have a basic idea of how the parts relate before delving into the details of state variables. Figure 5.3.1 contains a brief overview of the key figures in the simulation and their role. The centerpiece of the simulation is the newcomer undergoing

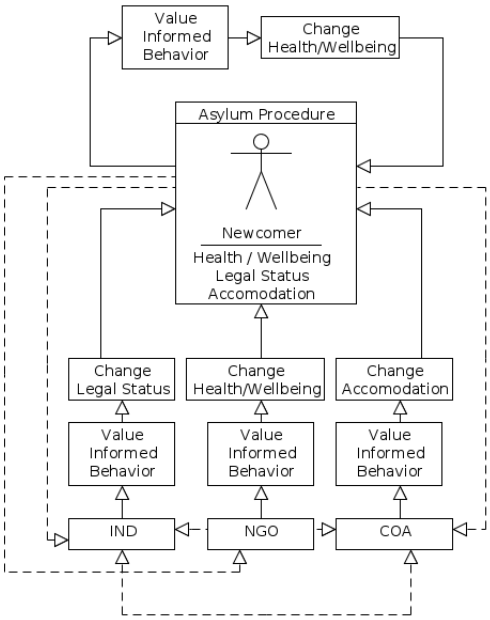


Figure 5.1: This figure displays the simplest possible explanation of the roles played by various agents in the simulation. Emphasis is placed on the newcomer agent's attributes as they are centerpiece of the model. Black lines are direct influence and dashed lines represent feedback. This the interactions between agents are expanded upon into Figure 5.2

.

the asylum procedure and pursuing the satisfaction of its values. IND chiefly changes newcomers' legal statuses, NGOs provide for their wellbeing, and COA's set their living conditions. Feedback between agents is denoted by the dashed lines. This is left implicit for now as it will be later defined. While reading the entity state variable section, keep this figure in mind.

5.3.2 Model

The environment is contained in the *model* class, which is responsible for the canvas, scheduler, setting model constants, and adding new agents to the model. Model state variables can be found in Table 5.1. The scheduler functions by random activation of agents where each step corresponds to one day passing. The canvas is continuous and pseudo spatial in that there are distances between agents that inform their behavior, but, given the step day correspondence, agents do not actually traverse the space in real time. The canvas renders COL, POL, and AZC facilities, described in Chapter 3 Section 3.3, as blue circles with a red region whose radius corresponds to the current occupancy.

A model's state variables are as follows. *Step* is the current time step of the simulation. $Number - of - POLs$ and $POL - to - AZC - ratio$ control the size of the simulation by setting the total number of facilities. Model $coo - data$ is the Eurostat data on IND asylum decision outcomes per country of origin. Its rows are country of origin and its columns are $first - decision$ and $second - decision$ success rates. Recall that the $first - decision$ is made at the POL modality facility and the $second - decsion$ is made only in the event of an appealed negative $first - decision$

Table 5.1: Model State Variables

Variable	Abbreviation	Type	Range
height	M.H	Integer	400
width	M.W	Integer	600
$Number - of - POLs$	M.NP	Integer	[1,4]
$AZC - to - POL - Ratio$	M.APR	Integer	[2,5]
$public - opinion - uniform$	M.POU	Boolean	{True, False}
$shock - flag$	M.SF	Boolean	{True, False}
$shock - duration$	M.SD	Integer	[50,365]
$shock - period$	M.SP	Integer	[100,365]
$newcomer - arrival - rate$	M.NAR	Integer	[5,15]
$coo - data$	M.D	Matrix	n/a
$newcomer - arrival - frequency$	M.NAF	Integer	[20,100]
$newcomer - arrival - amplitude$	M.NAA	Integer	[3,8]
step	M.S	Integer	[1, inf)

Table 5.2: Model State Variables

in the AZC modality facility.

Shocks are periods of high influx of newcomer agents and $shock - flag$ controls the presence or absence of shocks. $Shock - duration$ and $shock - period$ determine how often shocks occur and for how long they last when $shock - flag$ is True, respectively. Furthermore, models are responsible for instantiating newcomer agents to the simulation. The number of newcomers added per time step is a sine function of $newcomer - arrival - rate$, *step*, $newcomer - arrival - frequency$ and $newcomer - arrival - amplitude$. $Public - opinion - uniform$ is a boolean flag that determines whether or not $public - opinion$, a city specific variable to be described in the following subparagraph, should be uniform or variable across cities.

5.3.3 Cities

Cities are the hub around which buildings and institutional agents revolve as summarized in Table 5.3. Cities have COA, IND, and AZC attributes so that agents can access critical attributes of one another when necessary. Cities are objects not agents because they have attributes but no actions. Cities have $public - opinion$, which changes over time and represents the degree to which the local populace thinks positively about newcomers. $Initial - public - opinion$ can be set to be uniform cross cities or distributed such that a range of possible $public - opinion$ values is assigned across all cities. Note, $public - opinion$ and $initial - public - opinion$ are kept as separate variables to facilitate the measurement of $public - opinion$ drift over time. Cities have *costs* and *crime* which count the number of times newcomers perform *Doctor* and *Crime* activities, clarified in Subsection 5.4.6. Cities have a *modality* indicating the *modality* of AZC that it contains. The possible modalities, as defined in Chapter 3 Section 3.3 are Centrale Ontvangslocatie (COL), Procesopvanglocatie (POL), and Asielzoekercentrum (AZC). Cities have an $intra - city - travel - cost$ and $inter - city - travel - cost$ set to 5 and 20, respectively. Cost of travel is important for newcomers budgeting travel between cities to satisfy values which cannot be satisfied in their current location. In addition, a city has COA, IND, AZC and NGO attributes which points to the agent contained in

Table 5.3: City State Variables

Variable	Abbreviation	Type	Range / Value
$initial - public - opinion$	CT.IPO	Float	[0,1]
$cost$	CT.CT	Integer	0
$crime$	CT.CR	Integer	0
$public - opinion$	CT.PO	Float	[0,1]
$intra - city - travel - cost$	CT.TR1	Integer	5
$inter - city - travel - cost$	CT.TR2	Integer	20
$modality$	CT.M	Factor	{COL, POL, AZC}
COA	CT.COA	Agent	n/a
IND	CT.IND	Agent	n/a
AZC	CT.AZC	Agent	n/a
NGO	CT.NGO	Agent	n/a

Table 5.4: City State Variables

the city. As will be seen later, each agent listed above has a their city as an attribute. This allows for one agent to easily access another agent in the city.

5.3.4 Newcomers

Table 5.5 summarizes newcomer low level state variables. Some state variables are fixed and others vary across circumstances. Regarding the former, newcomers have an *age*, which determines whether or not they do the *Study* or $Work$ activities. Newcomer *sex* is self explanatory. Eurostat was used to calibrate *age* and *sex* distributions. Furthermore, $Conservatism$, $Self - Enhancement$, $Self - Transcendence$, and $Openness - to - Change$ all refer to the amount by which a particular newcomer prioritizes a given value. These values coupled with *valuedecay*, indicating the rate by which value satisfaction decreases, defines a newcomer's unique *values* object, critical for decision making.

Regarding the state variables that change over time, newcomers have $current - value - satisfaction$, the degree to which a newcomer's *values* are satisfied in a given moment. In addition $legal - status$, $(ls \in EDP, AS, ASE, TR)$, changes over time. The first refers to externally displaced persons, second to asylum seeker, the third to asylum seeker in the extended procedure and the last to temporary resident. The legal statuses are explained in detail in Chapter 3 Section 3.3. In addition, newcomers have $documentation - quality$, a number that indicates the amount of documented proof a newcomer has gathered to justify their being granted asylum. $Documentation - quality$ grows during the asylum procedure which represents the newcomer gathering documents to prove their case. In addition, a newcomer agent has a $country - of - origin$, which is used to assign a probability of truly requiring refugee status from model $coo - data$. This probability is input to a Bernoulli distribution whose output determines the $first - decision$ and $second - decision$ variables, which are either 0 or 1. Note, IND does not know the $first - decision$ or $second - decision$ variables and only makes its decision based on $documentation - quality$ exceeding a given threshold. However, the $first - decision$ and $second - decision$ variables inform the rate at which $documentation - quality$ grows under the assumption that those who do not require

Table 5.5: Newcomer State Variables

Variable	Abbreviation	Type	Range / Value
Age	NC.A	Integer	{15,35}
Sex	NC.S	Factor	{Male, Female}
Country of Origin	NC.COO	Factor	{Syria, Eritrea, Iraq, Morocco}
$Conservatism$	NC.V.C	Integer	[0,100]
$Openness - to - Change$	NC.V.OTC	Integer	[0,100]
$Self - Enhancement$	NC.V.SE	Integer	[0,100]
$Self - Transcendence$	NC.V.ST	Integer	[0,100]
$value - decay$	NC.V.D	Integer	10
Values	NC.V	Values Object	With NC: [SE, ST, C, OTC]
$health$	NC.H	Integer	[0,100]
$wellbeing$	NC.W	Float	[0,1]
$legal - status$	NC.LS	Factor	{EDP, AS, ASE, TR}
$first - decision$	NC.FD	Integer {0,1}	
$second - decision$	NC.SD	Integer {0,1}	
$location$	NC.L	Building	n/a
$acculturation$	NC.A	Float	[0,1]
$documentation - quality$	NC.DQ	Float	[0,2]
$action - frequency$ NC.AF	Integer	1	
$current - procedure - duration$	NC.CPD	Integer	[2,270]
$budget$	NC.B	Integer	n/a: depends on NC.LS
$current - value - satisfaction$	NC.VT	Vector	[[0,100] for v in NC.V]

Table 5.6: Newcomer State Variables

asylum have more difficulty proving their case.

Furthermore, newcomers have a $current - procedure - duration$, an integer indicating how long they must wait until they receive a decision from IND. $current - procedure - duration$ is first set to time until POL placement, then it is time until $first - decision$, and, if negative, time until $section - decision$. Newcomers have a *budget*, which determines the radius of activity centers that they can visit. Once a week the budget is replenished by COA. Furthermore, newcomers have *health* and *wellbeing*. The former relates to physical health and decays a rate that depends on *wellbeing* and building *health*. $Wellbeing$ pertains to mental health and is the total amount by which $current - value - satisfaction$ is below the *value* thresholds as described in submodels section 5.6.3. Finally, newcomers have *acculturation*, which is the degree to which a newcomer has adapted to the local culture. City $public-opinion$ affects the amount of *acculturation* that newcomers gain when participating in certain integration activities, such as $Football$, $Volunteer$, or $Language - Class$.

5.3.5 Buildings

Table 5.7 outlines the state variables of the parent class, building. Attributes of buildings include $canvas - position$, which is necessary for rendering. Building *health*, *occupancy*, *decay*, and total *capacity* are all related. Essentially, Building *health* decays by *decay* units each time step. Moreover, building *decay* depends on ratio of *occupancy* to *capacity*, such that high *occupancy* buildings decay faster than lower ones. Building *health* is critical for newcomer *health* and the incidence of $Crime$, to be described later. Building *health* can increase when COA performs maintenance actions, such as $ImproveFacilities$. The set of Building *occupants* is used to iterate through and make changes to newcomers when necessary. Finally, *city* is included for ease of reference.

5.3.6 AZCs

A particular instance of the building class is the AZC, which inherits the building state variables and contains the following additional state variables summarized in Table 5.8. Each AZC has a $modality \in COL, POL, AZC$. COL modalities are initially designated for EDP newcomers, POL modalities for AS, and AZC modalities for ASE and TR newcomers. An AZC is both a modality type and a generic class of buildings designating any facility that houses newcomers as per its usage in popular discourse. AZC without any qualifiers will be taken to refer to the subclass as a whole. AZCs

Table 5.7: Building State Variables

Variable	Abbreviation	Type	Range / Value
capacity	B.C	Integer	[0,400]
$canvas - position$	B.P	(Integer, Integer)	([0, M.W],[0,M.H])
health	B.H	Integer	[0,100]
occupancy	B.O	Integer	[0,B.C]
city	B.CT	City	n/a
decay	B.D	Integer	1
occupants	B.OC	Set	n/a

Table 5.8: AZC State Variables

Variable	Abbreviation	Type	Range / Initial Value
$construction - time$	AZC.CU	Integer	[0, 180]
$problematic - threshold$	AZC.PT	Float	.6
$estimation - period$	AZC.EP	Integer	3
$shock - threshold$	AZC.ST	Integer	5
$modality$	AZC.M	Factor	{COL, POL, AZC}
$under - construction$	AZC.UC	Boolean	{True, False}
$crisis - threshold$	AZC.CT	Float	.90
Activity Center	AZC.AC	Activity Center	n/a
$state$	AZC.S	Factor	{Normal, Shock}
$shock - state$	AZC.SS	Factor	{Manageable, Problematic, Crisis}
$COL - sum$	AZC.CS	Integer	[0,inf)
$COL - squared - sum$	AZC.CSS	Integer	[0,inf)
$COL - variance$	AZC.CV	Integer	[0,inf)
$COL - counter$	AZC.C	Integer	[0,inf)
$estimated - need$	AZC.N	Integer	[0,inf)

have a boolean flag, $under - construction$, which determines whether it is operational or not. AZC $construction - time$ is the number of time steps until an AZC can be used to house newcomers.

AZCs keep track of their occupancies in order to identify anomalies and estimate future occupancies. An AZCs $COL - sum$, $COL - squared - sum$, and $COL - counter$ are all used to calculate the on-line variance, $COL - variance$, of the amount of newcomers passing through COL modality AZCs. $COL - variance$ is used for anomaly detection. When $COL - variance$ exceeds the $shock - threshold$, the number of standard deviations from the mean after which an occupancy is considered anomalous, then the $state$ changes from Normal to Shock. $Shock - state$ refers to the intensity of a shock once it has been detected. During a shock, an AZC uses a $estimate - period$ amount of previous occupancies to estimate future occupancies. Estimated occupancy is then compared to $problematic - threshold$ and $crisis - threshold$, which determines whether a shock $state$ is set to either Manageable, Problematic, or Crisis. In addition, the $estimated - need$ is the amount of estimated occupancy greater than AZC $capacity$. Finally, City and Activity Center are included as state variables for ease of reference.

Table 5.9: Hotel State Variables

Variable	Abbreviation	Type	Range / Value
$cost - per - month$	H.CPM	Integer	1000
$periodic - occupancy$	H.PO	Integer	[0,inf)

5.3.7 Activity Centers and Hotels

Activity Centers are another subclass of building whose state variable is summarized in Table 5.10. There is an Activity Center per AZC. An Activity Center has a set of $activities - available$. There is a base set of activities and an additional set of auxiliary

Table 5.10: Activity Center State Variables

Variable	Abbreviation	Type	Range / Value
$activities - available$	AC.AA	set	n/a
$attendance$	AC.A	dictionary	n/a

activities whose size depends on the presence of NGOs and $public - opinion$. Activity Centers keep a nested dictionary called $attendance$ that maps activities to day of the week which is mapped to daily attendance. The last subclass of buildings are Hotels, which represent commercial housing used when all other facilities are at capacity. As visible in Table 5.9, Hotels have a $cost - per - month$ of 1000. Additionally, Hotels have a $periodic - occupancy$ used to gather information about Hotel use per budget cycle.

5.3.8 COA

COA is an institutional agent whose state variables can be found in Table 5.11. COA is essentially responsible for housing newcomers in AZCs, maintaining AZC $health$, staffing AZCs and building new AZCs when estimated occupancies exceeds capacity. Its state variables are as follows. COA $staff$ refers to the current amount of $staff$ employed. $staff$ Estimation Frequency refers to how often COA assesses the fitness of its current staffing. City is for ease of look up and reference purposes. $Checkin - in - frequency$ determines how often COA performs the $Check - in$ action, to be described in Process Overview and Scheduling. Assessment frequency determines how often the AZCs associated with a particular COA check for shocks, the result of which determines a COA's State and $current - policy$. Furthermore, policies pertain to which AZC a given newcomer is assigned. $Newcomer - payday$ is the day of the week when residents are paid their allowance, where the day of the week is obtained by Model Step % 7. $Budget - frequency$ sets how often COA updates its budgets. COA has a $housing - budget$, $staff - budget$, $hotel - budget$ and $building - budget$. $Housing - budget$ refers to funds dedicated to AZC maintenance and Building Budget for the construction of new AZCs. The rest of the budgets are self-explanatory. $Occupants - to - housing - ratio$ refers to the amount of housing funds per occupant requested with each budget update. The $staff - to - resident - ratio$ is an ideal amount of staff per number of residents and is used to calculate the quality of current staffing as well as the amount of $staff$ funds to request per occupant. COA $costs$ keep track of total expenditures. In addition, COA has a high level state variable, $Thrift$ equal to $-1 \times costs$, that is used to compare the fiscal conservatism of COAs. $Thrift$ is not included in the chart because it is not a low level variable.

As with newcomers, COAs have values. $Conservatism$, $Self - Enhancement$, $Self - Transcendence$, and $Openness - to - Change$ all refer to the amount by which a particular COA agent prioritizes a given value. A priority in this case is a threshold over which a value is said to be satisfied. These values coupled with Value Decay, which indicates the rate by which value satisfaction decreases, defines COA's Values. Current Value Satisfaction is the degree to which COA Values are satisfied in a particular time step. Finally, COA's Actions are a set of functions which correspond to their Values.

Table 5.11: COA State Variables

Variable	Abbreviation	Type	Range / Value
$staf - to - resident - ratio$	C.SRR	Float	0.15
$staff$	C.STF	Integer	25
$staff - estimation - frequency$	C.SEF	Integer	90
City	C.C	City	n/a
$checkin - in - frequency$	C.CF	Integer	365/(C.V.ST*52/100)
$assessment - frequency$	C.AF	Integer	365/(C.V.OTC*52/100)
$newcomer - payday$	C.NPD	Integer	0
$budget - frequency$	C.BF	Integer	90
$occupants - to - housing - ratio$	C.OHR	Integer	4
$occupants - to - staff - ratio$	C.OSR	Integer	20
$Conservatism$	C.V.C	Integer	[20,80]
$Openness - to - Change$	C.V.OTC	Integer	[20,80]
$Self - Enhancement$	C.V.SE	Integer	[20,80]
$Self - Transcendence$	C.V.ST	Integer	[20,80]
$value - decay$	C.V.D	Integer	10
$values$	C.V	Values Object	With IND: [V.SE, V.ST, V.C, V.OT
$current - value - satisfaction$	C.V.S	Vector	[[0,100] for v in IND.V]
$current - policy$	C.CP	function	n/a
$state$	C.S	Factor	{Normal, Shock}
$housing - budget$	C.HB	Integer	25
$staff - budget$	C.SB	Integer	15
$hotel - budget$	C.HTB	Integer	10000
$building - budget$	C.BB	Integer	2000000
$actions$	C.A	set	n/a
$costs$	C.O	Integer	[0,inf]

5.3.9 IND

IND agents are responsible for changing the $legal - status$ of newcomer according to their $documentation - quality$. The state variables describing an IND agent can be found in Table 5.12. First, an IND is tied to a City for reference purposes. Furthermore, IND has two thresholds, $threshold - first$ and $threshold - second$, for initial and appeal decisions, respectively. In addition, IND has a variable $margin$ which reduces the threshold by some small amount. When IND makes a decision it compares a newcomer's $documentation - quality$ to one of the thresholds such that positive decisions occur if the threshold is exceeded. $Number - of - interviews$ corresponds to how many times a newcomer can increase its $documentation - quality$ before the decision is made.

$Conservatism$, $Openness - to - Change$, $Self - Enhancement$, and $Self - Transcendence$ are all individual values, which, in combination with $value - decay$, all combine to form an IND specific $values$ object. $Current - value - statisfaction$ then corresponds to the degree to which $values$ are satisfied at a particular moment in time. IND $staff$ determines newcomer wait times and $staff - budget$, the amount of funds available for the acquisition of further staff. $staff - to - occupant - ratio$

Table 5.12: IND State Variables

Variable	Abbreviation	Type	Range / Value
City	IND.C	City	n/a
$threshold - first$	IND.TF	Float	1
$threshold - second$	IND.TS	Float	1.5
$staff - to - occupant - ratio$	IND.SOR	Integer	4
$number - of - interviews$	IND.NI	Integer	2
$Conservatism$	IND.V.C	Integer	[20,80]
$Openness - to - Change$	IND.V.OTC	Integer	[20,80]
$Self - Enhancement$	IND.V.SE	Integer	[20,80]
$Self - Transcendence$	IND.V.ST	Integer	[20,80]
$value - decay$	IND.V.D	Integer	10
$values$	IND.V	Values Object	With IND: [V.SE, V.ST, V.C, V.OT
$current - value - statisfaction$	IND.V.S	Vector	[[0,100] for v in IND.V]
$budget - frequency$	IND.BF	Integer	[30,730]
$margin$	IND.M	Float	0.05
$staff$	IND.S	Integer	20
$staff - budget$	IND.SB	Integer	10
$statement$	$IND.ST$ Float	[0,1]	

is a preferred amount of occupants per IND staff member, similar to that of COA. Finally, $budget - frequency$ corresponds to how often the budget is update to accord with current occupancy levels.

5.3.10 NGO

NGO agents develop custom activities to meet the unsatisfied value needs of newcomers. Essentially, each NGO has a city whose $public - opinion$ can be converted into $funds$, and spent on either marketing campaigns or custom activities. The former temporarily boosts $public - opinion$ and the latter adds a custom activity to the city's Activity Center. As summarized in Table 5.13, NGOs have a set of *activities* that they have developed for newcomers. *Activities* are not to be confused with the set of *actions*, which they employ themselves. NGOs have a $cost - per - activity$ which determines how many activities they can make from $funds$ raised from $public - opinion$. Furthermore, $overhead$ refers to the minimum amount of funds that must be raised in order to either organize custom activities or marketing campaigns. NGO $activity - records$ and $activity - attendance$ are nested dictionaries of activities mapped to the days of the week mapped to average attendance per week. $Current - campaign$ is the amount of $public - opinion$ boost funded by the marketing campaign. $Conservatism$, $Openness - to - Change$, $Self - Enhancement$, and $Self - Transcendence$ comprise NGO *values*. The set of *values* coupled with $value - decay$ defines an NGO *values* object. $current - value - satisfaction$ then correspond to the degree to which *values* are satisfied. $Testing$ is a boolean flag that can make an NGO completely inactive. $Action - frequency$ determines how often an NGO acts and is defined relative to an NGO's $Openness - to - Change$ value and weeks of the year.

Table 5.13: NGO State Variables

Variable	Abbreviation	Type	Range
$funds$	NGO.F	Float	[0,1]
$activity - records$	NGO.AR	Dictionary	n/a
$activities$	NGO.AC	Set	n/a
$actions$	NGO.AC	Set	n/a
$Activity - attendance$	NGO.AA	Dictionary	n/a
$current - campaign$	NGO.CC	Float	[0,1]
$overhead$	NGO.O	Float	0.2
$Conservatism$	NGO.V.C	Integer	[20,80]
$Openness - to - Change$	NGO.V.OTC	Integer	[20,80]
$Self - Enhancement$	NGO.V.SE	Integer	[20,80]
$Self - Transcendence$	NGO.V.ST	Integer	[20,80]
$value - decay$	NGO.V.D	Integer	10
$action - frequency$	NGO.AF	Integer	365 / (NGO.V.OTC*52/100)
$values$	NGO.V	Values Object	With IND: [V.SE, V.ST, V.C, V.OTC]
$testing$	NGO.T	Boolean	{True, False}
$cost - per - activity$	NGO.CPA	Float	0.05
City	NGO.CT	City	n/a
$current - value - satisfaction$	NGO.V.S	Vector	[[0,100] for v in IND.V]

5.4 Process Overview and Scheduling

As stated previously, one scheduling step corresponds to one day. Upon initialization the model class generates the one COL modality AZC, model $number - of - POL$ modality AZCs, and model $number - of - POL \times$ model $AZC - to - POL - ratio$ number AZC modality AZCs. Each AZC is located in one city with an IND, NGO, COA, Hotel, and Activity Center. During each step, all agents are activated in random order and if the current model *step* coincides with the agents $action - frequency$ (model *step* % agent $action - frequency == 0$), they act accordingly. Note, newcomers have no $action - frequency$ because they have the option to act every step. State variables are updated asynchronously.

5.4.1 General Process

The simulation consists of a non-cyclical sequence of events, the asylum procedure, that is repeated for every newcomer agent entering the simulation. The asylum procedure is described in more detail in Subsection 5.5.1 The actions of institutional agents, COA, IND and NGOs, influence the conditions that newcomers face as they pass through the asylum procedure. Given that the actions institutional agents choose depends on their values, the model output is unique to the particular combinations of institutional value profiles. Newcomer behavior is also value governed; however, unlike institutional agents, newcomer *values* are heterogeneous. The mechanics of value based decisions are described briefly in Subsection 5.5.1 and in depth in Chapter 4. For now it is only necessary to understand that agents have four values Conservatism, Self-Enhancement, Self-Transcendence, and Openness-to-Change, each of which corresponds to an action. Taken together, the process is best characterized by describing the actions available to

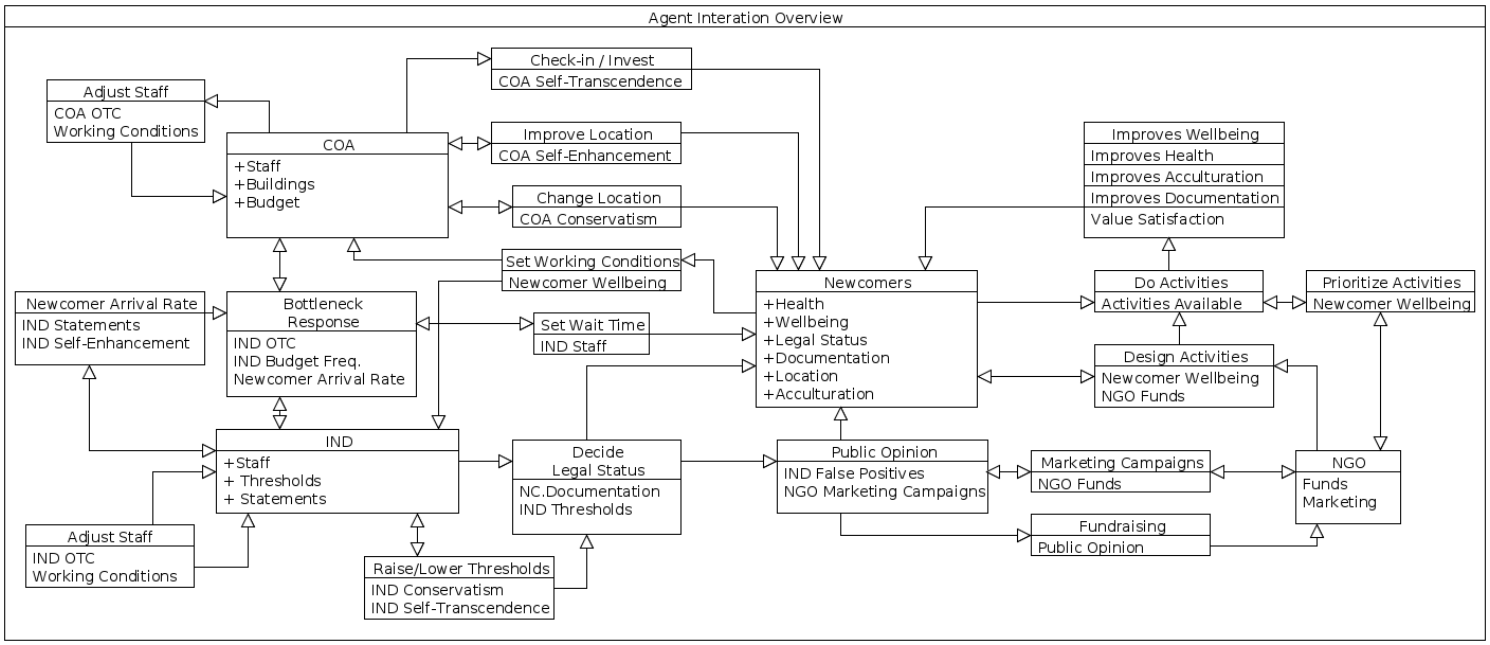


Figure 5.2: An overview of the interactions between agents.

each agent and the step function that organizes their actions.

5.4.2 Step Function

Figure 5.3 illustrates the step function. Both the model and individual agents have a step function. The model is responsible for adding new agents to the simulation and scheduling their step functions. After adding new agents to the simulation, the model's scheduler selects all agents in random order. Once selected an agent begins its step function. If an agent's $action - frequency$ permits action on that particular step, then the agent can try to act. In order to act, an agent must prioritize their values and identify possible actions. Then, the agent goes through their values in order of priority and identifies the action which best reduces unsatisfied values. If an action is identified then it is performed. Finally an agent updates its state variables, ending its step.

5.4.3 COA

As illustrated in Figure 5.4, there are two categories of COA behavior, capacity management and value informed. The former refers to a set of actions intended to ensure that adequate housing is available for incoming newcomers. The later refers to a set of actions which influence newcomer living conditions. Capacity management is clarified in section 5.5.1 and will not be addressed here. COA's value informed actions are the following. First, COA's Conservative actions, $Segregate$, separates newcomers by their likelihood of gaining temporary residency, sending the low likelihood newcomers to lower quality facilities. Second, COA satisfies $Self - Transcendence$ by $Invest$, the allotment of travel vouchers to newcomers allowing free travel to other cities offering a greater diversity of value satisfying activities. Third, COA's $Openness - to - Change$

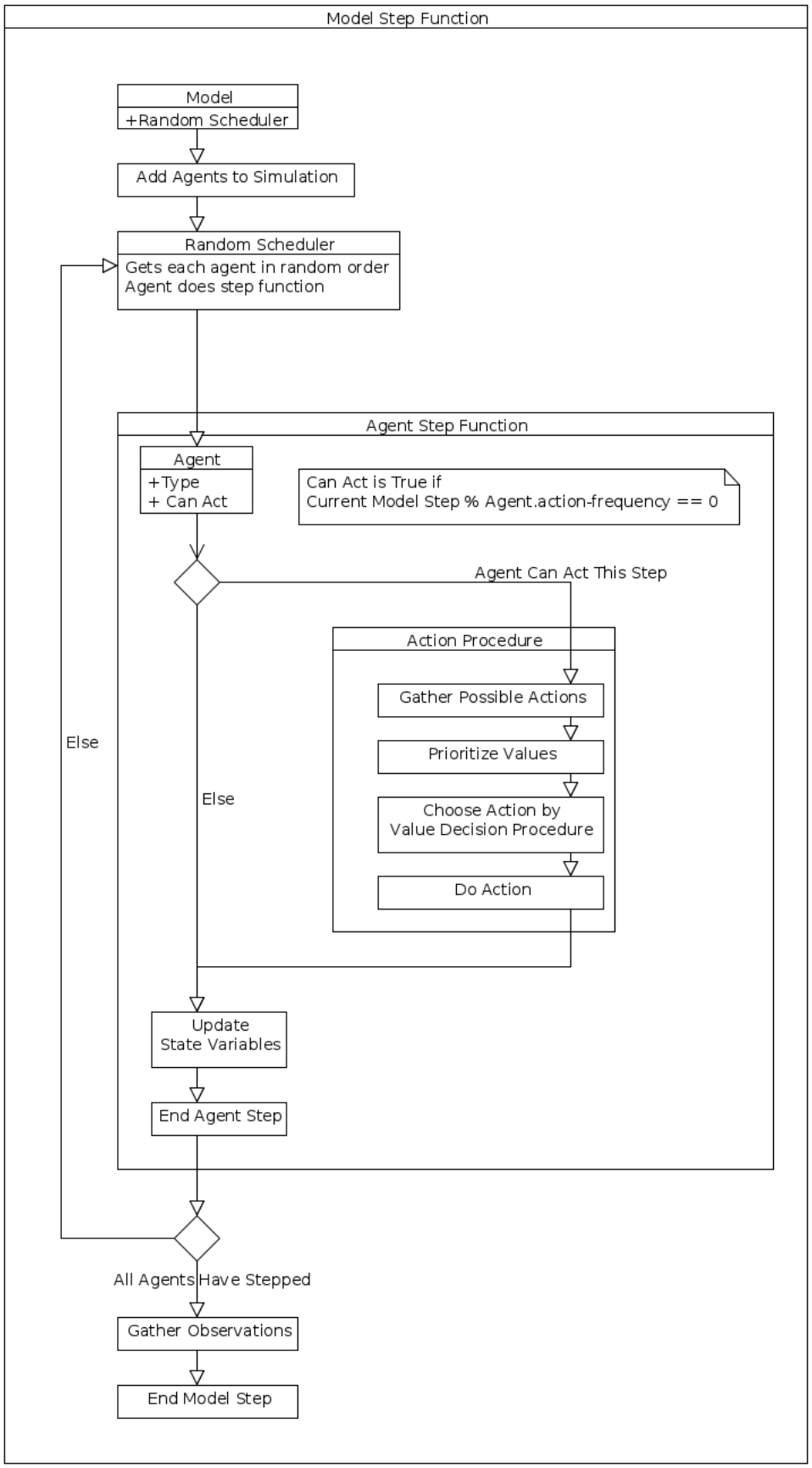


Figure 5.3: This diagram illustrates how the agent step function fits in with the larger model step function.

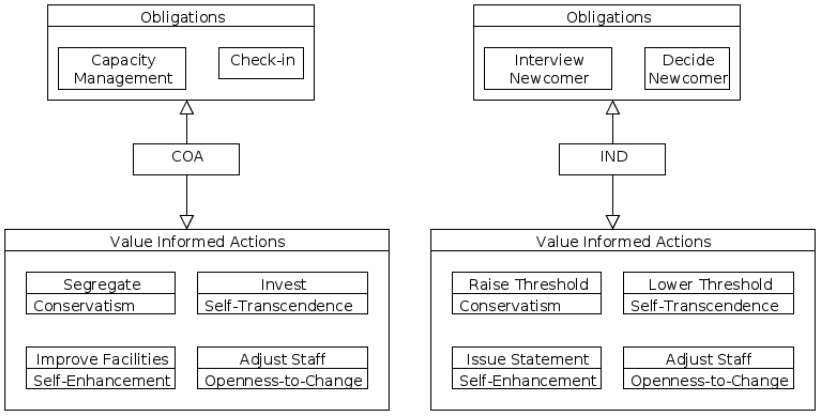


Figure 5.4: This figure summarizes COA and IND's obligatory and value informed actions

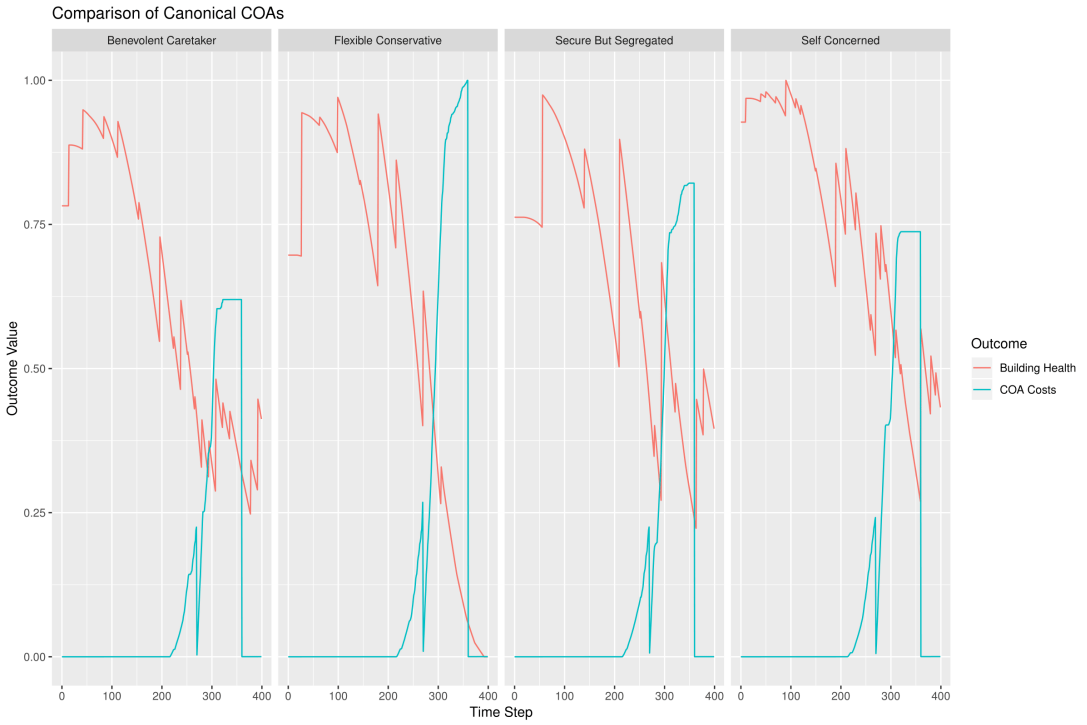


Figure 5.5: This graphic illustrates basic COA dynamics of basic canonical COA types. A shock occurs at time step 200. Note how some COAs respond by spending more on building maintenance than others.

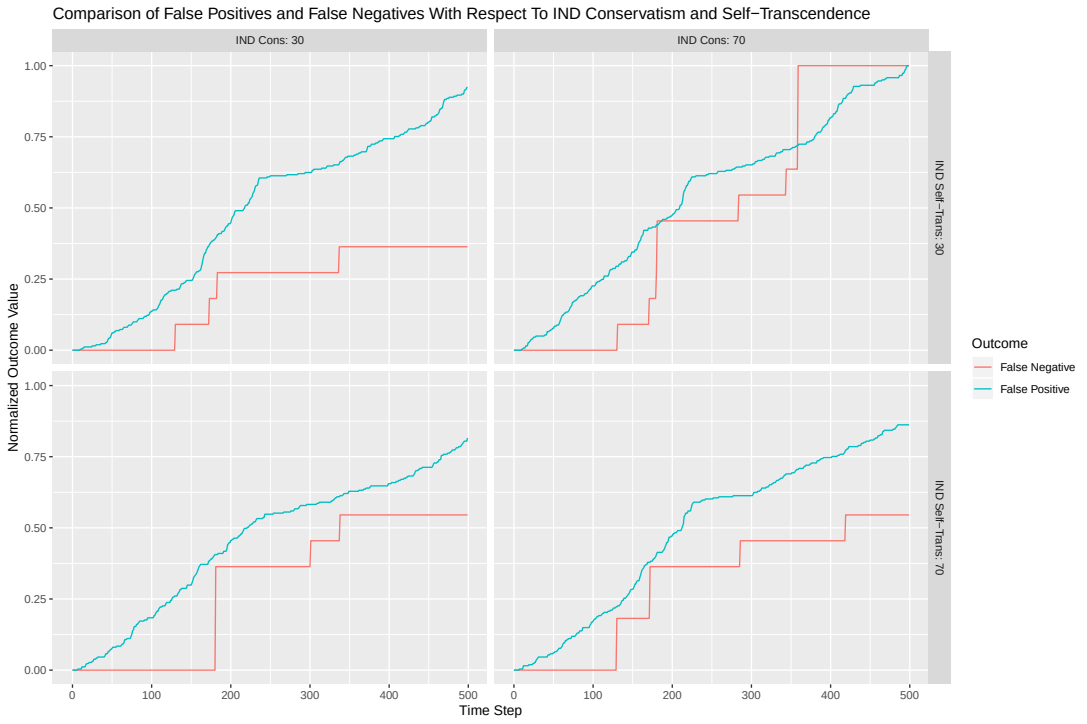


Figure 5.6: This graphic illustrates IND behavior across different value configurations.

is manifest in $AdjustStaff$. Adequate per a given occupancy level determines COA's effectiveness during $Check-in$, a periodic survey of newcomer health. Finally, COA satisfies $Self-Enhancement$ by $ImproveFacilities$, which maintains building health, improving the quality of life of residents therein. Further information regarding the mechanics of COA actions can be found in Section 5.6.5 of submodels.

5.4.4 IND

IND obligatory and value informed actions are summarized in Figure 5.4. IND is responsible for changes in newcomer Legal Status. The chief non-value informed action is to *Decide* on a newcomer's asylum case. The decision is made depending on the strength of the newcomer's Documentation quality relative to a threshold of admittance. False positive (FP) decisions decrease city $public-opinion$. The value informed actions of IND influence the parameters of the decision. The Conservative and Self-Transcendent associated actions, $RaiseThreshold$ and $LowerThreshold$, result in their namesake, respectively. Furthermore, IND's $Openness-to-Change$ associated action, $AdjustStaff$ informs the length of time a newcomer must wait before receiving a decision. Finally, IND satisfies $Self-Enhancement$ by $IssueStatement$, which dissuades certain newcomers from beginning the asylum process at all. During the phase of the model stil in which newcomers are added, $IssueStatement$ cancels the addition of newcomer with a probability total equal to $occupancy$: total $capacity$. Detailed descriptions of IND actions can be found in submodels Section 5.6.6.

5.4.5 NGO

NGO actions are summarized in Figure 5.7 and illustrated in Figure 5.4.5. NGOs

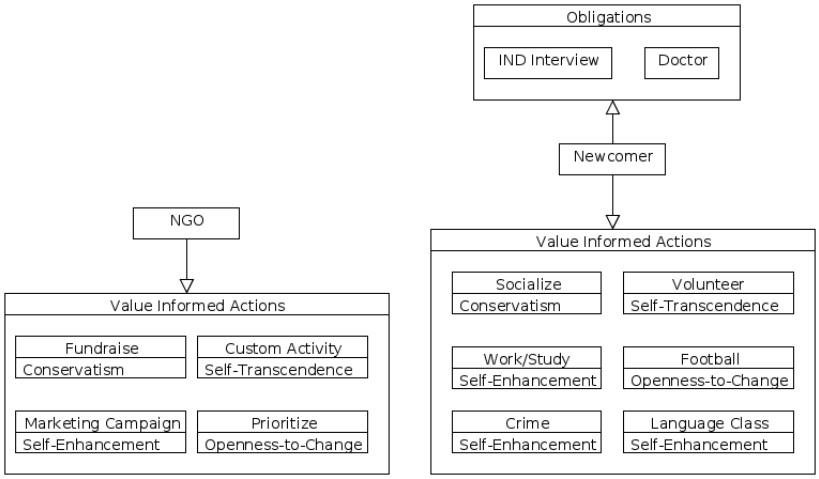


Figure 5.7: This figure summarizes NGO and Newcomers' obligatory and value informed actions. Note that NGOs have no obligatory actions.

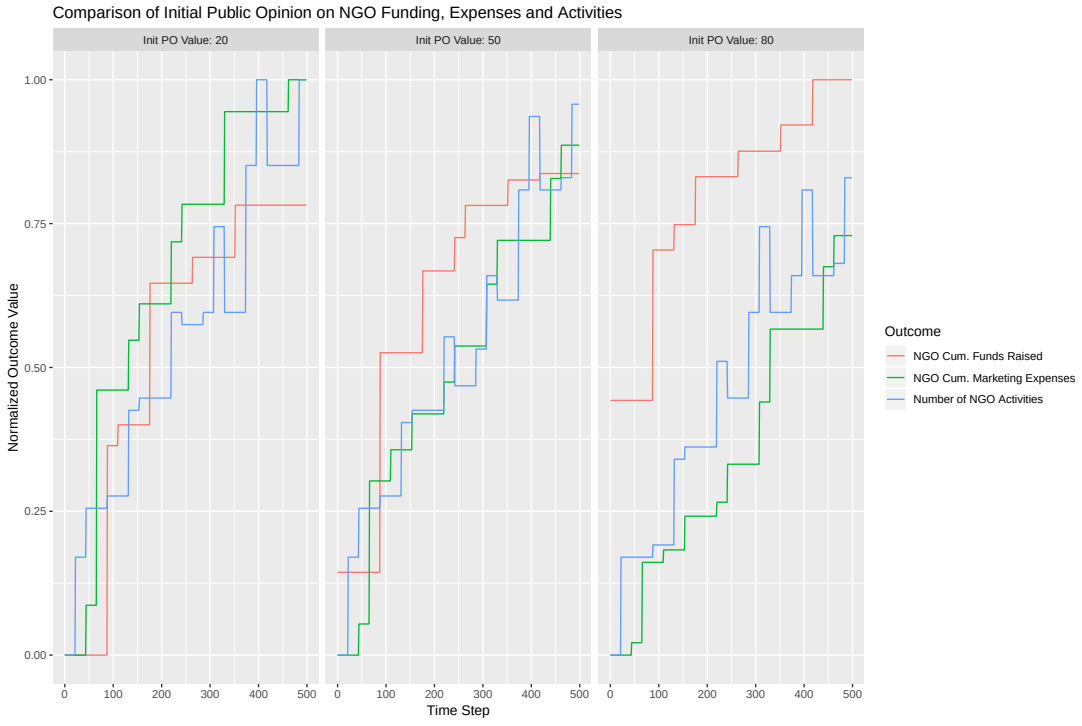


Figure 5.8: This figure illustrates the basics of NGO behavior. It contains cumulative activity and marketing expenditures alongside cumulative funds raised. It is visible how the startup capital is different in cities with different $inital - public - opinion$. The NGO on the left had to start from the bottom, and the NGO on the right could begin with a large amount of funding opportunities.

support the welfare of newcomers by converting $public-opinion$ into $funds$ and subsequently investing those $funds$ into the community. Specifically, NGOs' value associated actions are as follows. NGOs satisfy $Conservatism$ with $Fundraise$, which converts $public-opinion$ into $funds$. An NGO satisfies $Self-Enhancement$ by employing a $MarketingCampaign$. A campaign is an investment of $funds$ into temporary increase of $public-opinion$. Furthermore, NGOs satisfy $Self-Transcendence$ by with the $CustomActivity$ action. $CustomActivity$ identifies the most unsatisfied value in a population of newcomers and develops an activity satisfying it. Finally, $Openness-to-Change$ is satisfied by $Prioritize$ which adjusts the scheduling of activities to best meet the value requirements of local newcomers. Refer to submodels Section 5.6.7 for a complete description of NGO actions.

5.4.6 Newcomers

The behavior of newcomers can also be broken down into obligatory and value informed categories, as evident in Figure 5.7. The former relates to the actions required by immigration proceedings and the later to a variable set of activities. Note, newcomers perform activities and institutional agents, COA, NGOs and IND, perform actions. The distinction is made to contrast the fixed set of institutional actions and the changing set of newcomer activities. While both actions and activities satisfy values, only the latter has a certain weekly frequency such that the set of possible activities is temporally variable. A snapshot of newcomer value satisfaction as per *wellbeing* is visible in Figure 5.4.6. Both class architectures are outlined in subformula Section 5.6.7.

Newcomers are obligated to $Interview$ with IND. During an interview, a newcomer's $documentation-quality$ increases by a value which depends on their $country-of-origin$. In addition, newcomers are obligated to go to the $Doctor$ when their health is critically low. $Doctor$ incurs a cost to their municipality that is recorded by increasing city *cost*.

Aside from NGO developed Custom Activities, the following activities form the core base of newcomer behavior. First, newcomers satisfy $Conservatism$ by the action, $Socialize$. Second, $Openness-to-Change$ is satisfied by $Football$ activity, which affords *health* and Acculturation. Third, $Self-Enhancement$ corresponds to $Work$, $Study$, and $Crime$ activities, for adults, minors and highly distressed newcomers, respectively. While, $Crime$ can be rare in occurrence, it halves local $public-opinion$ and increases city *crime*. Fourth and finally, $Volunteer$ satisfies $Self-Transcendence$, improving local $public-opinion$ and newcomer *acculturation*.

5.5 Design Concepts

5.5.1 Basic Principles

The Asylum Procedure The backbone of the simulation is the asylum procedure, which functions as follows. First, a newcomer enters the simulation with $legal-status$ EDP and resides in a COL modality facility. There the newcomer is registered by the COA and IND. After two to four days, the newcomer is then sent to a POL modality facility, their $legal-status$ changes to AS, and the General Asylum Procedure begins. The General Asylum Procedure lasts from eight days to one month, depending on IND $staff$. Those newcomers who have $documentation-quality >$ IND

Figure 5.9: This figure illustrates some basic newcomer dynamics with respect to well-being and health. The left panel contains newcomers whose values are in congruence with the values of the environment. The middle panel contains newcomers whose values are completely random, for the sake of control. The right panel illustrates the case of cultural opposition, in which newcomer values are opposed to the values of the environment. In all cases, the values of the environment are taken to mean the values behind the actions possible in a given location.

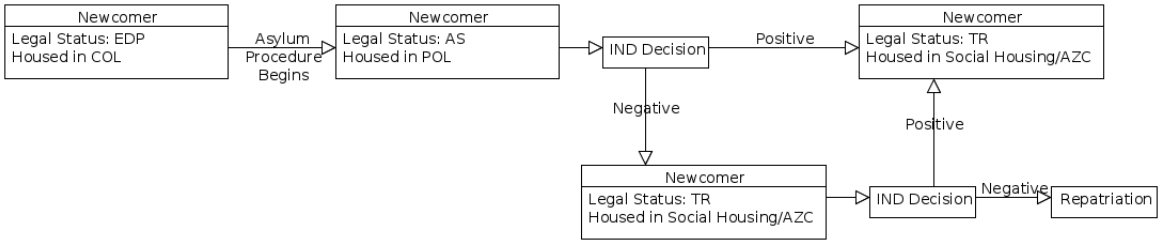


Figure 5.10: An overview of a simplified asylum procedure.

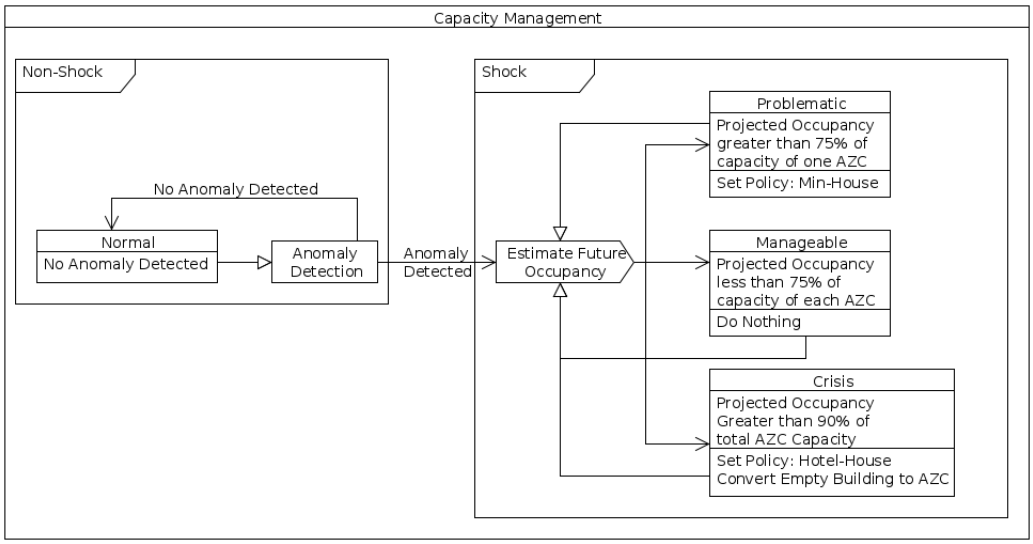


Figure 5.11: The above figure illustrates the actions which comprise COA capacity management. After a shock has been identified and classified as either manageable, problematic or crisis, future occupancies are estimated again as a way of monitoring the shock.

$threshold - first$ are given refugee status. The rest are sent to the Extended Asylum Procedure in an AZC facility and their $legal - status$ is changed to ASE. The Extended Asylum Procedure can last up to 270 days in the current simulation, depending on IND $staff$. At the end of the Extended Asylum Procedure, IND makes a second decision. If an ASE newcomer's $documentation - quality >$ IND $threshold - second$, then newcomer is either granted TR $legal - status$. Otherwise the removed from the simulation. Note, given the shortage of social housing in the Netherlands, newcomers with temporary status must also wait in an AZC facility before receiving housing. Every time a final IND decision is made, the outcome is recorded to calculate success rates over time per newcomer $country - of - origin$.

Shocks Shocks are periods of increased arrival of newcomers used to evaluate the Crisis response of COA, IND and NGOs. COA is responsible for the detection of shocks. The timing of IND procedures and the effectiveness of COA actions depends largely on the ratio of staff to residents. If shocks are unanticipated, IND and COA performance suffers.

Capacity Management As referenced previously, capacity management is the set of actions designed to ensure that adequate housing is available for an estimated amount of incoming newcomers. A graphical overview of capacity management actions can be found in Figure 5.11. Under normal operating conditions there is sufficient housing available. COA learns normal conditions by continually calculating the variance of number of newcomer arrivals, clarified in submodels section 5.6.5. A key component of capacity management is recognizing when current operating conditions are abnormal by periodically checking the occupancy of the COL modality AZCs for anomalies.

When an anomaly has been identified, COA must then look at the occupancy of its associated AZC and, estimating future occupancies from historical data, classify the shock. The shock classification determines changes in COA placement policies.

If the Shock is Manageable, then no change in newcomer placement policy occurs and newcomers are housed in the AZC whose modality corresponds to their legal status. If the shock is problematic, COA's newcomer placement policy changes to place newcomers in the facility with the lowest occupancy. Furthermore, if a Shock is deemed a Crisis, then a new facility is built sized for the amount of estimated newcomers greater than current capacity. The outcomes of COA's logistical behavior depends on its value informed behavior.

Values

Values are a framework for agent behavior which allows for agents to pursue multiple goals. An individual value is a affected belief about the world which requires satisfaction, thereby motivating action [76]. According to cross cultural surveys identifying axes of human values, there are 10 fundamental values [74]. However, the present simulation employs only four, each standing for a highly correlative subgroup of the original 10. An in depth formalization of values can be found in Chapter 4.

Values in the present simulation function as follows. Agents have four *values*: $Conservatism$, $Self-Enhancement$, $Self-Transcendence$, and $Openness-to-Change$. Each value is ascribed a number in [0,100] indicating its importance to the agent and the threshold at which the value is said to be satisfied. Agent *values* are ordered by importance. $Current-value-satisfaction$ decays by $value-decay$ uniformly over time. $Current-value-satisfaction$ is increased by the execution of actions associated with each value. Note, performing a value associated action and satisfying a value are synonymous. Critically, the amount by which a $current-value-satisfaction$ is increased upon satisfaction depends on the difference between the maximum possible valuation, 100, and the value threshold. As such, high importance values require a greater number of associated actions in order to cross the threshold of satisfaction than lower importance values. Finally, the previous mechanism of decay and satisfaction is implemented in a decision procedure, clarified in sub-models section 5.6.3, where the agent chooses the action that minimizes the total difference between value thresholds and current value satisfaction.

Public Opinion As Non-newcomer individual agents are not discretely rendered in the current simulation, their influence must be approximated through $public-opinion$, which plays a number of roles in the following simulation. The dynamics of $public-opinion$ are graphically summarized in Figure 5.12. First, it controls the amount of newcomer *acculturation* that can be gained from integrative activities, such as $Football$ and $Volunteer$. Second, $public-opinion$ controls the ability of NGOs to raise funds to develop activities for newcomers as well as the accuracy of the values needs analysis performed during $CustomActivity$. $Public-opinion$ is improved in small increments by newcomers engaging in $Volunteer$ activities and NGO Marketing Campaigns. Moreover, $public-opinion$ is drastically reduced by newcomers engaging in $Crime$.

5.5.2 Emergence

Emergence is evident in unintentional logistical bottlenecks. An intentional bottleneck is caused by a shock and an unintentional bottleneck is caused by the same principles as a phantom traffic jam. For comparison, a phantom traffic jam occurs on a road of drivers moving at approximately the same speed. One driver breaks enough that the driver immediately behind must also break in order to avoid collision. Each driver

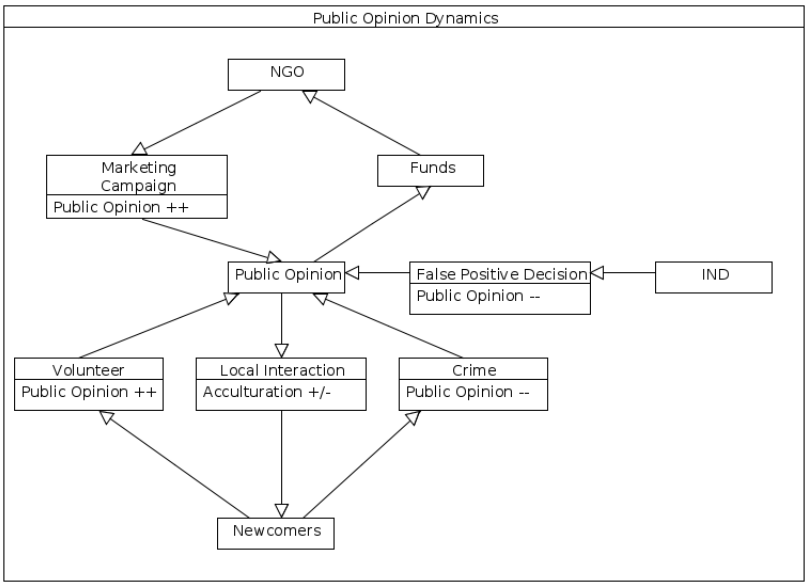


Figure 5.12: This graphic illustrates the dynamics of $public-opinion$ and the agents who influence it. IND FP decisions decrease $public-opinion$ but false negative (FN) decisions do not increase it. This is because a FN removes the asylum seeker in question from the community so that they are not aware that a decision error has occurred.

behind must break with at least as much force as the previous driver. Eventually, the amount of break force applied exceeds the amount forward force and a car must stop entirely. Periodic traffic jams can occur from the confluence of small decisions [61].

A similar principle of self-organization to be found in traffic flows is evident in unintentional bottlenecks. The qualifier intentional is used in order to distinguish from shock-associated bottlenecks. IND $staff$, IND $Openness-to-Change$, IND $budget-frequency$ and COA $Openness-to-Change$ determine the rate of bottleneck response. That is, if IND is slow to update its staff due to low IND $Openness-to-Change$ or slow IND $budget-frequency$, then wait times grow increasingly long. Eventually, IND updates its budget according to larger than normal AZC *occupancy* and hires a large amount of additional $staff$. Subsequently, newcomer $current-procedure-durations$ go down, reducing AZC *occupancy*. Finally, the inverse occurs where IND updates its budget to accord with the low *occupancy* levels, and upon arrival of another shock, the cycle repeats itself.

5.5.3 Adaption

COA and IND budgets are adaptive. That is, the size of budgets change from period to period. For each budget item there is an associated arbitrary ratio constant used to determine the required budget for a given amount of newcomers. For example, COA has $occupants-to-staff-ratio$ and at the end of each budget period it compares its AZC's mean occupancy to the said ratio, returning the size of the subsequent budget.

5.5.4 Objectives

An agent's *values* associated actions are its objectives and the time that it dedicates to their pursuit is proportional to the importance ascribed. In addition, agent's have

objectives related to their obligatory actions. COA has one non-value objective: keep occupancies below critical thresholds. Newcomers have the objective of reaching temporary resident status which they pursue by increasing $documentation-quality$. IND has the objective of ensuring that only those with sufficient $documentation-quality$ are awarded temporary residency. The threshold IND employs to judge $documentation-quality$ is variable, as $RaiseTreshold$ and $LowerThreshold$ actions change it. NGOs have the objective of raising at least NGO $overhead$ amount of $funds$. NGOs cannot do $CustomActivity$ or $MarketingCapaign$ actions unless it has at least $overhead$ amount of funds. After an NGO has more than $overhead$ $funds$, its objectives are entirely value-based.

5.5.5 Learning

COA learns the distribution of normal flow of newcomers. By calculating the mean and variance of newcomer occupancy levels during non-shock periods, it learns the parameters which define a distribution approximating typical occupancies. The functions responsible for calculating on-line variance can be found in submodels Section 5.6.5.

5.5.6 Prediction

Prediction is used to estimate future occupancies and assess the severity of shocks. At a frequency dependent on COA.OTC, occupancy samples are gathered from AZCs. When a shock is recognized, the rate of change is derived from the samples and used to estimate future occupancy. The functions used to estimate future occupancy levels are found in submodels Section 5.6.5

5.5.7 Sensing

All agents are aware of their own state variables. The following sense descriptions are inter agent or environmental. COA is sensitive to current and historical occupancies and capacities of AZCs and Hotels. In addition, COA is aware of the Building $health$ of each of its facilities and the schedule of its local Activity Center. Furthermore, COAs share knowledge such that one COA can query another. NGOs are aware of the local CT.PO and the Current Value Satisfaction of each newcomer residing in their City. IND is aware of newcomer $documentation-quality$. Furthermore, IND is privy to current and historical AZC occupancies.

5.5.8 Stochasticity

Newcomer $country-of-origin$, sex, and age are drawn from multinomial distributions whose values are calibrated to $coo-data$. Newcomer values are stochastically drawn from truncated uniform distributions in order to observe behavior. In the current simulation, there are two value profiles consisting of low to high ranges of the uniform distributions to lend some consistency across the value variance. As such, no two newcomer values are the same, but newcomer value cluster easily in the aggregate. In addition, newcomer First and Second Decision variables are stochastic in that they are a Bernoulli distribution whose probability parameter is the real world rate for the country of origin of the applicant. Similarly, the amount by which newcomer $documentation-quality$ increases during the $Interview$ action is drawn from a normal distribution with mean newcomer Second Decision and variance 1 - Country of Origin Success Rate.

A common construction within the simulation is the dependency of an event frequency on another variable. For example, when an NGO takes stock of unsatisfied values, the number of newcomers sampled depends on CT.PO. Similarly, When COA does $AdjustStaff$, the proportion of required staff actually hired depends on working conditions, the mean of local newcomer *health* and *wellbeing*. Finally, when performing $Check - in$ the number of newcomers actually met with depends on the $staff - to - resident - ratio$.

5.5.9 Collectives

Currently there are no collectives in the simulation. The addition of social networks would change that, but it is beyond the scope of the current report.

5.5.10 Observations

At each time step the following values are averaged across agents of the declared type. For Cities, $public - opinion$, *costs*, *crime* are gathered. Additionally, while testing COA Values, separate City data is recorded for Segregated and Non-Segregated Cities as per the *Segregate* action. Regarding IND, $false - positives$, $false - negatives$, and $staff$ are recorded. Furthermore, COA *costs*, COA $thrift$, $percent - segregated$, and AZC Building *health* are gathered. Finally, newcomer *health*, *wellbeing* and *acculturation* are recorded. These data are gathered for the experiments outlined in Chapter 7. However, data can be gathered on any state variable of any entity.

5.5.11 Initializations

To run the model, the following parameters must be set: Canvas Width, Canvas Height, $number - of - POL$, COA *values*, IND *values*, and NGO *values*.

5.5.12 Input Data

The model uses Eurostat data from 2016 regarding the refugee status decisions by IND for varying countries of origin. Some modifications are made to the data, as there are multiple degrees of approval. For the present implementation there is simply approval, appeal and rejection. Age and Sex data is from 2013 - 2017 Eurostat reports. Small children and the elderly were removed from the Age data, leaving only minors and adults. This was done for the sake of simplicity. Elderly and children can be easily added to the model once its fully validated using the calibration data that can be found in Section 5.6.2 of Submodels.

5.6 Submodels

5.6.1 Code

To reference a specific implementation, consult the code on github. The website is: `https://github.com/phillipjw/humanitarian_logistics/tree/reboot`

5.6.2 Data

Country	First Decision	Second Decision	Multinomial	ShockDist
Syria	0.97	0.96	0.4	1
Eritrea	0.96	0.89	0.25	0
Iraq	0.482	0.611	0.1	0
Morocco	0.02	0.1	0.25	0

Table 5.14: These figures are pulled from the Eurostat 2016 figures per country of origin

Year	2013	2014	2015	2016	2017	Total		
By Age	9,815	21,780	43,035	19,285	16,090	110,005	Total By Age	
<18	2,790	4,675	10,205	5,875	3,850	27,395	24.90%	
>65	165	245	330	170	145	1055	0.96%	
18-65	7,190	17,350	33,160	13,580	12,385	83,665	76.06%	By Sex
Males	6,095	15,915	31,415	13,330	11,685	78,440	Males by Age	71.31%
<18	1,510	2,830	6,845	3,545	2,395	17,125	21.83%	
>65	75	115	160	75	60	485	0.62%	
18-65	4,660	13,200	24,730	9,860	9,350	61,800	78.79%	
Females	3,720	5,865	11,545	5,955	4,390	31,475	Females by Age	28.61%
<18	1,285	1,840	3,350	2,330	1,450	10,255	32.58%	
>65	90	130	170	95	85	570	1.81%	
18-65	2,525	4,155	8,365	3,720	3,025	21,790	69.23%	

5.6.3 Values

Class: Values
procedure Initialize(Self,Decay, SE, ST, OTC, C, Agent)
    self.decay = [Decay, Decay, Decay, Decay]
    self.values = [SE, ST, OTC, C]
    self.action-satisfaction = [100,100,100,100] - self.values
    self.current-satisfaction = [U(0,100), U(0,100), U(0,100), U(0,100)]
    self.agent = Agent
procedure Decay(Self)
    self.current-satisfaction -= self.decay
    lack = self.values - self.current-satisfaction
    lack[lack < 0] = 0
    agent.wellbeing = 1 - $\frac{sum(lack)}{sum(self.values)}$
procedure Prioritize(Self)
    priorities = self.values - self.current-satisfaction
    sorted-priorities = sort(priorities)
    sorted-values = []
    for priority in sorted-priorities **do**
        sorted-values.append(priorities.index(priority))
    return sorted-values

5.6.4 Actions and Activities

Class: Action
procedure Initialization(Self, Name, Agent, Value-Index)
    self.name = Name
    self.agent = Agent
    self.value-index = Value-Index
    self.counter = 0
procedure Precondition(Self)
    Condition is variable across actions **return** Condition
procedure Do(Self)
    value-increase = self.agent.values.action-satisfaction[self.value-index]
    self.agent.values.current-satisfaction[self.value-index] += value-increase
    Remaining Content of *Do* varies across Actions.

```
Class: Activity
procedure Initialization(Self, Name, Frequency, Value-Index)
    self.name = None                          ▷ Names are assigned with Custom Activities
    self.frequency = Frequency                ▷ a set of integers in [0,7)
    self.value-index = Value-Index
    self.counter = 0
    self.local-involvement = 0                ▷ updated to CT.PO
    self.obligatory = False                   ▷ Obligatory activities are prioritized
    self.critical = False                     ▷ Critical activities are prioritized over obligations
    self.attendance =                         ▷ empty dictionary
    self.basic = 1                            ▷ basic activities are non-NGO activities
    for for day in frequency: do              ▷ frequency days are keys mapped to 0
        self.attendance[day] = 0
procedure Precondition(self, agent)
    condition = agent.health ¿ .2             ▷ Conditions vary across Activities return
Condition
procedure Satisfy(self, agent)
    value-increase = agent.values.action-satisfaction[self.value-index]
    agent.values.current-satisfaction[self.value-index] += value-increase
procedure Do(self, agent)
    today = agent.model.steps % 7
    self.attendance[today] += 1               ▷ update local attendance counter
    agent.city.activity-center.counter[self.name] += 1   ▷ update activity center
attendance counter
    if intra-city travel required then
        agent.budget -= 4
    else if inter-city travel required then
        agent.budget -= 20
    if basic < 1 then
        self.local-involvement = agent.city.PO
    acc-increment = self.local-involvement × (1−agent.acculturation)/50
    agent.acculturation += acc-increment
```

```
procedure Value Based Decision(agent)
    priorities = values.prioritize            ▷ gets a list of ordered values
    run agent.V.Decay()                       ▷ runs value decay procedure
    possible-actions = [action ∈ agent.actions s.t. action.precondition == True]
    current-action = None
    for priority in priorities: do
        for action in possible-actions do
            if priority == action.value-index then
                current-action = action
                break
            if current-action != None then
                break
```

5.6.5 COA and AZC

procedure Improve-Facilities(COA,AZC)
increase-amount = (AZC.Max-Health - AZC.Health) × (self.agent.conservatism/100)
new-health = max(AZC.Operational-Health, AZC.Health + increase-amount)
expenses = min(COA.Budget[Housing], new-health - AZC.Health)
AZC.Health += expenses
COA.Budget[Housing] -= expenses

```
1: procedure Adjust Staff(COA)
2:     working-conditions = μ(((NC.health+NC.wellbeing)/2) for NC in COA.CT.AZC.occupants)
3:     required-staff = COA.CT.AZC.occupancy / COA.OSR
4:     adjustment = required-staff - COA.staff
5:     if adjustment > 0 then
6:         while COA.SB > 0 and adjustment > 0: do
7:             if U(0,1) < working-conditions: then
8:                 COA.staff += 1
9:                 COA.Budget -= 1
10:            adjustment -= 1
11:    else
12:        while adjustment < 0: do
13:            COA.Staff -= 1
14:            COA.Budget += 1
15:            adjustment += 1
```

procedure Segregate(COA)
unlikely-status = newcomer ∈ COA.City.AZC.occupants if newcomer.SD == 0
candidates = AZC ∈ Model.Schedule.Agents if AZC.Modality != COL
candidates.sort(key = AZC.Activity-Center.Number-Activities)
count = 0
candidate-idx = 0
while count < length(unlikely-status) & candidate-idx ¡ length(candidates **do**
current-highest-security-azc = candidates[candidate-idx]
while current-highest-security-azc not full **do**
newcomer = unlikely-status.pop() ▷ gets a member of set
newcomer.segregated = True
count += 1
candidate-idx += 1

```
procedure Check-In(COA)
    staff-fitness = self.agent.staff / COA.City.AZC.Occupancy × COA.Staff-to-Resident-Ratio
    for NC ∈ COA.City.AZC.Occupants do
        if not NC.invested & NC.Wellbeing ¡ .5 and U(0,1) < staff-fitness & NC not in COA.Voucher-Requests then
            lack = NC.Values - NC.Values.Satisfaction
            need = lack.index(max(lack))                                    ▷
            for City in Model.Cities do
                for A doctivity in City.AZC.Activity-Center.Activities-Available
                    if Activity.Value-Index == need then
                        COA.Voucher-Requests.add(NC)
                        break
```

```
procedure Invest(COA)
    crisis-gravity = 1-COA.Gravity                          ▷ Intensity of housing crisis
    voucher-budget = gravity × COA.Values.ST/100 × length(COA.Voucher-Requests)
    while COA.Voucher-Requests not empty & voucher-budget ¿ 0 do
        current-nc = COA.Voucher-Requests.pop()
        NC.Current-Allowance += COA.City.Inter-City-Travel-Cost
        current-nc.invested = True
        COA.Net-Investment += 1
        COA.Net-Costs += 1
        Voucher-Budget -= 1
```

```
procedure Online-Variance(AZC)
    B.C += 1
    B.S += AZC.O
    B.SS += AZC.O^2
    Difference = B.SS - B.S^2
    B.V = sqrt( Difference / (B.C × (B.C − 1)) )
    return B.V, B.S, B.SS
```

```
procedure Estimate(AZC, period)
    if length(AZC.Occupancies < period then return AZC.Occupancy
    else
        current = AZC.Occupancies[-1]                       ▷ last entry in occupancy list
        previous = AZC.Occupancies[- period]
        rate = (current - previous) / period
        estimation = rate × period + current
    return estimation
```

Budget Updates Budgets are updated by the update-budget procedure. The only non-straightforward part about it is punishment, the proportion of newcomers in a city that reside in a hotel. The idea is that if a COA needs to use commercial housing, there should be left funds available for staff and building maintenance.

procedure UPDATE-BUDGET(punishment, budget, budget-ratio)
    COA.budget = punishment*mean(COA.City.AZC.occupancies) / budget-ratio

5.6.6 IND

Actions, *RaiseThreshold* and *LowerThreshold* have not been included as they simply consist of decreasing and increasing the margin, respectively. The reader can check the attached code for clarification if necessary.

The action, *IssueStatement* functions as follows. First, the *intensity* of the statement is $\frac{\sum \forall \text{AZC in Model: AZC.occupancy}}{\sum \forall \text{AZC in Model: AZC.capacity}}$. During the part of the model step where a newcomer is added to the simulation, if the Newcomer is unlikely to gain status, then the newcomer is removed from the simulation with probability *intensity*. Unlikely to gain status newcomers are those with $second - decision = 0$.

```
1:  procedure ADJUST STAFF(IND)
2:      working-conditions = μ(NC.health+NC.wellbeing / 2 for NC in IND.CT.AZC.occupants)
3:      required-staff = IND.CT.AZC.occupancy × IND.STR
4:      adjustment = required-staff - IND.staff
5:      if adjustment > 0 then
6:          while IND.SB > 0 and adjustment > 0: do
7:              if U(0,1) < working-conditions: then
8:                  IND.staff += 1
9:                  IND.Budget -= 1
10:             adjustment -= 1
11:     else
12:         while adjustment < 0: do
13:             IND.Staff -= 1
14:             IND.Budget += 1
15:             adjustment += 1
```

```
procedure SET-TIME(NC, IND)
    current-capacity = IND.CT.AZC.O / IND.CT.AZC.C
    preferred-staff = AZC.O / IND.SOR
    staff-fitness = 1 - (IND.S / IND.SOR)
    if NC.LS == 'AS': then
        NC.CPD = staff-fitness × 27 × capacity + 8
    else if NC.LS == 'ASE': then
        NC.CPD = staff-fitness × 180 × capacity + 90
    else if NC.LS == 'EDP': then
        NC.CPD = 2
    else
        NC.CPD = 100                                  ▷ For NC.LS == TR
```

1: **procedure** Interview(NC, IND)
2: μ = NC.SD
3: σ = M.D[NC.COO, 1]
4: NC.DQ += $\frac{X \sim \mathcal{N}(\mu, \sigma^2)}{IND.NI}$

Interview

Newcomers are obligated to *Interview* with IND. During an interview, a newcomer's NC.DQ increases by a value which depends on their Country of Origin and the newcomers Second Decision. Note, if a newcomers First Decision is 1, then its second is as well. As such, the Second Decision value contains the ground truth of whether or not the newcomer indeed requires asylum.

5.6.7 NGOs

Identify need

1: **procedure** Identify Need(NGO)
2: total = [0,0,0,0]
3: **for** (Each newcomer NC in AZC.occupants) **do**
4: unsatisfied-values = NC.V - NC.V.S
5: unsatisfied-values[unsatisfied-values < 0] = 0
6: total += unsatisfied-values
return Index of total[max(total)]

Fundraise

NGOs NGO.C associated action is *Fundraise*. There are two cases of *Fundraise* which depend on the relationship between existing capital, net worth of Custom Activities and Marketing Campaigns, and CT.PO. First, If existing capital is greater than CT.PO, then the NGO must drop a Custom Activity and recover the Cost Per Activity in usable funds. As the funds behind existing capital stem from CT.PO, their net worth cannot exceed CT.PO under the assumption that the NGO cannot employ more services than the public is willing to support. Second, if CT.PO is greater than existing capital, then the difference between CT.PO and the net value of existing capital in CT.PO terms is added to Usable Funds

Prioritize

As the value profiles of newcomers shift over time, the NGO.OTC associated action *Prioritize* is a means of coping with changing population needs. Essentially, prioritize looks at the distribution of unmet value satisfaction in a population and the distribution of funding allocation of existing Custom Activities. The scheduling of activities is rearranged to best match the needs of the local populace. For example, suppose an NGO has a Custom Activity held six days a week satisfying OTC and a Custom Activity satisfying C twice a week. Moreover, suppose the original newcomer population has left and among the new arrivals C comprises 66% and OTC comprises 33% of the total unmet need. *Prioritize* would decrease the OTC activity by sessions and increase the C activity by two. Note, *Prioritize* only looks at the values which correspond to Custom Activities already employed. As such, a newcomer population's distribution

```
procedure Fundraise(NGO)
    capital = NGO.Funds + NGO.Current-Campaign + |Activities| × NGO.Cost − Per − Activity
    if capital ¡ NGO.City.Public-Opinion then
        NGO.Funds += (1 - NGO.Funds) × NGO.City.Public-Opinion
    else
        if  then |Activities| 0
            difference = NGO.City.Public-Opinion - capital
            while difference > 0 do
                least-attended = min(Activities, key = attendance)
                NGO.Remove-Activity-Session(least-attended)
                NGO.Funds += NGO.Cost-Per-Activity
                difference -= NGO.Cost-Per-Activity
        else
            NGO.Funds += NGO.Current-Campaign
            NGO.City.Public-Opinion -= NGO.Current-Campaign        ▷ Reset PO
            NGO.Current-Campaign = 0
```

```
procedure Marketing-Campaign(NGO)
    expendable-funds = NGO.Funds - NGO.Overhead
    marketing-potential = 1 - NGO.City.Public-Opinion / (100 - NGO.Values.SE)
    NGO.Current-Campaign = min(expendable-funds, marketing-potential)
    NGO.City.Public-Opinion += NGO.Current-Campaign
    NGO.Funds -= NGO.Current-Campaign
    During Step:
    if NGO.Current-Campaign ¿ 0: then
        degrade = NGO.Current-Campaign/10
        NGO.Current-Campaign -= degrade
        NGO.City.Public-Opinion -= degrade
```

```
procedure Custom-Activity(NGO)
    value-in-need = NGO.Identify-Need
    if value-in-need ∈ NGO.Activities then      ▷ For NGOs with a custom activity already
        NGO.Add-Session(value-in-need)
    else
        name = 'Custom-Activity' + string(value-in-need)
        frequency = random-integer(0,7)                    ▷ Random day of the week
        new-activity = Activity(name, frequency, value-in-need)
        NGO.New-Activity(activity)                         ▷ Update attendance registers
    NGO.Funds -= NGO.Cost-Per-Activity
```

Algorithm 1 Prioritize

```
procedure Funding-Distribution(NGO)
    funding-allocation = [0,0,0,0]          ▷ A vector with length number of values
    for activity in NGO.Activities do
        for day in activity.frequency do
            funding-allocation[act.v-index] += 1
    fund-sum = sumfunding-allocation
    funding-allocation /= fund-sum ▷ converted to normalized distribution of funds
    non-empty-funds = [where funding-allocation > 0]          ▷ list of indices of
non-empty funds
procedure Wellbeing-Allocation(NGO)
    wellbeing = [0,0,0,0]
    for NC in NGO.CT.AZC.occupants do
        NC-lack = NC.V - NC.V.S                          ▷ vector of unsatisfied values
        for fund in non-empty-funds do
            wellbeing[fund] += NC-lack[fund]
procedure Remove-From-Over-Allocation(NGO)
    new-capital = 0
    diff = [0,0,0,0]
    for fund in non-empty-funds: do diff[fund] = wellbeing[fund] - funding-
allocation[fund]
        if diff[fund] > 1/(fund-sum): then
            diff-sessions = ⌊diff[nef] × fund-sum⌋
            activity = NGO.get-activity(fund)                    ▷ gets activity object
            if diff-sessions ≥ 2 and |activity.frequency| ≥ 2 then
                new-capital += 1
                NGO.remove-session(activity)
procedure Add-To-Under-Allocation(NGO)
    new-capital /= NGO.Cost-Per-Activity              ▷ convert to monetary terms
    diff[diff < 0] = 0
    diff /= sum(diff)                          ▷ convert to under allocation distribution
    for value in diff: do
        if value × new-capital ≥ 1: then
            value-idx = diff.index(value)              ▷ value's position in diff vector
            activity = NGO.get-activity(value-idx)               ▷ gets activity object
            num-possible-sessions = ⌊value × new-capital⌋
            i = 0
            while i < num-possible-sessions do
                if NGO.sessions-possible(activity): then
                    NGO.add-session(activity)
                else
                    NGO.Funds += NGO.Cost-Per-Activity
        else
            NGO.Funds += value × new-capital
procedure Main(NGO)
    Funding-Distribution(NGO)
    Wellbeing-Allocation(NGO)
    Remove-From-Over-Allocation(NGO)
    Add-To-Under-Allocation(NGO)
```

of unsatisfied values may shift in the direction of a value for which an NGO has no Custom Activity. In such a case, sessions are still removed where necessary, but are added to the NGO's usable funds on a Cost Per Activity basis.

---

procedure Football(newcomer)
Initialization:
Football.Legal-Status = TR, AS, ASE
Football.Health-Threshold = 60
Football.Health-Increase
Football.Value-Index = 1 ▷ $Openness - to - Change$
Precondition:
possible = newcomer.Legal-Status in Football.Legal-Status
possible = possible & newcomer.Health > Football.Health-Threshold
return possible
Do:
local-update = newcomer.Wellbeing × newcomer.City.Public-Opinion
Football.Local-Involvement = local-update
Football.Parent-Class.Do() ▷ Do as per Activity Class
newcomer.Health = min(newcomer.Health + Football.Health-Increase, 100) ▷ 100 is max health

---

Newcomers

---

procedure Volunteer(newcomer)
Initialization:
Volunteer.Legal-Status = TR, AS, ASE
Volunteer.Health-Threshold = 40
Volunteer.Value-Index = 1 ▷ $Self - Transcendence$
Precondition:
possible = newcomer.City.NGO != None
possible = newcomer.Legal-Status in Volunteer.Legal-Status
possible = possible & newcomer.Health > Volunteer.Health-Threshold
return possible
Do:
local-update = newcomer.Wellbeing × newcomer.City.Public-Opinion
Volunteer.Local-Involvement = local-update
Volunteer.Parent-Class.Do() ▷ Do as per Activity Class
current = newcomer.City.Public-Opinion
newcomer.City.Public-Opinion += (1 - current) / 100 ▷ Max-PO is 1

---

procedure Language-Class(newcomer)
Initialization:
Language-Class.Legal-Status = TR
Language-Class.Health-Threshold = 40
Language-Class.Value-Index = 2 ▷ *Conservatism*
Precondition:
possible = newcomer.Legal-Status in Language-Class.Legal-Status
possible = possible & newcomer.Health > Language-Class.Health-Threshold
return possible
Do:
Language-Class.Parent-Class.Do() ▷ Do as per Activity Class
local-update = newcomer.Wellbeing × newcomer.City.Public-Opinion
Language-Class.Local-Involvement = local-update
acc-increase = (1 - newcomer.Acculturation) / 10
newcomer.Acculturation += newcomer.Wellbeing × acc-increase

procedure Work(newcomer)
Initialization:
Work.Legal-Status = TR, AS, SE
Work.Health-Threshold = 70
Work.Value-Index = 0 ▷ $Self - Enhancement$
Precondition:
possible = newcomer.Legal-Status in Work.Legal-Status
possible = possible & newcomer.Age > 18
possible = possible & newcomer.Health > Work.Health-Threshold
return possible
Do:
Work.Parent-Class.Do() ▷ Do as per Activity Class
earnings = 10
newcomer.Budget += Earnings × .5
COA.Savings += Earnings × .5

procedure Study(newcomer)
Initialization:
Study.Legal-Status = TR, AS, SE
Study.Health-Threshold = 40
Study.Value-Index = 0 ▷ $Self - Enhancement$
Precondition:
possible = newcomer.Legal-Status in Study.Legal-Status
possible = possible & newcomer.Age < 18
possible = possible & newcomer.Health > Study.Health-Threshold
return possible
Do:
local-update = newcomer.Wellbeing × newcomer.City.Public-Opinion
Study.Local-Involvement = local-update
Study.Parent-Class.Do() ▷ Do as per Activity Class
newcomer.Education += (100 - newcomer.Education) / (100 - newcomer.V.SE)

procedure Crime(newcomer)
Initialization:
Crime.Legal-Status = TR, AS, SE
Crime.Health-Threshold = 40
Crime.Value-Index = 0 ▷ $Self - Enhancement$
Precondition:
possible = newcomer.Wellbeing ¡ .05
possible = possible & newcomer.V.SE ¿ 58.9 ▷ Near Max SE
possible = possible & newcomer.AZC.Health ¡ 50
if $U(0,100)/2 >$ newcomer.AZC.Health: **then**

self.basic = 1
return possible
Do:
Crime.Parent-Class.Do() ▷ Do as per Activity Class
newcomer.City.Public-Opinion /= 2 ▷ Halves PO
newcomer.City.Crime += 1

procedure Doctor(newcomer)
Initialization:
Doctor.Legal-Status = EDP, TR, AS, SE
Doctor.Health-Threshold = 30
Doctor.Value-Index = 0 ▷ $Conservatism$
Doctor.Critical = True ▷ Highest priority action
Precondition:
possible = newcomer.Legal-Status in Doctor.Legal-Status
possible = possible & newcomer.Health ¡ Doctor.Health-Threshold
if newcomer in Hotel.Occupants **then**
possible = possible & newcomer.Budget ¿ newcomer.City.Intra-City-Travel-Cost
return possible
Do:
Doctor.Parent-Class.Do() ▷ Do as per Activity Class
newcomer.Health = min(newcomer.Health + Doctor.Health-Increase, Doctor.Health-Threshold)
newcomer.City.Costs += 1

Chapter 6

Model Development

6.1 Introduction

This chapter describes how we addressed **Goal 3: Build a companion model that utilizes values to capture both refugee and logistical behavior**. Here we outline the development of the model and its validation. The first phase of model development involved: gathering background information, formulating research questions, and proposing a model schema. The second phase revolved around actually implementing the schema. The last phase focused on gathering data to answer our research questions. The last section considers the validation of the model in the context of authentication.

6.1.1 Phase One

Literature Review From November 2017 to January 2018, I gathered relevant literature on humanitarian logistics and the asylum procedure. Additionally, I wrote periodic exploratory literature reviews. Finally, I compiled the relevant aspects of the smaller literature reviews into complete literature review to be used in the forthcoming proposal.

Proposal From January to March 2018 I developed an initial model proposal, implementing the content of the literature review. In order to do so accurately, I cross referenced my local definition of the asylum procedure with my colleague Dr. Christine Boshuijzen, an expert on the subject. The initial proposal delivered in early February was too large in scope, attempting to capture both the asylum procedure and following behaviors. I submitted a revised proposal in March which narrowed the focus of the model to the asylum procedure itself.

6.1.2 Phase Two

From March to June of 2018 the model was iteratively developed. The model was built using the Python programming language and the Mesa ABM library. The development trajectory for each key agent is listed below. After fully developing COA, Newcomers, and IND, the model was rebuilt from scratch to improve readability and cohesion. After the model reboot, as it is referred to below, NGOs were added.

COA The first iteration implemented COA capacity management and logistics in a single city. Newcomer agent's attributes were limited to country of origin and legal

status. Once COA was logistically capable of managing the capacity in a single city, the simulation was generalized to permit an arbitrary number of cities. Initially, COA was responsible for measuring capacity levels as well as performing value informed actions. Given that AZC's are extensions of COA, the AZC agent was assigned the responsibility of actually measuring occupancies and detecting anomalies. Said shift was functionally equivalent to the prior arrangement, but it clears up COAs step function to improve code readability.

Newcomers Initially, Newcomers' only attribute was country of origin, as this was the minimum necessary for the development of COA logistics. Newcomers behavior was expanded once activity center's and NGOs were in place for two reasons. First, they are the space and designer of activities which newcomers perform. Second, activities require metrics to be meaningful.

The first key attribute, wellbeing, was added alongside newcomer values, as it is defined from net unsatisfied values as per chapter 4. Once *Doctor* and *Football* were added as activities, newcomer health was added as an attribute. Recording health allows us to measure the amount by which health maintenance is a product of a healthy lifestyle or a burden on the local health care system. The acculturation attribute was added alongside city public opinion, *LanguageClass*, and *Volunteer* as a way of measuring their effect on newcomers.

Newcomer social networks were implemented late in the development to correspond with *Socialize*. While promising, they slow down the simulation considerably. As such, they are not included in the present report, but will be a key point of future developments.

Cities The function of cities has changed considerably over time. Initially, each city contained one AZC for each modality. Interviews with COA personnel, indicated that most cities have only one AZC, though large cities may have multiple. In the present state, each city has the capacity to add additional AZCs as circumstance requires. In addition, changes were made to how additional AZCs were constructed. At first, each city had a set of empty buildings which were converted into AZCs when estimated occupancy exceeded capacity. This was changed to a generic build function that instantiates a new building given a required size. This was necessary as the actual distribution of empty buildings in Dutch cities is unknown. In addition, it is known that during the refugee crisis, COA managed to procure sufficient housing for all that arrived. Consequently, we can assume that there are enough empty buildings available in the simulated country, such that they do not need to be explicitly instantiated.

After the reboot of the model, Cities became a record keeper of local health care costs, criminal activity and public opinion. The first two were added as City attributes in order to organize the data gathering during experiments. Public Opinion serves a vital function of influencing NGO funds and Newcomer acculturation.

IND IND's development went through three phases. First, IND decisions were determined probabilistically. That is, success rates per country of origin were used as input to a Bernoulli distribution whose output was the IND decision. Second, the decision procedure was replaced by a threshold system in which Newcomers have the opportunity to increase the strength of their asylum case. This is more in line with reality, modeling how asylum seekers meet with a Raad Voor Rechtsbijstaad lawyer [70]. Furthermore, this allows for IND decisions to be measured using a confusion matrix, this allows errors in IND decision making to influence other aspects of the simulation,

such as public opinion. Third, value informed actions influencing the threshold were added. This allows us to measure how value variance influences IND and those affected by IND behavior.

NGOs After the reboot, NGOs were added, causing design modification to other agents. Activity Centers were added as a building type and attached to each AZC in order to keep record of activities and attendance. Public opinion was added to cities. There were no phases of NGOs development as they were added after the values framework was already in place.

6.1.3 Phase Three

During June and July of 2018, hypotheses were investigated, data gathered, and results interpreted. In order to test the hypotheses, a parameter explorer class was developed to run simulations whose input parameters sweep a space values. After testing hypotheses, R scripts were written to graphically analyze output. Results were compared with hypotheses and interpreted accordingly. While investigating cases in which our hypotheses were not supported, small bugs and weak points in the model were identified. Finally, a plan for continued development on the model was outlined.

6.2 Validation

Model validation is the assessment of the degree to which an ABM approximates a real world data generating process [97]. Empirical validation is typically performed by comparing the time-series output of model variables to corresponding historical data. According to Windrum et al. ABM designers rarely employ purely mathematical validation methods, such as precision, accuracy, soundness and generality [97]. Instead, alternative validation methods are used, such as authentication [60]. Authentication validation, also referred to as companion modeling, requires taking input from stakeholders regarding their perceptions of the real world data generating process [14]. Authentication validation has been used for ABMs whose purpose is to aid policy decision making [14] [11]. The goals of the present model are in line with this type of ABM. A valid model is then one which incorporates stakeholder accounts of the phenomena of interest, aids in stakeholder communication, and supports stakeholder decision making process [60].

6.3 Interface and Artifacts

The graphical user interface (GUI) used during model development is pictured in Figure 6.1. The sliders on the left set values of COA, IND and NGOs. The takes place on the canvas in the center were circles on the top are COLs, middle POLs, and bottom AZCs. The graph given below is record newcomer wellbeing for varying legal status. Graphs are primarily used for debugging purposes during development and clarifying internal dynamics. The model is set up to report graphs on AZC occupancy, COA staff, IND staff, social network health (not included in reported version), a confusion matrix of IND decisions, and success rates per country of origin. The more graphs displayed the slower the simulation runs, so typically only one is displayed at a time.

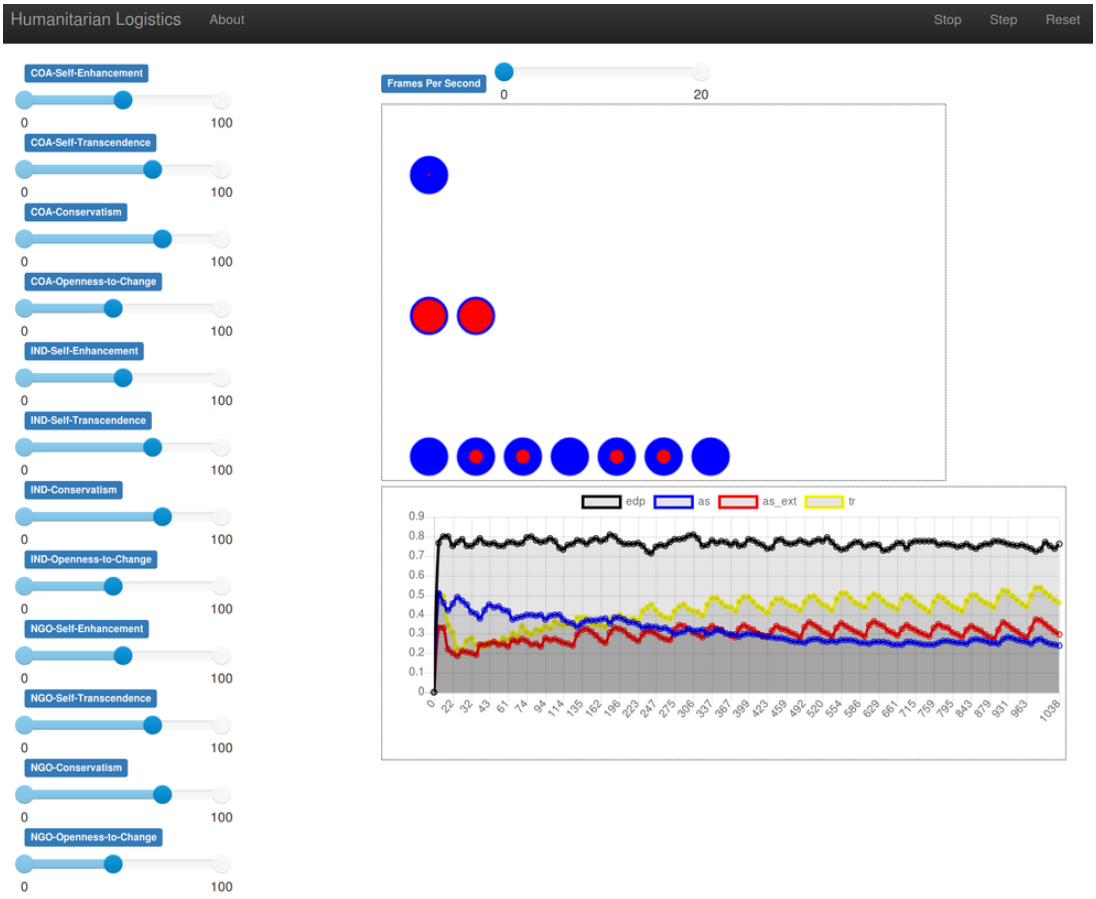


Figure 6.1: The graphical user interface of the model. The circles represent AZCs whose current occupancy is given in red. Below the simulation is a graph of newcomer wellbeing of different legal statuses. Notice the saw tooth pattern of the wellbeing time series. The size of the sawtooth corresponds to the weekly schedule, as certain days are more value satisfying than others. Also notice how EDP newcomers seem happier than TR newcomers. This is only because they have not been in the simulation long enough to feel sad.

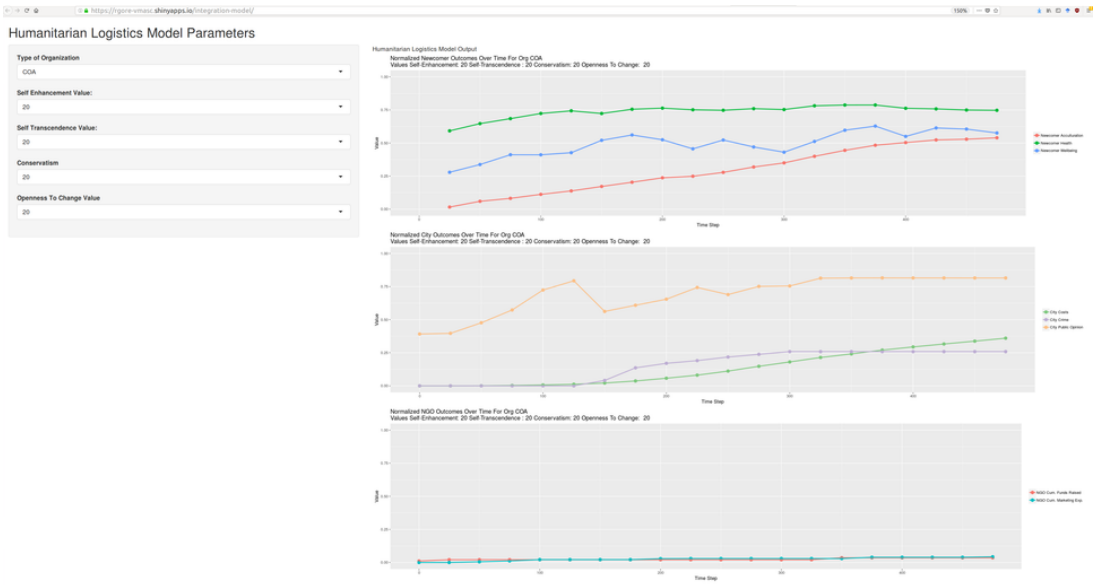


Figure 6.2: The model artifact is a web page in which the user can explore different value input parameter settings and view the output

In addition, there is a model artifact that the public can interact with. The artifact pulls from a database of the outcomes of the value sweep mentioned in Chapter 8. Users select a value setting for either COA, IND, or NGOs and the output is graphed to the side. In the future, the artifact can be expanded to include the results of other experiments. The purpose of the artifact is for stakeholders to be able to use it to entertain different scenarios to gain insight into effects of possible policy changes.

6.4 Chapter Summary

There were three key phases to the model development. Phase one involved gathering relevant literature and designing a proposal. Phase two required actually building the proposed model. Phase three revolved around developing tools to experimentally answer research questions concerning the simulation and interpret the results. The results of the development are a GUI model interface useful for model development and engineering and a publicly accessible artifact useful for stakeholder communication.

Chapter 7

Hypotheses

7.1 Introduction

This chapter contains hypotheses for the three research questions: the correlation of values and outcomes, inter-institutional cooperation, and NGO influence. For each research question, the hypothesis will be followed by a line of reasoning rooted in literature and model design. The first research question addresses **Goal 4: Analyze the degree to which values correlate with outcomes**. The last two research questions address **Goal 5: Use model to make recommendations to stakeholders**

7.2 Research Question 1: Values Sweep

To what degree are the values of institutional agents, COA, IND and NGOs, correlated with outcomes of other agents and cities?

The relative ordering of values determines the frequency with which certain actions are performed as the desirability of post-action states changes with respect to the lack of value satisfaction. As values change across agents, behavior changes along with its contingent outcomes. In order to gauge the degree to which variance of outcome corresponds to varying value profiles, the value parameter space must be fully explored. The goal of the values sweep is to map out the positive, negative or neutral contribution of each value's variance to the relevant outcomes of each other agent.

It is important to clarify what 'contribution' is taken to mean. For the present investigation, contribution is not synonymous with cause as per its deterministic definition in the philosophy of science literature [20]. Rather, contribution is synonymous with associative causality in which one event causes another if they are positively associated [25]. A positive association of two events A and B implies that $P(A|B) > P(A|\neg B)$. Though association doesn't imply correlation, correlation implies association [2]. Correlation will be used to measure the degree to which one input contributes to an output.

It should also be noted that this value sweep is intended to be a small first step in a continued series of parametric analysis. Finer grain value sweeps can be conducted in the future followed by sensitivity analyses. However, a coarse grain value sweep is generally a good place to start to analyze the contribution of values on outcomes. The hypotheses the follow then are merely indicates of what was currently believed about model behavior before running the experiment.

	Hypothesized Correlation	
Value	Positive	Negative
C	NS newcomer *health*	S newcomer *health*
	NS newcomer *wellbeing*	S newcomer *wellbeing*
	NS newcomer *acculturation*	S newcomer *acculturation*
	NS City building *health*	S city building *health*
	COA $thrift$	NS city *crime*
	S city *crime*	NS city *costs*
	S city *costs*	
	$percent - segregated$	
SE	newcomer *health*	COA $thrift$
	building *health*	city *costs*
ST	newcomer *wellbeing*	COA $thrift$
	newcomer *health*	city *crime*
	newcomer *acculturation*	
OTC	newcomer *wellbeing*	COA $thrift$
		city *crime*

Table 7.1: COA value sweep hypotheses

7.2.1 Hypotheses

Given that the number of variables hypothesized about is large, the hypotheses themselves are stored in tables 7.1, 7.2, and 7.3.

COA

Conservatism The COA C associated action is *Segregate*, described in Chapter 5 Section 5.6.5, which relocates unlikely to gain TR status newcomers to the AZC with the least number of activities. Given that each time the action is called the size of the segregated population grows, we hypothesize a positive correlation with Percent Segregated. It is hypothesized that non-segregated (NS) building *health* will increase and segregated (S) building *health* will decrease. This follows naturally from the *Segregate* action which decreases *occupancy* in one location and increases it in another. Building $health - decay$ depends on occupancy. In addition, we hypothesize that COA $thrift$, the inverse of COA *costs* ($-1*$COA *costs*), is positively correlated with COA C. This is because the other COA value actions, $AdjustStaff$, $Invest$, and $ImproveFacilities$, are all expensive. The more COA does *Segregate*, the less it does other, expensive actions, reducing costs. COA Thrift is made a separate variable from COA Costs in order to evaluate conservatism in terms of the amount unspent.

Furthermore, we hypothesize that such an action increases NS newcomer *health*, *wellbeing*, and *acculturation* and decreases S newcomer *health*, *wellbeing*, and *acculturation*. The rate of newcomer $health - decay$ depends on AZC building *health*, which depends on building occupancy, as stated in Chapter 5 Section 5.3.4. *Segregate* decreases the *occupancy* for NS newcomers and increases the *occupancy* for S newcomers. We hypothesize S newcomer *wellbeing* will decrease because the AZC they are moved to has less opportunities for value satisfying activities. We hypothesize that NS newcomer

wellbeing will increase. As evident in their preconditions in Chapter 5 Section 5.6.7, most activities have minimum newcomer *health* preconditions, and the hypothesized *health* boost will lead to more activity participation. It is similarly hypothesized that the *health* boost will increase participation in activities which increase NS newcomer *acculturation*. Conversely, the AZC to which S newcomers are sent has few activities. Thereby S newcomers have less opportunities to increase their *acculturation*. Given that newcomer *health* stems from either $Football$ or *Doctor* activities, the AZC with the least amount of activities would have less opportunities to play $Football$, such that their *health* is rooted in the city *cost* increasing *Doctor* activity participation. On the other hand, NS newcomer *health* increases due to reduced *occupancy* would decrease the need to go to the *Doctor*. Therefore, we hypothesize a positive correlation with NS city *costs* and a negative correlation with S city *costs*. The negative correlation with NS city *crime* and positive correlation with S city *crime* are grounded in the number of activities in the NS and S locations. A greater number of activities equates to a greater number of opportunities to satisfy values and, subsequently, a greater *wellbeing*. Low *wellbeing* is a precondition of the $Crime$ activity, found in Chapter 5 Section 5.6.7, such that S city *crime* would increase. The same logic regarding increased NS *health* boosting NS *wellbeing* through increased activity participation grounds the negative correlation of COA C with NS city *crime*.

Self-Enhancement The SE associated action is $ImproveFacilities$, which increases building *health* at the expense of COA $thrift$. The negative correlation with COA $thrift$ and positive correlation with building *health* then follow naturally. Improved building *health* reduces the decay of newcomer *health*, as per the newcomer $health - decay$ description in Chapter 5 Section 5.3.4. As such, we hypothesize that COA SE is positively correlated with newcomer *health*. Moreover, increased newcomer *health* would decrease the dependency on the *Doctor* activity, described in Chapter 5 Section 5.6.7, thereby reducing city *costs*.

Self-Transcendence The ST associated action is $Invest$, described in Chapter 5 Section 5.6.5, which supplies travel vouchers to newcomers such that they can participate in activities in other cities. Travel vouchers are costly as such, we hypothesize a negative correlation with COA $thrift$. The increase in newcomer *health*, *wellbeing* and$acculturation$all stem from the ability to participate in custom activities, $Football$, and $Volunteer$ in other cities. The positively correlative relationship between access to said activities and *health* and *acculturation* is evident in their effects, described in Chapter 5 Section 5.6.7. Furthermore, the increase in number of possible activities due a travel voucher creates more alternatives to $Crime$ and the hypothesized *wellbeing* boost would decrease the number of newcomers who meet the low *wellbeing* precondition of $Crime$, described in Chapter 5 Section 5.6.7. .

Openness-to-Change The OTC associated action is $AdjustStaff$, described in Chapter 5 Section 5.6.5, which ensures that the number of $staff$ employed at an AZC corresponds to the *occupancy* level within budget constraints. Hiring $staff$ is costly hence the negative correlation with COA $thrift$. The ratio of preferred $staff$ given an *occupancy* level to actual $staff$ given an *occupancy* level determines the likelihood of a mistake being made during $Check - in$. A mistake is when a newcomer isn't included in $Check - in$. Recall that during $Check - in$ unhealthy newcomers are added to the travel voucher wait list. As such, a COA whose $staff$ levels are too low is less capable of identifying those newcomers who need travel vouchers. This lowers newcomer *wellbeing*. As OTC promotes proper staffing, we hypothesize that

COA OTC is positively correlated with newcomer *wellbeing*. Both $Adjust - Staff$ and $Check - in$ can be found in Chapter 5 Section 5.6.5. The hypothesized boost to *wellbeing* should spillover into city *crime* as there are more alternatives to *Crime* and less newcomers who meet *Crime*'s low *wellbeing* precondition, described in Chapter 5 Section 5.6.7.

NGO

Conservatism NGOs C associated action is $Fundraise$, which converts local $public - opinion$ to $funds$ as per its definition in Chapter 5 Section 5.6.7. It follows that C would then be positively correlated with an NGOs cumulative $funds$ raised. As an overemphasis on raising $funds$ can get in the way of actual service delivery, we hypothesize a negative correlation with newcomer *health* and *wellbeing*.

Self-Enhancement The SE associated action is $MarketingCampaign$, described in Chapter 5 Section 5.6.7, which temporarily boosts public opinion. Naturally, we expect SE to be positively correlated with public opinion. As the amount of *acculturation* gained from the $Volunteer$ activity (Chapter 5 Section 5.6.7) depends on the local public opinion, we hypothesize that SE will also be positively correlated with pubic opinion. NGOs can use their $funds$ for either marketing or the design of custom activities. We hypothesize that an overemphasis on marketing results in a decreased amount of activities.

Self-Transcendence NGOs satisfy ST by the $CustomActivity$ action, described in Chapter 5 Section 5.6.7, which identifies the most unsatisfied value in a population of newcomers and organizes an activity to satisfy it. Naturally, activities which addressed unmet value needs will then boost newcomer *wellbeing*. In addition, newcomer *wellbeing* influences $health - decay$ such that a distressed newcomer gets sick faster than a contented one (Chapter 5 Section 5.3.4). Consequently, we hypothesize that ST positive correlates with newcomer *health*. The hypothesized *health* boost should extend into city *costs* as less newcomers will need to resort to the *Doctor* activity. Finally, increased *wellbeing* reduces the number of newcomers who meet the *Crime* precondition. Both activity preconditions are described in Chapter 5 Section 5.6.7. Therefore, we hypothesize a negative correlation with city *crime*.

	Hypothesized Correlation	
Value	Positive	Negative
SE	$public - opinion$	$number - activities$
	$acculturation$	
ST	newcomer *health*	city *crime*
	newcomer *wellbeing*	city *costs*
C	NGO $cumulative - funds$	newcomer *health*
		newcomer *wellbeing*
OTC	newcomer *wellbeing*	
	NGO $funds$	

Table 7.2: Value sweep hypotheses for NGO agents

	Hypothesized Correlation	
Value	Positive	Negative
SE	building *health*	$false - positive$
ST	$false - positive$	$false - negative$
	building *health*	$public - opinion$
C	$false - negative$	building *health*
	$public - opinion$	$false - positive$
OTC	building *health*	COA *costs*
	IND $staff$	

Table 7.3: Value sweep hypothesis for IND Agents

Openness-to-Change The OTC associated action is *Prioritize*, described in Chapter 5 Section 5.6.7, which rearranges the schedule of custom activities to best meet the value needs of the population being served. We hypothesize that NGO OTC is positively correlated with newcomer *wellbeing*, because it ensures that activities are not organized for values which are already satisfied. It may be the case that activities are removed from the schedule, but none are added to a different value. In such circumstances, the cost of the activity is added to the NGOs funds. Consequently, we hypothesize a positive correlation with NGO funds.

IND

Conservatism The C associated action is *RaiseThreshold*, which decreases the margin of documentation quality acceptability, making it more difficult for Newcomers to gain TR status. As such, we hypothesize that IND will make less $false - positive$ decisions and more $false - negative$ decisions as the threshold goes up. Furthermore, a higher threshold means more negative first decisions, leaving more newcomers awaiting an appeal decision with ASE status. Therefore, we hypothesize a negative correlation with building *health* as *occupancy* accelerates building decay, described in Chapter 5 Section 5.7. False positives reduce $public - opinion$ as per the $public - opinion$ dynamics described in Chapter 5 Section 5.5.1. The hypothesized reduction in $false - positive$ should then increase public opinion.

Self-Enhancement The SE associated action is $IssueStatement$, described in Chapter 5 Section 5.12, which has the effect of temporarily reducing the number of newcomers who are unlikely to gain TR status. As such, less newcomers pass through the simulation, reducing *occupancy* levels and slowing the decay of buildings (Chapter 5 Section 5.7). As such, we hypothesize a positive correlation with building *health*. Conversely, it is unlikely to gain TR status newcomers who cause $false - positive$ decisions.

Self-Transcendence The ST associated action *LowerThreshold* acts to increase the margin of acceptability, thereby lowering the barrier of entry to gaining TR status. As such, we hypothesize that a lower threshold increases $false - positive$ and decreases $false - negative$ decisions. As $public - opinion$ is reduced by $false - positive$ decisions, we hypothesize a negative correlation with $public - opinion$ as per $public - opinion$

Agent / Value	SE	ST	C	OTC
COA	55	65	45	60
NGO	10	35	40	60
IND	52	45	49	70
Variable	Value	Step-Size		
Number-of-POLs	2	n/a		
COA-Values	[20,80]	20		
IND-Values	[20,80]	20		
NGO-Values	[20,80]	20		
Public-Opinion-Uniform	True, False	n/a		

Table 7.4: Input parameters for research question 1. As values were swept one agent type at a time, the top part indicates the the value profiles of the agents whose values were not being swept.

dynamics in Chapter 5 Section 5.5.1. As a lower threshold hypothetically results in less ASE status newcomers waiting in appeals, AZC *occupancy* levels should be lower. By extension, we hypothesize that building *health* will be higher (Chapter 5 Section 5.7).

Openness-to-Change The OTC associated action is $AdjustStaff$ which acts to keep IND $staff$ at levels adequate for the current *occupancy* level. We hypothesize a reduction in COA costs as inadequate IND staffing can result in a bottleneck for COA by driving up newcomer wait times. Newcomer wait time's are set according to $Set - Time$, described in Chapter 5 Section 5.6.6. Similarly, we hypothesize that building *health* is positively correlated with OTC as adequate $staff$ reduces newcomer wait times, lowering *occupancy* levels. In addition, we hypothesize a positive correlation with IND $staff$ as high OTC indicates more opportunities to hire staff, as per $AdjustStaff$ in Chapter 5 Section 5.6.6.

7.2.2 Methods

The input parameterization for research question 1 can be found in Table 7.4. For each value $v \in SE, ST, C, OTC$ parameters values were swept from the interval [20,80] in step sizes of 20 and a run was conducted lasting 500 time steps. Data was gathered during time steps 350-500, giving the simulation time to stabilize. A total of 256 runs were completed per institutional agent, COA, NGO, and IND.

The following conditions were unique between value sweeps. Firstly, COA requires that pubic opinion is evenly distributed across cities, such that some cities have higher $public - opinion$ than others. Otherwise, some of its actions are meaningless. As such, evenly distributed $public - opinion$ means that each city has a $public - opinion$ in the range of [0,1] in steps of .1. Secondly, IND and NGO require that $public - opinion$ be uniform across cities. This is necessary to clearly view the influence of their values on $public - opinion$ and $public - opinion$ mediated outcomes, such as *acculturation*. When $public - opinion$ is evenly distributed as in the COA case, outcomes at the upper end of the spectrum balance out those in the bottom, resulting in muted data collection. Consequently, $public - opinion$ is uniformly set to .5 in IND and NGO sweeps.

After gathering data, correlation plots were generated to compare the covariance of the set of outcomes per single value. Spearman rank correlation coefficient was used as we are concerned with monotonic, ordered change in one variable with respect to another. In addition, outcome value centric heat maps were generated to characterize the correlation of the set of values per single outcome.

7.3 Research Question 2

How does inter-institutional cooperation effect bottleneck response during simulated shocks?

Clarification It is first necessary to operationalize cooperation and bottleneck. Cooperation here refers timely shock response to avoid a bottleneck. Historically, the cooperation breakdown in early 2015 was rooted in the former's delayed $staff$ increase [50] [49]. A $staff$ increase depends on three things, $budget - frequency$ (BF), IND OTC, and COA OTC. Budgets are updated according to previous AZC *occupancy* levels. As such, if previous *occupancy* levels contain the shock, then budgets will be updated to provide for the increased number of asylum seekers. Openness-to-Change influences determines $staff$ increase as $AdjustStaff$ is its value satisfying action. $Adjust - Staff$ is described in Chapter 5 Section 5.6.6, for reference. If Openness-to-Change is highly valued then the likelihood of $AdjustStaff$ occurring is subsequently higher than otherwise. Finally, COA OTC informs the accuracy of IND's $staff$ adjustment as the frequency with which COA gathers AZC *occupancy* data, assessment-frequency, is determined by OTC. Assessment frequency is described in Chapter 5 Section 5.11. Taken together, COA and IND cooperate when the former has high enough OTC to gather accurate *occupancy* data and the latter has the BF and OTC to act upon that data in response to a shock.

Furthermore, a bottleneck occurs with a poorly timed BF relative to shock frequency, low IND OTC and low COA OTC. A bottleneck has the following consequences for COA and Newcomer agents. First, a bottleneck results in longer newcomer $wait - times$ (as described in $Set - Time$ in Chapter 5 Section 5.6.6), increasing building *occupancy* and, subsequently, building decay rate. As such, COA must spend more of its budget on building maintenance. *occupancy* determination of building decay can be found in Chapter 5 Section 5.3.5. Second, COA runs out of room faster, sending more newcomers to commercial housing which is costly, further constraining the budget. Third, the first two budget constraints limit COA's ability to hire further staff. A low $staff$ COA is less capable of addressing the needs of its residents, which negatively impacts their *health* and *wellbeing*. In summary, bottlenecks increase newcomer $wait - times$ and COA costs (CC). Conversely, bottlenecks decrease building *health*, newcomer *health* and *wellbeing*. As bottlenecks are sensitive to a host of variables which the following analyses hypothesizes over, it is worth defining the effect for the sake of brevity.

Definition 7.3.1 *Improved Bottleneck Response An increased IND $staff$ and a decreased COA costs and average newcomer wait time relative to another experimental condition.*

Agent	Sub-type	SE	ST	C	OTC
NGO	Normal	10	35	40	60
COA	Benevolent Caretaker	70	75	35	50
	Secure-Segregated	35	70	75	50
	Flexible-Conservative	35	50	70	75
	Self-Concerned	75	30	50	70
IND	Stiff	50	51	49	70
	Flexible	50	51	49	30
Variable	Value	Step-Size			
Number-of-POLs	2	n/a			
IND Budget Frequency	60,230,365	n/a			

Table 7.5: This table contains input parameters for Research Question 2.

7.3.1 Hypothesis

There are two main hypotheses, one with regards to BF and the other with regards to IND OTC condition.

Hypothesis 1 *Anticipatory and high frequency BF groups will display increased bottleneck response relative to the annual BF group.*

Hypothesis 2 *Flexible groups display improved bottleneck response relative to stiff ones.*

7.3.2 Methods

To gauge whether IND's funding schedule is a determinant of relevant newcomer outcomes, a between group comparison will be made. The necessary input parametrization can be found in Table 7.5. One group utilizes an annual funding scheme, another utilizes an anticipatory funding scheme, and the last utilizes a flexible funding scheme. A funding scheme is a $budget - frequency$. Anticipatory funding schemes are those that occurs after the arrival of the shock and, thus, has some awareness of the amount of incoming newcomers.

Furthermore, given the IND OTC relevancy to adequate shock response, each group will contain a stiff, low OTC, and flexible, high OTC, subgroup. Finally, provided that COA OTC influences the accuracy of the *occupancy* information upon which IND bases its decisions, the bottleneck outcomes will be compared using the four canonical COAs, which have varying OTC. Our interviews with COA revealed great heterogeneity between COAs. The canonical COAs are merely four common types of COAs that can be found within that heterogeneity. By testing our hypothesis across COAs of different types, we can evaluate how COA independent the bottleneck response is.

Data Generation Each run of the simulation will gather aggregate statistics across 10 cities, were each city contains an IND, COA, and NGO. Each condition, consisting of a group, sub-group, and COA type will be repeated 10 times.

Variable	Description
newcomer *wellbeing*	Mental *health* / amount of value unsatisfaction
newcomer $wait - time$	Average second decision duration
COA *costs*	Amount COA spends on Housing and Transportation
IND $staff$	Amount of IND $staff$

Table 7.6: The table details all of the coarse data gathered per simulation run. Note that average $wait - times$ are gathered from the newcomer's second decision. This is because the bottleneck is a result of those waiting in the extended asylum procedure.

Each run will continue for 500 time steps. At the 200 time step mark, a shock which lasts 100 time steps will occur. The mean outcome variables mentioned in Table 7.6 will be gathered during time steps 350-500, giving the simulation time to stabilize. Groups will be compared using single tailed paired t-tests in the direction hypothesized. Single tailed t-tests are used because we're hypothesizing about a specific direction of difference between one treatment condition and another.

7.4 Research Question 3: NGO Influence

What is the influence of NGOs on refugees and municipalities?

Clarification NGOs promote newcomer *health*, *wellbeing* and*acculturation*by the following behaviors. NGOs generate custom activities for newcomers based on their unsatisfied values with $CustomActivity$, described in Chapter 5 Section 5.6.7. Custom activities create opportunities for newcomers to satisfy their values. In addition, the NGOs offer $Football$ and $Volunteer$ activities which increase newcomer *health* and acculturation, respectively. The effects of the aforementioned can be found in Chapter 5 Section 5.6.7.

NGOs also impact cities. As $Football$ increases newcomer *health*, participating newcomers go less frequently to the doctor thereby reducing *health* care costs. NGOs have the potential to reduce city *crime* in two ways. First, custom activities offer alternative behaviors which satisfy the same value as $Crime$, SE. Second, the $Crime$ activity preconditions are low newcomer *wellbeing*, high newcomer SE, and poor living conditions. NGO boosted *wellbeing* reduces the number of newcomers who fail to meet the $Crime$ preconditions, as described in Chapter 5 Section 5.6.7.

NGOs ability to develop custom activities so depends on $public - opinion$. That is, they convert $public - opinion$ into usable $funds$ with $Fundraise$, which are then converted into either marketing campaigns or activities as per its description in Chapter 5 Section 5.6.7. Marketing campaigns temporarily increase $public - opinion$. $Initialpublic-opinion$, then acts as an upper bound on the amount of capital available to NGOs without further investment in marketing campaigns.

The goal of research question 3 is to gauge the influence of NGOs of increasing $initial - public - opinion$ on newcomer outcomes. Note, the case of no NGOs at all is included as separate from $initial - public - opinion = 0$, and the $initial - public - opinion$ is set to .5 in order to best measure the trajectory of $public - opinion$ in the absence of NGOs.

Variable	Description
newcomer *health*	Physical *health*
newcomer *wellbeing*	Mental *health* / amount of value unsatisfaction
newcomer *acculturation*	Degree of entrance into host culture
city *crime*	Amount of criminal activity
city *costs*	Healthcare costs
NGO $funds$	NGOs working capital derived from $public - opinion$
city $public - opinion$	$public - opinion$ which varies over time
$initial - public - opinion$	$initialpublic - opinion$ Value at step 0

Table 7.7: The table details all of the coarse data gathered per simulation run.

7.4.1 Hypothesis

There are two hypotheses. The first pertains to binary presence or lack of NGOs and the second to the effect of NGOs of variable influence.

Hypothesis 3 *NGOs are necessary for a significant reduction in city crime and improvements in newcomer wellbeing*

That is, cities with NGOs will have less crime and improved newcomer *wellbeing* compared to cities without NGOs. It is theorized that *wellbeing* improves with the addition of NGO custom activities. Naturally, it follows that city *crime* will be reduced from an increase in alternative activities and increased newcomer *wellbeing*.

Hypothesis 4 *IPO is positively correlated with newcomer wellbeing, Newcomer.Acculturation and newcomer health and negatively correlated with city costs and city crime.*

As $initial-public-opinion$ is an upper bound on NGO $funds$ which is the basis for activities that increase newcomer *wellbeing*, *health* and acculturation, they should all be positively correlated. Given that $Football$ increases *health*, reducing the necessity of doctor visits and the previously mentioned relationship between city *crime* and *wellbeing*, city *costs* and crime should be negatively correlated with $initial - public - opinion$.

7.4.2 Methods

$Initial - public - opinion$ was swept from [0,1] in .1 size steps. In addition, a special case containing no NGOs and an $initial-public-opinion$ of .5 was run. All simulations ran for 500 time steps. Mean outcome statistics from Table 7.7 were gathered during steps 350-500 were calculated. In addition, a times series of each variable of interest was gathered for further analysis. Correlation plots were then generated to compare the covariance of $initial - public - opinion$ and variables of interest.

7.5 Chapter Summary

The current chapter described and justified the hypotheses for each research question. The goal of research question one is to map out the influence of values. By correlating

Agent / Value	SE	ST	C	OTC
COA	55	65	45	60
NGO	10	35	40	60
IND	52	45	49	70
Variable	Value	Step-Size		
$Number - of - POLs$	2	n/a		
$initial - public - opinion$	[00,1]	.1		

Table 7.8: Input Parameters for Research Question 3. The upper region of the table contains the value initializations for COA, NGO and IND agents. The lower part contains non-value input parameters. Note, step-size is only for parameters being swept.

value variance with specific outcome variance, we can measure which variables in the model are truly value sensitive. Correlations will be gathered by sweeping the value input parameter space. The goal of research question two is to compare simulated historical funding policies with potentially improved policies with respect to bottleneck response. Our hypothesis will be tested using a t-test between groups comparison of INDs with different funding schemes. Finally, the goal of research question three is to measure the influence of NGOs on newcomers and their municipalities. To answer this question, two experiments were conducted. The first compared simulations with and without NGOs using a t-test, and the second swept the input parameter space of the NGO-limiting $initial - public - opinion$ measuring outcome correlations.

Part III

Outcome

Chapter 8

Results

This chapter contains the results of each research question investigation. The results of research question one are a series of correlations between input value variance and outcome variance. The results of research question two consist of a t-test of significance difference between groups. Research question three has two parts. The first part is a t-test of significance between groups and the second part is an input parameter sweep that measures correlations between input and output covariance. Section 8.1 addresses the degree to which we have addressed **Goal 4: Analyze the degree to which values drive outcomes**. Sections 8.2 and 8.3 address the degree to which we have addressed **Goal 5: Use model to make recommendations to stakeholders**.

8.1 Research Question 1: Value Sweep

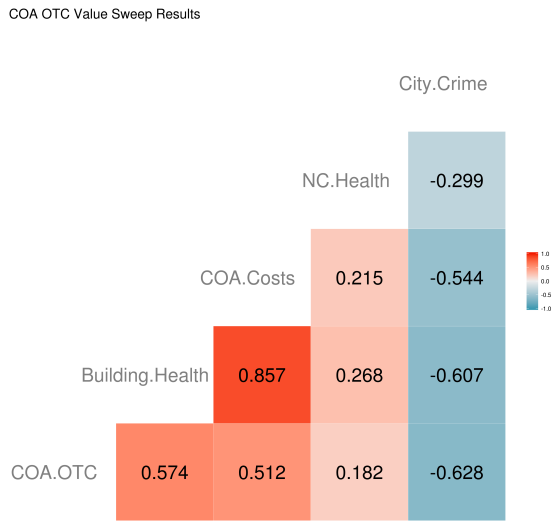
Given the number of variables in question, the results are broken down by agent type and value.

8.1.1 Results

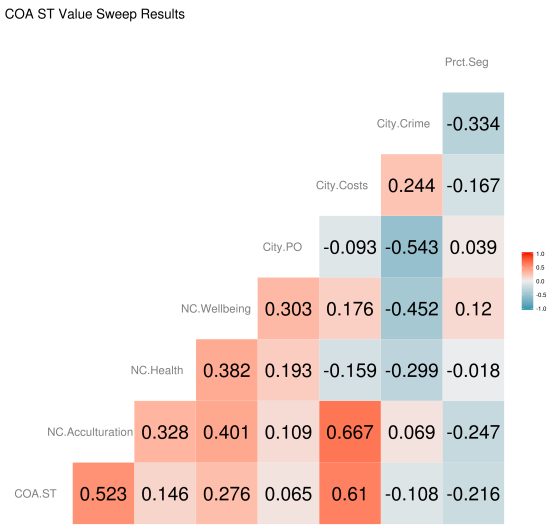
COA

Conservatism

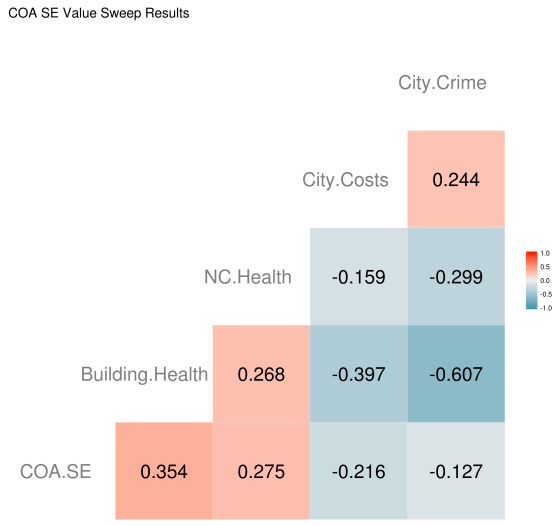
The parameter space of COA values was swept and compared to the variance of relevant outcomes, yielding the following correlations. Firstly, COA *Conservatism* is marginally positively correlated with NS newcomer *health* (r = .017) and NS newcomer *wellbeing* (r = .041). Curiously, COA *Conservatism* is also positively correlated with S newcomer *health* (r = .175) though marginally negatively correlated with S newcomer *wellbeing* (r = -.004). Taken together, COA's conservative polices seem to improve the *health* and *wellbeing* of the non-segregated population but not at the expense of the segregated one. Furthermore, COA *Conservatism* is positively correlated with NS newcomer building *health* (r = .266), but also positively correlated with S newcomer building *health* (r = .205). As such, COA *Conservatism* tends to increase building *health* in general regardless of the population being moved around. COA *Conservatism* is slightly negatively correlated (r = -.08) with S newcomer *acculturation* and positively correlated with NS newcomer *acculturation* (r =



(a)

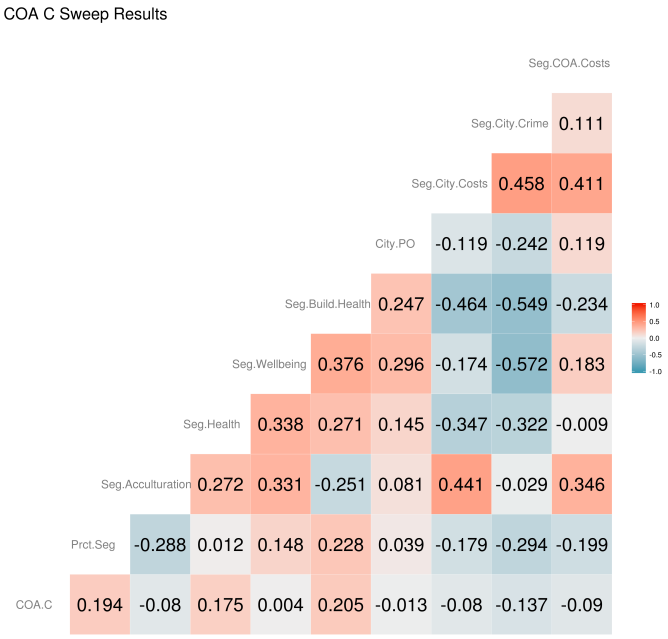


(b)

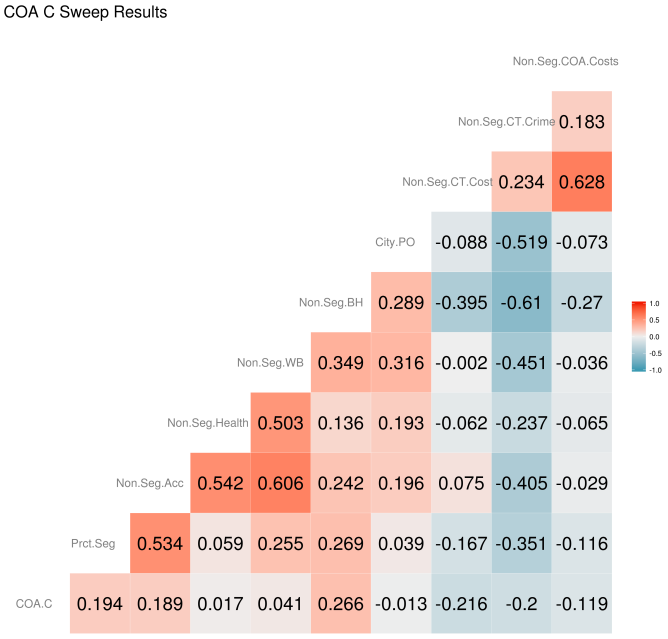


(c)

Figure 8.1: The above figures illustrate the correlations between all COA values except *Conservatism* and relevant outcome variables.



(a)



(b)

Figure 8.2: The above figure illustrates the correlations between COA *Conservatism* in Segregated and Non Segregated populations on relevant outcomes variables.

.19). That is, COA's *Conservatism* motivated policies slightly increase the acculturation of NS newcomers and slightly decrease the acculturation of S newcomers. Similar to building *health*, both segregated and non segregated city *costs* are negatively correlated (r = -.08, r = -.216, respectively). That is, COA *Conservatism* generally reduces city *costs*, but much more so for the non-segregated population. The same holds for city *crime* where COA *Conservatism* is negatively correlated with NS city *crime* (r = -.2) and less so with S city *crime* (r = -.137). Simply, conservative policies reduce crime, but more so in non segregated cities than segregated ones. Finally, as is to be expected, the size of the segregated population is positively correlated with COA *Conservatism* (r = .194).

Self-Transcendence

Secondly, COA $Self - Transcendence$ is positively correlated with newcomer *health*, newcomer *wellbeing* and newcomer *acculturation* (r = .146, r = .276, and r = .523, respectively). That is, the giving of travel vouchers to newcomers is beneficial to their physical, mental, and culturally adaptive health. COA $Self - Transcendence$ is negatively correlated with city *crime* (r = -.108). That is, as COA invests in the *wellbeing* of its population, the incidence of *Crime* is reduced. Curiously, COA $Self - Transcendence$ is positively correlated with COA $thrift$ (r = .248). That is, through COA must pay for the travel vouchers, its overall expenditures are lowered.

Self-Enhancement

Third, COA $Self - Enhancement$ is positively correlated with newcomer *health* (r = .275) and building *health* (r = .354). That is, as COA maintains its facilities, newcomer physical *health* also increases. Conversely, COA $Self - Enhancement$ is negatively correlated with city *costs* (r = -.216) and city *crime* (r = -.127). Therefore, building maintenance reduces delinquent activity and municipal *health* care costs. Furthermore, COA $Self - Enhancement$ is negatively correlated with COA $thrift$ (r = .415). Unsurprisingly, building maintenance is costly.

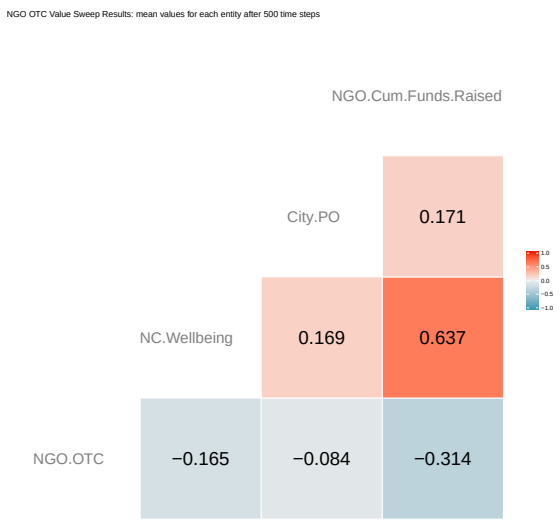
Openness-to-Change

Fourth and finally, COA $Openness - to - Change$ is positively correlated with newcomer *wellbeing* (r = .313). That is, keeping staff levels adequately in line with the requirements of *occupancy* improves newcomers ability to satisfy their own values. Additionally, COA $Openness - to - Change$ is negatively correlated with city *crime* (r = -.628). Following from the previous correlation, adequate staff and satisfied residents are less likely to engage in criminal behavior. Finally, COA $Openness - to - Change$ is negatively correlated with COA $thrift$ (r = -.512) implying that restaffing is costly.

NGO

Conservatism

NGO values were compared with relevant outcomes and the following correlations were identified. NGO *Conservatism* was negatively correlated (r = -.11) with cumulative NGO funds raised (CFR). That is, NGO *Conservatism* does not result in an increased turnover of $public - opinion$ into usable NGO capital. However, NGO *Conservatism* is negatively correlated with newcomer *health* (r = -.159) and newcomer *wellbeing*



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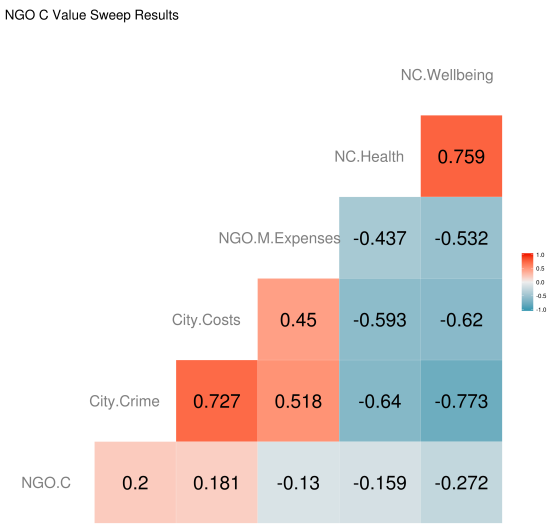

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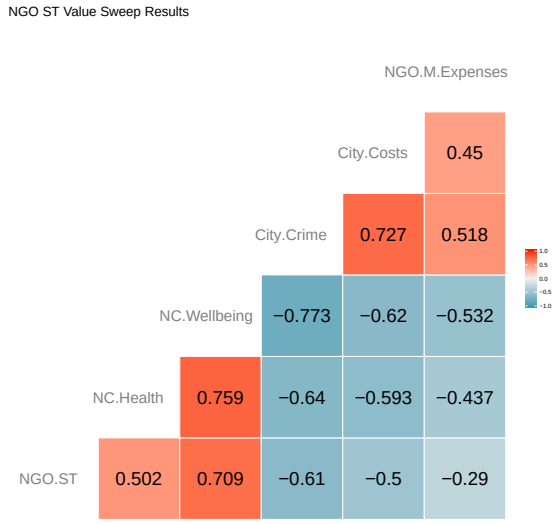

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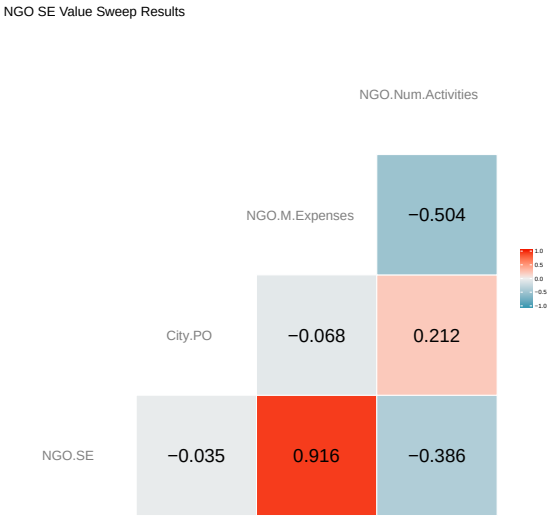


(d)

Figure 8.3: Correlation plots for the NGO Values sweep

(r = -.272). That is, when NGOs prioritize *Conservatism* motivated fund raising, newcomer *health* and *wellbeing* are decreased.

Self-Enhancement

In addition, NGO $Self - Enhancement$ had a marginal negative correlation with $public - opinion$ (r = -.035) and a very strong positive correlation (r = .9) with marketing expenditures. This is to say that marketing expenditures are failing to raise $public - opinion$ as intended. On the other hand, NGO $Self - Enhancement$ was negatively correlated (r = -.39) with number of NGO activities. Basically, NGO's which prioritize marketing campaigns tend to organize less actual activities for newcomers.

Self-Transcendence

NGO $Self - Transcendence$ has strong positive correlations with newcomer *health* (p = .5) and newcomer *wellbeing* (r = .71). Intuitively, NGO $Self - Transcendence$ strongly negatively correlates with city *crime* (r = -.61) and city *costs* (r = -.5). Taken together, the NGO $Self - Transcendence$ motivated organization of activities is beneficial to both newcomers and their local surroundings.

Openness-to-Change

Finally, NGO $Openness - to - Change$ positively correlates with NGO $funds$ (p = .19). That is, as NGOs adjust their activity schedules in response to demand, they increase their amount of immediately usable funds. Curiously, NGO $Openness - to - Change$ is negatively correlated with newcomer *wellbeing* (p = -.17). That is, $Openness - to - Change$ motivated activity schedule adjustment is not always beneficial to the population being served.

IND

Conservatism

After comparing value and relevant outcomes variance the following correlations were identified. Firstly, IND *Conservatism* is negatively correlated with $false - positives$ (FP) (r = -.286) and positively correlated (r = .247) with $false - negatives$ (FN). IND *Conservatism* is not correlated with $public - opinion$ (r = -.006). Essentially, IND *Conservatism* increases the difficulty of passing through the asylum procedure, reducing building *health*.

Openness-to-Change

Secondly, IND $Openness - to - Change$ is positively correlated with building *health* (r = .261) and IND $staff$ (r = .32). Additionally, IND $Openness - to - Change$ is very weakly negatively correlated with COA *costs*. That is, IND $Openness - to - Change$ varies such that buildings require less maintenance, IND staff is more robust, and presumably COA has less expenditures.

Figure 8.4: The figures illustrate the correlation between IND values and relevant outcome variables.

Self-Enhancement

Third, IND $Self-Enhancement$ has a very weak negative correlation with building *health* (r = -.095) and a negative correlation with FP (r = -.181) That is, when IND issues a statement motivated by $Self-Enhancement$ to reduce the number of unlikely to receive status applicants, less $false-positives$ occur and, counter intuitively, buildings require less maintenance.

Self-Transcendence

Fourth, IND $Self-Transcendence$ has a strong positive correlation with FP (r = .77) and a strong negative correlation with FN (r = -.6). That is, IND's $Self-Transcendence$ policies lower the threshold of admittance such that less applicants are denied who should be and more applicants are admitted who shouldn't be. Furthermore, IND $Self-Transcendence$ has a weak positive correlation with building *health* (r = .274) and a weak negative correlation with $public-opinion$ (-.23).

8.1.2 Discussion

IND With respect to SE and in reference to Table 7.3, the hypothesized negative correlation to $false-positives$ held, but not the positive correlation with building *health*. The former is easily explained by the reduction in unlikely status applications due to direct effects of the $IssueStatement$ action described in Section 5.6.6. That is, less opportunities for a FP results in less FPs overall. The latter reveals a shortcoming of the $IssueStatement$ action. Essentially, the action filters incoming newcomers who are unlikely to gain TR status. The percentage of unlikely to gain status newcomers filtered out corresponds to the *occupancy*:*capacity* ratios across all AZCs, which is more or less constant across value conditions. As described in Chapter 5 Section 5.3.5, building *health* depends on *occupancy*, which is a value independent variable. Therefore, there is very little correlation to be seen. The $Self-Enhancement$ independence of building *health* can be rectified by putting a time limit on the statement issued, such that it depends less on *occupancy*:*capacity* ratio and more on the number of times the action is called. There is also an inherent weakness to $IssueStatement$. It is impossible to calibrate or validate $IssueStatement$ as there are no available data on how many asylum seekers didn't come as a result of reading a statement.

Regarding IND ST, all of the hypotheses found in table 7.3 is fully supported for the hypothesized reasons. That is, lowering the threshold of entry increases FP. More interesting is the positive correlation with building *health*. A lowered threshold of entry reduces the number of applications in appeals, subsequently lowering the *occupancy* of the buildings, softening their decay as per Chapter 5 Section 5.3.5. There were unanticipated spillover effects within IND ST. For example, IND $Self-Transcendence$ reduced city *crime* (r = -.262) and city *costs* (r = -.116). The former can be explained by the improved building *health*, which reduces the incidence of $Crime$ due to its building *health* precondition visible in Chapter 5 Section 5.6.7. The latter can be explained by the decreased $public-opinion$ which has an unanticipated relationship with city *costs* which is further examined in Discussion of research question 3.

It was expected that IND $Conservatism$ would function exactly inverse to $Self-Transcendence$ as its action essentially raises the barrier of entry. The hypotheses with respect to building *health*, FP and FN held; however, $public-opinion$ hypothesis was not supported. $Public-opinion$ was uncorrelated with IND $Conservatism$. This makes sense given the design of the $public-opinion$ system. That is, $public-opinion$

is punished for FP, but not improved for FN under the premise that the public is less aware of FNs. If necessary the lack of correlation can be rectified by addition a $public-opinion$ increase to FN.

Regarding IND $Openness-to-Change$, the hypotheses with respect to building *health* and IND $staff$ were supported and positively correlated as predicted. However, the COA *costs* hypothesis was not supported and not found to be negatively correlated with IND $Openness-to-Change$. Building *health* and IND $staff$ can be explained by a similar logic as IND $Self-Transcendence$. Essentially, $Openness-to-Change$ keeps IND $staff$ in line with *occupancy* requirements, which is a determinant of the duration of asylum procedure. The mechanics of duration determination are in IND $Set-Time$ in Chapter 5 Section 5.6.6. Contrary to our intuition, improved building *health* did not result in decreased COA expenditures. However, the direction of the correlation was incorrectly negative. As such, the effect may still be present but operating a smaller scale.

NGO All hypotheses with respect to NGO $Self-Transcendence$ were fully supported. Unsurprisingly, the organization of activities to satisfy the *health* and *wellbeing* of newcomers is effective and further improves municipal conditions. Furthermore, our NGO *Conservatism* predictions were almost entirely supported. Indeed, NGO *Conservatism* results in decreased newcomer *health* and newcomer *wellbeing* as is to be expected given that neither are directly addressed in the *Conservatism* associated action, *Fundraise*, found in Chapter 5 Section 5.6.7. However, NGO *Conservatism* was not positively correlated with $cumulative-funds-raised$. This is rooted in the uniformity of $public-opinion$ across value conditions. Recall that variable $public-opinion$ results in the obscuring of outcome data because positive effects in high $public-opinion$ cities balance out negative effects in low $public-opinion$ cities. Consequently, we opted for a uniform $public-opinion$ across all cities of $public-opinion = .5$. This puts a value independent cap on the amount of funds that can be raised in a given simulation. If .5 is easily convertible in 500 time steps to liquid capital even with low NGO C, then .5 is too small of a $public-opinion$ to show the gradations of fund raising ability. Rather, if the uniform $public-opinion$ value was set nearer to 1, then, presumably, only high NGO *Conservatism* agents would be capable of converting all of the $public-opinion$ into usable capital.

Furthermore, some of the results of NGO $Openness-to-Change$ were in line with our hypotheses. Our hypothesis of NGO $funds$ held and was positively correlated with NGO OTC. The aforementioned makes intuitive sense because the $Openness-to-Change$ associated action *Priotize* can turn unnecessary activity sessions into available capital as described in Chapter 5 Section 5.6.7. However, our hypothesis with regard to newcomer *wellbeing* was not supported. This is rooted in a shortcoming of the *Prioritize* action. Essentially, NGOs must have enough actions already in place before they can be meaningfully switched around to best meet the needs of newcomer *wellbeing* . However, NGOs do not amass sufficient activities until the simulation is nearly over. Moreover, pre-assigning NGOs activities from the start of the simulation is difficult as the newcomers they will be serving have not arrived yet and their values are stochastic. This can be rectified by allowing an initial 50 time steps after which NGOs can set up initial custom activities depending $public-opinion$.

Regarding $Self-Enhancement$, our hypothesized negative correlation with $number-activities$ held. That is, NGOs with higher $Self-Enhancement$ develop less activities, as their priorities are largely directed towards marketing. However, our hypotheses with respect to $public-opinion$ and *acculturation* did not hold. The chain of hypothesized versus observed variable interactions is in Figure 8.5. That is, overem-

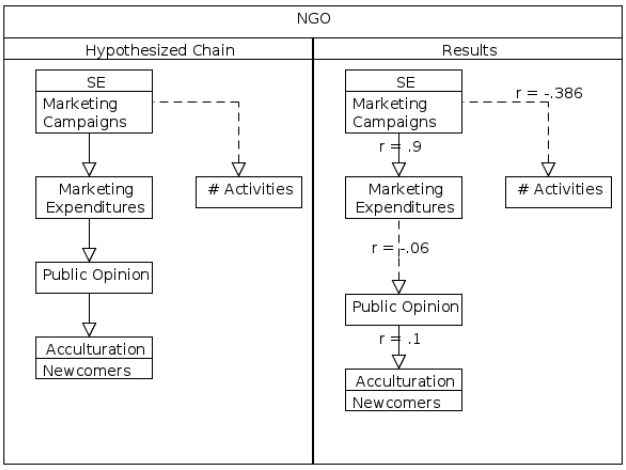


Figure 8.5: This graphic illustrates the shortcomings of the NGO $Marketing - Campaigns$. Contrary to our hypothesis, marketing expenditures do not translate directly into $public - opinion$, thus have no spillover into *acculturation*. Note, normal lines are meant to indicate a positive relationship and dashed a negative one.

phasis on marketing does not result in an increase in $public - opinion$ or newcomer *acculturation*. NGO $Self - Enhancement$ is very highly correlated with cumulative marketing expenditures (r = .917), but only weakly positively so with $public - opinion$ (r = .032). The purpose of the $MarketingCampaign$ action is to temporarily boost $public - opinion$, and it is described in Chapter 5 Section 5.6.7. During the boosted period, funds can be raised and additional acculturation can be gained for NGOs and Newcomers respectively. However, the $public - opinion$ being boosted returns to its original position after the boost, so positive $public - opinion$ effects are balanced out. The weak positive correlation with $public - opinion$ indicates that there is some slight effect, but it is operating on a much smaller scale. This can be rectified by either extending the duration of the $public - opinion$ boost from marketing campaigns or the magnitude.

COA Firstly, the results of COA $Openness - to - Change$ correlation analysis fully support our hypotheses. That is, keeping COA $staff$ at adequate levels with $AdjustStaff$ for the *occupancy* is simply good for newcomers' mental health, reduces crime and, unsurprisingly, is expensive. Recall that $AdjustStaff$ informs COA $staff$, which in turns informs $Check - in$ accuracy described in Chapter 5 Section 5.6.5. Similarly, the results of COA $Self - Enhancement$ support our hypotheses and make intuitive sense. Prioritizing building maintenance improves newcomer *health* and the quality of facilities through $ImproveFacilities$, described in Chapter 5 Section 5.6.5. Newcomer *health* decays at a rate that depends on building *health* as described in Chapter 5 Section 5.3.4. Said effects spillover into a reduction in *health* care costs as more newcomers are living in more favorable conditions. As with OTC, such investments are obviously expensive, as evident in the negative correlation with COA $thrift$.

Second, the results support our hypotheses of COA $Self - Transcendence$ for all outcome variables except for COA $thrift$, where a design mistake was made. Basically, COA's investment in travel vouchers for its residents unsurprisingly boosts newcomer *health*, newcomer *wellbeing* and newcomer *acculturation*. With a travel voucher, a

newcomer can satisfy its values in different cities where NGOs have a more diverse array of activities. $Check-in$ and $Invest$ are the two actions that result in travel voucher allocation, and their descriptions can be found in Chapter 5 Section 5.6.5. In line with the positive effects on newcomers is the reduction in city *crime*, clarified by the reduction in conditions, low newcomer *wellbeing* , which lead to $Crime$, described in Chapter 5 Section 5.6.7. Curiously, COA $Self-Transcendence$ was not negatively correlated with COA $thrift$. The simulation engineer forgot to include travel voucher cost with net COA *costs*, so the COA $Self-Transcendence$ related expenditures were not included.

Third and finally, our results for COA $Conservatism$ are mixed. COA $Conservatism$'s corresponding action, *Segregate*, is complex, as evident in the results. The plethora of hypothesized outcome variables is explained by the dynamics of the action itself. For reference, *Segregate* is described in 5 Section 5.6.5. *Segregate* takes unlikely to gain status newcomers and sends them to a separate 'high security' facility, where security is the inverse of number of activities. Mostly clearly in line with our hypotheses is the difference between segregated and non-segregated newcomer *acculturation* and Percent Segregated. Simply, there is a slight negative correlation among segregated and a relatively stronger positive correlation among non-segregated newcomers, indicative of preferential treatment. Similarly straightforward is the increase in percent segregated. Simply, the size of the segregated population grows in accordance with COA C.

We anticipated that a concentration of segregated newcomers would decrease the building *health* in segregated facilities and visa versa in non-segregated facilities. The aforementioned held for non-segregated building *health*, but not for building *health*. Rather, COA $Conservatism$ improved segregated building *health* as well, though to less of a degree. Taken together, COA $Conservatism$ improves building *health* overall, but more of the improvement is concentrated in the non-segregated population. The same dynamic holds for city *costs* and city *crime*, where conditions improve overall, though less so for segregated populations that non-segregated ones. Furthermore, the results pertaining to segregated and non-segregated newcomer *wellbeing* and newcomer *health* are problematic. There appears to be little correlation with newcomer relevant variables except for segregated newcomer *health*, where there is a positive correlation (r = .175), contrary to our hypothesis. This could be due to the fact that the least hospitable AZC may have more available room, subsequently less building decay which results in improved *health* outcomes.

The ambiguity of COA $Conservatism$ outcomes could be rooted in the value independent issue of size of simulation. Note that COA $Conservatism$ is positive correlated with size of segregated population. However, once the segregated population grows too big for any one facility, the population is spread out across multiple facilities, mingling with non-segregated populations. Consequently, segregation becomes increasingly meaningless the more newcomers are dispersed across facilities. Another cause of the ambiguity of $Conservatism$ outcomes is the mechanism for identifying the destination of the segregated population. As the simulation runs, NGOs accrue more and more resources and organize activities, even in low $public-opinion$ cities. As such, using the minimum number of activities as a proxy for security could still result in a decent quality of life city being chosen. By declaring one city to be NGO-free, there would be a designated location for the segregated population, which would likely increase the contrast between segregated and non-segregated outcomes.

Comparison	Variable	Tail	T	P
BF 365 - 60	COA Costs	Greater	2.47	**0.0213
DF = 7	Wait-Time	Greater	9.48	***1.52e-05
Paired	IND Staff	Less	-21.46	***6.009e-08
BF 230 - 60	COA Costs	Greater	2.6225	**0.01714
DF = 7	Wait-Time	Greater	4.1708	***0.002093
Paired	IND Staff	Less	15.349	***6.007e-07
BF 365 - 230	COA Costs	Greater	0.40188	0.3499
DF = 7	Wait-Time	Greater	6.6896	***0.0001401
Paired	IND Staff	Less	-17.901	***2.096e-07
Stiff - Flexible	COA Costs	Greater	0.2611	0.3994
DF = 11	Wait-Time	Greater	0.9149	0.1899
Paired	IND Staff	Less	-1.9098	*0.04128

8.2 Research Question 2

8.2.1 Results

A series of pairwise t-tests comparing groups (annual, anticipatory, and high frequency), subgroups (stiff and flexible), and canonical COAs found the following results. With respect to COA *costs* there were significant differences between groups A and *Conservatism* (p¡$.02, t = 2.4736$) and groups B and *Conservatism* ($t = 2.6225, p$¡0.02). However, there were not significant differences between groups B and A even when comparing stiff group A with flexible group B. Taken together, high frequency BF results in decreased COA expenditures on additional and commercial housing compared to annual and anticipatory BF conditions. Across groups, there were no significant differences between flexible and stiff subgroups with regards to COA *costs*.

With respect to IND $staff$, there were significant differences between all groups ($p < .001$ in all cases). That is, both high frequency budgeting and anticipatory budgeting result in improved staffing bottleneck response in comparison to annual budgeting. Across groups there was a significant difference in IND $staff$ between flexible and stiff subgroups (p ¡ .05). In other words IND $Openness - to - Change$ appears to improve bottleneck staffing response irrespective of BF.

With respect to average newcomer wait time, there were significant differences between all groups (p ¡ .002 in all cases). As such, both high frequency budgeting and anticipatory budgeting improve bottle response by lowering newcomer wait times. Across groups, there were no significant differences between flexible and stiff subgroups with regards to newcomer wait times.

8.2.2 Discussion

The results support our hypotheses. That is, the frequency with which IND adjusts both its budget and its staff has logistical implications for COA. For IND $staff$ and newcomer Wait-Time, anticipatory funding schemes and high frequency funding schemes are both improvements over annual funding schemes. Which is to say that if IND found high frequency budgeting unreasonable, investing in shock-detection capa-

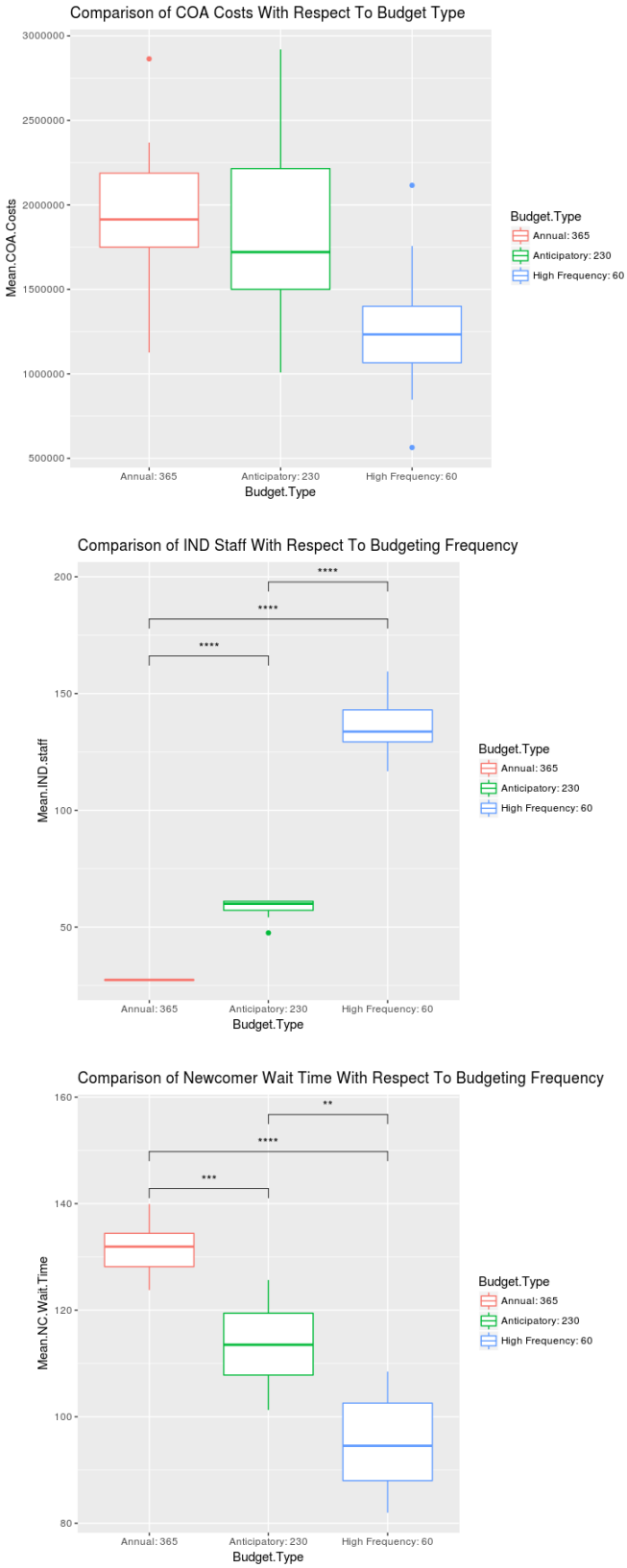
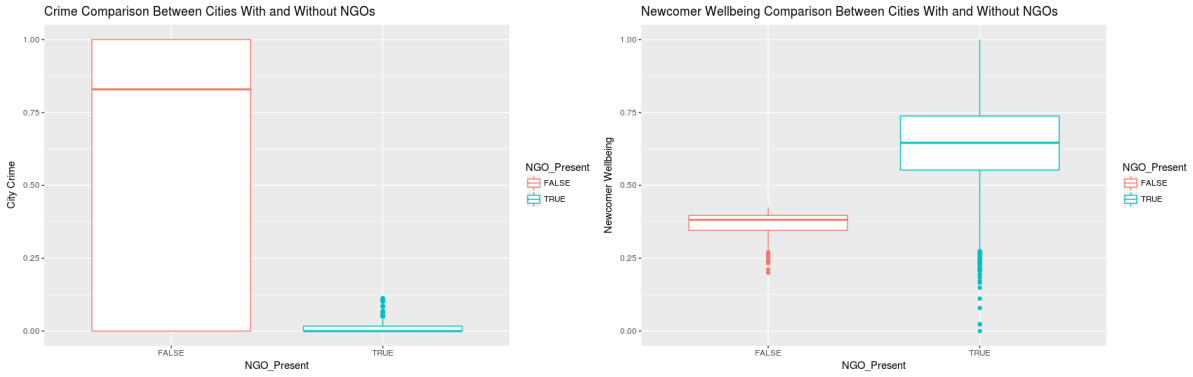


Figure 8.6: The above figures contain the results of Research Question 2 regarding COA *costs*, newcomer $wait - times$ and $staff$. Note in the COA *costs* graph, there are significant differences between all groups except annual, anticipatory, and high frequency



(a) (b)

Figure 8.7: This figure contains the results of the research question 3 experiment. Note that the presence of NGOs drastically reduces *Crime*, yet city *crime* seems to grow with $initial - public - opinion$.

ble of immediate post-shock budgetary adjustments can yield similar benefits. With regards to COA *costs*, only high frequency budgetary adjustment results in a significant difference. This result is intuitive, as COA must incur substantial costs during the time between the arrival of a shock, its 'anticipation', and the moment IND actually adjusts its budget.

It is important that effects were consistent across COAs. This means that IND policies are more responsible for effective bottleneck response than COAs, who is only responsible for setting the periodicity of *occupancy* information gathering.

The follow-up experiment to this should explore effects on newcomers between IND budget frequency groups. Clearly, IND's response has financial implications for COA. What remains to be seen is how that plays out for newcomers.

8.3 Research Question 3

8.3.1 Results

A two-tailed t-test reveals that there are significant differences in newcomer *wellbeing* between groups with and without NGOs ($p < .001$). That is, the presence of NGOs results in a strong improvement of newcomer wellbeing. Furthermore, there are significant differences between NGO and non-NGO groups with respect to city *crime* (p ¡ .001). Essentially, the presence of NGOs appears to foster a safer environment.

The covariance between $initial - public - opinion$ and hypothesis relevant outcome variables was calculated and the following results were found. There is a positive correlation between $initial - public - opinion$ and newcomer *health* ($r = .45$) and newcomer *wellbeing* ($r = .51$). That is, newcomer physical and mental *health* is improved in cities with higher initial public opinion. Very interestingly, $initial - public - opinion$ is negatively correlated with newcomer *acculturation* ($r = -.271$). While increasingly empowered NGOs produce positive *health* outcomes, they do not promote cultural adaptation. Anomalously, both city *crime* ($r = .154$) and city *costs* ($r= .448$) were positively correlated with $initial - public - opinion$. That is, cities with higher public opinion tend to increase criminal activity and *health* care costs, respectively.

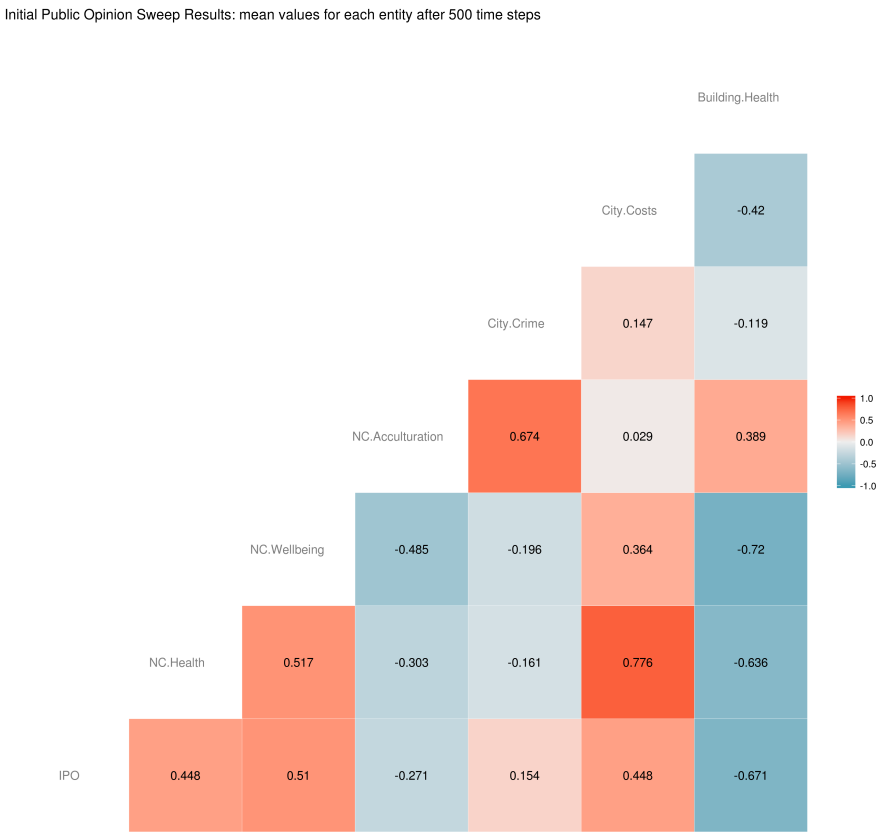


Figure 8.8: This is the correlation plot for the *initial − public − opinion* sweep. It is interesting that newcomer *acculturation* and newcomer *wellbeing* are negatively correlated.

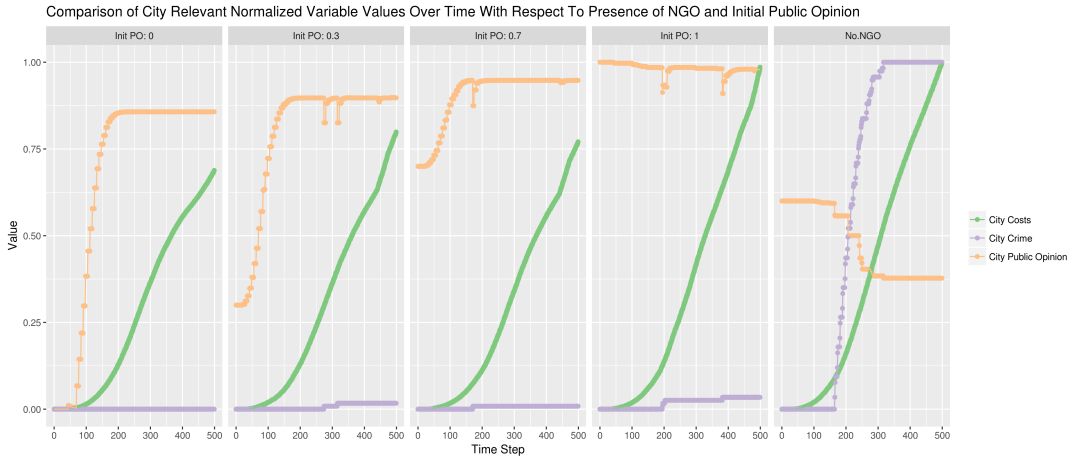


Figure 8.9: This figure shows the time series data of city related variables. The panel on right shows a city without NGOs that has a high jump in city *crime* around time step 200. This dramatic increase in *Crime* is the result of the building decaying to levels which meet the *Crime* preconditions.

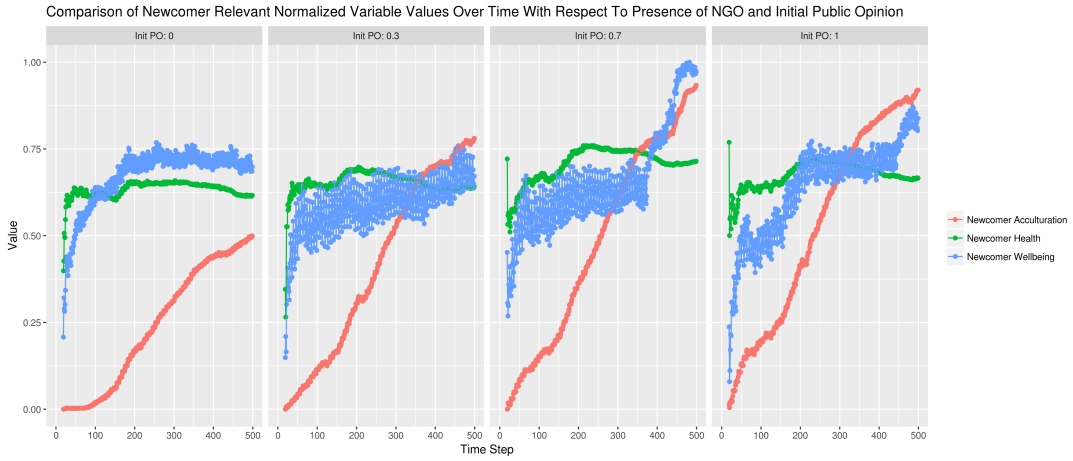


Figure 8.10: This is a graph of the times series of the simulation in action. Notice how simulations with higher $initial - public - opinion$ have a peak in newcomer *wellbeing* occurring around step 400. This is presumably due to NGOs developing a full schedule of activities.

8.3.2 Discussion

The results indicate that hypothesis 3 is fully supported. That is, the presence of NGOs is critical for *wellbeing* and city *crime*. NGOs design custom activities to meet the most unsatisfied value of the residents of an AZC. Moreover, low *wellbeing*, aka high distress, is a necessary precondition for engaging in criminal activity. As such, it follows by implication that the presence of NGOs reduces city *crime*. The effect of NGOs on city *crime* is curious with respect to the second hypothesis.

The second hypothesis was not supported in its entirety. That is, $initial - public - opinion$ is indeed a predictor of positive newcomer *health* and *wellbeing* outcomes as per Figure 8.10. However, $initial - public - opinion$ also predicts increased *health* care costs and crime. A side by side comparison of the hypothesized versus observed chain of variable interactions can be found in Figure 8.11. Though the presence of NGOs reduces city *crime*, the increased influence of NGOs appears to increase it,

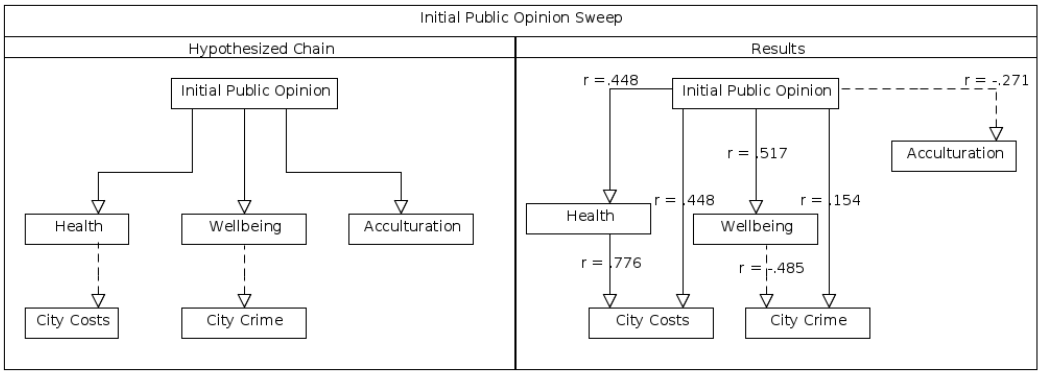


Figure 8.11: This graphic illustrates the chain of variable interactions that was hypothesized versus the chain of variable interactions that was observed.

as visible in Figure 8.9. The preconditions of *Crime* are low newcomer *wellbeing* , high $Self - Enhancement$ value and poor living conditions. *wellbeing* has been accounted for and $Self - Enhancement$ is stochastic, which leaves building *health*. The aforementioned is strongly negatively correlated with $initial - public - opinion$ (r = -.671) as visible in figure 8.8. It appears that increased NGO activities hastens the decay of buildings. There is intuitive sense in the idea of buildings receiving more use if more activities are offered there, but the exact mechanism remains to be pinned down. With respect to city *costs*, the negative correlation has a more straightforward explanation. *health* can be increased through either exercise or visiting the doctor. NGOs inevitably design custom activities which satisfy the same value as exercise, yet offer no *health* benefit.

Finally, the negative correlation with newcomer acculturation follows similar reasoning, but reveals a unique quirk of the model. The data from hypothesis 3 shows that the presence of NGOs results in significantly improved acculturation compared to simulations without NGOs ($p < .001$) as visible in figure 8.7. Taken together, NGOs are necessary for improved *acculturation*, but their progressive empowerment through $initial - public - opinion$ decreases the amount amount of acculturation that results. Note that newcomer *wellbeing* (r = -.485) and newcomer *health* (r = -.303) are negatively correlated with newcomer *acculturation* as visible in figure 8.8. This is to say that cultural adaptation often comes a cost to one's welfare. The *health* component can be explained through the same lack of exercise reasoning, as the $Football$ activity improves *health* and acculturation. Therefore, if newcomers were playing football, both would be positively correlated, but they are not. Consequently, it appears that when newcomer behavior is only driven by the satisfaction of values, *wellbeing* takes precedence over health, which reveals a limitation of a purely value driven approach.

The aforementioned anomalies can be addressed through the following mechanisms. Firstly, NGO custom activities can be made to also offer additional attribute bonuses. Just as NGOs poll a location to gather data on its unsatisfied values, it can also poll a location to gather data on its unsatisfied attributes, such as health, income, education and so on. Secondly, a learning mechanism can be implemented to offer auxiliary behavioral orientation to newcomers such that values are satisfied when possible but never to one's detriment. Third and perhaps more simply, the $Football$ activity can be tweaked such that it is prioritized over NGO activities satisfying the same value.

Chapter 9

Discussion

This chapter compares our findings with the literature. Finally, the strengths and weaknesses of the model are taken into account. They will be inform the development plan in Chapter 10.

9.1 General Discussion

The results provide insight into the strengths and weaknesses of the model. Regarding the strengths, the model effectively captures mental and physical health. The model provides in silico evidence in line with previous research that grounds *wellbeing* in the congruence of individual values and environmental opportunity to satisfy those values [73] [80]. This is evident in the positive correlations between COA ST, NGO ST, $initial - public - opinion$ and newcomer wellbeing. In addition, the same correlations echo the results of Porter et al. who found that lack of activity is strongly tied to poor mental *health* [68]. Specifically COA ST's positive correlation with *wellbeing* supports the recommendation of Strijk et al. that increasing weekly allowance could improve *wellbeing* [84]. Furthermore, the positive correlation between *health* and *wellbeing* echoes the case study on physical activity at AZCs [95]. The spillover of the activity *wellbeing* correlation into city *crime* is also supported in the literature. Dylan O'Driscoll reported that financial pressure coupled with long periods of inactivity can lead refugees to criminal activity [65].

The model also captures the underlying logistical procedure and its failings during times of crisis. As evident in the results in research question 2, in section 8.2, flexible staffing and periodic budget updates can attenuate the shock bottleneck. This is echoed in case studies and IND's own reports on how they addressed the crisis [50] [49]. Additionally, the increased financial burden on COA in the same set of results aligns with COA's own analyses published in a report just prior to the crisis. COA expresses concern that there could be dire financial consequences if a large and sudden influx of asylum seekers arrived [62].

The model's weaknesses are evident in the areas in which the results are either counter intuitive or not supported by the literature. The financial and marketing aspects of NGOs are problematic. NGOs were the last major agent type added to the model and, as such, still require additional development with respect to $MarketingCampaigns$. In addition, the design decision to place only one NGO per city misses the mark with respect to the market competition that drives NGO behavior towards dysfunction [24] [39] [54]. Furthermore, the main COA weakness lies in the *Segregate* action. As it is based on a proposed policy, there is not yet existing literature on it. However, one can

imagine that its effectiveness is predicated on polarized spectrum of AZC conditions. The Netherlands features AZCs that range from alienating to integrated [92] [9]. The present simulation requires further engineering to ensure greater heterogeneity of AZC conditions, as there lies the basis of the *Segregate* action.

Methodologically, the model evaluation procedure can be improved. The value sweep step size was 20. While useful for a coarse grain exploration of value driven outcomes, a finer grain is necessary for a validation purposes. Moreover, multiple simulations per value profile would permit a value based analysis of variance. In addition, the model has not yet been broken. John Miller (1998) provides a framework for model breaking called Active Non-Linear Testing [59]. Model breaking reveals weak points in the model.

Finally, the values framework should be extended beyond quadrants and an exhaustive list of institutional agent actions should be compiled. The strength of the values framework is evident in its ability to support realistic mental *health* and logistical behavior using only four values. However, complex organizational and individual behavior should not be reduced to four actions. Attempting to do so results in actions which are large and unwieldy, such as COA's *Segregate* and NGO's *Prioritize*. Moreover, adding the full set of values allows the framework to incorporate relative importance of values condition in its entirety [76] [74]. That is, adjacent values could be positively correlated and opposite values negatively so.

9.2 Chapter Summary

This chapter compared results to hypotheses and literature, offering explanations where necessary. The results of research question one shed light on weaknesses in the model. COA *Segregate* and NGO *MarketingCampaign* require overhaul in further validation work. However, the remaining unsupported hypotheses were rooted in design quirks or addressable bugs. Research question 2 was fully supported and can serve as the basis for further recommendations on IND funding policies. The first part of the research question 3 hypothesis was supported. NGOs play a role in improving *wellbeing* and reducing city *crime*. Unintentional but interesting model artifacts are behind the unsupported aspects of the research question 3 hypothesis, such as the wellbeing-acculturation trade off.

Chapter 10

Conclusion

This chapter takes account of the degree to which the project has met its goals. Then, we list the novel contributions made by the project. Finally, we take the model strengths and weaknesses from Chapter 9 and incorporate them into the development plan. This addresses **Goal 6: Define development plan for the continuation of the project**.

10.1 Project Goals

This section describes each goal and comments upon the degree to which it was either completed or undressed.

Goal 1 Consult with literature and SMEs to codify asylum policy, asylum procedure and simulation requirements.

This goal was met as evident in Chapter 3 Literature Review and described in Chapter 6 Section 6.1.1 on phase one of the model's development. Previous literature on refugee and logistically focused ABMs were reviewed. Interviews with COA caseworkers, COA logistics personnel, and refugees themselves were conducted.

Goal 2 Implement a decision mechanism and wellbeing metric based on Schwartz's theory of values.

This goal was met using the formalization found in Chapter 4. A decision mechanism capable of identifying which actions best minimize the amount of unsatisfied values was developed. Furthermore, a metric measuring an agent's total amount of unsatisfied values was built on top of the values framework and functions as a proxy for wellbeing.

Goal 3 Build a model that utilizes values to capture both refugee and logistical behavior

As outlined in Chapter 5 a model was developed that captures both refugee and logistical behavior. The development of the model is chronicled in Chapter 6 Section 6.1.2. The logistical procedures contained in the model are the result of SME

consultation and feedback. The refugee behavior is a combination of SME consultation and the implemented values framework.

Goal 4 Analyze the degree to which values correlate with outcomes

This goal was addressed in Chapter 8 Section 8.1. A coarse sweep of the value input parameter space was conducted and correlations with output variables calculated. The results of which informed the designers as to weak points in the model design. However, addressing Goal 4 requires a lengthier procedure than a single coarse parameter sweep. Sensitivity and uncertainty analyses and model breaking are follow up efforts towards the same goal.

Goal 5 Use model to make recommendations to stakeholders

This goal was very addressed in Chapter 8 Sections 8.2 and 8.3. By comparing INDs with historical and counter factual budgeting schemes and values, we found that shorter budgeting frequencies can attenuate logistical bottlenecks in times of crisis. While changing institutional values may be a difficult recommendation to follow, our budgetary advice is actionable. By examining the effects on newcomers with and without NGOs of increasing strength, we found that NGO presence is not only good for newcomers, but also for municipalities. This finding can inform how municipalities allocate public funds to NGOs.

Goal 6 Define development plan for the continuation of the project

10.2 Contributions

This section summarizes novel contributions made to the literature of refugee and logistically focused ABMs.

Contribution 1 *A values defined formalization of wellbeing*

Previous wellbeing metrics are grounded in objective happiness theory, but happiness and wellbeing are distinct [52] [4]. Literature indicates that wellbeing is related to congruence between individual values and the environment [73]. The wellbeing formalization found in Chapter 4 characterizes this.

Contribution 2 *An AZC abstraction level simulation that includes crisis conditions*

The majority of refugee focused ABMs are heavily abstracted and model refugee movements across large distances [37] [53] [21]. To the best of our knowledge, only one group has modeled a low abstraction refugee population; however, they did so before the refugee crisis [4] [3]. As such, the work of Anderson et al. makes assumptions regarding the stability of logistical pipeline behind the asylum procedure. Our simulation allows the crisis to occur during a single run.

Contribution 3 *In silico evidence supporting alternative bottleneck response policies*

IND's unpreparedness and slow response to the refugee crisis has been commented upon [50]. In addition, COA was well aware of the fragility of its AZC infrastructure before the crisis [62]. The results of research question 2 provide the first in silico experiments testing alternative logistical responses.

10.3 Future Directions

These models have life cycles longer than a single thesis. Continued work on the model should focus on the following aspects: adjusting actions, activating social networks, allowing for NGO competition, adding other sociological theories, extending research methodology, and exploring other counterfactual experiments.

Regarding action adjustment, the following changes must be made before exploring the other future directions. First, $MarketingCampaign$ requires adjustment. It can be improved by extending the duration of the $public - opinion$ boost. Second, $IssueStatement$ should be removed. Conversations with a SME found the action naive. Historically, IND enhanced itself by streamlining processing procedures. A similar action could be employed to increase IND $staff$ efficiency by reducing the newcomer $wait - time$ per IND $staff$ member. Third, COAs $Segregate$ action requires a city whose AZC has especially prison like living conditions to be meaningful. Moreover, the AZC in question must be avoided during non-shock periods.

Social networks have been implemented, however their execution is too slow for the device with which much of the simulation has been built. The present implementation allows for the formation of relationships which strengthen and decay over time and activity participation. In the current simulation, we assume that all newcomers are fully aware of activities in their city. This is unrealistic as information of any kind is rarely completely known. The social network can act as a mechanism for information transfer. High $Openess - to - Change$ newcomers could gather information from the Activity Center and high $Conservatism$ newcomers could gather information from their culturally similar social network.

The role of NGOs should be expanded to include NGO competition, as therein lies the interesting component of NGO behavior. Literature indicates that market pressure drive dysfunctional behavior among NGOs [24]. The market could function as follows, public funds are gathered from $public - opinion$ increases. Cities adopt a value profile which corresponds to the types of NGOs it favors when allocating public funds. For example a high ST city awards the public funds to the NGO with the most $number - activities$ relative to its size, while a high SE city aware the public funds to the NGO with the strongest marketing campaign.

Other sociological theories, such as learning, goals, and norms, must be added if the phenomena modeled is to be more realistic. First, learning must be implemented as it lends autonomy and realism to newcomers. It is nearly offensive to newcomers that institutions can adapt to their surroundings through budget updates and $staff$ adjustments but newcomers cannot adapt to their surroundings. Practically, learning can avoid the problem of newcomers neglecting their own health for the sake of value satisfaction. Indeed, there is commonsense realism in the idea that a small degree of dissatisfaction can be beneficial in the long run. Goals would increase newcomer heterogeneity and improve capacity management. Regarding the former, some newcomers may have the goal of increasing *acculturation* or forming the largest social network. As there are multiple opportunities to gain *acculturation* and connect with other newcomers, goals are not incompatible with values. Regarding the latter, capacity management lends itself to goals in the form of occupancy targets for each building

type. Some COAs may have a goal of minimizing occupancy, favoring multiple AZCs; while other COAs may have the goal of maximizing occupancy, using as few AZCs as possible. Finally, norms can be added to the simulation using the same mechanics as COA policies but with added measures of sanctions and level: private, social, or legal. For example, newcomers can have a social norm of forming relationships with other newcomers same culture unless a common goal is shared. IND can have a legal norm of immediately repatriating newcomers from certain countries without an interview.

Methodologically, the value's sweep needs to be repeated with a finer grain step size and more simulations per value setting. Then, after fully addressing the above mentioned model shortcomings a sensitivity analysis must be performed as a means of model validation. The sensitivity analysis protocol mentioned by Thiele et al. could be used [87]. Finally, the model can be validated by breaking. That is, running extreme parameter configurations with the intent to see where outputs deviate from expectation. Model breaking can be performed according to the Active Non-linear Testing methodology [59].

Finally, once the model is validated, the stakeholders represented should have the opportunity to interact with it using the web page artifact. As the model is stakeholder informed, its results should be made accessible to them. Their thoughts on the model should be systematically compiled into an accompanying case study.

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